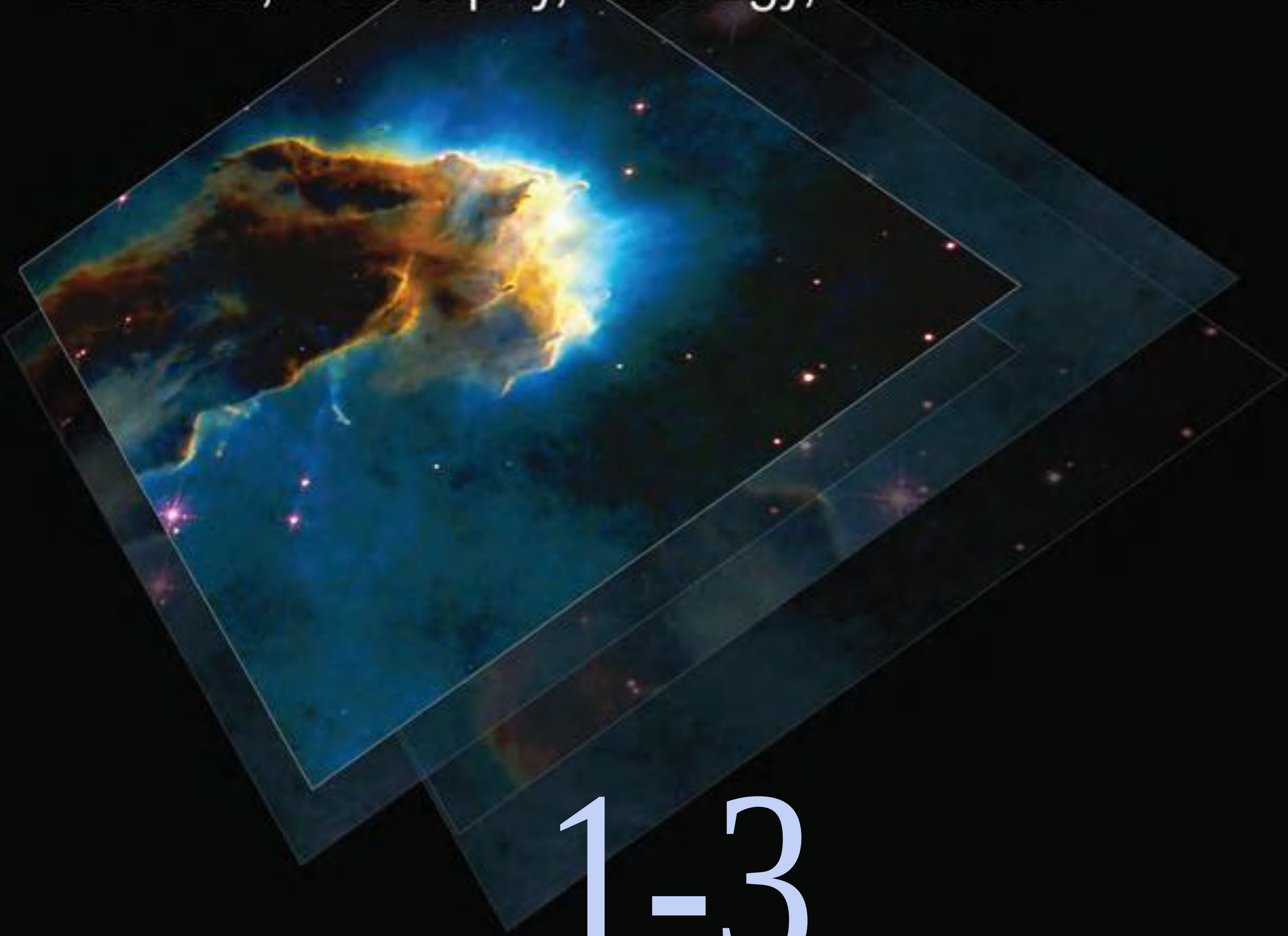
H. James Birx Editor

ENCYCLOPEDIA OF TIME

Science, Philosophy, Theology, & Culture



1-3

ENCYCLOPEDIA OF TIME

Editorial Board

ENCYCLOPEDIA OF TIME

Science, Philosophy, Theology, & Culture

H. James Birx *Editor*

Canisius College | State University of New York at Geneseo | Buffalo Museum of Science

1-3

SAGE

Los Angeles • London • New Delhi • Singapore • Washington DC

A SAGE Reference Publication

For information:

SAGE Publications, Inc.
2455 Teller Road
Thousand Oaks, California 91320
E-Mail: order@sagepub.com

SAGE Publications Ltd.
1 Oliver's Yard
55 City Road
London EC1Y 1SP
United Kingdom

SAGE Publications India Pvt. Ltd.
B 1/I 1 Mohan Cooperative Industrial Area
Mathura Road, New Delhi 110 044
India

SAGE Publications Asia-Pacific Pte. Ltd.
33 Pekin Street #02-01
Far East Square
Singapore 048763

Printed in the United States of America.

Library of Congress Cataloging-in-Publication Data

Encyclopedia of time : science, philosophy, theology, and culture / H. James Birx, editor.
p. cm.
Includes bibliographical references and index.
ISBN 978-1-4129-4164-8 (cloth : alk. paper) 1. Time—Encyclopedias. I. Birx, H. James.

BD638.E525 2009
115.03—dc22 2008030694

This book is printed on acid-free paper.

09 10 11 12 13 10 9 8 7 6 5 4 3 2 1

Publisher:	Rolf A. Janke
Assistant to the Publisher:	Michele Thompson
Developmental Editor:	Sanford Robinson
Reference Systems Manager:	Leticia Gutierrez
Production Editor:	Kate Schroeder
Copy Editors:	Kristin Bergstad, Colleen Brennan, Cate Huisman
Typesetter:	C&M Digitals (P) Ltd.
Proofreaders:	Kristin Bergstad, Kevin Gleason, Penelope Sippel
Indexer:	David Luljak
Cover Designer:	Ravi Balasuriya
Marketing Manager:	Amberlyn Erzinger

Contents

O man! Take heed!
What says deep midnight's voice indeed?
"I slept my sleep—,
"From deepest dream I've woke, and plead:—
"The world is deep,
"And deeper than the day could read.
"Deep is its woe—,
"Joy—deeper still than grief can be:
"Woe says: Hence! Go!
"But joys all want eternity—,
"—Want deep, deep eternity!"

Friedrich Nietzsche
Thus Spake Zarathustra
The Drunken Song, Section 12

H. James Birx [Trans.]

List of Entries

Reader's Guide

Biography
Abelard, Peter
Albertus Magnus
Alexander the Great
Alexander, Samuel
Alighieri, Dante
Anaximander
Anaximines
Anselm of Canterbury
Apollodorus of Athens
Aquinas, Saint Thomas
Aristotle
Asimov, Isaac
Attila the Hun
Augustine of Hippo, Saint
Avicenna
Baer, Karl Ernst Ritter von
Bakhtin, Mikhail Mikhailovich
Barth, Karl
Baxter, Stephen
Bede the Venerable, Saint
Bergson, Henri
Berkeley, George
Boethius, Anicius
Bohm, David
Bonaparte, Napoleon
Boscovich, Roger Joseph
Boucher de Perthes, Jacques
Bradbury, Ray
Bruno, Giordano
Caesar, Gaius Julius
Calvin, John
Campanella, Tommaso
Carroll, Lewis
Cartan, Élie Joseph
Chambers, Robert
Charlemagne
Chaucer, Geoffrey
Clarke, Arthur C.
Coleridge, Samuel Taylor
Columbus, Christopher
Comte, Auguste
Copernicus, Nicolaus
Dali, Salvador
Darwin, Charles
Deleuze, Gilles
Derrida, Jacques
Descartes, René
Diderot, Denis
Dilthey, Wilhelm
Donne, John
Dostoevsky, Fyodor M.
Doyle, Arthur Conan
Duns Scotus, John
Durkheim, Emile
Eckhart, Meister
Einstein, Albert
Eliade, Mircea
Eliot, T. S.
Empedocles
Engels, Friedrich
Eriugena, Johannus Scotus
Farber, Marvin
Feuerbach, Ludwig
Fichte, Johann Gottlieb
Flaubert, Gustave
Frege, Gottlob
Galilei, Galileo
Gamow, George
Gehlen, Arnold
Genghis Khan
Gibran, Kahlil
Gödel, Kurt
Goethe, Johann Wolfgang von
Gosse, Philip Henry
Haeckel, Ernst
Harris, Marvin
Harrison, John
Hartshorne, Charles
Hawking, Stephen
Hegel, Georg Wilhelm Friedrich
Heidegger, Martin
Heraclitus
Herder, Johann Gottfried von
Herodotus
Hesiod
Hitler, Adolf
Homer
Hume, David
Husserl, Edmund
Hutton, James
Huxley, Thomas Henry
Jaspers, Karl
Josephus, Flavius
Joyce, James
Kafka, Franz
Kant, Immanuel
Kierkegaard, Søren Aabye
Knezevic´, Bozidar
Kropotkin, Peter A.
Kuhn, Thomas S.
Lamarck, Jean-Baptiste de
Laplace, Marquis Pierre-Simon de
Leibniz, Gottfried Wilhelm von
Lemaître, Georges Édouard
Lenin, Vladimir Ilich
Lucretius
Luther, Martin
Lydgate, John
Lyell, Charles
Lysenko, Trofim D.
Mach, Ernst
Machiavelli, Niccolò
Malthus, Thomas

Biology/Evolution

Culture/History

Geology/Paleontology

Philosophy

Physics/Chemistry

Psychology/Literature

Religion/Theology

Theories/Concepts

About the Editor

H. James Birx, Ph.D., D.Sci., is professor of anthropology at Canisius College in Buffalo, New York. He received both his M.A. in anthropology and Ph.D. with distinction in philosophy from the State University of New York—University at Buffalo. His writings and lectures in natural science and process philosophy embrace both a cosmic perspective and an evolutionary framework. During the past 40 years, his teaching experience has included biological anthropology, sociocultural anthropology, forensic anthropology, theories in anthropology, and interpreting evolution.

Born in Canandaigua, New York, Birx grew up on a nearby farm and attended public schools in the East Bloomfield Central School District. During these years, he was greatly influenced by motion pictures, which introduced him to prehistoric life forms, ancient civilizations, and the exploration of outer space. Such films as *King Kong* (1933), *Quo Vadis* (1951), and *2001: A Space Odyssey* (1968) resulted in his having a lasting interest in paleontology, anthropology, and astronomy.

At the State University of New York at Geneseo, Birx was introduced to the academic discipline of anthropology, as well as serious music (particularly opera) and philosophy. His reading of the compelling works of Charles Darwin and the neo-Darwinians of the 20th century solidified a lifelong commitment to the factual theory of organic evolution and its far-reaching implications for understanding and appreciating the place our recent species occupies in this dynamic universe. However, he became aware of the crucial distinction between the fact of evolution and those different interpretations of this process that are given in science, philosophy, and theology.

At the State University of New York–University at Buffalo, Birx furthered his studies in anthropology, specializing in human craniometry. He was particularly interested in fossil hominids and the great apes. Next, under the guidance of world-renowned distinguished professor Marvin Farber, Birx completed his doctoral degree in philosophy with a thesis on Pierre Teilhard de Chardin. His ongoing focus on evolutionary thought had expanded to include such diverse thinkers as Samuel Alexander, Henri Bergson, Giordano Bruno, Marvin Farber, Ernst Haeckel, Stephen W. Hawking, Ernst Mayr, Friedrich Nietzsche, Herbert Spencer, and Leslie A. White.

Extensive worldwide travels have taken Dr. Birx to scientific sites and academic conferences from Australia to Russia. His research interests have taken him to Athens, Ayers Rock (Uluru), Cairo, the Galapagos Islands, Giza, Koobi Fora/Masai Mara, Machu Picchu, Rarotonga, Rome, Stonehenge, Teotihuacan, Uxmal, and the Wyoming Dinosaur Center (among many other significant locations).

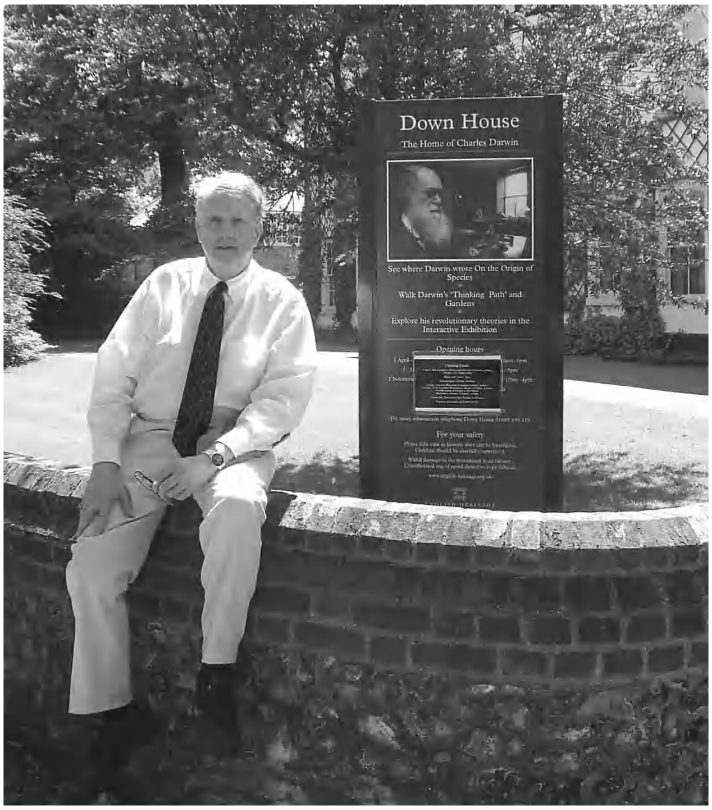
Dr. Birx has been a visiting scholar at the University of Cambridge and twice at Harvard University. He has also given invited presentations at Harvard, Princeton, Yale, MIT, Johns Hopkins University, University of Oxford, University of Hawai'i at Manoa, University of Kansas, University of Montana, University of San Francisco, Rockhurst College, University of Auckland, Tacamoa Theological College in Rarotonga, Trinity College in Dublin, University of Zaragoza, Catholic Academy Schwerte in Germany, both the Free University and Humboldt University in Berlin, University of Nis in Serbia, Comenius University in Slovakia, Moscow State University, Ludwig Maximilian University of Munich, Max Planck Institute for Evolutionary Anthropology in Leipzig, and both the Jagiellonian University and the Pontifical Academy of Theology in Krakow. He has also given invited presentations for the New

York Academy of Sciences, the Russian Academy of Sciences in both Moscow and St. Petersburg, and the Slovak Academy of Sciences in Bratislava. Dr. Birx has organized conferences at St. Petersburg State University and the State Darwin Museum in Moscow, among others. He has been an invited conference participant in Australia, Canada, Costa Rica, Egypt, England, Germany, Greece, Mexico, New Zealand, Panama, Slovakia, and Spain.

Dr. Birx has published over 400 chapters, articles, introductions and reviews, authored six books, and edited 11 other volumes, receiving awards for both his *Theories of Evolution* and the five-volume *Encyclopedia of Anthropology*. His other works include *Human Evolution*, *Interpreting Evolution: Darwin & Teilhard de Chardin,* and the scientific monograph *Craniometry of the Orchid Site Ossuary.* Recently, in Germany, he was one of the editors for and contributors to *Eugenik und die Zukunft*, *Pierre Teilhard de Chardin: Naturwissenschaftliche und Theologische Perspektiven Seines Werks,* and *Wagner und Nietzsche: Kultur-Werk-Wirkung*. He is presently editing the two-volume *21st Century Anthropology: A Reference Handbook* for Sage Publications.

Dr. Birx was the recipient of the 2003 Professional Achievement Award from the State University of New York at Geneseo, where he holds the title distinguished research scholar and where the annual H. James Birx Distinguished Scholar Award has been established. He is also a research associate at the Buffalo Museum of Science and a member of both the scientific board of the Nietzsche-Forum Munich and the international scientific advisory board of the Ethics Center at the Friedrich Schiller University of Jena in Germany, where he was a visiting professor for several summers. His professional listings include *Who's Who in the World.*

Birx has been interested in time since childhood, when he first learned about dinosaur fossils and distant stars. This encyclopedia and other present writings reflect an outgrowth of his ongoing interest in science and philosophy. Anticipating a neo-Enlightenment, Birx's own ideas include the will to evolve, dynamic integrity, emerging teleology, *Homo futurensis,* exoevolution, and cosmic overbeings.



H. James Birx, Charles Darwin's Down House/Museum in Downe, Kent, England.

Contributors

Reyk Albrecht
Friedrich Schiller University of Jena

Laia Alegret
University of Zaragoza

Theodor Alpermann
Friedrich Schiller University of Jena

Charles Anderson
Seattle, Washington

Roger Andrews
University of the West Indies

Ignacio Arenillas
University of Zaragoza

Stefan Artmann
Friedrich Schiller University of Jena

José Antonio Arz
University of Zaragoza

Christian Austin
Buffalo, New York

Beatriz Azanza
University of Zaragoza

Christopher T. Bacon
Millville, New Jersey

Vidisha Barua
Penn State Altoona

Virginia A. Batchelor
Medaille College

Adam L. Bean
Emmanuel School of Religion

Clemens Beckstein
Friedrich Schiller University of Jena

Ralf Beuthan
Friedrich Schiller University of Jena

Timothy Binga
Center for Inquiry

H. James Birx
Canisius College, State University of New York at Geneseo, Buffalo Museum of Science

Rebecca M. Blakeley
McNeese State University

Robert Bollt
Honolulu, Hawai'i

James P. Bonanno
University at Buffalo

Christophe Bouton
University of Michel de Montaigne Bordeaux 3

Raymond D. Bradley
Simon Fraser University

Stephen L. Brusatte
American Museum of Natural History, Columbia University

Marcus Burkhardt
Friedrich Schiller University of Jena

Christiane Burmeister
Friedrich Schiller University of Jena

Karlen Chase
Bureau Veritas Consumer Products Services

Ann Louise Chenhall
North Thurston Public School, Olympia, Washington

Patricia N. Chrosniak
Bradley University

Jill M. Church
D'Youville College

Jacqueline O. Coffee
High Point, North Carolina

Suzanne Colligan
Buffalo & Erie County Public Library, Central

Timothy D. Collins
Western Illinois University

Bill Cooke
University of Auckland at Manukau

Christopher D. Czaplicki
Canisius College

Suzanne E. D'Amato
Medaille College

Irina Deretic
University of Belgrade

Malte C. Ebach
Arizona State University

Terry W. Eddinger
Carolina Evangelical Divinity School

Stacey L. Edgar
State University of New York at Geneseo

Patricia E. Erickson
Canisius College

Carolyn Evans
University at Buffalo

Jennifer R. Fields
Tulsa, Oklahoma

Carlo Filice
State University of New York at Geneseo

Bryan Finken
University of Colorado at Denver

Isabelle Flemming
Mount Prospect Public Library

Yvonne Förster
Friedrich Schiller University of Jena

Michael Joseph Francisconi
University of Montana–Western

Marko J. Fuchs
Ludwig Maximilian University of Munich

Catherine M. Mitchell Fuentes
Charlotte, North Carolina

Betty A. Gard
Seattle, Washington

Michael F. Gengo
University at Buffalo

Jennifer Goul
Brock University

John K. Grandy
Buffalo, New York

John R. Grehan
Buffalo Museum of Science

Joseph Grossi
Canisius College

Stephan Günzel
University of Potsdam

Matthias S. Hauser
Heidelberg, Germany

Anja Heilmann
Friedrich Schiller University of Jena

Michael Heller
Pontifical Academy of Theology, Copernicus Center for Interdisciplinary Studies, Vatican Observatory

Matthew A. Heselton
Johnson Bible College

Helmut Hetznecker
Ludwig Maximilian University of Munich

Susan W. Hinze
Case Western Reserve University

C. A. Hoffman
Ventura, California

Dustin B. Hummel
University of Aberdeen

Philippe Huneman
University Paris 1 Panthéon-Sorbonne

Li-Ching Hung
Overseas Chinese Institute of Technology in Taiwan

Pamela Rae Huteson
Edmonds, Washington

Linda Mohr Iwamoto
Chaminade University of Honolulu

Andrea Tricia Joseph
University of the West Indies

Harald Jung
Friedrich Schiller University of Jena

Veronika Junk
Ludwig Maximilian University of Munich

Verena Kammandel
Friedrich Schiller University of Jena

Derik Arthur Kane
University at Buffalo

J. Lee Kavanau
University of California, Los Angeles

Peter King
Pembroke College, Oxford

Joachim Klose
Konrad Adenauer Foundation, Dresden

Nikolaus J. Knoepffler
Friedrich Schiller University of Jena

Corrine W. Koepf
University at Buffalo

Matthias Kossler
Johannes Gutenberg University of Mainz

Mark Koval
Buffalo, New York

Carol Ellen Kowalik
University at Buffalo

Josef Krob
Masaryk University

Franziska Kümmerling
Friedrich Schiller University of Jena

Amanda Kuhnel
University at Buffalo

Ramdas Lamb
University of Hawai'i at Manoa

Luci Maire Latina Fernandes
University of Connecticut

Oliver W. Lembcke
Friedrich Schiller University of Jena

Gregory L. Linton
Johnson Bible College

Karen Long
Farmington Public Library, New Mexico

Stefanie Lotz
University of Frankfurt

Garrick Loveria
Charter School for Applied Technology, Buffalo, New York

Debra Lucas
D'Youville College

David Alexander Lukaszek
University of Alaska Fairbanks

Edward J. Mahoney
Director of Astronomy, Hyatt Maui

Christophe Malaterre
University Paris 1 Panthéon-Sorbonne

Sara Marcus
City University of New York in Queens

Jessica M. Masciello
University at Buffalo

Gerald L. Mattingly
Johnson Bible College

Leslie A. Mattingly
Johnson City, Tennessee

David V. McFarland
Friedrich Schiller University of Jena

Jaclyn McKewan
D'Youville College

Belete K. Mebratu
Medaille College

Daniel J. Michalek
Michigan State University

Eustoquio Molina
University of Zaragoza

James V. Morey
University of Cambridge

Muhammad Aurang Zeb Mughal
Islamabad, Pakistan

Sophie Naumann
University of Erfurt

Ralph Neuhäuser
Friedrich Schiller University of Jena

Mark Nickens
Averett University

Jan Novotný
Masaryk University

John C. Nugent
Great Lakes Christian College

Neil Patrick O'Donnell
Canisius College

Sabine Odparlik
Friedrich Schiller University of Jena

Carl Olson
Allegheny College

Martin O'Malley
Friedrich Schiller University of Jena

Silvia Ortiz
University College London

Erin M. O'Toole
University of North Texas

Alessandra Padula
University of L'Aquila

Marián Palenčár
University of Matea Bel

Jennifer Papin-Ramcharan
University of the West Indies

Marianne E. Partee
Erie Community College, South Campus

Bethany Peer
Johnson Bible College

Jared N. Peer
Coker Creek, Tennessee

Matthias Perkams
Ludwig Maximilian University of Munich

Donald R. Perry
University of California, Los Angeles

Markus Peuckert
Friedrich Schiller University of Jena

Sebastian Pfotenhauer
MIT, Friedrich Schiller University of Jena

Dawn M. Phillips
University of Warwick

Jocelyn Phillips
University of Guelph

Dirk Preuss
Friedrich Schiller University of Jena

Robert Ranisch
University of Warwick

Elisa Ruhl Rapaport
Molloy College

Elaine M. Reeves
Carlson University

Sanford Robinson
Pasadena, California

Erin Elizabeth Robinson-Caskie
Canisius College

Debika Saha
University of North Bengal

Helen Theresa Salmon
University of Guelph

Laura Sare
Texas A&M University

Michael Schramm
University of Leipzig

Patricia Sedor
Bryant & Stratton College

Hans Otto Seitschek
Ludwig Maximilian University of Munich

Linda Cara Katherine Shippert
Washington State University

Dennis E. Showers
State University of New York at Geneseo

Michael J. Simonton
Northern Kentucky University

Christopher Ben Simpson
Lincoln Christian College

John Sisson
University of California, Irvine

Cary Stacy Smith
Mississippi State University

Olena V. Smyntyna
Mechnikov National University

Emily Sobel
State University of New York at New Paltz

Dirk Solies
Johannes Gutenberg University of Mainz

Stefan Lorenz Sorgner
University of Erfurt

Andreas Spahn
Ruhr University Bochum

Anthony J. Springer
Belhaven College

Eric J. Stenclik
Canisius College

Victor J. Stenger
University of Colorado at Boulder, University of Hawai'i at Manoa

Richard A. Stephenson
East Carolina University

Amy L. Strauss
D'Youville College

Marianne Sydow
Martin Luther University Halle-Wittenberg

Mark James Thompson
Perth, Western Australia

Beth Thomsett-Scott
University of North Texas

Joyce K. Thornton
Texas A&M University

Jacek Tomczyk
Cardinal Stefan Wyszynski University

Stan Trembach
Texas A&M University

Ryan J. Trubits
Buffalo, New York

Fernando Valerio-Holguin
Colorado State University

Kyle Walker
Los Angeles, California

Christian Warns
Friedrich Schiller University of Jena

Florian Weber
German National Academic Foundation

Wolfgang Weigand
Friedrich Schiller University of Jena

Patricia West
American University

Quentin D. Wheeler
Arizona State University

Greg Whitlock
Parkland College

Mat T. Wilson
Montgomery County Memorial Library System

Marc Wittmann
University of California, San Diego

Patrick J. Wojcieson
Buffalo, New York

Dan Zakay
Tel-Aviv University

Zhiming Zhao
State University of New York at Geneseo

Introduction

What is time? Did it have a beginning? Will it ever end? These are profound questions that have been asked by serious thinkers over the centuries, from early speculations among the ancient Greeks to the startling discoveries in the modern sciences. Both philosophers and theologians have offered dynamic worldviews to accommodate new facts and ideas about time and change. Because of its elusiveness, time still challenges those individuals who strive to understand and appreciate the flux of reality and the pervasive influence of time on all objects and events within it (including our own species). Perspectives on time range from subatomic particles to cosmic evolution. Temporal changes may encompass merely attoseconds or billions of years. Remarkable advances in technology, particularly in telescopes and microscopes, along with rapid improvements in computers, have greatly increased our scientific knowledge of this universe in general and our planet in particular. The history of life on Earth stretches back about 4 billion years, while human culture began less than 3 million years ago. Even so, this expanding cosmos is expected to endure for billions of years into the future. And, no doubt, human views about time will change over the coming centuries if our species survives.

This encyclopedia surveys those major facts, concepts, theories, and speculations that infuse our present comprehension of time. Its inclusive orientation recognizes the contributions of not only scientists and philosophers, but also theologians and creative artists from various fields. Especially significant are the temporal frameworks that were offered by Charles Darwin (1809–1882) and Albert Einstein (1879–1955). To grasp the modern awareness and appreciation of time requires that an individual embrace both evolutionary biology and relativity physics. The awesome perspective of cosmic evolution now includes such incredible objects as quasars, pulsars, and black holes. The human mind struggles to glimpse an evolving universe with billions of galaxies, each with billions of stars. When looking beyond our planet into outer space, one actually sees this universe as it existed millions of years ago; as such, one is gazing back into time. Furthermore, when one digs deep into the earth, one is also going back into time: Rocks, fossils, and artifacts are the remains of evolutionary time.

Ideas and Perspectives

The ancient Greeks pondered time and change. Of special importance was the idea from Heraclitus that this cosmos is endlessly changing, manifesting ongoing cyclical patterns. Later, Plato and Aristotle interpreted this universe in terms of geometry and biology, respectively. A philosophical dispute emerged as to whether reality is a static being in which change is an imperfection or an illusion, or an eternal becoming in which permanence is an illusion. Since antiquity, ingenious attempts have been made to synthesize change and fixity in a worldview that does justice to both. Such attempts are found in the cyclical cosmologies of Eastern philosophies.

With the coming of Christianity, religious thinkers attempted to reconcile an eternal and perfect personal God with a temporary and imperfect material universe. Concerning time, different beliefs emerged about the divine creation of this finite cosmos and its ultimate destiny. Saint Augustine of Hippo and Saint Thomas Aquinas offered subjective and objective views of time, respectively. For both, the origin of this universe was held to be an event that occurred only several thousand years ago. This created cosmos had the earth at its center and the human being occupying a special place in static nature. The end of time was held to be in the near future. Until the emergence of modern astronomy and physics, earlier believers could never have imagined either the vast age of this universe or the complex history of life forms on our planet.

During the Italian Renaissance, the artistic genius Leonardo da Vinci (1452–1519) reflected on the marine fossils he discovered in rock strata while walking in the Swiss Alps. He reasoned that these fossils were the remains of once-living organisms in the remote past; natural forces had elevated the fossil-rich sedimentary layers of the Mediterranean Sea over thousands of years. In fact, at a time when the common consensus maintained that this universe was created only a few thousand years ago, Leonardo's dynamic view of earth history held that our planet is at least 200,000 years old. Furthermore, his cosmology held the universe to be eternal, infinite, and filled with other planets. Taking change seriously, Leonardo claimed time to be the evil destroyer of everything. Speculating on the end of the earth, he foresaw a future catastrophic event in which fire would destroy all living things on the planet (including our species).

At the end of the Italian Renaissance, the monk Giordano Bruno (1548–1600) challenged the entrenched Aristotelian philosophy and Thomistic theology that dominated Western thought. Using his critical intellect and remarkable imagination, he envisioned an eternal and infinite universe with an endless number of stars and planets. His cosmology also included other inhabited worlds with intelligent beings. Consequently, Bruno's bold interpretation of this universe paved the way for new ideas about time and change. It may be argued that he ushered in the modern cosmology, which is free from geocentrism, anthropocentrism, and a fixed ceiling of stars. His worldview even anticipated the relativity framework in modern physics.

With the Age of Enlightenment, natural philosophers stressed the value of science and reason. Rejecting earlier beliefs and opinions, they emphasized critical thought and open inquiry. For them, history was a progressive process, and scientific advances promised freedom from dogmatism and superstition. These enlightened thinkers established an intellectual atmosphere that was crucial for paving the way for the emergence of the social sciences, including anthropology and psychology. The new social sciences would supplement the established natural sciences. Extolling the value of individuals, the academic stage was now set for exceptional naturalists and philosophers to make substantial contributions to understanding and appreciating both cosmic time and earth history.

At the end of the Enlightenment, long before nanotechnology and genetic engineering, the visionary philosopher Marquis de Condorcet (1743–1794) foresaw ongoing advances in the natural sciences resulting in future human beings enjoying an indefinite life span.

At the beginning of the 19th century, naturalists began to take the study of rocks, fossils, and artifacts seriously. Their investigations challenged the traditional ideas concerning the age of our earth, the fixity of species, and the recent appearance of the human animal on our planet. Historical geology, comparative paleontology, and prehistoric archaeology became distinct sciences that together offered an incredibly vast temporal framework. Over the decades, the accumulation of empirical evidence clearly demonstrated the enormous age of our earth, the evolution of species over eons of time, and the great antiquity of the human animal. Throughout geologic time, the fossil record even revealed that many past species had become extinct. Nature was no longer perceived as manifesting a divinely preestablished design; the alleged fixed order of our planet was now replaced by pervasive and ongoing change. Earth time was now recorded in the millions of years, and the origin of this universe had occurred in a remote past lost in the immensity of cosmic time.

During the recent past, four great thinkers had the luxury of time for reflection: Charles Darwin, Albert Einstein, Alfred North Whitehead, and Pierre Teilhard de Chardin. Each contributed original and lasting insights into the nature of time in terms of evolution, relativity, or a process worldview grounded in philosophy or theology.

The Evolution Framework

A major contribution to recognizing the significance of time came with Charles Darwin's scientific theory of organic evolution. The brilliant naturalist had synthesized facts and concepts from various disciplines (especially geology, paleontology, and biology) into a new interpretation of life on earth in terms of continuous change. The indisputable facts demonstrated the mutability of all species; plant and animal types had evolved over vast periods of time. This paradigm shift from fixity to change turned the Aristotelian/Thomistic worldview upside down. The evolutionary perspective alarmed philosophers and theologians, as well as naturalists; in fact, the rise of natural philosophy challenged natural theology. One could no longer view this planet, life forms, or our species in terms of permanence. Time took on a new meaning and significance for those who replaced the biblical story of creation with the Darwinian theory of evolution. Furthermore, biological evolution opened up new areas for scientific research, particularly concerning the mechanisms of inheritance. With the discovery of the DNA molecule in 1953, genetic information supplemented the fossil record in substantiating the evolutionary history and organic unity of life forms on our planet.

However, one must distinguish between the factual theory of organic evolution and those various interpretations of this process that appear in the philosophical literature. Interpretations of evolution range from materialism and vitalism to spiritualism and mysticism. Even so, these dynamic worldviews take both time and change seriously. It is not surprising that some philosophers extended their interest in evolution to include the history of this universe. Herbert Spencer wrote about a cyclical cosmos, Friedrich Nietzsche taught the eternal recurrence of this same universe, and Henri Bergson claimed that time itself is the metaphysical essence of creative evolution. In the 20th century, an inevitable conflict emerged between those biblical fundamentalists who clung to a strict and literal interpretation of Creation as presented in Genesis and the scientific evolutionists who accepted the new temporal framework that is clearly upheld by the empirical evidence in geology, paleontology, and biology, as well as the results from radiometric dating techniques. In fact, this conflict between traditional religion and modern science continues today and shows no sign of ending in the foreseeable future.

The Relativity Framework

With more sophisticated telescopes and computers, astronomers discovered that our universe has been expanding and evolving over billions of years, with countless galaxies forming and dying over incredible periods of time. Furthermore, some scientists have speculated that there has been sufficient time for organisms, including intelligent beings, to emerge on other worlds elsewhere in this cosmos. On the subatomic level of reality, particles appear and disappear instantaneously; it has even been argued that some subatomic particles may actually travel backwards in time. Obviously, this modern perspective is far removed from the Aristotelian/Thomistic worldview.

After the beginning of the 20th century, the genius Albert Einstein presented to the intellectual world his special and general theories of relativity. The physicist challenged the basic ideas of Galileo Galilei and Isaac Newton by denying that space and time are independent absolutes and, instead, maintaining that they constitute a space-time continuum in a four-dimensional reality (with time being the fourth dimension). Moreover, for Einstein, there is no fixed frame of reference in this universe from which absolute judgments may be made concerning time and motion; his only fixed constant is the speed of light. His new interpretation of this universe had startling ramifications for comprehending the four cosmic forces (especially gravity) and those consequences that result as the velocity of an object approaches the speed of light. With the probability of dark matter, dark energy, and wormholes existing in this universe, our cosmos is far stranger than the ancient thinkers could have imagined and far more complex for human beings to grasp now than it was a mere century ago. In fact, the more scientists explore this universe, the older and larger and more peculiar they find it to be.

Dynamic Worldviews

With a greater awareness of time came thinkers who speculated on the distant future of our species and this universe. The visions of Joseph Ernest Renan (1823–1892) and Miguel de Unamunoy Jugo (1864–1936) offered an interpretation of reality that saw the end of this universe in terms of a distinct cosmic entity analogous to a single human being. However, ongoing advances in astronomy and cosmology revealed an expanding universe with a size far beyond the imagination of most 19th-century thinkers. As such, human-centered worldviews in natural philosophy and process theology were now regarded with suspicion by many scientists. Even so, two impressive attempts were made to give our species an important role in evolving reality.

To accommodate relativity physics to a dynamic view of this universe, philosopher Alfred North Whitehead (1861–1947) offered a process cosmology that emphasized pervasive creativity from epoch to epoch. For him, endless reality is the manifestation of interrelated and ongoing events, with these events forming inorganic, organic, and reflecting societies. The realm of events or actual occasions reflects structures or eternal objects throughout the everlasting advance of this cosmic continuum. Whitehead envisioned no final end or ultimate goal for cosmic time. His worldview is a form of panentheism; both God and nature are involved in the continuous process of creating novelty throughout eternal reality.

To accommodate natural theology to cosmic evolution, the Jesuit priest and geopaleontologist Pierre Teilhard de Chardin (1881–1955) interpreted our dynamic universe in such a way as to argue for the uniqueness of both this earth in general and our species in particular. However, his cosmology is actually a planetology. Over vast periods of time, directional evolution (as he saw it) passed from inorganic, through organic, to human stages of development, thereby forming three distinct layers: the geosphere, biosphere, and noosphere, respectively. For Teilhard, the arrow of time is now preparing our earth for the spiritual Omega Point, the planetary end of time for human evolution in the distant future. He believed that a personal God is both the first and the final cause of reality, with evolutionary time unfolding between the beginning and the completion of cosmic existence. It is not surprising that Teilhard was silenced for his acceptance of evolutionary time. His bold ideas, grounded in a scientific framework but mystical orientation, were far removed from natural theology and traditional belief.

The Human Factor

Following geology and paleontology, the emerging discipline of anthropology embraced the evolutionary framework and extended this theory to account for the origin and history of our own species. The human animal was placed within the primate order, because it shared many obvious biological similarities with the apes and monkeys. As the search for hominid fossils continued during the 20th century, major discoveries were made in the eastern hemisphere. In time, empirical evidence favored Africa as the birthplace of the earliest hominids, and the evolution of our species was seen to have taken place over 2 million years. Today, both fossils and the DNA molecule substantiate the concept of human evolution. Furthermore, accumulating archaeological evidence, ranging from stone implements and burial sites to bone carvings and cave murals, offers an ever-clearer picture of prehistoric sociocultural evolution. Like species, past societies with their cultures have emerged and thrived, only to vanish. Of special interest for modern anthropologists is the origin of symbolic language as articulate speech. Some linguists speculate that the evolution of speech may have had its beginning in the hominids of Africa over 1 million years ago.

The evolution of the human brain has given our species a superior intellect with a capacity for reasoning, memory, and creativity. With the coming of civilization, group behavior accelerated cultural evolution. The emergence of consciousness is mirrored in the rapid flowering of material culture. One intriguing area of modern research involves investigating the evolutionary relationship between morality and the brain. If future space travel takes human beings to other planets and even beyond, then our species would still carry within it the genetic information linking it to the apes of today.

The engaging motion picture *2001: A Space Odyssey* (1968) depicts evolution from past fossil apes, through our species, to a future starchild. Within its cosmic perspective, this film includes superior beings that exist elsewhere in the universe. If humans ever make contact with such possible creatures, then one wonders what information they would communicate to us about the nature of time beyond our present comprehension of it.

A quintessential example of an artwork that focuses on time is Richard Wagner's epic tetralogy *Der Ring des Nibelungen* (1876), with its changing characters and altering events unfolding within a dynamic cosmology of pervasive symbolism and mythic significance.

Other artists have also attempted to portray the fluidity of time. One recalls the ingenious paintings of Salvador Dalí, for example, *The Persistence of Memory* and *The Discovery of America by Christopher Columbus*. Novels focusing on historical eras include Gustave Flaubert's *The Temptation of Saint Anthony* (1874) and Henryk Sienkiewicz's *Quo Vadis* (1896). Likewise, major authors have dealt with the stream of consciousness. Such insightful novels include James Joyce's *Ulysses* (1922), Thomas Mann's *The Magic Mountain* (1924), and Marcel Proust's *Remembrance of Things Past* (1913–1927). Yet, despite centuries of human inquiry, time itself still eludes scientists, philosophers, and theologians.

We are constantly aware of time. Tides, erosion, lunar phases, solar eclipses, returning comets, recurring seasons, and alternating days and nights illustrate for us that this universe is always changing. The birth, development, and death of organisms are a sobering reminder of the finitude of life forms on our planet. With such awesome and disturbing examples of time and change, it is not surprising that great minds have attempted to grasp the flux of reality. Even measuring time and change to ever-greater degrees of certainty is an ongoing challenge to modern science and technology.

* * *

I first became fascinated with time as a youngster impressed with dinosaurs and stars. In high school, I learned about the theory of evolution that linked these two interests within a cosmic continuum that also includes humankind. Later, university studies introduced me to the academic disciplines of anthropology and philosophy. As years passed, I found it increasingly difficult to comprehend how anyone could doubt the fact of evolution in light of overwhelming empirical evidence, from fossils to genes. Of course, the acceptance of our changing universe requires using a disciplined imagination that is open to the astonishing sweep of cosmic time. It is a humbling moment, indeed, when one first realizes the insignificance of our species against the awesome background of an incomprehensible universe that is utterly indifferent to human existence. Yet, the very fact that one may ponder the age of stars and evolving life forms gives meaning and purpose to our consciousness, no matter how ephemeral it may be.

My own extensive travels and academic interests have taken me to numerous sites where the brute reality of objective time expresses itself in no uncertain terms. Relevant experiences have included my discovering *Allosaurus* in Wyoming, exploring the unique Galapagos Islands, searching for fossil hominids at Koobi Fora, admiring the enigmatic Sphinx of Giza, and visiting the Inca ruins of Machu Picchu in the ancient Andes (to name only five). Such glimpses of pervasive change remind us of our own fleeting existence. It is hoped that the *Encyclopedia of Time* will contribute, to its readers, a greater understanding of and deeper appreciation for the elusive phenomenon experienced as time.

Further Readings

Alexander, S. (2005). *Space, time, and deity.* Boston: Adamant Media.

Aydon, C. (2002). *Charles Darwin.* Philadelphia: Running Press.

Barbour, J. (1999). *The end of time: The next revolution in physics.* Oxford, UK: Oxford University Press.

Barrow, J. D. (2005). *The infinite book: A short guide to the boundless, timeless, and endless.* New York: Random House/Vintage Books.

Bergson, H. (2007). *Creative evolution* (K. A. Pearson, M. Kolkman, & M. Vaughan, Eds.). New York: Palgrave Macmillan. (Original work published 1907)

Birx, H. J. (1984). *Theories of evolution.* Springfield, IL: Charles C Thomas.

Birx, H. J. (1991). *Interpreting evolution: Darwin & Teilhard de Chardin.* Amherst, NY: Prometheus Books.

Birx, H. J. (Ed.). (2006). *Encyclopedia of anthropology* (5 vols.). Thousand Oaks, CA: Sage.

Blackwell, R. J., & DeLucca, R. (Eds.). (1998). *Giordano Bruno: Cause, principle and unity.* Cambridge, UK: Cambridge University Press.

Condorcet, M. de. (1980). S*ketch for a historical picture of the progress of the human mind*. New York: Hyperion Press. (Original work published 1795)

Darwin, C. (1991). *The origin of species by means of natural selection.* Amherst, NY: Prometheus Books. (Original work published 1859)

Darwin, C. (1998). *The descent of man.* Amherst, NY: Prometheus Books. (Original work published 1871)

Davies, P. (1995). *About time: Einstein's unfinished revolution*. New York: Simon & Schuster/Touchstone.

Diamond, J. (2005). *Collapse: How societies choose to fail or survive*. New York: Viking Books.

Dupré, J. (2003). *Darwin's legacy: What evolution means today.* Oxford, UK: Oxford University Press.

Einstein, A. (1961). *Relativity: The special and the general theory* (R. W. Lawson, Trans.). New York: Random House/Three Rivers Press.

Eliade, M. (2005). *The myth of the eternal return: Cosmos and history*. (W. R. Trask, Trans.). Princeton, NJ: Princeton University Press.

Fortey, R. (1999). *Life: A natural history of the first four billion years of life on earth*. New York: Vintage Books.

Gorst, M. (2002). *Measuring eternity: The search for the beginning of time*. New York: Random House/ Broadway Books.

Gott, J. R., III. (2001). *Time travel in Einstein's universe: The physical possibilities of travel through time*. New York: Houghton Mifflin/Mariner.

Greene, B. (2004). *The fabric of the cosmos: Space, time, and the texture of reality.* New York: Random House/ Vintage Books.

Guthrie, W. K. C. (1968). *The Greek philosophers: From Thales to Aristotle*. New York: Routledge.

Harris, J. (2007). *Enhancing evolution: The ethical case for making better people*. Princeton, NJ: Princeton University Press.

Hatab, L. J. (Ed.). (2005). *Nietzsche's life sentence: Coming to terms with eternal recurrence*. London: Routledge.

Hawking, S. W. (2007). *The theory of everything: The origin and fate of the universe*. Beverly Hills, CA: Phoenix Books.

Hawking, S. W., & Mlodinow, L. (2005). *A briefer history of time*. New York: Random House/Bantam Books.

Heraclitus. (1981). *The art and thought of Heraclitus* (C. H. Kahn, Ed.). Cambridge, UK: Cambridge University Press. (Original work c. 6th century BCE)

Isaacson, W. (2007). *Einstein: His life and universe*. New York: Simon & Schuster.

Kaku, M. (2005). *Parallel worlds: A journey through creation, higher dimensions, and the future of the cosmos*. New York: Random House/Anchor Books.

Kragh, H. (1996). *Cosmology and controversy: The historical development of two theories of the universe*. Princeton, NJ: Princeton University Press.

Le Poidevin, R. (2003). *Travels in four dimensions: The enigmas of space and time*. Oxford, UK: Oxford University Press.

Lewis, W. (1993). *Time and Western man* (P. Edwards, Ed.). Santa Rosa, CA: Black Sparrow Press. (Original work published 1927)

Löwith, K. (1997). *Nietzsche's philosophy of the eternal recurrence of the same*. Berkeley: University of California Press.

Novikov, I. D. (1998). *The river of time* (V. Kisim, Trans.). Cambridge, UK: Cambridge University Press.

Palmer, D. (2005). *Earth time: Exploring the deep past from Victorian England to the Grand Canyon*. Hoboken, NJ: Wiley.

Pinker, S. (2007). *The stuff of thought: Language is a window into human nature*. New York: Viking Press.

Price, H. (1996). *Time's arrow and Archimedes' point: New directions for the physics of time*. Oxford, UK: Oxford University Press.

Primack, J. R., & Abrams, N. E. (2006). *The view from the center of the universe: Discovering our extraordinary place in the cosmos*. New York: Penguin/Riverhead.

Rachels, J. (l999). *Created from animals: The moral implications of Darwinism*. Oxford, UK: Oxford University Press.

Ridderbos, K. (Ed.). (2002). *Time*. Cambridge, UK: Cambridge University Press.

Sawyer, G. J., & Deak, V. (2007). *The last man: A guide to twenty-two species of extinct humans*. New Haven, CT: Yale University Press.

Singh, S. (2004). *Big bang: The origin of the universe*. New York: HarperPerennial.

Smoot, G., & Davidson, K. (2007). *Wrinkles in time: Witness to the birth of the universe*. New York: HarperPerennial.

Sober, E. (2008). *Evidence and evolution: The logic behind the science*. Cambridge, UK: Cambridge University Press.

Stenger, V. J. (2007). *God: The failed hypothesis*. Amherst, NY: Prometheus Books.

Teilhard de Chardin, P. (1975). *The phenomenon of man* (B. Wall, Trans.). New York: HarperCollins/ HarperPerennial. (Original work published 1955)

Vilenkin, A. (2006). *Many worlds in one: The search for other universes*. New York: Hill and Wang.

Watson, J. D., & Berry, C. (2003). *DNA: The secret of life*. New York: Knopf.

Wells, H. G. (1995). *The conquest of time.* Amherst, New York: Prometheus Books. (Original work published 1942)

Wells, S. (2002). *The journey of man: A genetic odyssey.* Princeton, NJ: Princeton University Press.

Whitehead, A. N. (1979). *Process and reality.* New York: Simon & Schuster/Free Press. (Original work published 1929)

Yourgrau, P. (2004). *A world without time: The forgotten legacy of Gödel and Einstein*. New York: Basic Books.

Acknowledgments

At Sage Reference, I was particularly fortunate to have the confidence and support of Rolf A. Janke, vice president and publisher. His vision and commitment to this project were essential for its advancement and fulfillment. Likewise, as its development editor, Sanford Robinson gave meticulous attention to the content and relevance of the entries and provided ongoing enthusiasm for this comprehensive and unique work. The excellent preparation of this *Encyclopedia of Time* would not have been possible without his steadfast interest and exceptional skill.

The production of this multidisciplinary encyclopedia benefited substantially from the diligent concern for all details given by production editor Kate Schroeder and copy editors Kristin Bergstad, Colleen Brennan, and Cate Huisman. I am deeply indebted to them for their dedicated and invaluable assistance.

Also at Sage, I am very grateful to Ravi Balasuriya for his outstanding artistic contributions.

Furthermore, I am especially indebted to Sylvia S. Bigler, whose persistent focus on all facets of preparing the entries for publication was an enormous benefit. This encyclopedia would not have been possible without her professional administrative assistance throughout the whole project.

The range and depth of the subjects covered in the *Encyclopedia of Time* clearly attest to the ongoing interest in and significance of investigating the concept of time from multiple perspectives. It is a heartfelt pleasure for me to acknowledge the contributing authors for their scholarly entries. The following writers were particularly helpful in providing numerous entries or essential contributions for this work: Stefan Artmann, Clemens M. Beckstein, Robert Bollt, James Pleger Bonanno, Patricia N. Chrosniak, Jill M. Church, Suzanne E. D'Amato, Terry Wayne Eddinger, Michael Joseph Francisconi, Betty Anne Gard, John K. Grandy, John R. Grehan, Helmut Hetznecker, Pamela Rae Huteson, Debra M. Lucas, David Alexander Lukaszek, Gerald L. Mattingly, James V. Morey, Ralph Neuhaeuser, Neil Patrick O'Donnell, Donald R. Perry, Debika Saha, Hans Otto Seitschek, Stefan Lorenz Sorgner, Victor J. Stenger, Mark James Thompson, Jacek Stanislaw Tomczyk, Greg Whitlock, and Patrick J. Wojcieson.

Over the years, these individuals have been indispensable in offering encouragement and providing inspiration: Christopher C. Dahl, Linda A. Dinsdale, Marvin Farber, Edward G. Garwol III, Shirley A. Garwol, Debra G. Hill, Claudia A. Hoffman, Albertha F. Kelley, Rose M. Malone, Dianne Marie Murphy, Sophie Annerose Naumann, Joseph F. Rizzo, and the Reverend Edmund G. Ryan.

For their ongoing loyalty during the preparation of this three-volume work, I am most appreciative to Sylvia S. Bigler, Pat Bobrowski, David Alexander Lukaszek, and Stefan Lorenz Sorgner. They enlivened the time I spent on this project.

H. James Birx
Professor of Anthropology, Canisius College
Distinguished Research Scholar,
State University of New York at Geneseo
Scientific Advisory Board,
Friedrich Schiller University of Jena
Scientific Board, Nietzsche-Forum Munich
Research Associate, Buffalo Museum of Science

A

Abelard, Peter (1079–1142)

Peter Abelard (Petrus Abaelardus), the most famous intellectual of the 12th century, addresses the problem of time especially in the context of his reevaluation of Aristotelian logic, which he knew from the *Categories* and *De interpretatione*. Although in his *Dialectica* (c. 1117), Abelard still follows the realist approach of many of his contemporaries, in his *Logica Ingredientibus* (c. 1119) he moves toward an ontologically more parsimonious position. According to him, time has to be understood as "a quantity according to the permanence of which we measure the existence of all things, when we show something to be, to have been or to come into being at a certain existing time (*quaedam quantitas* [. . .] *secundum permanentiam cuius rerum quarumcumque dimetimur existentiam, cum monstramus esse aliquid, fuisse vel fore tempore aliquo existente*)."

Abelard contradicts the suggestion that everything has its own time, while arguing for one single time which is suited to measure everything, including itself. This time pertains to the whole world and can be predicated on every element within it. It is indivisible, insofar as in all the different elements of the world there is one time, as there is one unity in the human body or in the whole world with its different elements. On the other hand, Abelard denies the objective reality of a "composite" time, that is, of time insofar as it consists of successive elements such as hours, days, years, and so on. These time elements are only constructions of the human mind which constitutes the presence of every span of time that is conceived by a human being. In reality, though, there is only one simple, indivisible flux of subsequent, inseparable instants. Consequently, one can speak of a composite time and its parts "according to the imposition of names, not according to the existence of things (*secundum nominum appellationem, non secundum rerum essentiam*)."

The problem of time and eternity plays only a minor role in Abelard's thought. He states only that time can be regarded as a part of "eternity," because time, which began to exist together with the Creation, covers only a small stretch of that totality, which can be called the eternity of God's existence (Abelard's starting point here is the same quotation of Cicero that his contemporary, William of Conches, uses for his third definition of time). In Abelard's later works on theology, however, one can find in his linguistic remarks some kind of a *via negativa* theology of time: Humans are not able to speak directly about God, because human language consists of sentences that contain verbs. Verbs, however, always designate a change, which falls within the realm of time. Thus the human language is absolutely not suited for speaking about God, and consequently theologists have to invent analogies (*similitudes*) to describe God's peculiar nature.

The problem of time and eternity is also in the background of Abelard's discussion about the foreknowledge of God and human freedom: To God, every instant of time is present such that he knows what will be happening according to human free will, but this does not mean that human freedom does not exist.

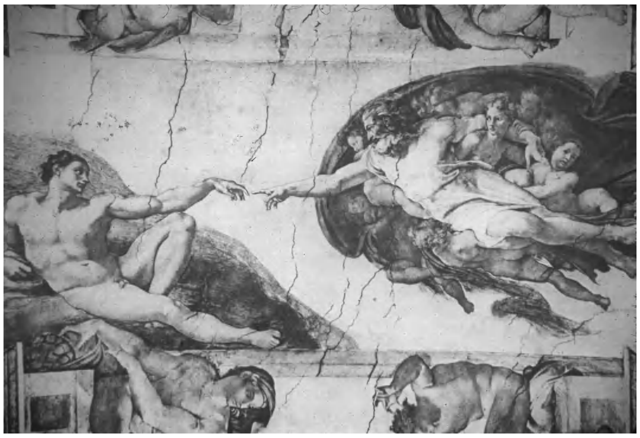
Abelard's theory of time represents, in a typical contrast with that of the Platonist William of Conches, one of the first approaches of a philosopher of language to the problem of time, which results in a skeptic stance toward superfluous ontological assumptions.

Matthias Perkams

See also Eternity; God and Time; God as Creator; Time, Subjective Flow of; William of Conches

Further Readings

Marenbon, J. (1997). *The philosophy of Peter Abelard*. Cambridge, UK: Cambridge University Press.



This detail of the ceiling of the Sistine Chapel in Vatican City shows The Creation of Adam, *a panel in the massive narrative work by Italian artist Michelangelo Buonarroti, completed between 1508 and 1512.*

Source: Getty Images.

ADAM, CREATION OF

Throughout history many explanations have been given about the creation of the human species. The monotheistic Abrahamic traditions—Judaism, Christianity, and Islam—believe in the Creation story of Adam. This account is found in the Book of Genesis, the first book of the Torah, which comprises the first five books of the Hebrew Bible (for Christians, the Old Testament). The word *genesis* in Latin means birth, creation, or beginning. According to the Book of Genesis, God created the entire world in 6 days. On the 6th day he made in his own image Adam, the first man, out of dust from the ground. He was given dominion over all things on earth, both great and small. God then decided that Adam should not be alone, and from his side created Eve, the first woman. God told them to be fruitful and multiply, and all of humankind descends from their union.

All of the Abrahamic faiths are proponents of creation ex nihilo (out of nothing). This is the belief that nothing in the universe but God and the heavens existed before the Creation. However, each faith emphasizes different aspects of the story. There are two versions of the Creation story offered in Genesis. This dichotomy seems to stem from the fact that the Books of the Torah are compiled from various ancient stories and not written by one author. The first chapter is known as the "P" or Priestly version and was written in about 715–687 BCE. The second chapter is the "J" or JHWH version, from the Hebrew word for God, written between 922 and 722 BCE. This explains why Genesis 1 and 2 offer two similar but slightly different accounts of the same event and why the language used does not always match up.

The J story describes the Creation of man simply. "And Yahweh God formed man from the dust of the ground and breathed into his nostrils the breath of life, and man became a living being" (Gen 2:7, Revised Standard Version).

In the P version it is written, "Then God said, Let us make man in our image. So God created man in his own image, in the image of God he created him; male and female he created them" (Gen 1:26–27). The language of this passage has caused debate among scholars and theologians. First, the use of the plural tense when describing the creation implies that more than one man was made. Second, it says "male and female," implying that men and women were made at the same time.

Some believe that man was made to be, like God, a hermaphrodite (God having no gender). Then God decided it was not good for this human to be alone and thus removed a piece of it, leaving two separate parts, male and female. There are Jewish scholars who bring these two stories together by emphasizing the passage in the J version, "Therefore, a man shall leave his father and his mother, and shall cleave to his wife and they shall become one flesh" (Gen 2:24). This language suggests that man and woman were once one and need to be together as partners to be whole again.

The origin of the name Adam is also a topic of discussion. There are two popular explanations. In the Sybilline Oracles, verses composed from the 2nd century BCE to the 5th century CE, it is said that the name is an acronym for the four directions in Greek: *anatole* (east), *dusis* (west), *arktos* (north), and *mesembria* (south). A 2nd-century (CE) rabbi put forth the idea that the name comes from the words *afer, dam,* and *marah,* Hebrew for dust, blood, and gall.

Most branches of Christianity accept the version of Creation in Genesis. There is debate as to whether the text should be taken literally or figuratively. Some Christians join together the ideas of modern science with the biblical account—for example, saying the Creation happened as described but over billions of years, thus supporting geological evidence. However, strict biblical proponents believe Creation actually occurred in six 24-hour days and that the earth is only a few thousand years old. The Christian belief in original sin also derives from this story. Christians believe that at Creation humans were infallible but that through their own weaknesses evil came into the world. "Wherefore, as by one man sin entered into the world, and death by sin; and so death passed upon all men, for that all have sinned" (Rom 5:12).

The Islamic tradition states that Adam was created from mud from all over the earth and that is why there is such diversity in humans' physical appearances. The story in the Qur'an claims that after God made man, he was inanimate for 40 days and then sprang to life. Muslims agree that Adam was given power over all other things. Because God spoke to him directly, he is also considered a prophet of the Muslim faith.

Many theologians consider Adam and Eve to be analogies for all people who challenge God. Their story of banishment is a stark warning for people of faith. However, others view them as real people from history. The Book of Genesis contains a genealogy of their descendants, who include historic kings and leaders of the ancient world. Early European Christians interpreted the Bible as being historical fact, and early scientists even calculated the time of their creation to be approximately 4000 BCE.

Modern archaeological finds have aged the earth closer to 4.5 billion years and disputed the concept that all things on earth were created at the same time. The classical theory of evolution denies the creation of man directly by God and suggests a slow progression of life from simple one-celled organisms to complex life forms like human beings. The study of genetics suggests that if the population of a species is ever only two, the species would inevitably become extinct. But the Bible's description of Adam and Eve's old age at death, nearly 900 years, suggests a way in which two could have created enough offspring to perpetuate the species.

Jessica Masciello

See also Bible and Time; Christianity; Creationism; Genesis, Book of; Islam; Michelangelo Buonarroti; Time, Sacred

Further Readings

Filby, F. A. (1964). *Creation revealed: A study of Genesis chapter one, in light of modern science.* London: Pickering & Inglis.

von Franz, L. M. (1995). *Creation myths.* London: Shambhala.

Afterlife

Many people believe that some aspect of the self continues to exist after death. Throughout history most religions and philosophies have offered a rationale for, and description of, life after death to encourage adherence to their codes of belief and conduct.

Theorists view the relationship between the afterlife and time in various ways. Some view the afterlife as a timeless state of existence after death or after the end of the world. Others view it as a state of never-ending time. Still others view it as the cyclical repetition of incarnation in various forms.

Early Egyptian writings describe the king's ascent to the sky where he becomes a star and is admitted into the company of the gods. Later the promise of immortality was extended beyond the Pharaoh and his family to the general population. Some Egyptian writings describe the journey of the dead in the underworld. Those who pass the tests on the journey would arrive at the realms of the blessed, which are located either on earth or in heaven.

In contrast to the Egyptians, most people in the ancient Near East (including Sumerians, Assyrians, Babylonians, Canaanites, and Israelites) believed that the dead continued to exist in an underworld, which was only a gloomy reflection of their former life. The Hebrew scriptures describe the dead as "shades" (*rephaim*) who descend to Sheol, a dark and dusty pit located under the earth. Some passages speak of a hope in Yahweh's help and presence beyond death, but scholars debate whether such passages indicate a belief in either immortality or resurrection. The clearest references to the resurrection of the dead are Isaiah 26:19 and Daniel 12:2. Ecclesiastes 3:19–21 suggests the ascent of the righteous dead to heaven.

The Zoroastrian texts of Persia describe a bridge that leads over hell to paradise. The righteous pass over successfully, but the wicked fall off the bridge into hell where they suffer eternal darkness and sorrow. The good person passes through three levels of heavens to arrive at paradise ("garden" or "park"), a blissful place free of pain and suffering.

Hinduism believes in an endless cycle of death and rebirth (called *samsara*). Karma, the law of moral cause and effect, determines the future existence of the person. Through the practice of yoga, one can acquire true knowledge that the physical world, including death, is an illusion and thereby obtain *Samadhi,* the highest level of spiritual perfection. The union of *Atman* (the essential self) with *Brahman* (that which is truly real) will result in liberation (*moksa*) from samsara. Between death and rebirth, people are rewarded in heaven or punished in hell based on the nature of their deeds.

In contrast to Hinduism, Buddhism insists that death is an unavoidable fact of human existence that must be accepted. To overcome the desire for exemption from death, one should follow the Eightfold Path in order to achieve *anatman* (or *Anatta*), a state of *nirvana* or "non-self." Karma determines in which of six realms a person is reborn. Some Buddhists, however, reject the idea of reincarnation. Buddha's contemporary, Confucius, accepted the reality of death also but was agnostic regarding life after death. However, many Confucianists today believe in the reincarnation of the soul.

Early Greek thought reflects the concept of a shadowy underworld called Hades, but increasingly it was supplanted by the concept of astral immortality. Orphism and Pythagoreanism promoted an explicit concept of the immortality of the soul, and Plato (and later, Cicero) developed extensive arguments to defend this view. In contrast, Epicureans believed that the person ceases to exist at death, Aristotle was skeptical of individual immortality, and Stoics disagreed among themselves. The mystery religions offered attainment of astral immortality to all who would submit to their secret rites of initiation. Greeks and Romans generally abhorred the idea that the body would have any role in the afterlife. The Romans believed in the apotheosis (exaltation to divinity after death) of certain emperors such as Julius Caesar, Augustus, and Claudius.

Second Temple Judaism, influenced by Persian and Greek thought, developed various conceptions of the afterlife. Some writings teach the immortality of the bodiless soul, but the resurrection of the body became the more popular view. Some writings describe the righteous as transformed into stars or angels. However, they are also said to dwell on a transformed earth. Some Jewish writings divided Sheol into two compartments so that after death the righteous experience the delights of paradise and the wicked suffer the torments of hell.

In the 1st century CE, the Sadducees denied any conception of an afterlife, but their views were not widely held. The Pharisees believed in the resurrection of the body. The Jewish philosopher Philo of Alexandria argued for the preexistence and immortality of the soul. Josephus described the Essenes as believing in the immortality of the soul, but evidence from the Dead Sea Scrolls suggests that they actually believed in resurrection of the body. Apocalyptic literature often described the abodes of the blessed and the place of punishment for the condemned. Rabbinic Judaism and modern Judaism have taught an intermediate state and future resurrection of the dead, but some Jews have held more to a Platonic concept of the immortality of the soul.

Both Jesus and Paul accepted the Jewish concept of the resurrection of the body. They taught the conscious existence of the disembodied individual between death and resurrection. Later Christians claimed to find warrant in the New Testament for two other views of the intermediate state: soul-sleep and immediate resurrection. Christians believe that after the Judgment the redeemed will experience the blessings of a renewed heaven and earth, and the unredeemed will either be annihilated or consigned to a state of eternal torment. Later Christian theologians attempted to integrate the Platonic concept of immortality with belief in the resurrection of the body. Through the centuries, Christian mystics and theologians have attempted to describe the blessings of the afterlife.

According to Islam, the dead receive a foretaste of either heaven or hell while they are in the tomb. Martyrs will be admitted immediately to heaven where they receive a special reward. On the last day, the souls of all humankind will arise and be reunited with the body. After being judged according to their deeds, they will spend eternity either in the bliss of heaven or in the torments of hell.

Throughout human history, people have claimed to experience visions of the afterlife. These accounts often took the form of tours of heaven or hell. More recently, some have argued for the reality of the afterlife on the basis of the phenomenon of "near-death experiences."

Gregory Linton

See also Christianity; Dying and Death; Ecclesiastes, Book of; Eschatology; Eternity; Immortality, Personal; Judaism; Reincarnation; Zoroaster

Further Readings

Badham, P., & Badham, L. (1987). *Death and immortality in the religions of the world.* New York: Paragon House.

McDannell, C., & Lang, B. (2001). *Heaven: A history* (2nd ed.). New Haven, CT: Yale University Press.

Segal, A. F. (2004). *Life after death: A history of the afterlife in the religions of the West.* New York: Doubleday.

AGING

Aging is a physiological process of change that occurs in organisms over time. Indeed, in all cultures the aging of humans is the primary symbol for time's passing. This entry focuses on the biological theories of aging and of the way in which the aging process affects human beings.

Theories of Aging

There are many theories that attempt to explain the cellular and molecular processes involved in aging. Some evidence appears to support the assumption that the aging of a given species is programmed in some way. Monozygotic twins, for example, are much more likely to have nearly the same life span than are dizygotic twins. In laboratory settings, the maximal life span of specimens is often similar. For example, the median life span of a housefly is around 30 days and of a rat approximately 3 years. The maximum human life span is approximately 100 years, although in rare instances, individuals have lived as long as 115 years. In general it is possible to distinguish between systemic and genetic theories of aging.

Systemic theories propose that there is a systemic pacemaker for aging. One theory claims that the hypothalamus, a structure in the brain, has the function of a biological hourglass that begins to deteriorate in its hormonal output with the progress of time. This could lead to disorganization in the body's homeostasis (balance of body functions).

A second theory is that the involution of the thymus, an immune system organ responsible for the imprint of T lymphocytes (T cells), leads to lower immunity. This could lead to more malignant processes in the human body.

Third, the autoimmune theory explains aging as an autoimmune process. Following this theory the body produces different antibodies against its own structures. These autoantibodies accumulate and lead to organ failures and dysfunctions.

Genetic theories are divided between damage and programmed theories. In contrast to systemic theories, they explain aging not by focusing on the organs, which work as an hourglass, but propose that aging happens in every cell of the human organism.

Damage theories of aging explain the process of aging by the accumulation of events damaging the genetic code of a cell. Oxygen radicals, which are developed in the metabolism of the cell, are being considered as one of the main mechanisms. Oxygen radicals damage the genetic code. Evidence for the relevance of oxygen radicals is given by the fact that the content of the enzyme superoxide dismutase, which catches free oxygen radicals, is proportional to the life span of different species. Cells of mice (life span 3 years), for example, have a low content of superoxide dismutase, gorillas (life span 55 years) a much higher one, and humans have one of the highest to be found in mammals. Other mechanisms discussed are oxidation, radiation, and glycation.

Theories of programmed aging conceive of aging as a process that is in some way programmed in the genetic code. The most famous among these theories is the "length of telomere" theory. Telomeres are repetitive DNA sequences at the ends of chromosomes that stabilize the chromosomes. After every cell division, the telomere, which is about 2,000 base pairs long, is shortened by 50 base pairs. When a critical length is reached, the cell cannot divide itself any more and often dies by apoptosis (programmed death of a cell). The telomere can also be elongated by the enzyme telomerase. Cells that express telomerase are factually immortal. In mammals this enzyme can be found only in cells of the germline, in stem cells, and in more than 90% of carcinomas. In Hutchinson-Gilford syndrome (progeria) there is a genetic mutation that leads to faster shortening of the telomeres. People with this syndrome age far more rapidly than other people and die at the age of around 13 of stroke or cardiac infarction. Patients with this syndrome have atherosclerosis, osteoporosis, arthrosis, and aging of the skin, but other typical aging problems like dementia, hardness of hearing, diabetes mellitus, and cataract are missing.

This leads to the observation that no single theory of aging is sufficient to explain all phenomena that occur in aging. The process has to be multifactorial.

Aging of the Human Organism

It is possible to understand the word *aging* in two different senses. In the wider sense it deals with the whole human development; in the narrower sense it means the process of senescence, which under normal physiological conditions begins for most organs at about age 50. Death can of course occur at any phase of human development, but it occurs often the end of the described processes of aging. The physiological changes over time are the main physical characteristics of the passing of time for humans.

Three phases can be differentiated in the process of human aging. First, the embryonic phase from conception to birth; second, childhood (here understood to span the time from birth to the end of puberty); third, the time from sexual maturity to death. This differentiation is not fully sufficient if the focus lies on the organs.

The embryonic period begins with the fusion of the nuclei of sperm and ovum. After this moment the cell begins its development into a human being. After about 4 days of cell division, a trophoblast and an embryoblast are distinguishable. The first will develop to the organs of nutrition and implantation of the embryo, and the embryoblast will further differentiate itself to the fetus with functioning human organs. Between the 5th and 6th day the embryo implants in the mucosa of the uterus. The further differentiation takes place by three so-called blastoderms, which develop into the organ systems. This differentiation ends between the 8th and the 12th week of development. After this point all the organs exist, but they still have to run through a process of maturation until they are able to keep the newborn alive. Under natural conditions this point is reached around the 32nd week, although a normal pregnancy lasts 37 to 40 weeks. With intensive care it is possible for a newborn to survive from the 22nd week onward.

After birth the human development is characterized by growth and maturation of the musculoskeletal system and of most of the organs. The gonads start to grow during puberty (beginning between the 10th and 14th year); until then their size remains constant. After puberty the human skeleton usually stops growing around the 18th to 22nd year. The process of senescence begins at different times in the different organ systems. In general there is a so-called organ reserve, which is the difference between the maximal and the basal organ function. The basal organ function is sufficient to keep the organism working properly under physiological conditions. If there is a change in these conditions, the organ reserve is needed to compensate for these conditions. The cardiac output, for example, can be five times as high as the basal output. For most of the organs this organ reserve declines from the 30th life year onward.

The brain loses about 20,000 neurons per day from the 20th year on, a process finally leading to senescent atrophy of the brain. A symptom of this is a slight form of dementia, the benign senescent forgetfulness, which is physiological. Alzheimer's disease is not regarded as physiological, as it involves the development of plaques that are deposited in the neurons, and results in an abnormally high loss of neurons. In lower amounts the plaques can also be found in the normal senescent brain. The dopaminergic system in the brain also degenerates, which leads to stiffer ambulation. Parkinson's disease is another extreme form of a process of aging that can be found primarily in elderly people. In Parkinson's disease the peripheral nerves are demyelinating, meaning that their fatty covering or sheath slowly shrinks. This process leads to slower reactions. Other synthesizing activities of the brain are also deteriorating.

The endocrine system goes through different changes. In women the cyclical ovarial function terminates during menopause, usually between the 45th and 55th life year. Men, on the other hand, can have constant levels of testosterone from the 20th to 90th life year. In general the answer of organs to hormonal signals deteriorates, which may lead to illnesses. In the case of insulin, which is secreted by the pancreas, this process can lead to diabetes mellitus.

Presbycusis, with the difficulty of hearing high frequencies, is usually caused by degeneration of regions in the inner ear because of noise exposure during life. Decreased vision is most commonly a consequence of the reduced flexibility of the lenses although there are many other possible degenerations of the eye, such as in the vitreous body and the retina.

The lungs become less and less compliant, while the chest becomes stiffer and the cough reflex is reduced. These events lead to a lower level of oxygen in the blood and to an increased rate of respiratory infections.

In the cardiovascular system the arteries become stiffer because of atherosclerosis; this leads to higher blood pressure. The heart muscle fibers usually become atrophic. Atherosclerosis of the coronary arteries can lead to disturbances of perfusion, which are followed by cellular necrosis.

With aging, the function of liver, kidneys, and gut is reduced. Like all other organs, these also become atrophic as a result of cells not being replaced after their physiological death. In general there is a lower amount of total body water and a higher amount of body fat. The connective tissue of the body is progressively reduced in its flexibility from the 30th life year on. This leads to wrinkles of the skin, which may be the most obvious sign of human aging.

Markus Peuckert

See also DNA; Dying and Death; Longevity; Medicine, History of; Senescence

Further Readings

Johnson, M. L. (Ed.). (2005). *The Cambridge handbook of age and ageing.* Cambridge, UK: Cambridge University Press.

Macieira-Coelho, A. (Ed.). (2003). *Biology of aging.* New York: Springer.

Sauvain-Dugerdil, C., Leridon, H., & Mascie-Taylor, N. (Eds.). (2006). *Human clocks: The biocultural meanings of age.* New York: Peter Lang.

Albertus Magnus (c. 1200–1280)

Albertus Magnus (Albert the Great), was a Dominican priest born in Bavaria, who in his lifetime attained a reputation for immense learning. After study at the University of Bologna, he taught at several universities, including the University of Paris, where he received his doctorate and was the teacher of Saint Thomas Aquinas. His knowledge was encyclopedic, encompassing theology, philosophy, logic, astronomy, music, botany, zoology, and mineralogy.

Albert's theory of time shows those tendencies that are typical for his whole philosophical project: Aspects that are inspired from Aristotle find their place within a framework largely determined by Albert's theological and noetic interests, which echo Averroes and some Neoplatonic sources (Boethius, Pseudo-Dionysius, *Liber de causis,* Proclus's *Elements of Theology*). By integrating such very divergent streams of thought, Albert's philosophical synthesis became the point of departure for various developments in subsequent medieval thought (e.g., Saint Thomas Aquinas; the Averroists; the German Dominicans, including Meister Eckhart; Renaissance Aristotelianism; and Nicholas of Cusa).

This integration also holds true for his ideas on time, which are explained in what follows, according to Albert's systematic presentation in his "Sum of the admirable science of God" (*Summa de mirabili scientia Dei;* written after 1270). As do other Platonic thinkers (William of Conches, Nicholas of Cusa), Albert discusses time always in the horizon of eternity; even in his *Physics* commentary he adds a treatise on eternity to his explanations of Aristotle's theory of time, which is concerned mainly with movement. Albert defines eternity and time in the traditional way as duration of God or of changeable objects, respectively. The most specific definition of time is that it is "a passion of the first movement and by that the measure and number of all movements." Furthermore, Albert distinguishes from time and eternity a third form of duration, "eviternity" (*aeviternitas* or *aevum*), which "is a duration existing in the middle between time and eternity." This eviternity has a beginning (*duratio principiata*) but does not have an end; although the objects of eviternity are free from bodily changes or movements, they are subject to some succession. This is because they have, as do all created objects, a tendency toward the "nothing" (*nihil*), which means that they are not capable of receiving at one moment their whole perfection (*totum simul*). This explanation of *aevum* is a typical Christian adaptation of a Neoplatonic concept, which can be found in Proclus and Boethius.

For Albert, however, all three forms of duration are determined by the particular moments that constitute them; that is, Albert applies the Aristotelian concept of a "now" as the constitutive element of time also to eternity and eviternity. Even more important is regarding time as the distinction of an "in-which-way-it-is" (*quo est*) and a "what-it-is" (*quod est*). Albert distinguishes these two aspects, following Boethius, in any nonmaterial objects. In the case of time, both aspects can be grasped only by understanding the "now" as the fundamental unity that constitutes the flow of time.

In his commentary (1254–1257) on the third book of Aristotle's *De anima,* Albert connects these ontological speculations with the fundaments of ethics. Here, Albert presupposes an "absolute good" (*bonum simpliciter*), which he takes from the Greek words meaning "practical good" which had been translated into Latin as "actual good" (*bonum actuale*). From this absolute good, Albert distinguishes a "good for the moment" (*bonum ut nunc*), which is valid only in time, whereas the absolute good is "always good" (*bonum semper*). Whereas this eternal good is right at any place and in any respect, the "good for the moment" may be an apparent good, which is incorrectly regarded as good; this may lead human beings to false action. Thus, the Aristotelian theory of action is embedded in an ontological theory that distinguishes a temporal good and an eternal good. In this way, Albert's Neoplatonic theory of time becomes the background for his understanding of Aristotle's practical philosophy.

Matthias Perkams

See also Aquinas, Saint Thomas; Aristotle; Boethius, Anicius; Christianity; Eckhart, Meister; Ethics; Nicholas of Cusa (Cusanus); William of Conches

Further Readings

Anzulewicz, H. (2001). *Aeternitas–aevum–tempus.* The concept of time in the system of Albert the Great. In P. Porro (Ed.), *The medieval concept of time: Studies on the scholastic debate and its reception in early modern philosophy* (pp. 83–129). Boston: Brill Academic.

Steel, C. G. (2000). Dionysius and Albert on time and eternity. In T. Boiadjiev, G. Kapriev, & A. Speer (Eds.), *Die Dionysius—Rezeption im mittelalter* (pp. 317–341). Turnhout, Belgium: Brepols.

Alexander, Samuel (1859–1933)

Influenced by the Darwinian movement of the late 19th century, the philosopher Samuel Alexander developed a dynamic worldview that focused on time and emergence. He presented a comprehensive metaphysical system in his major work *Space, Time, and Deity* (1920). Alexander distinguished between spacetime or motion as the infinite whole of this universe and those finite units of spacetime or motion that fill the endless cosmos. As such, evolving reality is a complex continuum of interrelated events grounded in the psychic point-instants of spatiotemporal motions.

Alexander maintained that the dynamic universe manifests an innate creative trend that generates new emergent qualities throughout cosmic time. The resultant hierarchy of empirical levels consists of motion, matter, life, mind, and a future deity. Consequently, through time and evolution, the existence of each higher level emerges from the preceding level of reality (from the metaphysical perspective, it was time that generated spacetime).

As an emergent evolutionist, Alexander held that mind, or consciousness, emerged from and is dependent upon life, just as life emerged from and is dependent upon matter. Furthermore, matter emerged from and is dependent upon motion. This whole creative process is ultimately grounded in time, the quintessential quality of all existence. The appearance of our own species is a recent event within the spatiotemporal progress of cosmic evolution. Because the universe continues to evolve, a new quality or level of existence will emerge in the future. Presumably, emergent evolution will continue to generate empirical qualities as long as time exists. Clearly, Alexander's dynamic worldview is in sharp contrast to earlier ideas and traditional beliefs that taught the sudden and complete creation of the entire universe with all its entities fixed in nature.

In his scheme of abstract ideas, Alexander attempted to reconcile pantheism and theism in terms of emergent evolution. To do this, he made a crucial distinction between the infinite God that already exists now and the finite deity that will appear sometime in the future within the creative advance of this universe. Because God is held to be spacetime or motion, this represents the pantheistic aspect of his metaphysical system. However, in this dynamic universe, a new finite quality will emerge from the level of human consciousness. Alexander claimed that this new level of existence will be the deity. As such, deity is the next empirical quality to appear within the creative evolution of time. This is the theistic aspect of Alexander's metaphysical system. The emergent deity will be only a finite, yet the divine, quality of God as the infinite universe itself. Therefore, God is totally imminent, but the deity is transcendent in terms of the time to come; in philosophy, this position is a form of panentheism.

Samuel Alexander's metaphysical reconciliation of pantheism with theism (i.e., imminence with transcendence) clearly demonstrates how challenging the evolutionary framework was to entrenched religious beliefs and established philosophical ideas about God and time. Previous views of humankind within a world of fixed objects and recurring events needed to be replaced by a dynamic interpretation of this evolving universe and everything within it. Alexander's systematic interpretation of emerging reality was a rigorous attempt to take both time and change seriously.

H. James Birx

See also God and Time; Metaphysics; Spacetime Continuum; Teilhard de Chardin, Pierre; Unamuno y Jugo, Miguel de; Universe, Evolving; Whitehead, Alfred North

Further Readings

Alexander, S. (1939). *Philosophical and literary pieces.* London: Macmillan.

Alexander, S. (1966). *Space, time, and deity* (2 vols.). New York: Dover.

Alexander the Great (356–323 BCE)

Alexander was a Macedonian king whose extraordinary military conquests ensured him a lasting place in the annals of war and empire. Despite the brevity of his life, Alexander enjoyed a favorable locus in time; his career would be the bridge linking what historians refer to as the Hellenic and Hellenistic periods of ancient history.

Alexander the Great (*Megas Alexandros* in the vernacular), otherwise known as Alexander III, was born in Pella, Macedon, the capital of the kingdom, in 356 BCE. The exact date of his birth is uncertain but is traditionally assigned to July 20. Alexander's youth was marked by a rocky relationship with his sovereign father, Philip II of Macedon, though sources indicate Philip II was proud of his son after Alexander tamed his legendary steed, Bucephalus ("ox-head" in Greek). Alexander's mother, Olympias of Epirus, on the other hand, seems to have enjoyed a close relationship with Alexander. Speculation continues as to whether Olympias and Alexander were co-conspirators in the assassination of Philip II.

Nevertheless, both parents thought Alexander deserved the best in education, and Philip II arranged for private tutelage from the Greek philosopher Aristotle, who nursed young Alexander on rhetoric and literature, including Alexander's favorite work, Homer's *Iliad*. Alexander often likened himself to Achilles, the celebrated hero of the Trojan War, and claimed descent from the hero by way of Olympias's lineage. In fact, one of Alexander's tutors, Lysimachus, referred to Alexander as "Alexander Achilles," and referred to himself as Phoenix, the famous tutor of Achilles in the *Iliad*. From his father's line, Alexander was linked genealogically to Hercules. By extension, Alexander was therefore related to Zeus, but this idea was further cemented by Olympias, who proclaimed that it was Zeus himself who had impregnated her, leaving Alexander as the resulting offspring. Ideas of his own divine descent remained with Alexander throughout his life.

After the assassination of Philip II in 336 BCE, Alexander rose to the throne; although years earlier, in 340 BCE, Alexander had been appointed to act as sole regent in Macedon when Philip II went to attack Byzantium. Alexander quickly crushed any hopes of rebellion in his southern Greek neighbors, whom Philip II was able to bring under his control, largely due to the economic and political distress caused by the Peloponnesian War. In 334 BCE Alexander began perhaps his most famous conquest, that of the Persian Empire, held under the leadership of King Darius III.

It was during these conquests that Alexander is reported to have loosed the infamous "Gordian Knot," which, according to prophecy, was a feat to be accomplished only by the king of Asia. Whether the intricate knot was loosed by a stroke of Alexander's sword, or by his removing the pole pin to which the knot was attached, remains unsettled. Regardless, the prophecy had been fulfilled by Alexander, and so it followed that he became the next king of Asia Minor.

Relief of Alexander the Great in Thessaloniki, Greece: the King of Macedonia who conquered the Persian Empire and annexed it to Macedonia, Alexander the Great is considered one of the greatest military geniuses of all time.
Source: Yiannis Papadimitriou/iStockphoto.

Alexander had conquered much of the known world, including Phoenicia, Egypt, and Mesopotamia, and extended the boundaries of his empire to Punjab, India, the site of Alexander's epic battle against the satrap Porus, immortalized in Handel's operas, *Alessandro* and *Poro*. Along the way, Alexander had established some 70 towns and outposts, many of which bear his name, including perhaps most famously, Alexandria, Egypt. Alexander's image became commonplace in many of these towns, in the form of either plaques, busts, or statues.

Alexander's conquests were unique in that he was not as much of a destroyer as a preserver, especially regarding the traditions and the customs of the peoples he conquered. For instance, during his Persian campaigns, he adopted the custom of *proskynesis* (symbolic "kissing towards" a hand of a social superior to acknowledge rank), much to the chagrin of his Greek subjects. Proskynesis was believed to be a reservation for deities and was considered blasphemous by his Greek troops. Alexander was not yet considered a deity in their view, despite his own claim of divine descent.

On June 10, 323 BCE, Alexander met a sudden death in the palace of Nebuchadnezzar II of Babylon, which had become the cultural capital of Alexander's empire. Theories abound as to the cause; malaria, poisoning (both alcohol and other toxins, such as arsenic, have been considered), typhoid fever, and even the West Nile virus have all been named as possible culprits. The matter of the division of his empire was asked of the dying Alexander. One supposed response was the Greek word *krateroi,* an ambiguous statement that could have meant either that his empire was to be bequeathed to the "stronger" or to Craterus, one of Alexander's leading commanders of his army. Regardless of what was said, chaos ensued after Alexander's death, and wars over rightful succession were waged.

The empire was eventually divided into three new empires: the Seleucid Empire of Persia and Mesopotamia, the Antigonid Empire of Macedon and Greece, and the Ptolemaic Kingdom of Egypt (which included the land of Palestine). Though the land remained divided, it still maintained a cohesion that had been established by Alexander the Great. The new Hellenistic period had dawned upon the ancient world, and with it a profoundly Greek linguistic and cultural influence spread far and wide across the empire Alexander had created.

After Alexander's death, literature based on the life of the historic king of Macedon flourished. "Alexander romance," legends, myths, and lore surrounding the life and conquests of Alexander, continued to be written, revised, and expanded well through the Middle Ages. Even in contemporary times, Alexander continues to be represented in popular media, including cinema. One such example is Oliver Stone's 2004 film *Alexander,* which garnered both praise and controversy for its approach to the subject.

Dustin B. Hummel

See also Attila the Hun; Caesar, Gaius Julius; Genghis Khan; Peloponnesian War; Rameses II

Further Readings

Mossé, C. (2004). *Alexander: Destiny and myth* (J. Lloyd, Trans.). Baltimore, MD: Johns Hopkins University Press. (Original work published 2001)

Prevas, J. (2004). *Envy of the gods: Alexander the Great's ill-fated journey across Asia.* Cambridge, MA: Da Capo Press.

Worthington, I. (Ed.). (2003). *Alexander the Great: A reader.* London: Routledge.

Alighieri, Dante (1265–1321)

For Dante Alighieri (1265–1321), one of the greatest poets in history, earthly time was intimately related to Judeo-Christian eternity, the timeless abode of God. In his treatise *De vulgari eloquentia* (written in the early 1300s; sometimes translated as *On Eloquence in the Vernacular*), he argues that the first language was created by God and would be spoken today if humanity's presumption in building the Tower of Babel had not spurred God to fracture that pure idiom into a myriad of different forms of speech. In both the *Vita nuova* (or *New Life,* early 1290s) and his *Commedia* (*The Divine Comedy,* c. 1310–1321), Dante transforms Beatrice, with whom he had fallen in love as a boy, into an agent of divine revelation. The allegory is developed systematically in the latter work, in which Beatrice assists the Dantean pilgrim in his quest for spiritual self-understanding and redemption. Significantly, God's grace comes to the protagonist of the *Comedy* (through the mediation of Beatrice and others) *before* he explicitly asks for divine mercy: This aspect of the poem is a literary rendering of the orthodox Roman Catholic teaching Dante knew well. Also in accord with the church, the Italian poet believed that human past, present, and future are enfolded in eternity, over which God presides. It is no wonder, then, that Dante should have portrayed the fictional pilgrim version of himself in the *Comedy* as a struggling penitent for whom, nevertheless, at least the *potential* for salvation had already been worked out ahead of time.

Dante Alighieri was born in 1265 in Florence, Italy. Although not descended from the most important families in his city, he nevertheless took part in its political life, serving for 2 months in 1300 as one of its seven "priors." While he was away on a diplomatic mission to Pope Boniface VIII the following year, a rival faction took control of power and, once firmly established, banished various prominent political opponents from Florence. One of these was Dante, who wrote the *Divine Comedy* and other works in exile. He died in 1321 in Ravenna, where his remains are still located despite repeated entreaties by the Florentine civic authorities for their return. Although as a young man Dante had married Gemma Donati and had had three sons and a daughter with her, he idealized Beatrice Portinari, whom he had known when they were both children and who died in 1290. In the *Comedy,* this earthly woman attains supernatural stature: She symbolizes, among other things, divine revelation and helps to convey God's intentions for humanity to Dante directly.

Dante's view of time was heavily indebted to traditional Christian thought. He and his contemporaries believed that God dwells in eternity and that human beings, though temporarily confined within linear time, are ordained for higher, transcendent ends. Even from across the abyss between eternity and time, God, in this view, discloses his will to human beings in history rather than remaining wholly aloof from us. To be saved, we are obliged to conform our own individual wills to the divine order, though we are ultimately free to accept or reject that saving grace, as God intended.

Nevertheless, to attribute Dante's conception of time solely to his reading of the Bible, the church authorities, and medieval theology is to underestimate the complexity of his thought. The political observations scattered throughout the *Commedia* and concentrated in the *Convivio* (*The Banquet*) and the *De monarchia* (*On Monarchy*), both written probably when Dante was in his 30s, illustrate the poet's debt to the cultural traditions of ancient Greece and Rome as well, especially the latter. Many scholars have noted his use of classical authorities, particularly Virgil. In Dante's view, providential history as unfolded in the Bible and church tradition could turn to good account even the "pagan" past, whose philosophical and literary achievements had proved a source of discomfort for some medieval writers and thinkers before (and after) Dante's time.

Especially vivid manifestations of his notions of time appear in Dante's verse masterpiece, divided into the three sections or "canticles": Hell, Purgatory, and Paradise (*Inferno, Purgatorio,* and *Paradiso*). Hell is reserved for those who, while alive, indefinitely postponed repentance in order to enjoy their dissolute lives. Despite differences in the gravity of their sins and thus the harshness of their punishments, what all of the damned share is the infinite time they have in which to suffer the consequences of their spiritual negligence. On his journey through hell with his guide, the soul of Virgil, Dante confronts sinners who are usually eager to talk to him at length and so gain some respite from their torments. When he reaches purgatory, Dante sees that souls undergoing expiation there have less time for conversation, as they are eager to end their purgation and ascend to heaven. Even so, the poet Dante's abiding interest in literary influences allows for the occasional prolonged discussion, as when in the 22nd *canto* ("song" or chapter) the shades of the Roman poets Virgil and Statius talk at length about the whereabouts of other ancient writers. Digressions about poets and poetic craft are never permitted to overwhelm the larger theological import of the *Divine Comedy,* however: Even within those digressions, reference is often made to the specifically spiritual condition of the souls of those departed writers. In the *Paradiso* section of Dante's long poem, there is neither the despair found in the *Inferno* nor the sense of expectation characteristic of the *Purgatorio.* Aided by the great mystic Saint Bernard of Clairvaux, the Dantean pilgrim beholds heaven, the blessed souls therein, and images of the Trinity itself. The narrator finds himself struggling to understand this vision of timelessness and to convey it to readers bound in time. Ultimately, however, he puts his faith in God's eternal love, which, he now sees, governs the entire universe despite our inability to understand fully how he does so.

Joseph Grossi

See also Christianity; Eternity; God and Time; Last Judgment; Parousia; Poetry; Time, Sacred

Further Readings

Alighieri, D. (1961). *The divine comedy* (3 vols.; J. D. Sinclair, Trans.). New York: Oxford University Press.

Alighieri, D. (2003–2005). *The divine comedy* (3 vols.; A. Esolen, Trans.). New York: Modern Library.

Bergin, T. G. (Ed.). (1967). *From time to eternity: Essays on Dante's* Divine Comedy. New Haven, CT: Yale University Press.

Holmes, G. (1980). *Dante.* Oxford, UK: Clarendon Press.

Jacoff, R. (Ed.). (1993). *The Cambridge companion to Dante.* Cambridge, UK: Cambridge University Press.

Limentani, U. (Ed.). (1965). *The mind of Dante.* Cambridge, UK: Cambridge University Press.

Mazzotta, G. (Ed.). (1991). *Critical essays on Dante.* Boston: G. K. Hall.

Altamira Cave

Altamira Cave's recognition as the "Sistine Chapel of Quaternary Art" is well deserved, given the cave's magnificent paintings (and engravings) and importance to our understanding of similarly decorated caverns throughout Europe. Found in 1879 by an intrepid little girl who happened to stumble upon this incredible find, Altamira Cave is located in northern Spain. The cave zigzags through the ground, extending almost 300 meters in total length. The ceiling varies in height to a maximum of 12 meters and in width to 20 meters. The age of the cave is a story in and of itself. While many scholars early on doubted Altamira Cave's artwork was ancient in origin, its antiquity eventually became well established, with a large proportion of occupations of the cave occurring between 18,000 and 14,000 years before the present (BP) as determined in part through the use of carbon-14 dating of charcoal from artwork within the cave.

The paintings and engravings within Altamira Cave depict an assortment of abstract images, including a variety of animal species and miscellaneous designs. Often designed with the use of iron oxides to provide an array of colors, the images range from basic charcoal outlines to detailed color images. Designs vary from abstract images of bison, deer, stag, horses, goats, and humans to images whose identity is questionable.

Additional material discovered within Altamira Cave provides information regarding its human occupations. These miscellaneous items include a variety of lithics such as projectiles and multiuse tools as well as bone and antler tools. Other items found within Altamira Cave include the remains of multiple animal species including horse, goat, fish, and deer. Collectively, all the materials provide information regarding Paleolithic populations. However, one important question in particular remains unanswered. Why were the paintings and engravings made? Theories about the images being part of a ritual or a form of magic have circulated for years. The images have also been argued to be nothing more than art for art's sake. Ultimately, we will likely never know the answer to this question.

Altamira Cave's assemblage provides researchers with a glimpse of the activities carried out by its occupants, making Altamira a time capsule of sorts. Time is an especially important issue for Altamira Cave from one additional perspective: Time is a commodity that Altamira and other caves with Paleolithic art are running out of. The paintings within caves like Altamira have been adversely affected by changing environmental conditions partially caused by the volume of visitation these archaeological sites have received. Government agencies are now limiting visitors' access to Altamira and other caves in an attempt to preserve the art within them. Time will tell if their efforts are successful in saving these relics of the distant past.

Neil Patrick O'Donnell

See also Anthropology; Chauvet Cave; Geology; Lascaux Cave; Olduvai Gorge

Further Readings

Laiz, L., Groth, I., Gonzalez, I. , & Saiz-Jimenez, C. (1999). Microbiological study of the dripping waters in Altamira cave (Santillana del Mar, Spain). *Journal of Microbiological Methods, 36,* 129–138.

Saura Ramos, P. A. (1999). *The cave of Altamira.* New York: Abrams.

Willermet, C. (2006). Altamira cave. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (pp. 52–53). Thousand Oaks, CA: Sage.

Amnesia

Amnesia is the condition in which a loss of memory occurs and extended periods of time are forgotten. People afflicted with amnesia experience difficulty accurately estimating time, sometimes even after a recovery in which they fully regain their lost memories. Symptomatically, amnesic patients typically underestimate the time they spend engrossed in any particular activity. They also overestimate time that has passed after a certain activity ended. Even though they are coherent in their thought processes, amnesic and postamnesic patients maintain difficulties in dating past events and in constructing frameworks of time.

These amnesic memory losses may result from many organic occurrences, or medical issues like brain injury or trauma, shock, fatigue, disease, infection, or illness. They may also be triggered by addictions to drugs or alcohol. Amnesias that are not organic or associated with a detectable injury or illness are usually called psychogenic amnesias. These memory losses can be caused by suggestion under hypnosis, or they may arise spontaneously as a result of psychological conflict or stress. This may also be a defense mechanism in which a victim of amnesia represses unpleasant memories. Psychogenic memory losses are often reversible.

Organic memory disorders are the most frequently observed category of memory loss. These losses may be transitory, such as the loss of time and memory during or after binge drinking alcohol or experiencing an epileptic seizure. Memory losses that are more enduring are most often associated with brain disease or head injuries. There are three main types of organic amnesias: anterograde, retrograde, and transient global. Anterograde amnesia is the loss of memory of events or time occurring after a trauma. A patient is unable to maintain and store memories of current events or new experiences after an organic episode. Retrograde amnesia occurs when the memories occurring immediately before a trauma or disease are forgotten. Posttraumatic or traumatic amnesia are posttraumatic confusional states that can last for several hours, days, or weeks after regaining consciousness or recovering from such traumas as a blow to the head. With severe or extensive retrograde amnesia, a person afflicted can lose up to 20 years of memories prior to the trauma.

Alternately, psychogenic amnesias are not caused by physical injury or disease. The loss of personal memories, such as one's identity or past personal experiences, is a psychogenic memory loss and is most often linked to a substantial emotional occurrence, acute conflict, or significantly stressful experience.

Hysterical amnesia is sometimes motivated by a patient's need or desire to escape a traumatic or frightening event or series of events that had caused great conflict or anxiety. It is not linked to a physical condition or medical disorder. This loss is also commonly referred to as repression or motivated forgetting. Although hysterical amnesia sometimes extends to forgetting school-based knowledge, such as reading, spelling, or arithmetic, this type of memory loss is most often related to dementia or organic conditions or injuries. Repressed memories can often be recovered through psychotherapy. Memories can also be lost if a hypnotist suggests to the hypnotized patient that he or she should not remember anything from the session. Hysterical amnesia has two main types: One involves a failure to recall particular past events, and the other type involves failure to register current events.

Some amnesic episodes last for extended periods of time, during which people may begin new life patterns. They may wander away from home or work, leaving their life behind for hours, days, or weeks. When people recover from such periods, also called fugue states, they usually remember only the time previous to and occurring after this fugue state. The time and the events that occurred during the amnesic period or fugue state are entirely forgotten.

Debra Lucas

See also Consciousness; Diseases, Degenerative; Medicine, History of; Memory

Further Readings

McGaugh, J. (2003). *Memory and emotion.* New York: Columbia University Press.

Ribot, R. (1882). *Diseases of memory.* New York: Appleton-Century-Crofts.

Schacter, D. (1996). *Searching for memory: The brain, the mind and the past.* New York: Basic Books.

Terr, L. (1994). *Unchained memories: True stories of traumatic memories, lost and found.* New York: Basic Books.

Thompson, R., & Madigan, S. (2005). *Memory: The key to consciousness.* Washington, DC: Joseph Henry Press.

Anaximander (c. 610–c. 546 BCE)

Among the Presocratic philosophers, Anaximander of Miletus, a student of Thales, had neither an elaborate nor a fully articulated concept of time, but the word *chronos* (time), which emerges in the one preserved statement of his lost book, signifies a personified cosmic power. In this much-discussed and variously interpreted fragment, time is depicted as a mighty arbiter that, like a magistrate, amends injustice by determining the compensation and the retribution that things at a continuous, cosmic strife are to pay to one another. The notion of time as a judge, whose assessment no act of injustice can escape, also appears in the political and moral reflections of Solon, approximately a generation later. Generally speaking, these reflections imply that a culprit will be punished sooner or later and that time is the best judge of who and what we are.

Anaximander's time acts as a judge in the cosmic affairs in the sense that it determines when the predominance of one occurrence is to be replaced by the predominance of some other, opposite occurrence, and this process is reversible. By these phenomena he presumably understood warring opposites, like hot and cold, light and darkness, wet and dry, seasonal and mortal changes, progressive drying out of moisture by fire and vice versa.

As something that is "boundless," time fixes the boundaries of certain processes, punishing any kind of excess. Restricting the supremacy participants in a cosmic strife, Anaximander's time creates balance in the world as a unified whole. Consequently, the role of time is not only to lay down the sequence of physical occurrences but also to maintain measure and stability in nature's functioning. It is a criterion used to determine the birth, development, duration, and the limits of one occurrence in relation to another.

The shift of hot and cold, of the seasons of the year, of old age and youth as well as their mutual limitations are governed by the same periodic law. Anaximander believed that physical cycles happen in a strictly defined periodical order, which applies to both celestial and meteorological phenomena. With his notion of time as a cosmic judge that dispenses justice by imposing inevitable and immutable norms in the functioning of physical processes, Anaximander, in a way, inaugurated the concept of natural law in Western science and philosophy.

Results concerning the measurement of time are also attributed to Anaximander. He introduced in Greece the *gnomon,* an upright stick for measuring shadow lengths, which was used to give the time of the day, the position of the sun on the elliptic, and the seasons of the year.

Irina Deretic

See also Anaximines; Empedocles; Heraclitus; Presocratic Age; Thales; Xenophanes

Further Readings

Diels, H. (1952). *Die Fragmente der Vorsokratiker* (6th ed., Vols. 1–3; revised by W. Kranz). Berlin: Weidmannsche Buchhandlung. (Original work published 1903)

Jäger, W. (1967). *The theology of the early Greek philosophers.* Oxford, UK: Oxford University Press.

Kahn, C. H. (1994). *Anaximander and the origins of Greek cosmology.* New York: Hackett.

Kirk, G. S., Raven, J. E., & Schofield, M. (Eds.). (1983). *The Presocratic philosophers.* Cambridge, UK: Cambridge University Press.

Anaximines (c. 585–c. 525 BCE)

Anaximines is, after Thales and Anaximander, the third most ancient of the Greek philosophers. He belongs to the Presocratic philosophers, a range of thinkers who had little in common except their having lived before Socrates. These three philosophers hailed from Miletus, in Ionia, and are known as the Milesian school of Presocratics. Even less is known about the life of Anaximines than of his two predecessors. He was the son of Eurystrathus and is thought to have been about 25 years younger than Anaximander and to have been active around 546–545 BCE, the time Sardis was captured by Cyrus, king of Persia. He is described variously as the companion and the teacher of Anaximander. Only a few fragments of his writing have survived; his thoughts are known only from later writers who paraphrased them. He died probably between 528 and 525 BCE.

The contribution of Milesian philosophers like Anaximines was their seeing the need for finding a single source that could serve as a general explanation for the natural world. Their world abounded with supernaturalist and mythological explanations and explanations, but the Milesians had a naturalistic turn of mind. Homer attributed the origin of all things to the god Oceanus, whereas Thales taught that water was the prime element in all things. Anaximander posited instead the concept *Apeiron,* a composite of the four elements of earth, air, fire, and water. Anaximines shared with Thales in preferring a naturalistic explanation, but thought air (sometimes translated as mist) rather than water was the primal element.

Anaximines probably believed air had a better claim as the primal element than water because it had a better claim to be genuinely unlimited. And there was possibly more than a symbolic likeness to the notion of "breath," which was traditionally thought by the Greeks to be a source of life. An important fragment of Anaximines says: "As our soul, being air, holds us together, so do breath and air surround the whole universe." Even the gods sprang from the air, Anaximines was said to have believed.

The most valuable insight by Anaximines is his understanding that air can take different forms, according to the degree to which it is rarefied or condensed. When rarefied it can become fire; when condensed it becomes wind. Condensed even more, air turns into water, then earth, then stones. Before Anaximines, differences between primal elements could only be quantitative, but now they could be qualitative along a scale. This ranging of properties along a scale and attributing various qualities to them is probably the principal debt we owe to Anaximines, for that is a method of crucial importance to science.

Bill Cooke

See also Anaximander; Empedocles; Heraclitus; Presocratic Age; Thales; Xenophanes

Further Readings

Augustine. (1878). *The city of God* (M. Dods, Trans.). Edinburgh, UK: T & T Clark.

Burnet, J. (1958). *Early Greek philosophy.* London: Adam & Charles Black.

Long, A. A. (1999). *The Cambridge companion to early Greek philosophy.* Cambridge, UK: Cambridge University Press.

Wilbur, J. B., & Allen, H. J. (1979). *The worlds of the early Greek philosophers.* Amherst, NY: Prometheus.

Angels

In the Western spiritual traditions, angels are understood to be heavenly or divine beings that are greater than humans in knowledge and power, but less than deities. The word *angel* comes from the Greek word *angelos,* which means "messenger." In Hebrew, angels are called *mal'ak,* which also means "messenger." Both words are used to mean either divine or human messengers. Only in Latin and later Western languages is the term used solely of divine beings. Although not necessarily eternal, angels do not die; their relationship to time is thus somewhat ambiguous.

Angels in Early History

The idea of angels first appeared in Sumeria around 3000 BCE. The Sumerians were polytheists who believed that messengers mediated between the gods and humans. Also, they believed people had a spirit companion with them throughout their lives, perhaps a primitive version of a guardian angel. Archaeological excavations have discovered home shrines with images of winged humans, which seem to be dedicated to these spiritual beings. This trend continued into later Babylonian and Assyrian cultures. Around 650 BCE, Zoroaster claimed an angel revealed to him the tenets of a monotheistic religion, later called Zoroastrianism. Zoroastrianism portrays Mithras as an angel, along with a hierarchy of six archangels and many lesser angels. Zoroastrian angelology influenced Judaism, Christianity, and Islam.

Angels in the Bible

In the biblical text, angels appear to be genderless attendants of God. They are created beings. Though they are not timeless, they do not die. Their roles are to praise God, serve in the heavenly council, and carry out God's bidding. Many are heralds, but some are warriors and guards. As spiritual beings, angels are usually invisible (formless) but can take on humanlike form, even to the point of being indistinguishable from other humans. The Bible does not always distinguish between the angels and God. For example, an angel of the Lord appeared to Moses in a burning bush, but two verses later the text says God called to Moses from the same bush.

The Hebrew Bible mentions at least two other types of heavenly beings—seraphim and cherubim. Seraphim are heavenly fiery serpents with six wings. In medieval Christianity, they are assigned to the highest order of angelic beings as attendants to God's throne. Cherubim are also winged beings, perhaps with human characteristics. Such beings guarded the Garden of Eden after the expulsion of Adam and Eve. As described in the Book of Exodus, golden images of two cherubim sat upon the Ark of the Covenant facing each other. Their wings spreading toward each other formed the mercy seat of God.

Angels are sparsely mentioned in the early writings of the Hebrew Bible, or Old Testament. In this section, they function primarily as messengers; however, they also serve as protectors and guides, agents doing God's bidding, attacking enemies, and leading God's people. In later Old Testament writings, angels become more prominent with a shift in roles and nature, perhaps due to Babylonian and Zoroastrian influence. Here, angels reveal secrets about the future and interpret visions and dreams. The Book of Daniel provides the first occurrence of named angels—Gabriel and Michael. Daniel also introduces the beginning of a hierarchy of angels, where Michael is called the "great prince."

From the time of Constantine the Great (280–337 CE) and afterward, angels have regularly been depicted as having wings as shown on this statue in Seville, Spain.

Source: Duncan Walker/iStockphoto.

During the Intertestamental period (4th to 1st centuries BCE), angelology greatly expanded, perhaps due to Persian influence (specifically Zoroastrianism). Angels were thought of as too numerous to count. They began to be placed in an ordered hierarchy, giving rise to the development of archangels. Also introduced is the idea of "fallen angels," thus the beginning of the dualistic idea of good and evil angels. In this thought, angels have free will and the ability to choose to disobey God. Some angels were a part of angelic armies. Other angels took on the role of protector or guardian angel. For example, Raphael protects Tobit as he travels to Media.

In the Christian Bible, or New Testament (1st century CE), angels announce the birth of Jesus and continue to carry out God's works. They attend to Jesus's needs while he is in the wilderness; however, they are inferior to him. The Book of Jude speaks of angels who rebelled against being held for the Day of Judgment. In the Book of Revelation, angels play a prominent role in the final battle between good and evil forces. The archangel Michael leads an army of angels into a battle against Satan. Satan loses the battle, and he and his angels are cast down to the earth.

Angels in Islam

Islam portrays angels in a manner similar to Jewish and Christian views. They are seen as servants of God and agents of revelation to humans. However, in Islam, angels do not possess free will and cannot sin or disobey God; thus they cannot be evil. Angels exist in a hierarchy and have specific tasks. For example, Jibril (Gabriel) dictated God's message to the prophets, including giving the Qur'an to Muhammad. Angels accompany each person on Earth in order to record that person's deeds—both good and bad.

Angels in Later History and in Art

Angelology continued to develop after the New Testament period. Pseudo-Dionysius, a person associated with a 5th-century CE philosopher, arranged angels in nine orders, divided into three hierarchies containing three choirs each. Saint Thomas Aquinas, a scholastic (1225–1274 CE) following Pseudo-Dionysius, added that the hierarchies are arranged according to their proximity to the Supreme Being. The superior angels have more knowledge of truth and enlightenment than do lower ones. This view of the angelic hierarchy continues to be the generally accepted Catholic view.

Protestant reformers such as John Calvin downplayed the earlier development of angelology. They tended to de-emphasize a hierarchy and focus on the role of guardian angel. In the Age of Enlightenment angels began to be marginalized or even dismissed as mere fantasy. A diminished emphasis on angels continues to be a main Protestant position.

Art presents a good view of the development of angelology. Angels are regularly depicted as having wings from the time of Constantine the Great (280–337 CE) and afterward. Byzantine artists frequently depict angels in military uniforms, especially Gabriel and Michael wearing officer uniforms. This trend continued into later periods. Also, artists tend to depict angels in pale or white clothing, except during the Renaissance when red and blue garments became the norm. During the Renaissance, angels erroneously began to be associated with *putti*—chubby winged babies—and began to be depicted as such until this appearance became normative. Angels continue to be a common theme in the arts, including in the modern film industry.

As intermediaries between God and mortals, angels are usually thought of as inhabiting the spiritual realms of heaven and earth. However, some people believe angels also inhabit other worlds in this universe.

Terry W. Eddinger

See also Christianity; Devils (Demons); Genesis, Book of; God and Time; Grim Reaper; Islam; Judaism; Revelation, Book of; Satan and Time; Sin, Original

Further Readings

Davidson, G. (1994). *Dictionary of angels: Including the fallen angels.* New York: The Free Press. (Original work published 1967)

Guiley, R. (2004). *Encyclopedia of angels.* New York: Checkmark.

Anselm of Canterbury (1033–1109)

Anselm, Archbishop of Canterbury, was a great theologian of the medieval Western church. Some consider him the father of scholasticism (the philosophical approach to faith through reason). He is known for his ontological argument for the existence of God and for his theory of substitutionary atonement.

Anselm was born in Aosta, Italy. In 1059 he became a Benedictine monk and resided at the abbey of Bec in Normandy. In 1063 he was made prior and then was appointed abbot in 1078. He held this position until 1093, at which time he became Archbishop of Canterbury. He remained the Archbishop until his death in 1109. King William II, and later, Henry I, called Anselm to England where they disagreed on investitures and other issues of church and state. Contrary to the king, Anselm believed that the church was independent of the king and was under the sole leadership of the Pope. Because of Anselm's position, King Henry I exiled him to continental Europe for much of the time he was Archbishop. In 1720, Pope Clement XI declared Anselm a "Doctor of the Church."

Anselm, like Saint Augustine of Hippo, believed that Christian faith comes through revelation, not philosophy. However, Anselm thought reason allowed one to understand one's faith more fully and therefore found philosophy helpful for theology, especially in proving the existence of God. Anselm expounded on this belief in his work called *Monologion* in 1077. Anselm's most famous work on the ontological existence of God, called *Proslogion,* came out a year later. In this work, he asserts that God is greater than the greatest conceivable being. He argues that this being must exist because if he did not, then God would be inferior to this being. Furthermore, he argues that a nonexistent being cannot be declared to be; therefore, God must exist. Also, he argues that God is eternal and timeless. If God were bound by the laws of time, then he would not be the greatest conceivable being; therefore, he must not be constrained by time. Anselm's arguments are difficult to follow. Furthermore, they are short and succinct, so much so that philosophers and theologians continue to debate their meaning.

In another major work, *Cur Deus Homo* (Why God Became Man) completed in 1098, Anselm employed the same method of using reason to understand faith in explaining the incarnation of Christ and in developing his theory of substitutionary atonement, that is, why Christ has to die for humanity. This work takes the form of a dialogue with another monk at Bec. His basic argument is that because sin is against an infinite God, then its penalty is infinite. Because humanity sinned, only a human can pay the penalty. Thus, the incarnate Christ, God made human, is the only one who can legitimately pay the penalty and redeem humanity. Anselm's theory gained wide acceptance in the 12th century, was held through the Protestant Reformation, and continues to be the dominant understanding of the atonement of Christ today.

Terry W. Eddinger

See also Augustine of Hippo, Saint; Christianity; God and Time; Salvation; Sin, Original

Further Readings

Davies, B. (Ed.). (1998). *Anselm of Canterbury—The major works*. New York: Oxford University Press.

Deane, S. N., & Evans, G. (Eds.). (1974). *St. Anselm: Basic writings* (2nd ed.). Peru, IL: Open Court.

Anthropic Principle

The anthropic principle, which rose to popularity in the 1980s, is conspicuous among attempts at answering the question of the position of human beings in the universe. The application of the principle basically means determining limiting suppositions of models of the universe that must respect its recent state, deductive without contradictions from the past states. Real existing phenomena in the universe, especially the existence of an observer, a human being (which gave the name to the principle), act as strongly limiting suppositions of the selection of all possible states of the universe in its past. This entry reviews the sources of those considerations.

Starting Points

The starting points could be divided in at least two related groups: the existential and epistemological causes of the anthropization of the universe. The existential sources could be briefly characterized by the word *surprise:* surprise of human beings at the "starry sky above," astonishment provoked by the organization of the surrounding world, as if waiting for guests at a prepared table. The surprise does not diminish with the increasing knowledge of nature and its laws; rather, the surprise is increased by the fact that humans do not deal with a single improbability but with a chain of improbable events during the whole history of the universe, starting with the big bang until the present. For example, the elements and anti-elements' ratio during the moments close to the beginning of the expansion of the universe had to allow, after reciprocal annihilation and radiation, precisely the quantity of elements remaining as the building material for the universe. This universe can be neither too dense (it would collapse again to the singularity) nor too thin (the matter would then spread out quickly and there would be no material for construction). At the same time, the presently observed stars had to be preceded by the stars of the first generation that created heavier chemical elements and dispersed them after their annihilation to the surrounding space where these elements could become building stones of emerging planetary systems. The created planets must be at an optimal distance from the central star, which must have a relatively stable form. Tolerated deviations—the range enabling the creation of life and basic physical interactions—are expressed by fractional parts of a percentage, while the physical possibility of these deviations is expressed in tenths of a percent. The real macrospace must have exactly three dimensions; no other physically possible case allows the existence of life. There is also the numerical coincidence: the size of proton 10^{27} centimeters and the size of the observed universe 10^{-27} centimeters.

As it concerns the accuracy of the "setting" of the speed of the expansion of the universe (for example), even a deviation that ranges from $1{:}10^{30}$ to $1{:}10^{29}$ would mean the existence of the universe without life. Is it all just a coincidence, very improbable, yet still a coincidence? Or is it an impact of something that is beyond reach, something humans are not able to embrace with knowledge, which, despite all progress, is still limited?

Versions

B. Carter, who named the principle, formulated its two basic versions in 1968:

Weak—The presence of observers in the universe determinates its time dimension; the universe has to be at least as old as to allow the emergence of an observer. The existence of the observer is thus the determinant for statements concerning the physical state of the universe and the conditions that enable this proper existence. The concatenation of this type of condition offers the most probable picture of the past of the universe.

Strong—The presence of an observer determines not only the time dimension of the universe, but also the whole system of features. The strong version states that in every physically real universe, an observer must once appear, so every universe has to create the conditions for the existence of observers.

In the following years, the proponents of the anthropic principle modify the formulations and two completely new versions appear:

Participatory—This version puts the universe and the observer on the same level; their existence is thus conditioned reciprocally. The version stems from the fact that physically possible states of the universe allow life in only a very narrow range, and the probability of the realization of the universe in this narrow zone is very limited (a slight deviation and the universe would still exist, only without any life); even lower probability could be found in the presumption that these particular improbable relations would organize in a chain of continuous conditions that would culminate with the creation of an observer. Based on the final improbability, the participatory version of the anthropic principle draws the conclusion that reason had to participate in the realization of the present improbable state of the universe. There is, however, no explicit mention of the Reason-Creator. Rather an analogy can be observed with the knowledge of micro and macro worlds; for example, in the physics of elements, in the same way as the subject becomes an inseparable part of the object during the observation and makes a natural part of the macro world, it is possible to find the subject in the mega world when its past and recent structures are studied. Nevertheless, if the statement is hidden or explicit in the strong and weak version of the anthropic principle, a double understanding of the role of the subject in the universe can be observed.

1. *Ontogenetic role*. In the literal meaning, the spirit is considered as the crucial agent in the construction of the universe. "The more I examine the universe and the details of its architecture, the more evidence I find that the universe in some sense must have known we were coming" (Freeman Dyson, *The Argument from Design: Disturbing the Universe,* 1979). Why is the spirit "favorable" to life and intelligent observers, and why does it construct a universe where the observer is welcome? (The response is right at hand: The spirit creates according to "its own image.")
2. *Noogenetic role*. The spirit realizes the universe by accumulating its knowledge. This interpretation refers directly to the example of the position and role of the observer in quantum mechanics: "A phenomenon is not a phenomenon without being an observed phenomenon. Observers are necessary to bring the universe into existence" (John Wheeler in the discussion on the congress of cosmology, Krakow 1973. http://ptta.pl/pef/angielski/hasla/a/anthropicprinciple.pdf). The universe is real only when it includes its observer; if it is real, the universe must be able to welcome this observer.

   According to the participatory version, the existence of the universe is as important for the observer as is the existence of the observer for the universe. If the universe is supposed to be real, it must have qualities that would enable the existence of the observer.

Intelligent observer—The fourth and the last version of the anthropic principle is its final version: Intelligent systems of processing information have to appear in the universe, and they will never disappear after their emergence. An intelligent observer is the aim because it gives meaning to the existence of the universe.

As previously mentioned, in the background of all these interpretations of the anthropic principle is the surprise at the character of the universe that allows the creation of life, while it would be more probable to dispose of at least slightly different features. Why did the universe "choose," out of many possibilities available at every moment of its evolution, such a slightly probable succession that led to the creation of life? If the question is asked in the sense of the weak version of the anthropic principle and if its heuristic value is used, then the question "why" is appropriate because it offers a possibility to choose out of the number of possibilities only those that lead to the creation of life, which undoubtedly exists, in order to complete the picture of the past of the universe that best describes the past events. The question becomes more problematic when the strong or the participatory version of the anthropic principle is considered, because the answer is looked for in the activity of the spirit that is "responsible" for all. However, that means only that the primary "why" falls apart into many other questions that cannot be principally answered. The original surprise that had a positive constructive character as it led to the research of the most probable version of the image of the universe is gradually, in its consequences, changing into uncritical astonishment and resignation to continue the research.

While the main point from which the strong, and especially the participatory, version of the anthropic principle start is the improbability of the state of the universe, there is another solution available. The French astrophysicist M. Lachièze-Rey problematizes the proper notion of probability: "As it concerns the original and continuous setting of the condition of the universe, we do not have (apart from the law of the increasing entropy) any precise law of probability and we can hardly decide what data are probable. We do not know what we would like to know." (M. Lachieze-Rey, C.N.R.S. Institute d'astrophysique, private communication, Paris 1991) Another possible answer is offered by the inflation theory of the universe. The inflation theories are used as a more physical solution and they are put in opposition to the anthropic principle; however, based on preceding experience, it would be more prudent and appropriate to avoid the excluding "either–or" (for what remains, I will try to show that such an extreme solution has not been fruitful) in order to try to unite the positive features of both perspectives. What solution will offer this proposition? Especially, the earlier-mentioned surprise at the readiness of the universe for life will obtain again its constructiveness, and it will be possible to use the heuristic characteristics of the weak version of the anthropic principle. The fact that the inflation theory studies the possibility of the existence of an infinite number of physically independent universes with variable physical parameters changes the improbability into a highly probable phenomenon, if not a statistical need. Most of these independent universes have physical conditions that do not allow the creation of life, but it is not surprising that there has been at least one universe in the infinite number that unites a combination of conditions that enable life. Human beings should not be surprised at having appeared just in this "vital" universe. It remains "just" to disclose the past of the real universe with respect to the fact that past states had to contain such qualities that led to the creation of life; they had to be "biogenetic." Among these physical solutions are not entirely proved but promising theories, for example, Linde's modification of inflation models.

> This work on inflationary models showed that the present state of the universe could have arisen from quite a large number of different initial configurations. This is important, because it shows that the initial state of the part of the universe that we inhabit did not have to be chosen with great care. (Stephen Hawking, *A Brief History of Time: From the Big Bang to Black Hole*)

Moreover, according to Stephen Hawking, "Must we turn to the anthropic principle for an explanation? Was it all just a lucky chance? That would seem a counsel of despair, a negation of all our hopes of understanding the underlying order of the universe." (Stephen Hawking, *A Brief History of Time: From the Big Bang to Black Hole*)

Even if the anthropic principle is not motivated by anthropocentrism, a common ground can be found. The whole history of cosmology—from ancient history until the present—is basically, in a rough scheme, a history of the dethroning of humans from the center to the periphery of the universe. The anthropic principle seems to restore the privileged position of human beings, their reason and life, by saying that the history of the universe led to the creation of human beings. Nevertheless, related to the inflation theory, the anthropic principle offers results that correspond to the previous tendency (concerning the spatial forms of centrism), more precisely expressed—results that correspond even more that anyone could ever imagine. It makes insignificant not only human beings but also the whole universe that can appear only as one of many universes. The partisans of the anthropic principle would certainly protest against mentioning the anthropic principle in the context of anthropocentrism. It is true that the anthropic principle does not place human beings in the center, but living observers, whatever planet they live on. However, that does not change the fact that the idea of the center is conserved where the subject of knowledge is central, whether it is a human being or any other existing thinking being. A comparison can be made between Aristotle and the anthropic principle. The compatibility of Aristotle's considerations and the anthropic principle could be observed in the applied method that leads to the idea of the privileged position of subject. Thanks to the observation of a falling stone, Aristotle came to the conclusion that heavy objects tend to fall down and that the earth, not able to fall anywhere because of its heaviness, forms the center of the universe; it is the "down" for everything else. The anthropic principle stems from the simple presumption that an observer does exist. To ensure the existence of the observer requires specific, precisely defined conditions. To "offer" these conditions in a certain moment, the universe had to be precisely limited in its past and realize many, even very improbable, possibilities. This fact leads the followers of stronger versions of the anthropic principle to the conclusion that the universe is oriented to the creation of life, which had to appear. Some of them are even persuaded that the spirit directly participates (ontogenetically or noogenetically) in the construction of the universe appropriate for life.

Aristotle's stance and the anthropic principle stem from the irrefutable arguments, purely empirical ones (a stone falls down, observer does exist), and lead to the idea of a privileged position of human beings in this universe; in the case of the anthropic principle, which is a far more large-scale framework than Aristotle's was, the idea is still maintained that a thinking being in particular and life in general hold a privileged position in this cosmos.

Inevitability

Are humans actually able to create a non-anthropocentric image of the universe? The proper essence of the cognition process—principal epistemological anthropocentrism—leads to the assumption that every image created by human beings will bear the traces of its producer. If we suppose that the real universe exists and is unique, we have to realize continuously our subjective role in the formation of the image of the world, and we have to get rid of the illusion of objective knowledge that reflects reality and consider as more adequate the one that would consciously include itself and its creator. It is obvious that even in this case, we could obtain approximate results only. In a possible solution of the anthropocentric principle, it would mean acknowledging that the universe is anthropic and non-anthropic at the same time.

Just as a distinction can be made between the final and the limited, thanks to the relativistic physics of spacetime and modern cosmology—even the pair "final and infinite" is only a relative opposition—some other polarities previously considered irrefutable should now be abandoned, including yes or no, white or black, man or woman, word or action, subject or predicate, anthropic or non-anthropic. We humans are continually confronted with the dualities of the world; however, we have to realize that they are the dualities of our world, the world of human scale. To what extent is this "yes or no" perspective useful in other, completely different levels? In the world of elementary particles and galaxies? Nevertheless, even "our" world corrects its own oppositions in many ways. What used to be good could be bad today; a friend could behave as an enemy; the disguises of love and hate are hard to recognize. The universe is anthropic in terms of what we know about it and non-anthropic in our ignorance of it.

Josef Krob

See also Aristotle; Cosmogony; Hawking, Stephen; Teleology

Further Readings

Barrow, J. D., Tipler, F. J., & Wheeler, J. A. (1988). *The anthropic cosmological principle.* New York: Oxford University Press.

Carter, B. (1990). Large number coincidences and the anthropic principle in cosmology. In J. Leslie (Ed.), *Physical cosmology and philosophy* (pp. 291–298). New York: Macmillan. (Reprinted from *Confrontation of cosmological theory with astronomical data,* by M. S. Longair, Ed., 1974, Dordrecht, The Netherlands: Reidel)

Peebles, P. J. E. (1993). *Principles of physical cosmology.* Princeton, NJ: Princeton University Press.
Polkinghorne, J. (1998). *Belief in God in an age of science.* New Haven, CT: Yale University Press.

ANTHROPOLOGY

The human preoccupation with time extends into humankind's study of ourselves: anthropology, the science of humanity's past, present, and future. Only by studying ourselves, and how our ancestors behaved in the past, can we learn about our nature. In the past, human societies rose and fell, subject to external and internal factors. We respond to the environment we find ourselves in, struggle to adapt to or overcome obstacles, and attempt to thrive and perpetuate ourselves. To be human is to have a human nature, and the more we learn about our past the clearer it becomes that we have not changed much in the past 100,000 years since developing into what we call "modern humans." By studying past and present human mistakes and triumphs, we hope to improve our own future.

Anthropology is a broad discipline that has been steadily growing since its inception in the 19th century. It contains many subbranches and undoubtedly will acquire more as time passes. In North America anthropology is known as a "four-field" discipline. Its major branches are biological anthropology, archaeology, sociocultural anthropology, and linguistic anthropology.

History of Anthropology

Given human nature, it is clear that our ancestors began speculating about their origins long before the written word was invented. The early creation myths of ancient civilizations such as Egypt and Mesopotamia that have come down to us in writing, date to the 2nd millennium BCE When true "anthropological" thinking came about is a matter of speculation. The term *anthropology* is a 19th-century combination of two Greek words: ἀνθρωπος, *anthropos,* "human being, man," and λόγος, *logos,* "knowledge"), and the earliest writing we have on the scientific speculation of human origins is Greek as well. The 6th-century BCE philosopher Anaximander (c. 610–c. 546 BCE) lived in Miletus in Ionia (modern western Turkey, i.e., Anatolia) and became a part of a school of philosophy called Milesian (named after Miletus). Although his works survive in only one fragment, citations by later classical authors provide us with what little we know about him. Among his influential ideas, which ranged from astronomy to cartography, he developed the earliest known "scientific" hypothesis of human evolution. Anaximander believed that the earth was once composed entirely of water and that the first life forms came from there, and in this he was basically correct. Furthermore, according to Anaximander, when parts of the earth dried up, some of the fishlike animals came up on shore, bearing human beings within themselves like fetuses, which then emerged from their aquatic parents when fully acclimatized. However, Anaximander's ideas that humans developed somehow from other organisms were eclipsed by those of Plato (c. 428/427–c. 348/347 BCE) and Aristotle (384–322 BCE), two later philosophers whose ideas would dominate Western thinking for centuries to come. Plato was a believer in *essentialism,* a point of view that maintained that any given entity was created as perfect and possessed a series of characteristics, all of which any entity of that kind must have. Plato believed in eternal, ideal forms, which are reflected in material objects although far superior to them; these ideal types (Platonic ideals) had neither the need nor the ability to change. Aristotle believed that all creatures were arranged in a *scala naturae,* or "great chain of being": a system of 11 grades of perfection beginning with plants and ending with human beings. Higher creatures gave birth to warm and wet live offspring, and the lower ones bore theirs cold and dry, in eggs. These ideas were prevalent for centuries, essentially hindering any thought of human evolution or change through time. The 5th-century Greek (also from western Anatolia) Herodotus (c. 484–c. 425 BCE), often referred to as father of the study of history, could also be considered the father of another aspect of anthropology: ethnography, the writing down of firsthand observations of foreign cultures. In his travels throughout the ancient world, Herodotus was using many methods in common with those of modern anthropologists, such as locating the best-informed people to provide information about history and customs.

The medieval world saw little progress in anthropology. When Catholicism grew in power following the era of the Roman Empire, its dogmatic insistence upon a literal reading of the Bible, according to which God created each and every species as is, and that no species, once created, could be destroyed, held sway. The belief that the earth was fairly young also prevailed. The English bishop James Ussher (c. 1581–1656) developed a chronology based upon a careful reading of the Old Testament and concluded that the earth was created on the evening of October 23, 4004 BCE; how he arrived at such a specific date was in fact a remarkable act of scholarship.

By the 17th century CE, geologists were becoming increasingly dissatisfied with this sort of thinking because it failed to explain the collections of fossils and what was understood of geology; in chronologies such as Ussher's there was simply not enough time. In the 17th and 18th centuries the exploration of the globe drastically changed how people thought of the world. Human and animal diversity across the earth was too vast to be explicable in terms of a common ancestry in the Garden of Eden; change through time must therefore have taken place. The existence of fossils, in their geological contexts, of creatures that nearly, but not quite, resembled modern ones, was additional evidence for change. The presence of creatures such as dinosaurs, without modern equivalents, spoke strongly for the notion of extinction, also in contrast to the earlier beliefs regarding Creation. In the 18th century Carolus Linneaus (1707–1778), a Swedish botanist (who initially had believed that species were unchangeable), classified every species as a member of a genus, which in turn were classified into the progressively more general categories: family, order, class, phylum, and kingdom. The Linnean taxonomy was the culmination of 2,000 years of thought, and its development made Linneaus reconsider his earlier belief in the fixity of species.

Geologists in the 19th century were eventually unconvinced that the earth was less than 6,000 years old and believed that the earth formed and changed in the past by means of the same processes that existed in the present. The concept of *uniformitarianism* replaced the older notion of *catastrophism,* which held that catastrophic events (such as the Biblical Flood) were responsible for wiping out earlier life forms. The naturalist Charles Darwin (1809–1882) forever changed scientific thought with his volumes *On the Origin of Species* and the *Descent of Man,* in which he espoused the mechanism of natural selection to explain the variability of life on Earth and that ultimately humans were descended from apelike ancestors. The concept of evolution was thus born. At the same time, although unbeknownst to Darwin, an Austrian monk named Gregor Mendel (1822–1884) did pioneering experiments on the principles of inheritance using pea plants. Despite all these rapid and astounding developments in scientific thought, it would take more than half a century for ideas concerning inheritance, natural selection, and evolution to merge into the concepts we are familiar with today. By the 1950s enough research had been done so that the basics were widely understood. (The search for human ancestors had been under way since the late 19th century.)

Other branches of anthropology were also coming into their own. Archaeological excavations of sites such as ancient Troy began in the late 1800s, and the first ethnographers, ancestors of modern cultural anthropologists, were recording their observations on cultures and languages that were steadily vanishing in the face of Western encroachment. The four fields of modern anthropology—biological, sociocultural, archaeology, and linguistic—were all in place by the dawn of the 20th century.

Biological Anthropology

Also known as physical anthropology, biological anthropology is concerned primarily with the physical and biological attributes of humans and human ancestors as a species of animal. Biological anthropologists study human beings using much the same methodologies that they would use for other animals. Until recently, biological anthropology dealt largely with human bones and fossils, but advances in the fields of genetics and molecular biology have extended the discipline to include these aspects as well. Consequently, the study of human genetics, known as *molecular anthropology,* is included in the category of biological anthropology. Therefore the term *biological anthropologist* is rather general and may designate a specialist in a number of different areas, such as human evolution (paleoanthropology), nonhuman primate biology (primatology), variation among modern human populations, and forensic investigation (forensic anthropology).

Paleoanthropology

The study of human evolution (paleoanthropology) is the study of the processes that led to our becoming modern humans, which began around 65 million years ago with the emergence of the first primates. As human beings are primates, paleoanthropologists study the skeletons and fossilized remains of not only humans and human ancestors, but also nonhuman primates as well. Fossils in general are dated using the potassium-argon (K-Ar) method that measures the decay of potassium into argon gas; this dating method, like others, is constantly being refined.

In just over 100 years, scientists have amassed fossils from an increasing variety of human ancestors and distant relations. The field can be said to have originated in 1856 with the accidental discovery of the famous Neanderthal skeleton, named after the Neander Valley, Germany, where it was found. A long time passed before other important discoveries, such as that of *Homo erectus,* or "Peking man" by Eugène Dubois and "Java man" at the Trinil site in 1819. DuBois's discovery was remarkable because he had set out to find exactly that: a human ancestor. Unfortunately, few members of the scientific community accepted his "missing link," and DuBois retreated from the limelight, keeping his precious fossil remains under his bed and showing them to few. In the late 19th and early 20th centuries, great debate raged over where human ancestors originated. Racist beliefs of the time tended toward Asia rather than Africa. However, in the 1920s, important discoveries were made in Africa, most notably Raymond Dart's "Taung child," or *Australopithecus africanus,* one of the earliest human ancestors. Later important discoveries in Africa include that of *Australopithecus robustus* and *Homo habilis* by Louis Leakey in the 1950s and 1960s, and then the earliest-known hominid ancestor, *Australopithecus afarensis,* or "Lucy," in the 1970s by Tom Gray and Donald C. Johanson. Added to these basic genera are also (among others) *Homo ergaster, Homo rudolphensis, Homo georgicus, Homo heidelbergensis,* and *Homo florensiensis,* the most recent find that continues to amaze people. (*Homo florensiensis* appears to be a diminutive descendant of *Homo erectus* that gradually "shrank" after reaching the small island of Flores; it is estimated that the creature was under 4 feet tall.) It is certain that the more fossils that are found, the more complex a picture will emerge of the process of human evolution. It is a far cry from the "ladder" that earlier scientists had imagined and now resembles more a complicated web, with numerous branches, dead ends, convergences, and overlaps. The timeline of human evolution is constantly being modified, and any given textbook is guaranteed to be somewhat out of date by the time it is published because of an ever-increasing body of evidence. Although the fossil record is by nature very fragmentary and there are many gaps in our knowledge, we do have a broad understanding of the various factors that led our ancestors on the path to critical developments such as bipedalism and tool making. Because organisms are inseparable from their environments, paleoanthropologists must consider the big picture when hypothesizing about human evolution, climatic change being an essential variable. Genetic research has also contributed greatly to our understanding of evolution. While opinions are constantly fluctuating, genetic evidence has recently demonstrated that Neanderthals (*Homo neanderthalensis*) and *Homo sapiens* were too different in terms of their DNA to have been able to interbreed (modern humans having coexisted with Neanderthals for thousands of years). Neanderthals therefore were probably not our ancestors, but rather one of many hominid "offshoots" that left no descendants. Mitochondrial DNA (mtDNA) evidence has also called into question the hypothesis that *Homo erectus* developed independently into modern humans in different parts of the world (Africa and Asia), as the fossil evidence suggests. Genetic evidence supports a different hypothesis: the "Mitochondrial Eve," or "Out of Africa" school of thought, in which modern human beings developed only in Africa and then spread out, gradually replacing earlier populations of *Homo erectus.* Debates over large issues such as this demonstrate how much we have to learn about our own ancestry.

Primatology

As we can never observe what our ancestors actually looked like, or how they behaved, primatology, the study of nonhuman primates, is an essential component of paleoanthropology, and a very diverse discipline in and of itself. Some subjects that it comprises are primate anatomy, field studies of primate behavior, and experiments with communication and animal psychology. Observing nonhuman primate behavior in both the wild and in captivity gives anthropologists a scientific basis for hypothesizing on ancestral human behavior. Primates are our closest relatives in the animal kingdom and include Asian and African apes and monkeys, as well as the prosimians: lemurs, lorises, and tarsiers. Issues especially relevant to human evolution include social behavior, food gathering and sharing, patterns of conflict, communication, learning, and tool use. Perhaps the most famous primatologist is Jane Goodall (b. 1934), who has popularized the discipline on television and film through her work with chimpanzees and through her numerous scholarly and popular publications (such as children's books).

Forensic Anthropology

Forensic anthropology entails the identification and analysis of (generally modern) human remains. Forensic anthropologists are trained to recognize such things as time since death (based on the decomposition of soft tissue and bone); taphonomy (postdepositional changes); ethnic group, age, and sex of the individual; physical characteristics such as height and weight; abnormalities and trauma; and cause of death. Forensic anthropologists are able to assist in murder investigations and the identification of remains of victims of accidents, war, and genocide. Forensic anthropologists are also called upon to identify remains of the victims of mass-slaughter events and to locate and repatriate the remains of soldiers who died overseas. As more sophisticated techniques develop, the ability of these specialists to help solve crimes in cooperation with law enforcement agencies has grown. It comes as no surprise, then, that popular culture has, in recent years, highlighted the work of forensic anthropologists on television shows (both documentaries and dramas) and in novels.

Archaeology

Archaeology is primarily the study of past cultures through the excavation and analysis of material remains. Given the absence of time travel and the relatively short period in which history has been written down (about 5,000 years), archaeology is our only window into the past. In Britain and elsewhere in Europe, archaeology is considered a separate discipline from anthropology, although clearly related. In the United States, archaeology is still largely considered a branch of anthropology. Archaeologists study change through time. The archaeologist usually has a particular research question, or hypothesis, in mind before proceeding to fieldwork. A site appropriate to testing this hypothesis is then selected or searched for. Archaeological sites can be as massive as the Pyramids of Giza or as small as a 1 × 1 meter pit excavated into the ground where human beings have left any kind of trace behind. An archaeologist may use a combination of techniques to acquire data, such as surface survey of ruins, mapping, and excavation. Depending on the type of site, different methods are employed, and these vary from country to country as well. Archaeologists differ from paleoanthropologists in that they study the period following the advent of modern humans, although excavation techniques naturally are not very different. Like paleoanthropologists, archaeologists are above all concerned with the temporal perspective of human culture, that is, the diachronic perspective.

Archaeologists are, by nature, almost obsessed with time; dates are the subject of endless discussions and debates. Archaeologists have a number of tools at their disposal to date a particular site. Where available, written documentation is often the most accurate and valuable tool. (For example, the Maya were master astronomers, calendar makers, and date keepers.) This can be in the form of an inscription on a temple, stating when and by whom it was dedicated, or by a simple coin bearing a date. However, as writing has existed for only around 5,000 years, many archaeologists must rely on other means. The most basic means of dating a site is through the study of stratigraphy. A stratum is a layer of deposition, and in principle, the lower layers contain deposits older than the upper ones. However, this gives the archaeologists only a relative chronology, in that one thing can be said to be older or younger than another thing, without an absolute reference point. More scientific means are necessary to secure an actual date. The most precise scientific method for this is dendrochronology, or tree-ring dating. Using a vast database of tree-ring chronology throughout certain areas of the world, archaeologists can, in some cases, pinpoint the year in which a piece of wood, such as a house-post, was cut down (long-lived species of trees are necessary for this). However, this method works only for areas in which wood is preserved, namely, arid ones such as the American Southwest. A more universal method is C-14 radiocarbon dating, which measures the decay of the unstable isotope carbon-14, which is absorbed by all living organisms. This method tells us, within several decades, the date of an organism's death; a piece of charcoal from a fire pit, for example (the date comes from death of the piece of wood that was later burned). This method is usable for sites as old as 60,000 years; for (mainly fossils) prior to that, potassium-argon (K-Ar) dating is used. Thermoluminesence dating is a technique for dating ceramics, where they exist (it measures when the object was fired). Changes in artifact styles, especially pottery styles (shapes, forms of decoration, etc.) are also extremely important and are often used as a chronological basis.

An archaeologist's fieldwork is only a fraction of the process. Once all the data collection has been done, the material—which usually consists of broken tools, ceramics, and midden (food remains)—is transported back to a laboratory where analysis is undertaken. Among things that archaeologists look for are what kinds of food were being consumed and what kinds of objects were being produced and used. Patterns through time are carefully studied and hypotheses postulated. Because archaeologists recover only a small fraction of the remains that a given culture leaves behind, they must often resort to other aspects of anthropology to fill in the gaps. Linguistic data can be extremely valuable, as can ethnographies about either the culture's descendants or those of a similar one. To reconstruct the environment of the culture in question, an archaeologist will often collaborate with environmental specialists who study ancient pollen (palynologists). Other specialists, such as geologists and climatologists, and geneticists, are also brought into the field. Within archaeology there are many subdisciplines, such as archaeozoology, which studies animal remains, and archaeoastronomy, which focuses on ancient astronomies. Archaeology also is not confined to the surface of the earth; underwater archaeology focuses largely on shipwrecks and other submerged sites. By nature, archaeology is destructive: A site, once excavated, no longer exists. Extensive record keeping during excavation is therefore essential. Whereas the basic tools of the archaeologist, such as the shovel and trowel, have not changed much since the discipline began in earnest in the late 1800s, advances in technology continue to contribute to the sorts of questions that can be addressed. Computer modeling and simulations, geographic information systems, DNA studies, geochemical sourcing, and stable isotope analysis are but a few examples of the means now available.

Of increasing importance in archaeology is cultural resource management (CRM). In the past 30 years, CRM has grown in importance throughout the Western world. Although the laws vary from state to state, any building project participated in by the U.S. government is required to hire archaeologists to make sure that any site disturbed or threatened is assessed, studied, and documented. At the higher levels, professional archaeologists may have doctorate, master's, or bachelor's degrees. CRM is especially critical when human remains are unearthed, especially those of Native Americans (including Hawaiians). CRM, however, is hampered by difficulties such as time constraints, report submission, and legal and ethical issues. Much of the findings obtained through CRM, therefore, are not widely circulated or published, although everything must, by law, be put on record in the local State Historic Preservation Division's office. Although usually separate from academic institutions such as universities, many professional archaeologists are among the finest scholars working.

Sociocultural Anthropology

Also known simply as cultural anthropology (mainly in America) and social anthropology (in Britain), sociocultural anthropology is concerned with how human beings function, behave, and relate to one another within society. It treats human beings as transmitters of that complex set of standards and behaviors that we call culture. As human beings, the passage of time is naturally of great importance to us. How different cultures calculate and mark the passage of time is of great concern to sociocultural anthropologists. Rites of passage are rituals cultures employ to assist their members during life's important transitions, and they are an important component of any given culture. Key events are birth, puberty, the transition into manhood or womanhood, marriage, status changes, procreation, and ultimately death. The French ethnographer Arnold van Gennep (1873–1957) made a special study of rites of passage in *Les rites de passage* (1909). Van Gennep's work has influenced scholars throughout the 20th century, notably Joseph Campbell (1904–1987) in his studies of mythology and heroic archetypes, and Victor Turner (1920–1983) in his work on comparative religions.

To understand a given culture, cultural anthropologists generally spend a great deal of time doing their fieldwork, which can take years. They must immerse themselves completely into the society they are studying; this study necessitates learning the language and acquiring a new set of social skills. Within cultural anthropology there are two principal components: ethnography and ethnology. (*Ethnology* is a term often used in Europe to describe cultural anthropology as a field.) An ethnography is a description of every possible aspect of a given culture: its sociopolitical organization, religion, economy, laws, kinship system, and gender relations being among the main components studied. Ethnology is the broader, cross-cultural study of societies that bases itself upon the descriptive data of ethnographies.

To compile an ethnography, the anthropologist must observe and participate in as many aspects as possible (participant observation), within reason and morality, and strive not to interfere with the culture itself. Cultural anthropologists must be efficient and extensive note takers and learn to extract as much true and valuable information as possible by speaking with and interviewing members of the community. Known generally as *informants,* these local experts must be, above all else, reliable. In interviewing, the anthropologist must be extremely diligent so as not to lead the informant in a particular direction so as to extract a desired answer. Paying informants is also a sensitive issue fraught with the risk of obtaining misinformation. Information gathered must be confirmed from multiple reliable sources before it can be taken as fact. Perhaps the most famous case of misinformation given to an anthropologist is Margaret Mead's (one of the all-time "great" anthropologists) *Coming of Age in Samoa.* A classic still in print, the work made Mead's career. Years later it came out that her informants had made up much of what they told her, thus negating a large part of the work's value.

Among the most famous and influential thinkers in cultural anthropology were Franz Boas and Bronislaw Malinowski. Boas (1858–1942) was born in Germany and received his doctorate in physics in 1881. He later made his name in anthropology while working with the Native Americans of the Pacific Northwest; became a professor at Columbia University, where he started the first Ph.D. program in anthropology in the United States; and was a key founding member of the American Anthropological Association (Margaret Mead was Boas's most famous student). Boas insisted that each culture be examined in its own context and not compared with others in time and space. Bronislaw Malinowski (1884–1942) was born in Poland and did his fieldwork in New Guinea and the Trobriand Islands. His most famous work, *Argonauts of the Western Pacific* (1922), is a classic in the field, detailing the trading practice of the Kula Ring, a complex network of gift giving and alliances. Malinowski eventually became a professor at Yale University.

Sociocultural anthropology is often thought of as having to deal with "primitive" peoples in far-off areas such as New Guinea or Africa. However, since the early 20th century there are no more places on Earth where people live in complete isolation and ignorance of the modern world. As a discipline, therefore, sociocultural anthropology often has to turn its looking glass onto peoples closer to home, as it were. Today's sociocultural anthropologist may, for example, study some aspect of an ethnic minority neighborhood or the effects of the Internet upon a given population segment. The boundary between sociocultural anthropology and sociology is thus constantly being tested and blurred as the world we live in continues to shrink.

Linguistic Anthropology

Human beings are the only animals on Earth that have actual language, as opposed to communication. How we express ourselves, in terms of words and grammar, is inextricably linked to how we understand and interpret the world around us. Languages have a dazzling array of expressions to reflect the passage of time. For example, basic verbal concepts such as tense (the absolute location of an event or action in time) and aspect (how an event or action is viewed with respect to time, rather than to its actual location in time) are emphasized and combined differently from one language to another. How a given culture views time is embedded in its language. In Western culture new terms for measuring time in increasingly smaller or more precise intervals are constantly appearing. Computers, for example, work in terms of *nanoseconds* (a billionth of a second), a term first used in 1958 when it became measurable.

Linguistic anthropologists study languages from various perspectives. By understanding the relationships between modern languages, and, when available for study, their ancient ancestors, linguistic anthropologists have been able to hypothesize about when and where various populations lived, migrated, and interacted. In studying a particular language family, linguistic anthropologists examine all the members, find commonalities in vocabulary and grammar, and reconstruct an ancestral language that can then be placed, tentatively, in time and space. This means of working backward to understand past populations is an invaluable asset to archaeologists, who often resort to linguistic data as additional evidence. Linguistic anthropologists also study the relationship between modern language speakers and their cultures (sociolinguistics) and how languages work in terms of grammar and syntax. Linguistic anthropologists can help modern peoples better understand and maintain their languages, thus salvaging data that might otherwise become lost.

Applied Anthropology

Applied anthropology refers to the use of anthropological methods and theories to solve practical problems; virtually every aspect of anthropology can be put to such use. Medical anthropology is a subfield within cultural anthropology and is concerned specifically with human health and disease. Medical anthropologists focus on such things as traditional healing practices and conceptions of health and illness and how they relate to the society as a whole. Medical anthropologists are well positioned to put their knowledge to practical use (applied anthropology) by improving public health care and raising health-related awareness among the communities they study.

Anthropologists can also assist development agencies in their efforts to help developing nations. An anthropologist can provide knowledge and details about a given culture that would otherwise be unavailable, such as social needs, environmental constraints, and traditional labor organization. An anthropologist can also provide an impact assessment, by determining what the consequences of a given project would be on the local environment, in terms of pollution or deforestation, for example. All the factors are critical for the success of the long-term goals of a given project.

Ethnologists and linguistic anthropologists can also put their skills and knowledge to use in modern communities by clarifying the importance of such things as kin ties and dialect differences. The perspective offered by anthropologists can be invaluable when dealing with problematic cross-cultural situations.

Time and Anthropology

As anthropologists are scientists that study living and dead populations, time is always "of the essence." While a variety of theories about anthropology abound, causing endless debates among those so inclined, it is generally recognized that people do not behave according to hard scientific laws. Although generalizations can be made about subjects such as warfare, social complexity, migration, diffusion, the role of the individual, and gender issues, to name but a few, what an anthropologist concludes is often more of a reflection on the time and place he or she lives in than an absolutely objective assessment of the material.

As people, we cannot, of course, travel back in time. The only way we can observe and learn about the past is through observation of organic, material, and written remains. It is impossible to predict what anthropology will be like in, say, 100 years. New developments in science and technology will undoubtedly transform the discipline, as they have done in the past. Nevertheless, the basic goals of the anthropologist will remain constant: to study the past and present of humanity and the long journey it has taken and continues to take. As is the case with any other scientific discipline, an anthropologist's findings are fixed in space and time, and conclusions are never absolute: They are always subject to change, refinement, discussion, and perhaps dismissal. The best any anthropologist can hope for is to develop an interpretation that, for the moment anyway, is as valid as the data permit.

Robert Bollt

See also Altamira Cave; Archaeology; Chauvet Cave; Evidence of Human Evolution, Interpreting; Evolution, Cultural; Evolution, Social; Harris, Marvin; Hominid-Pongid Split; Language; Language, Evolution of; Lascaux Cave; Morgan, Lewis Henry; Olduvai Gorge; Rapa Nui (Easter Island); Tylor, Edward Burnett; White, Leslie A.

Further Readings

Birx, H. J. (2006). *Encyclopedia of anthropology.* Thousand Oaks, CA: Sage.

Chomsky, N. (1975). *Reflections on language.* New York: Pantheon.

Dawkins, R. (2006). *The selfish gene* (30th anniversary ed.). Oxford, UK: Oxford University Press.

Evans-Pritchard, E. E. (1976). *Witchcraft, oracles and magic among the Azande.* Oxford, UK: Oxford University Press.

Firth, R. (1963). *We the Tikopia.* Boston: Beacon.

Flannery, K. (1976). *The early Mesoamerican village.* New York: Academic Press.

Goodall, J. (1986). *The chimpanzees of Gombe: Patterns of behavior.* Cambridge, MA: Harvard University Press.

Malinowski, B. (1922). *Argonauts of the Western Pacific: An account of native enterprise and adventure in the archipelagoes of Melanesian New Guinea.* New York: Dutton.

Trigger, B. (2006). *A history of anthropological thought* (2nd ed.). Cambridge, UK: Cambridge University Press.

Apocalypse

Apocalypse is a term referring to divine revelation of hidden knowledge, usually of the future, conveyed by God through symbolic visions to a chosen prophet or believers. The English term is derived from the Greek *apokalypsis* (translated variously as "revealing," "uncovering," or "lifting the veil") and related to the Latin *revelatio,* which conveys a similar meaning. Early Jewish and Christian references understood an apocalypse to include any writings that revealed divine will to humans. Such examples in the Hebrew Bible, or Old Testament, include the appearance of God to Moses on Mount Sinai (Ex 24 and 34) and messages received by prophets, particularly as described in the Books of Daniel, Isaiah, Jeremiah, and Ezekiel, among others. In the Christian Bible, or New Testament, the words of Jesus are often considered revelations of God's will. This is reinforced in Matthew 11:27: "All things have been delivered to me by my Father; and no one knows the Son except the Father. Nor does anyone know the Father except the Son, and he to whom the Son wills to reveal him." In the contemporary secular sense, however, "apocalyptic literature" has become generally associated with writings that describe events preceding and culminating in the end of the world in its present form, usually through devastation, without reference necessarily to the salvation of the righteous. While this meaning, which refers exclusively to the "end times," is not precise, it has derived, in large part, from the last book of the New Testament, the Book of Revelation.

In Christian tradition, Apocalypse is the alternate title for the last book of the New Testament, interchangeably referred to as the Book of Revelation, Apocalypse of John, or the Revelation of Saint John the Divine. It is believed that the term Apocalypse, as a title for the Book of Revelation, was first used by German theologian Gottfried Christian Friedrich Lücke between 1832 and 1852. Lücke applied the term *apocalyptic* to other writings, such as the Old Testament Book of Daniel, which alluded to the future and, particularly, end times. Lücke also studied and wrote extensively on the authorship of the Book of Revelation, the only completely prophetic book of the New Testament.

Apocalyptic passages are also found briefly in the Gospel of Mark (13:1–37) when Christ reveals signs of the end times to his disciples, involving natural disasters and the rising of false prophets.

The author of the Book of Revelation is self-identified as "John, the servant of God" (1:1); however, it is uncertain whether he is also the apostle John, author of the fourth gospel. John described divinely inspired visions he received on the island of Patmos, off the coast of Turkey, most likely between 68 and 96 CE while he was in exile for preaching Christianity (1:9–10). In John's vision, Christ appears to him and directs him to write to the faithful with words of encouragement as well as warning. The book, comprising 22 chapters, describes the opening of heavenly scrolls containing divine disclosures describing great disasters (6); God's defeat of evil forces in the battle of Armageddon provoked by the false prophet or Antichrist (16:14–16); the Second Coming of Christ (19–20); the establishment of God's kingdom on Earth, referred to as the Millennium or a period of 1,000 years of peace and justice (20); and the final judgment, followed by the descending of a new heaven and earth replacing the old and referred to as the New Jerusalem (21).

The Book of Revelation is addressed to the seven Christian churches of Western Asia, and chapters 1 through 3 refer to each church, specifically warning the faithful not to compromise with the prevailing and dominant pagan beliefs. During the 1st century CE, Christians were considered members of a minor Jewish sect, although a threat to the Roman Empire and thus subject to persecution. Early Christians were also in conflict with Jewish religious authorities and therefore faced conflict on two fronts. Apocalyptic literature, in general, has been addressed to people suffering persecution and seeks to strengthen their fortitude, often predicting the end of the world, when evil will be destroyed and justice will prevail. The Apocalypse of John has been subject to more analysis, perhaps, than any other book of the Judeo-Christian Bible because it is filled with symbolic language and ambiguous imagery open to a wide range of interpretations. The number seven is particularly evident, for instance, in references to seven letters (1), seven torches and seven spirits of God (4:5), seven seals on the scrolls (5:1), the Lamb with seven horns and seven eyes (5:6), seven angels and seven trumpets of warning (8:2), the seven-headed beast (13:1), and seven bowls of God's wrath containing the seven last plagues (15:1). The number four also appears repeatedly. With the breaking of the first seal in chapter 6, John envisions the Four Horsemen of the Apocalypse coming forward as destroyers representing Pestilence, War, Famine, and Death, each riding a horse of a different color (white, red, black, and "sickly green," often referred to as pale).

Because the exact date of the final confrontation is not revealed in the Apocalypse of John, descriptions of the end times marked by famine, war, earthquakes, disease, and natural disasters have been interpreted for centuries as signs of the impending end of the world. Since the 1st century of the Christian era, periods of extreme crisis and upheaval, either natural or social, have led to resurgences in Millennialism, or the belief that the end times are imminent. Such beliefs were strongly held during the first hundred years after the crucifixion of Christ, reappeared during the medieval period and the Reformation, and have resurfaced in the 19th and 20th centuries. The Holocaust and the post–World War II creation of the state of Israel in 1948 also led to speculation about the fulfillment of prophecy. Twenty-first–century concerns over global survival, including nuclear devastation, global warming, cosmic threats, and the spread of pandemics are seen by some as signs that fulfill the vision of the future as presented in the Apocalypse of John.

Many major world religions and cultures adhere to eschatologies (doctrines concerning the "end times") that describe the return to Earth of revered deities or prophets and the establishment of justice, usually involving judgment and a battle resulting in the triumph of good over evil and the establishment of a period of peace and justice. In Islamic tradition (particularly Shi'ite) a messianic figure, Mahdi (in Arabic, "divinely guided one"), will bring justice to Earth before the end of the world. Islam, in general, holds that only God or Allah knows the future. However, the Qur'an refers to the end times: "The day will come when this earth will be substituted with a new earth, and also the heavens, and everyone will be brought before God, the One, the Supreme" (14:48). Some Islamic interpretations place that date at 2280 CE, which is revealed through numerological codes within the text. In some Buddhist traditions, Maitreya (the future Buddha) will descend to earth to restore Dharma (the law).

Whereas the Judaic Old Testament provides the basis for belief in the establishment of an eventual messianic kingdom, Christianity holds that the end times have already been initiated with the birth of Jesus Christ in Judea (what is now the West Bank in Israel). Judaism, however, holds that the Old Testament prophecies have not yet been fulfilled, and Jews still await the first coming of the Messiah. However, Christians believe that the Book of Revelation or Apocalypse of John is a prophetic book that serves as culmination of both the Old and New Testaments. But the issues arising from the Apocalypse of John continue to be applied to contemporary events in an effort to interpret the future in light of the present. This is illustrated in Apocalypticism, a contemporary belief that the significance of events, both present and future, is hidden and will be revealed in a major confrontation. It is both a religious and secular concept that is reflected in literal interpretations of the Bible, as well as serving as a secular theme in contemporary art forms, particularly books and films that pit good against evil with the fate of the world hanging in the balance. And theologians, and political and cultural analysts have continued for centuries to debate the identification of the Antichrist and the signs that will indicate the coming of a new order.

In 1947, atomic scientists at the University of Chicago created a symbolic doomsday clock to measure global human survival based on the threat of nuclear war. The clock was set at 7 minutes to midnight, with midnight representing catastrophic destruction. The clock was advanced to 5 minutes to midnight in January 2007, based on nuclear proliferation and environmental factors. Despite these scientific estimations, which have fluctuated over 60 years between 11:43 and 11:58, the future remains hidden and open to speculation. This is reinforced in the Gospel of Mark, when Christ offered an apocalyptic insight to his disciples regarding the destruction of the world in its present form: "As to the exact day or hour, no one knows it, neither the angels in heaven nor even the Son, but only the Father. Be constantly on the watch! Stay awake! You do not know when the appointed time will come" (13:32–33).

Linda Mohr Iwamoto

See also Armageddon; Bible and Time; Christianity; Ecclesiastes, Book of; Judaism; Last Judgment; Parousia; Revelation, Book of; Time, End of; Time, Sacred

Further Readings

Boyer, P. S. (1992). *When time shall be no more: Prophecy belief in modern American culture.* Cambridge, MA: Belknap Press.

Fuller, R. C. (1996). *Naming the Antichrist.* New York: Oxford University Press.

Web Sites

Online Bible: http://www.biblegateway.com

Apollodorus of Athens (c. 180–c. 120 BCE)

Apollodorus was a versatile Greek scholar and historian who worked in the 2nd century BCE. He was the author of many treatises on Greek mythology, grammar, and history, but his best-known works are *On the Gods* and *Chronicles,* a verse history of Ancient Greece from the fall of Troy in the 12th century BCE to the events of his own era. His work is an important link to pre-Homeric history and provided later writers with fertile resources for their interpretation of Greek history.

Apollodorus studied as a youth with the scholar Aristarchus in Alexandria and the Stoic Diogenes of Babylon. After traveling to Pergamum, Apollodorus settled in Athens and produced a number of scholarly works and commentaries on myth and history. The *Chronicles* is a four-volume encyclopedia that situates Greek history according to the ruling *archons,* or political leaders, each of whom held office for 1 year. This enabled later historians to identify events, philosophical schools, and major figures according to the rulers of the period in question. Apollodorus thus gives to Greek history not only a sense of continuity in time but also insight into the personalities that shaped the political climate of Greece at some of its most important cultural moments, such as the age of Socrates, Plato, and the tragic playwrights. The *Chronicles* are based on earlier research by Eratosthenes, but they enlarge the historical scope and strive for a more precise chronology of events. They are also notable for being written in iambic trimeter, a verse meter borrowed from comedy that may have helped in memorizing the stories. Although the *Chronicles* is Apollodorus' most influential work, his essay on Homer's Catalogue of Ships from the *Iliad* was also widely read and used as a critical source, notably by Strabo in his *Geography.*

Often attributed to Apollodorus is the famous *Library,* a compendium of Greek myth from epic and other archaic sources that became the most comprehensive guide to the heroes, legends, and gods of ancient Greece. But this work must have been written by a later author, probably in the 1st or 2nd century CE; it chronicles events that happened well after Apollodorus' death in around 120 BCE. The author of the *Library* remains anonymous but is sometimes referred to as pseudo-Apollodorus to distinguish him from the author of *On the Gods* and *Chronicles.*

Eric J. Stenclik

See also Alexander the Great; Herodotus; Hesiod; Homer; Mythology; Peloponnesian War; Plato

Further Readings

Fraser, P. M. (1972). *Ptolemaic Alexandria.* Oxford, UK: Oxford University Press.

Pfeiffer, R. (1968). *A history of classical scholarship from the beginnings to the end of the Hellenistic Age.* Oxford, UK: Oxford University Press.

Aquinas, Saint Thomas (1225–1274)

Born in Aquino, Italy, Saint Thomas Aquinas was noted for his scholastic synthesis of the philosopher Aristotle and Christian theology. This Dominican monk taught at the University of Paris and was best known for his two "summations" of medieval thought, *Summa Theologica* and *Summa Contra Gentiles,* but wrote in many other genres including Bible commentaries, all of which exerted a lasting influence on Christian thought.

Beginning with Boethius, medieval Catholic theologians had disagreed about the concept of time; among Aquinas's important achievements was his sorting out of these arguments. Aquinas's best discussion of time is in the first book of the *Summa Theologica,* Question 10, which discusses the eternality of God and compares eternity to time. Aquinas brings out six points of inquiry.

First, what is a good definition of eternity? Aquinas bases his definition on one given by Boethius in his *De Consol:* "Eternity is the simultaneously-whole and perfect possession of interminable life." Some scholars have stated that the use of the word *interminable* connotes a negative assessment of eternity. Also, the word *life* does not match with the ontological definition of eternity. The whole is improper when compared to the simplicity of eternity. Eternity is not instantaneous. The whole and the perfect are redundant. Also, eternity is not a possession. In response, Aquinas appeals to simplicity; for that, human beings must understand eternity by means of time. Time is both being and living. Time is the apprehension of the measuring of movement by the causality of time in the past and the future. Later in the first book, Aquinas saw the existence of time as a measure of duration. Therefore, eternity is the holistic and perfect apprehension of what is outside of movement. We can measure time, because it has a beginning and an end. Eternity is immeasurable. So what is eternal is interminable and has no succession and cannot be possessed.

Second, is God eternal? Some scholars object that because God is the creator of eternity, so he cannot be eternal. God is before and after eternity. One can measure eternity but not God. Time (as past, present, and future) is applied to God in the Bible, although the creeds apply eternality to God. In reply, Aquinas connects time to change, and eternity to immutability. Yet, God is not eternal only; but God is "His own eternity." For Aquinas, this is a "participated eternity" utilized from scripture through royal metaphors and images of time so that we may understand that eternity is nothing else but God himself.

Third, does eternality belong to God alone? While some see eternality in righteousness, judgment, and necessity, Aquinas said that because God alone is eternal, only God's sharing that eternality with his creation would allow someone or something other than God to be eternal.

Fourth, how does eternity differ from time? Some object to the difference between eternity and time because time is a part of eternity, their natures differ, and eternity swallows up time. Yet, a disagreement may arise because time has a "before" and an "after." For Aquinas, they are two different things, for eternity has a permanence and time is "a measure of movement: . . . that eternity is simultaneously whole, but that time is not so."

Fifth, how does aeviternity differ from time? *Aeviternity* (sometimes translated "everlasting" or "endless") is the eternity shared by God on the creation. For some thinkers, there is no difference between aeviternity and time because both measure duration and neither is eternal. Aquinas answers that they do differ and that aeviternity stands between time and eternity. While some differentiate among the three concepts in that "eternity has neither beginning nor end, aeviternity, a beginning but no end, and time both beginning and end" Aquinas sees this as an "accidental" case. Other thinkers then see a distinction based on "something old and something new": these three to consist in the fact that eternity has no "before" and "after" but that time has both, together with innovation and veteration, and that aeviternity has "before" and "after" without innovation and veteration.

Aquinas disagreed with this contradiction in terms: "The being that is measured by eternity is not changeable, nor is it annexed to change. In this way time has 'before' and 'after'; aeviternity in itself has no 'before' and 'after,' which can, however, be annexed to it; while eternity has neither 'before' nor 'after,' nor is it compatible with such at all."

And the sixth and final study is whether there is only one aeviternity. Some thinkers argued that there are multiple aeviternities based on all the spiritual entities in heaven. For others, aeviternity "is [a] more simple thing than time, and is nearer to eternity." Aquinas answers with a discussion that ties the oneness of time to aeviternity: "Therefore time is referred to that movement, not only as a measure is to the thing measured, but also as accident is to subject; and thus receives unity from it" For Aquinas, it would be necessary to say that there is one aeviternity only.

Saint Thomas Aquinas showed a difference between eternity, aeviternity, and time. Eternity has neither a beginning nor an end. Only God is eternal. Aeviternity has a beginning but has no end. Only the part of creation that accepts God's gift of eternity takes part in it. Then, time is the measured duration of movement that has a beginning and an end.

Anthony J. Springer

See also Aquinas and Aristotle; Aquinas and Augustine; Aristotle; Augustine of Hippo, Saint; Avicenna; Bible and Time; Boethius, Anicius; Christianity; Eternity; God and Time; God as Creator; Teleology; Time, End of; Time, Sacred

Further Readings

Davies, B. (1993). *The thought of St. Thomas Aquinas.* Oxford, UK: Oxford University Press.

Leftow, B. (1990). Aquinas on time and eternity. *American Catholic Philosophical Quarterly, 64,* 387–399.

Torrell, J.-P. (2005). *Saint Thomas Aquinas.* Washington, DC: Catholic University of America.

Aquinas and Aristotle

The relationship between Saint Thomas Aquinas and his sources Aristotle and Saint Augustine of Hippo illustrates a salient trait of medieval philosophy, namely, its voluntary dependence upon authorities, whose (often divergent) answers to a given problem had to be taken seriously, according to the standards of that time. Because of this, medieval thinkers attempted to solve philosophical (and theological) problems in a way that took into account all relevant sources. If an important source seemed to contradict the personal opinion of a philosopher, the philosopher then usually looked for an interpretation of that authority that could be integrated into his own solution; only in rare cases was the position of an acknowledged authority rejected. Consequently, for Aquinas, as for his contemporaries, a good theory on a certain topic had to do justice to both Aristotle's and Augustine's ideas on that subject, because of their authority in philosophy and theology, respectively. An examination of Aquinas's texts on time, however, reveals a completely different picture: Whereas Aquinas expounds Aristotle's theory at great length, he pays very little attention to Augustine's theory. This entry provides reasons for this remarkable exception to medieval standard practices and serves as an introduction into the most important theories of time that appeared between classical antiquity and the Latin Middle Ages.

Aristotle and Augustine on Time

Aristotle's and Augustine's texts on time—the fourth book of Aristotle's *Physics* and the eleventh book of Augustine's *Confessions*—describe two theories that seem difficult to reconcile with each other: Whereas Aristotle defines time as the "number of changes in respect of before and after" (Phys. IV 11, 219b 1; R. Waterfield, Trans.) and makes its existence and definition dependent upon change or, as the medieval translations had it, motion, Augustine defines time exclusively as a "distension of the mind" (*distentio animi*). Furthermore, Augustine explicitly denies that motion can be an adequate definition of time and that there can be time at all without the human mind, which counts the uninterrupted stream of the sensible world. In spite of not addressing directly Aristotle's definition (which he probably did not know), Augustine cannot have seen in it a serious option. Aristotle, on the other hand, is somewhat ambiguous regarding the relation between time and soul. He writes that there could not be time, if there is not be a soul, because without a soul there would not be any number to determine change and therefore time. However, he grants "that there might still be whatever it is that time is" (IV 14, 223a 21–29). Previously (219b 5–9) he had defined time as that number "which is numbered," not "that by which we number," that is, not as the mental activity of numbering, but as the flow of things that is apt for being counted, such that time should not depend entirely upon an activity of soul. Furthermore, it may well be that he is not talking here about the individual human soul but about soul as a cosmological phenomenon. Thus he would surely have rejected Augustine's solution.

The Aristotelian Tradition Before Aquinas

As with many of his contemporaries, Aquinas's theory of time is largely inspired by Aristotle's solution. Aquinas's most important discussion of that subject can be found in his *Physics* commentary. However, he did not have the Greek original of Aristotle's text, but a medieval Latin translation that had been carefully corrected by his contemporary, William of Moerbeke. Indeed, it is very close to the Greek and enabled Aquinas to discuss Aristotle's solution independently from older commentaries. This was important because the medieval understanding of Aristotle drew heavily on the interpretation that the 12th-century Arab philosopher Ibn-Rushd (Averroes) had given of Aristotle's texts. Averroes's interpretation rests upon the assumption that Aristotle's discussion of the dependence of time upon the soul concerns the human soul and does not have any cosmological implications. Consequently, Averroes draws a clear distinction between an "actual time" or "perfect time" that can exist due only to the activity of the human mind, and a "potential time" or "material time" that consists simply of the changes that take place within the material world. He even stresses that outside the mind (*extra mentem*), "there is nothing other than something which is moved and motion." Thus Averroes presented to medieval readers an Aristotle who is much more "Augustinian" than is the Greek original. Apart from Aristotle and Augustine, the medieval discussion relied on some further sources. Most of them (Proclus, Boethius, the *Liber de causis*) transmitted a Neoplatonism of the Greek type. This meant that they advocated unambiguously the existence of time outside the human mind, defining time as an image of eternity. No less important were the Latin translations of the Arab philosopher Ibn Sina (Avicenna), who discussed a whole range of explanations of time. He opted too for an extramental existence of time in the thing itself and attempted to show the incoherence of an approach that makes time dependent on an activity of the soul; thus his conception could be read as a refutation of both Augustine's and Aristotle's/Averroes's approaches. Thus medieval readers were not so much faced with an antagonism between Aristotle and Augustine; rather, there was an apparent conflict between both of them on the one hand and the Neoplatonic and Avicennian tradition on the other.

Albert the Great and Medieval Discussions of Time

Confronted with this alternative, most medieval thinkers opted clearly for the second alternative, assuming, against Augustine and Averroes, the real existence of time outside the human mind. This was probably due to some presuppositions that were fundamental to their own religion. For a Christian, many philosophical problems were determined largely by the question of the relationship between God and humankind. What was interesting about time to medieval authors, was, then, the relation between time—the mode of duration of the sensible world—and eternity—the mode of duration of God. As the mode of duration of God's creation, however, time had to have a form of existence outside the human mind; otherwise this creation could hardly be an image of God's own way of existing. All these points can be found in the work of Aquinas's teacher, Albert the Great (Albertus Magnus), who did the painstaking work of explaining the newly discovered Aristotelian writings to his contemporaries, while taking into account nearly all important earlier discussions and authorities; thus he created a synthesis that was the point of departure for many contemporary accounts of time (including that of Aquinas), even if their authors did not agree with everything Albert had said. Albert first discusses time around 1246, in his "Summa on the Creatures" (*Summa de Creaturis*) and again in his commentary on Aristotle's *Physics* (around 1255). In both works, he reads Aristotle with the help of Averroes's explanations. His result is that Aristotle, Averroes, and Augustine are quite close to each other, insofar as all of them reject a real existence of time outside the human soul; in this regard, Augustine seems even somewhat more radical than Aristotle and Averroes, because the last two authors grant to time at least a potential existence outside the soul. Albert, however, rejects all three approaches and sides with Avicenna and the Greek Neoplatonists, defending the real existence of time outside the soul. It exists "according to the habitual form of a distinction of the numbered elements," as Albert concludes from the fact that the soul is counting the single elements of time, while time itself is continuously flowing. Thus Albert ascribes existence not only to permanent, unchanging entities but also to timely succession. Consequently, he openly rejects not only Aristotle's and Averroes's solution but also that of the church father Augustine—a remarkable case within medieval literature. Albert justifies his reproach by denying to Augustine a competence in natural philosophy. Furthermore, he affirms that the relationship between soul and time should not be discussed within the realm of physics (natural philosophy) alone but also in philosophy or metaphysics, as Averroes had already postulated. Albert himself, though, includes a lengthy discussion of time for reasons of convenience in his *Physics* commentary, where he adds his own treatise on eternity that differs from Aristotle's text. Albert's opting for a realist theory of time found many successors in subsequent periods. Even the conservative theologian Henry of Ghent (1217–1293) stated explicitly that Augustine's theory of time was false. Indeed, the thesis that time has no existence outside the human soul was officially called heretical in the famous condemnation of 1277, 3 years after Aquinas's death.

Aquinas and Aristotle

Albert's student Aquinas depends largely on the approach of his master, especially regarding the prominent role that Aristotle must play in any discussion of that subject. But Aquinas develops two explanations of his own, both of which differ markedly from that of Albert and both of them relying on Aristotle's *Physics*. This becomes clear already in Aquinas's early commentary on *The Sentences* of Peter Lombard (around 1255), where he quotes the fourth book of Aristotle's *Physics* in most of the relevant sections, though he discusses time, following Boethius and Albert, within the schemes of three modes of duration: time, eternity, and eviternity. In his concrete explanations of what time is, however, he follows Aristotle, in many cases as Averroes interpreted him. This holds true also for the relation between time and soul: Although the changes within the sensible world are the matter of time, its form, the numerical measure, is constituted by the human soul; thus Aquinas, at this time of his career, does not follow Albert but rather Averroes and is not so far from Augustine, whom he does not, however, quote in this context. Whereas here and in other writings only casual remarks are made regarding the problem of time, a more complete discussion can be found in Aquinas's own *Physics* commentary, which was completed around 1269, 10 years after the *Sentences* commentary and after Albert's *Physics* commentary. This commentary is, however, quite different in form from Albert's, because Aquinas confines himself to explaining the content of Aristotle's text without any lengthy discussions like those that had been given by Albert to help clarify Aristotle's position. Consequently, Aquinas's commentary sticks much closer to Aristotle's own statements, without mentioning by name authors such as Averroes, Avicenna, and Augustine. Concerning the relationship between time and soul, Aquinas interprets Aristotle's solution as implying the existence of time, even if there would not be any soul that could count it. Only the act of numeration, not the existence of the things that are numbered and not the existence of the number itself, depends on the existence of soul. This new interpretation of Aristotle's text was possible because Aquinas could use the improved translation by William of Moerbeke, who rendered the sentence quoted earlier in this entry as "that there might still be that time is somehow being (*utcumque ens*)," suggesting that time should have some extramental reality. However, Aquinas further qualifies his position by saying that only the indivisible aspect of time exists in reality (i.e., a single instant of time), whereas time itself, not different from motion, has no firm being (*esse fixum*) in reality. Consequently, time receives its totality (*totalitas*) by "the ordering of the soul which numbers the before and after of change." Consequently, without the numbering soul, time exists only imperfectly (*imperfecte*). While this formulation resembles Averroes's solution, Aquinas differs from him by acknowledging that time does not only potentially exist outside the soul and by not mentioning the distinction of matter and form in this respect. Thanks to Moerbeke's improved translation, Aquinas is able to ascribe this solution to Aristotle himself, while Albert still reproached Aristotle together with Averroes and Augustine for denying to time its existence outside the soul.

Aquinas and Augustine

Augustine, unlike Aristotle, was not an important source for Aquinas's theory of time. In fact, in Aquinas's discussions of the problem, the name of Augustine appears rarely, and there are no quotations of the 11th book of the *Confessions*. This has been interpreted as a consequence of Albert's critics of Augustine's theory of time and of his assumed lack of competence in natural philosophy, but it may also be due to the methodical presuppositions of Aquinas's *Physics* commentary. In any case, it must have been convenient for Aquinas not to mention that his theory of time was implicitly criticizing the authority of Augustine; with Averroes, a renowned but ambivalent philosopher was at hand who could be criticized for advocating the unacceptable theory that the existence of time depends upon the human soul. There was no necessity to mention the venerable church father Augustine in such unreliable company.

Matthias Perkams

See also Albertus Magnus; Aquinas, Saint Thomas; Aristotle; Augustine of Hippo, Saint; Eternity; Ethics; God and Time; Metaphysics; Ontology; Teleology; Time, Sacred

Further Readings

Barnes, J. (Ed.). (1991). *Complete works of Aristotle* (Rev. Oxford Trans., Vols. 1–2). Princeton, NJ: Princeton University Press.

Davies, B. (1993). *The thought of St. Thomas Aquinas.* Oxford, UK: Oxford University Press.

Aquinas and Augustine

The concepts of time as depicted by Saint Augustine of Hippo (354–430) and Saint Thomas Aquinas (1225–1274) were to become two foundational perspectives in the philosophical and theological discourse of Christianity. Both writers sought to explain temporal issues regarding God and

Creation (e.g., conflicting accounts in the first two chapters of Genesis), the universe, and humankind in terms of logic, mysticism, or both, that would be philosophically justified. Influenced by earlier philosophers, such as Aristotle, Boethius, Plato, Plotinus, and Porphyry, both Augustine and Aquinas developed their constructs of time and its relationship with the divine in a way that reflected the prevalent thinking within a novel theological framework.

Although both philosophers' theological constructs agreed in the nonliteral interpretation of Creation (including all species) and the universe, their differences in the concept of time as it concerns God and human beings are reflected in Augustine's and Aquinas's respective views of ontology. Essentially, the basis of their differences reflects the major influence of Aristotelian and Neoplatonic perspectives. This would have a consequence in terms of defining eternity, finitude, infinity, and the objective/subjective reality of time. To synthesize the two major influences of Aristotle and Plotinus (Neoplatonism), among other philosophical perspectives, is to illuminate a dichotomy that appears to incorporate and express the common psychological dynamics of humankind. This delicate balance of rational explanation and conscious mysticism of the unknown appears to explain more about humankind and humanity than about the ontological status of God. Nevertheless, the element of time could be seen as a commonality or connection with the divine being that appears to transcend cultural barriers. In this manner, both Aquinas and Augustine attempted to illustrate the shared humanity of humankind under a reconcilable and loving God.

The major works of Aquinas and Augustine, *Summa Theologica* and *Confessions,* respectively, outline the concepts of time and its significance for humankind in relation to God. Aquinas held the view that God created the known material world via the First Cause. This God, dwelling in his own essence, infinite in perfection, immutable and eternal, is beyond the concept of time. This view is based on the ontological concept that God, belonging to no genus or species, has no beginning or end; thus the concept of time that incorporates the range of time (beginning, middle, and end) cannot be applied to a being that not only lacks form and matter but also potentiality, as seen in genus or species. Furthermore, God's very act of creation, as depicted in the motion and limits of the universe and aspects of life moving from potentiality to a state of actuality, is encompassed within time. Comparatively, all things existing from God are relatively infinite but not absolute. In human temporal matter, human teleology follows ontology within the encompassing view of the soul (substance). According to scripture, however, there will be a conclusive end and a day of judgment. Cosmologically, then, it would appear that time, at least for the universe and humankind, would end or perhaps change (viz., the reference to a New Jerusalem or new beginning).

Aquinas's temporal view of the universe appears to be objective. The movement of the celestial bodies, in themselves comprised of form and matter, would imply duration or time. This duration as evidenced by motion would be independent of humankind's existence. Both time and space would appear to be infinite but not absolute. Although Aquinas had made distinctions among eternity, time, and *aveum* in *Commentary on Metaphysics,* the concept of time as tied to the soul has conflicting perspectives of objective time. Time, which excludes God, is based on actualization (in degree) of potentiality as decreed in form and matter. However, whether time is objective in all instances—for example, the universe as compared to humankind—remains elusive. Lacking a rational soul, the universe cannot experience time. Yet, the motion itself is indicative of time. Even considering being and nonbeing, the coexistence of multiple temporal stages would be indicative of either an active participation by God in temporal time or infringing on the free will of God, humankind, or both. Theologically, it becomes a grand masterpiece by which each stroke of the brush depicts a lapse of time.

Augustine, by comparison, held a differing notion of time and the relationship between God and humankind. For Augustine, God had created both angelic nature and formless corporeal matter. By the very act of creation, the material world ex nihilo, God had created an existence from the indivisible and unorganized to the material reality of experience. In this manner, all things were due to, or a response to, the Creator. Consequently, Augustine held that time did not exist before this creation event and was held bound by the natural conclusion of the created event; namely, the impending dissolution of material existence. God, an eternal and omnipotent being, is not bound by the constraints of time. Time, as Augustine held, is an extension of the human mind and its ability to comprehend successive events. However, God is eternal, whereby time past, present, and future are presented as one and not successive events. The conceptual arrangement of time, for Augustine, becomes a subjective experience. These experiences are independent and purely human. However, human concepts of time, when juxtaposed against the concepts of God, give the eternal attribute to God. It is unknown if this eternal aspect is dependent on the created, whereby the end of humankind would suggest the end of God's eternity even though God is beyond time. Such a contradiction in definition would require a resolution in a God that is spatiotemporally isolated, a mystical and incomprehensible being not touched by the fabric of either space or time but who somehow becomes interactive with the created.

Aquinas and Augustine presented a unique aspect of time. This concept of time, though dependent on the act of creation, requires an ontological distinction. Ontology and relationship between God and the created are essential in understanding this temporal nature of being (and nonbeing). This ontological aspect of God or the supreme *Logos* remains elusive; that is, the laws of noncontradiction prevent epistemological certainty. However, today these views in their totality must be conditioned, whether rejected or modified, by the advancements of modern science. Reflectively, time becomes the common thread by which ontology and epistemology converge.

David Alexander Lukaszek

See also Albertus Magnus; Aquinas, Saint Thomas; Augustine of Hippo, Saint; Avicenna; Bible and Time; Causality; Christianity; Genesis, Book of; God and Time; God as Creator; Plotinus; Time, Sacred

Further Readings

Augustine, A. (1991). *Confessions* (H. Chadwick, Trans.). New York: Oxford University Press.

Augustine, A. (2003). *City of God* (H. Bettenson, Trans.). London: Penguin Books.

Aquinas, T. (1948). *Summa theologica* (3 vols.). New York: Benziger.

ARCHAEOLOGY

Time is an essential part of archaeology, serving as a focal point of archaeological inquiry and an important component of archaeological analyses. Archaeology, likewise, is integral to the understanding of time and its effects, not just in the uncovering of dates to significant events in the history of humanity, but by providing evidence regarding changes and developments in humanity, including its biological makeup, technology, and traditions. By virtue of its intimate alliance with time, archaeology provides not only a greater understanding of what humanity has endured through history but also a means to learn about what humanity will possibly see in the future.

Early Conceptions of Time and Humanity's Existence

How old is the universe? When was the earth created? When did humans first walk on the earth? When was the first writing system created? How long did it take for humanity to develop from earlier primate species? When were the bow and arrow first utilized? When did writing first surface?

Today, archaeologists, in conjunction with scholars from multiple fields, have a variety of methodologies at their disposal to determine answers to these questions. However, with the field of archaeology not attaining any cohesive structure until the 19th century, individuals from other occupations provided the initial research that dictated our understanding of humanity through time, and their conceptualizations were often supported by unique sources. One of the more prominent such conceptualizations in history was based on the Judeo-Christian Bible.

An Irish clergyman, Archbishop James Ussher, looked to the Hebrew Bible for clarification of the earth's creation. Ussher's estimate, which he generated based on an interpretation of chapters in the Bible, indicated the earth came into existence circa 4004 BCE. In effect, humanity's developments and accomplishments, which include the spread of humanity throughout the world as well as humankind's domestication of animals, cultivation of plants, and generation of multiple writing and language systems, were achieved during a period of less than 6 millennia. Today, such a time interval is difficult to accept given our more thorough understanding of geological processes and our ability to date natural materials directly, but 400 years ago when Ussher unveiled his estimate, many accepted this as the age of the planet and the duration of humanity's appearance and development. Yet, like most theories, Ussher's estimate was challenged by new thoughts about time and the antiquity of both the planet and our species.

Ussher, one among many who looked to religious documentation and beliefs to date the earth and humanity, preceded other noted scholars who sought the planet's age, although the next wave of researchers looked elsewhere for answers. Of particular importance among them were the uniformitarianists. These scholars, including James Hutton and Charles Lyell, spent considerable amounts of time observing the geology of the earth and natural processes like erosion. Noticing the length of time needed for the natural landscape to change, whether through water action, wind damage, or other act of erosion, the uniformitarianists argued that it would have taken considerably longer than 6,000 years for the earth to form mountain ranges, lakes, rivers, and canyons. Such observations ultimately led to questions about humanity's development alongside the planet's landscape. Enter the evolutionists.

The impact of uniformitarianism was profound in that it promulgated the idea that the earth and humanity had existed for a great deal of time and that changes were continually occurring. It was in this atmosphere that Charles Darwin, Alfred Wallace, and other scientists developed their ideas of humanity and other species evolving over millennia. Looking at biological organisms as opposed to rocks, strata, and natural processes, supporters of evolution reasoned that changes to species, like the formation and disintegration of rock, took time. With the discovery of remains relegated to earlier hominid species during the late 19th century, the idea that humanity had been around for a significant number of years became embedded in the minds of numerous scholars and accepted by many in society as well. Collectively, these early concepts of time and the duration during which the earth formed and humanity and other organisms emerged provided a framework of understanding. Today, archaeologists ask many of the same questions, although their tools for answering such questions provide more accurate answers.

Modern Measures of Time in Archaeological Analysis

Archaeologists today have a broad range of tools at their disposal to determine the age of artifacts, sites, and human remains. The exactness of each of these methods varies considerably, but for the most part, they provide a substantial benefit to the understanding of time. In a general sense, the technologies referenced here are divided into two categories, the first of which is absolute dating methods.

Absolute Dating Methods

Absolute or chronometric dating methods are the most recent dating methods developed; they are utilized to date artifacts and sites alike. Although the name implies these methods of dating can obtain an exact date for the object analyzed, the reality is that archaeologists actually obtain a range of dates during which the object was created. Still, absolute dating techniques are a world apart from relative techniques and are of special importance to our understanding of human history, particularly in the evolution of humanity through time. Of the absolute dating methods most often used by archaeologists, radiocarbon dating, or *carbon-14 dating,* is undoubtedly the most prominent and widely utilized. Radiocarbon dating can be used to date organic material such as bone or wood that is from 500 years old to 40,000 years old. The principle behind this method is that after a living being dies, whether plant or animal, the radiocarbon within the specimen begins to decay. Because the decay rate of radiocarbon is known, it is possible to determine the age of organic material based on how much radiocarbon is remaining. The actual process of determining dates based on the radiocarbon method is rather complex, especially with regard to the care required in the collection and containment of samples. Yet, the reward of utilizing this technology is a more precise date for an artifact or archaeological site than a researcher would receive from relative dating techniques (discussed in the next section).

A second absolute dating method utilized by archaeologists is potassium-argon dating. Used to date rocks from 50,000 years old to 2 billion years old, the potassium-argon procedure involves the observance of potassium-40, or rather the argon created by decaying potassium-40 particles, that collects within rock over time. The actual procedure allows archaeologists to date sites and artifacts based on their association with dated rock material.

Dendrochronology, establishing a timeline based on tree ring sequences, is another example of an absolute dating method that has provided archaeologists with a means of determining the age of artifacts and sites. Profiles of tree limbs and trunks reveal a series of rings indicative of the tree's growth patterns. Knowing that thick rings denote good growing seasons and thin rings denote poor growing seasons, researchers can establish environmental patterns that trees endured through time. Once environmental seasons are developed for a region, and for an extended period of time, future tree ring samples discovered can be compared to established sequences providing indications of the age of the tree specimen. In this way, a tree fragment used to construct a building, wagon, or fence can be dated.

A final method of absolute dating is the use of historical documentation. Newspapers, diaries, and photographs provide a significant amount of information with which to date events, places, and people. Additionally, coins, stamps, and other objects with dates inscribed on their surface can also provide estimates for artifact assemblages in which they are recovered. Such direct historical links are arguably one of the most accurate methods for measuring time.

These absolute measures of time, while not 100% effective in establishing periods, reflect the advances archaeologists and other scholars have achieved in dating sites and objects. They are very different from earlier methods that only provide a basic or *relative* measure of time.

Relative Dating Methods

Christian Thomsen, a Danish 19th-century curator, initiated a sorting of artifacts based on the ideas of a three-age system reminiscent of earlier classifications separating artifacts into materials made from stone, bronze, and iron, although his system showed remarkable improvements and analysis of archeological finds. However, although Thomsen's dating and classification system provided a significant improvement in the understanding of the past and dating of archaeological material, such methods of ascribing dates or measuring time fail to provide anything more than a general idea of when an artifact was used in relation to a fixed or already determined point in time. This includes dates of when a person died or when a site was occupied. Of the variety of relative dating techniques used by archaeologists, there are two that are commonly used. The first and most fundamental of these is *stratigraphy.*

Stratigraphy is straightforward in its conception, but it is far from being uncomplicated in its implementation. From a basic standpoint, stratigraphy is a careful observance by archaeologists of the layers of earth as they excavate. By noticing and acknowledging the placement of artifacts and soil features, it is possible to gauge the date of an object by its provenience and relative position to other artifacts. Essentially speaking, the deeper an artifact is within the soil, the older it is relative to the objects that lay above it. This system of observation and analysis becomes significantly more complicated by the disturbance of archaeological sites by human interaction with the ground or by natural occurrences such as earthquakes, flooding, and glacial activity. However, from a basic level, this is a manner of gauging the age of an assemblage whether it be an artifact, burial, or collection of artifacts. A second method of relative dating often utilized by archaeologists is *seriation.*

Although not as simple in explanation and implementation as stratigraphy, seriation is nevertheless a rather straightforward approach to determining the relative age of an artifact and associated assemblages. The approach of seriation as employed by archaeologists centers on the collection of artifact types and the observance of styles or varieties of artifacts produced by a society. Whether the types of artifacts collected and observed are pottery or projectile points, ornamentation or clothing, the principle behind this dating method is the same. After collecting artifacts of a specific type, such as a stone spear point, from a number of sites, the percentage of each variety of spear point is calculated. Given that every variety has a period of time during which it is popular, sites can be aligned or placed in order of occupation based on the presence of each variety. Limitations of this technique include the fact that excavation may fail to uncover all specimens of a variety found at a site. However, when used in conjunction with other dating methods, whether absolute or relative in nature, seriation can be an extremely effective means for determining the age of a site.

Archaeological Knowledge and Time

Archaeological reconnaissance, often conducted by researchers from other fields of study, has brought an awareness of major achievements made by humanity in the past. In that way, archaeology has provided knowledge of the past that otherwise would have remained lost. Of particular importance to such discoveries are sites and artifact assemblages related to human origins, early innovations, instances of human migration, and effects of contact on culture change.

Human Origins

Researchers have discovered much about humanity's development over time through archaeology. With major discoveries of early hominid remains surfacing in the late 19th century, archaeologists have had sufficient time with which to decode much of the past, although many answers to our questions about human origins remain elusive. As for some of the more significant discoveries in this area of research, a few stand out among the most critical. At Laetoli, in Tanzania, Africa, for example, Mary Leakey, in the late 1970s, uncovered a trail of footprints preserved by volcanic ash. The footprints, created by three australopithecines (*Australopithecus afarensis*), provided evidence that human ancestors were walking erect (bipedalism) by around 3.6 million years before the present (BP), a major discovery about humanity's development in time that archaeological efforts recovered.

Not far from Laetoli, and also in Tanzania, archaeologists uncovered more evidence regarding human origins and development. In the Olduvai Gorge, the Leakey family spent decades searching through the multiple layers of the canyon, which dated as far back as approximately 2 million years BP. The reward for their painstaking efforts included the remains of early hominids *Australopithecus boisei* and *Homo habilis,* both dated to nearly 1.8 million years BP. Additionally, among the remains of giraffes, antelopes, and elephants, the Leakeys uncovered lithic tools. Collectively, the hominid remains and tools found at Olduvai Gorge provided a clearer understanding of the emergence of the Homo line from earlier hominids and the initial tool tradition created by humankind, namely, the Oldowan tradition. A final discovery connected to archaeological excavations and humanity's development through time revolves around caves in Europe whose walls were decorated by paintings created during Paleolithic times.

Lascaux, Chauvet, and Altamira are among the many caves discovered since the 19th century with wall paintings scattered throughout multiple chambers. Often discovered by chance, these caves are adorned with paintings and engravings depicting human beings and an array of animal species, many of which are now extinct. Early on, these caves were often thought of as hoaxes, because many people found it hard to believe that Paleolithic peoples could have created such impressive renderings. Yet, as absolute dating techniques were created and improved and as more analysis was done on artifacts and remains recovered from the caves, it became clear that by nearly 30,000 years ago, human populations were able to create art depicting great detail and often abstract in nature, which indicated an advancement in human mental capacity.

Early Innovations

Humanity's continual adaptation to ever-changing environments still provides the impetus for technological innovation. Through archaeologically based examinations of the past, the innovations created by humanity have been unearthed along with the knowledge of when such technologies first surfaced. In the Mesopotamia region along the shores of the Euphrates River, for example, excavations of the ancient city of Uruk uncovered the earliest forms of writing, which date to roughly 5,400 BP. Although they were little more than clay tablets with tabulations made of merchandise in the form of depictions of ore, tools, food, and livestock, this discovery helped determine the earliest mode of writing. In a similar vein, researchers have uncovered evidence of when specific plants were domesticated in the New and Old Worlds.

Maize provided a main staple for many societies in South, Central, and North America, serving as a major contributor to the rise of large, nucleated villages and cities. The question is, where did it originate? Despite continued debates over maize's domestication, excavations throughout areas near and in the Tehuacán Valley indicated that maize was cultivated as long as 5,000 years ago. As for Old World domesticates, excavations in the Near East, near present-day Syria, Jordan, and other Middle Eastern nations, recovered plant remains that showed changes to barley and wheat composition, which followed the increased use of tools for processing food. The appearance of these plant alterations and technologies indicates that barley and wheat were cultivated roughly over 10,000 years ago. Once again, archaeological analysis provided insight into the time frame during which human activity occurred.

Migration

When did human populations first reach North America and the rest of the New World? When did the first New World culture emerge? To this day, multiple interested parties debate this question. From among scientists, estimates of when humankind first reached North, South, and Central America ran from 2,000 years to upward of 30,000 years ago. Native Americans, meanwhile, look toward their oral traditions for guidance on this issue with many arguing that they always have lived on the New World continents. Archaeological analysis has provided insight into this inquiry and has since the early 1900s when Paleoindian-related artifacts were uncovered near Clovis, New Mexico. Consequently, archaeology has proven effective in discovery information about when migrations occurred in time.

As for migration into North America, having already established that projectile points found near Folsom, New Mexico, were dated to roughly 10,000 years ago, researchers argued that the earliest peoples to enter North America had to have preceded the Folsom-using populations because the Clovis points were found in a layer of soil below Folsom points. Thus archaeological research provided an idea as to when the first culture (Clovis) surfaced and when humans first reached the New World (c. 12,000 BP). Excavations in Pennsylvania at the Meadowcroft site have uncovered evidence going back even farther, with assemblages dated beyond 15,000 BP. Collectively, these findings give ample evidence that human populations entered North America not long after 20,000 BP. Excavations in South America indicate that people reached the New World relatively early as well. At Monte Verde in Chile, evidence of stone tools and wood supports for structures has been unearthed after having been preserved in bog conditions for millennia. The radiocarbon dates acquired from the site date to roughly 13,000 BP. Today, debates regarding dates obtained from Monte Verde and Meadowcroft remain. However, from the combined evidence, archaeological research has provided some understanding of when in time humans first reached the New World, setting a window of likelihood from tens of thousands of years down to a few thousand.

The effectiveness of archaeology, although questioned by some, is tremendous in that the analysis of material culture recovered from the archaeological record continues to provide clues as to when various hominid forms surfaced, when innovations occurred, and when humans migrated to different parts of the globe. Archaeology also has assisted in determining when contact and culture change occurred between two or more human populations.

Contact and Culture Change

The initial arrival of European explorers, missionaries, and emigrants to North America occurred at a time when record keeping was not standardized or thorough. Many of the Europeans who arrived were illiterate; others recorded nothing more than lists of supplies. All told, records of the effect of contact between Europeans and Native Americans were void of great detail, leaving questions as to when contact occurred in many instances and how long it took for both populations to integrate styles or commodities utilized by the other. Archaeology fills this void. With excavations ranging in size from a few test units to entire sites being uncovered, archaeologists have amassed large collections from Native

American village sites dating to the contact period. Iroquoian village site assemblages dating to the early 1600s, for example, contain European products ranging from glass beads, copper pots, and components from firearms. From an analysis of material recovered, it is clear that Iroquoian peoples soon learned to rework the European objects and materials, copper and iron kettles for instance, into utilitarian objects such as weaponry and hunting implements (spear points, arrowheads, knives, etc.). What is the importance of archaeology to the understanding of contact between two populations? It assists in discovering roughly when contact occurred when no written record exists and how long it takes for the technologies and resources of two peoples to be shared.

Important Archaeological Sites and Their Temporal Significance

The mere mention of the word *archaeology* usually generates images of broken stonework, pottery sherds, stone projectile points, and monoliths strewn across a field. On a larger scale, people equate the study of human material culture with a few sites throughout the world that hold special temporal significance.

Cahokia

Located along the Mississippi River near St. Louis, Illinois, Cahokia was once one of the largest municipalities in North America. With extensive settlement of the area beginning roughly 1,300 years ago, dependent upon maize production and eventually reaching a size of approximately 40,000 people, Cahokia eventually developed into a series of populated sectors positioned around large, earthen mounds used for multiple purposes, including burial and public interaction. The largest of these mounds was the multileveled Monk's Mound, which reached a height of approximately 30 meters, covered an area greater than 5 hectares, and served as the center of Cahokia itself. Extensive analysis of Cahokia determined that the inhabitants traded extensively, lived in a stratified society, and utilized the wealth of natural resources available in addition to cultivating a variety of plants. In view of time, Cahokia's mounds are of particular significance, because the size, shape, and use of public space varied considerably, including areas where wooden beams were placed in order to plot and record astronomical events such as equinoxes. Cahokia additionally served as a prime example of a tradition known as *Mississippian,* which archaeologists equate with societies that shared multiple cultural characteristics, including the erection of earthen mounds and the dependence on maize cultivation between 1,300 BP and 500 BP.

Cuzco

The site of Cuzco, located in the Peruvian hinterland, was the capital of the Inca Empire. Supported by extensive canal and road systems and a repository for precious commodities from throughout South America, Cuzco served as the axis for the empire. Clergy, aristocracy, military commanders, and craftspeople lived within the immediate municipality while the general populace occupied the outlying regions. Cuzco exemplified the complexity of Inca architecture with buildings and temples made of fitted stone blocks, many of which serve as foundations for modern buildings to this day. Likewise, the Inca system of roads, which stretched thousands of kilometers throughout the empire and included depots and quarters to shelter and resupply travelers, were centered around the capital, making Cuzco the focal point for trade and control.

Much of Cuzco's history was recorded in documentation provided by Spanish explorers who first traveled throughout South America approximately 500 years ago. Ultimately, the Spanish and Incas clashed. The confrontation led to the Incas destroying Cuzco and the Spanish gaining considerable control of the region. In time, the Spanish forces rebuilt the city, preserving much of Cuzco's outline. Today, it is possible to see how Cuzco was organized by the Incas and what importance its structures served to the empire overall by the distribution of building types throughout the site. Additionally, the site—specifically its origins, development, and eventual reconstruction on the part of Spanish forces—reflects the metamorphosis that Inca civilization went through after contact with European entities.

The Pyramids of Giza

The pyramids at Giza often form the heart of people's image of the ancient civilization that populated the banks of the Nile. For many, pyramids were constructed and utilized by every Egyptian ruler during the ancient civilization's millennia of existence. As for the design of their pyramids, Egyptians erected step and flat-sided varieties with the larger structures reaching over 150 meters high and covering over 4 hectares in area. Yet, the larger pyramids at Giza, which include the Great Pyramid of King Khufu and are larger and more complex in their internal designs than later pyramids, are not typical of every dynasty that ruled Egypt. These early pyramids date to the Old Kingdom, approximately 4,200 to 4,700 years ago. Later Egyptian rulers constructed less elaborate burial chambers, with pyramids even being abandoned for tombs cut out of rock in later centuries.

Lascaux Cave

Europe is home to multiple caverns whose walls are decorated with paintings and engravings depicting abstract and realistic images of humans and of animals, many species of which are now extinct. Lascaux, located in southern France, is one of the more renowned of these sites. Spanning over 200 meters in total length, this cavern includes hundreds of engravings and paintings of humans, bison, horses, and other assorted animals. As for the techniques for applying the renderings to the cavern walls, the artists generated colors using charcoal, iron oxides, and manganese oxides, while engravings were created likely through the use of an assortment of flint tools. Since the initial discovery of such cave renderings over a century ago, a variety of arguments have surfaced as to the purpose of these art forms. Yet, whether these ancient paintings and engravings were believed to serve as magic or just art for art's sake is not the most crucial question.

With the advancement of dating techniques making it possible to directly date the cavern's renderings, researchers were able to determine that Lascaux was decorated approximately 17,000 years BP. This discovery, along with the complex nature of the mediums and painting/engraving techniques utilized by the artists, indicated that Paleolithic populations were more capable than researchers originally thought possible, both in their conceptualization of their world and their place within it.

Stonehenge

Located in the county of Wiltshire in southern England, Stonehenge remains one of the most noted archaeological sites to both enthusiasts and archaeologists alike. With initial construction beginning approximately 5,000 years ago, Stonehenge underwent multiple stages of construction over a span of roughly 1,500 years. The result of these stages was the erection of the monoliths for which the site is known. Additionally, the site's engineers established embankments, ditches, and other components, which have been partially damaged, rearranged, and destroyed by subsequent visitation to the site. Today, speculation as to the purpose of the site has included the belief that it serves as a calendar for predicting celestial events such as equinoxes and eclipses. However, the only calculation that appears credible is the timing of the summer solstice and its alignment to Stonehenge's Heel Stone and Avenue. However, the loss and movement of Stonehenge's monoliths and earthworks makes even this assertion questionable.

Teotihuacán

The ancient city of Teotihuacán has long augmented the landscape near present-day Mexico City. With occupation of the area beginning approximately 2,100 BP and continuing until roughly 1,000 BP, Teotihuacán developed into one of the largest cities in the world with a maximum population of over 100,000 people at times. As for total area of occupation, Teotihuacán expanded quickly through the centuries, ultimately covering approximately 20 square kilometers. The structures that were erected by the site's inhabitants were stone and plaster buildings, particularly living quarters and temples. Teotihuacán's occupants lived in various sized apartment compounds capable of sheltering multiple families, with total populations of over 100 persons in some instances. The temples were equally diverse in size and were positioned among the apartment compounds. All told, over 4,000 structures were erected at Teotihuacán, with the Pyramid of the Sun, which stood over 60 meters high, standing above everything else.

Interspaced among all of these structures were marketplaces, courtyards, and roadways that connected all of Teotihucán's living spaces and helped forge the footprint of this mammoth city.

Today, Teotihuacán is a favorite destination and research topic for both archaeologists and tourists alike, and every year, continued excavation and analysis of artifacts reveal more about the site's residents and their contact with neighboring peoples. Such investigation of the ruins of Teotihuacán is far from being a recent development, however. Throughout time, later populations, including the Aztecs, visited the site and utilized its space for their own purposes. The significance of this reality is that archaeological sites are often multicomponent in nature, playing host to several occupations. While each occupation will vary in its duration of stay and area of activity, the importance of each occupation is nevertheless an equal contributor to the site's history and time itself.

Zhoukoudian Discoveries

The Zhoukoudian caverns, located near Beijing, have yielded *Homo erectus* remains since the early decades of the 20th century along with an assortment of lithic tools and evidence of early fire use. While many specimens recovered were subsequently lost during World War II, the impact of the remains is still intense. Temporally speaking, the range in Homo erectus remains discovered in the Zhoukoudian region reflects the continual evolution of the species over the course of nearly 300,000 years (550,000 BP to 250,000 BP), particularly with regard to brain size.

Conclusion

Humanity's cultures are ever changing through time. Equipped with the technologies and theories of multiple fields, archaeologists continually seek to understand these changes through the careful collection and analysis of the material culture human populations have left in their civilization's wake. Although the interests and theoretical foundations among archaeologists vary considerably, and even as newer avenues of research such as paradigms based on critical thought and gender theory have taken center stage, an emphasis on time remains of central importance to most archaeological research.

Neil Patrick O'Donnell

See also Altamira Cave; Anthropology; Boucher de Perthes, Jacques; Chaco Canyon; Chauvet Cave; Dating Techniques; Egypt, Ancient; Evolution, Cultural; Lascaux Cave; Olduvai Gorge; Pompeii; Rapa Nui (Easter Island); Rome, Ancient; Rosetta Stone; Seven Wonders of the Ancient World; Stonehenge; Time, Measurements of

Further Readings

Binford, L. R. (1989). *Debating archaeology.* San Diego, CA: Academic Press.

Birx, H. J. (Ed.). (2006). *Encyclopedia of anthropology.* Thousand Oaks, CA: Sage.

Fagan, B. M., & DeCourse, C. R. (2005). *In the beginning: An introduction to archaeology* (11th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Garbarino, M. S., & Sasso, R. F. (1994). *Native American heritage* (3rd ed.). Prospect Heights, IL: Waveland Press.

Hodder, I. (1993). *Reading the past: Current approaches to interpretation in archaeology* (2nd ed.). Cambridge, UK: Cambridge University Press.

Nelson, S. M., & Rosen-Ayalon, M. (Eds.). (2002). *In pursuit of gender: Worldwide archaeological approaches.* Walnut Creek, CA: AltaMira Press.

Price, D. T., & Feinman, G. M. (1993). *Images of the past.* Mountain View, CA: Mayfield.

Shanks, M., & Tilley, C. (1992). *Re-constructing archaeology: Theory and practice* (2nd ed.). London: Routledge.

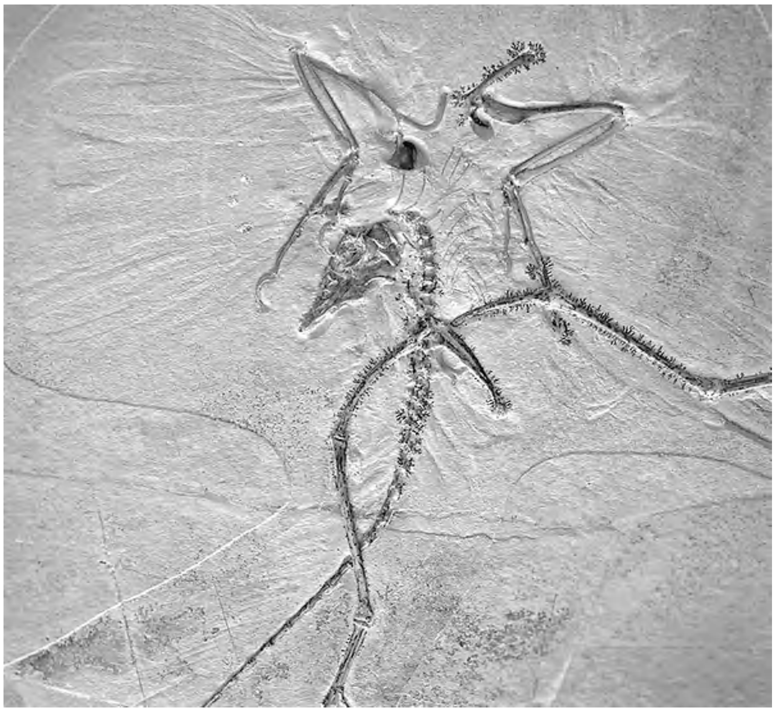
Tattersall, I., & Mowbray, K. (2006). Lascaux cave. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (pp. 1431–1432). Thousand Oaks, CA: Sage.

Trigger, B. G. (1993). *A history of archaeological thought.* Cambridge, UK: Cambridge University Press.

ARCHAEOPTERYX

Archaeopteryx is a dinosaur known from Jurassic fossils that remarkably exhibits feathers and other features once thought exclusive to birds. Specimens are regarded as among the most beautiful and significant ever found, as they document an important example of ancient life on the evolutionary path of flying birds arising from dinosaur ancestors. The first description of this "dinosaur-bird" in the 19th century famously helped ignite the evolution debate, and *Archaeopteryx* remains a relevant symbol of scientific enlightenment even today.

Adult *Archaeopteryx* was a crow-sized, bipedal, feathered dinosaur approximately 0.5 meters long. Although its exact evolutionary relationship has long been enigmatic, it is widely acknowledged to be a basal member of the Eumaniraptora, a branch of theropod dinosaurs that evolved in the Middle Jurassic and some of whose descendants would later give rise to modern birds, Aves.



Archaeopteryx *is an early, bird-like, feathered dinosaur, dating from about 150 million years ago during the Jurassic period, when many dinosaurs lived. Current research on this fossil and others using hi-tech methods has greatly strengthened our ideas about the evolutionary tie between dinosaurs and birds. This* Archaeopteryx *example, coined the "Thermopolis" specimen, is one of the most recently described discoveries.*

Source: Courtesy of Wyoming Dinosaur Center/Scott Hartman.

Specimens of *Archaeopteryx* have been discovered mostly in the 150-million-year-old rocks of Solnhofen, Germany, where finely laminated limestone preserves an exceptionally rich and diverse record of fossilized ancient life. The prehistoric landscape that formed this momentous resource is thought to have been a low, shrub-covered archipelago. Lime-rich mud washed into and filled its shallow lagoons, burying and preserving the mortal remains of its surrounding inhabitants, including dinosaurs, mammals, reptiles, fish, plants, and insects. Thanks to the fine-grained nature of the sediment and other taphonomic factors, the fossils of the Solnhofen limestone are often exquisitely detailed. Even soft tissues are preserved, such as the feathers that marked the epochal discovery of *Archaeopteryx* (which means "ancient wing" or "flight") in the 19th century.

Because of its being extensively covered with well-developed feathers, the *Archaeopteryx* has long been termed the world's most primitive bird. Indeed it seems to display many aspects common to modern birds and conducive to flight: arms with feathers to form broad wings, primary asymmetric "flight" feathers, small body size, hollow limb bones, relatively large brain with well-developed locomotor regions, and, the boomerang-shaped furcula (or "wishbone") commonly found in modern birds.

Unlike modern birds, however, *Archaeopteryx* also had jaws with sharp teeth, clawed forelimbs that extended forward of the "wing," and a long bony tail similar to other carnivorous dinosaurs at the time. Moreover, a plethora of recent discoveries of feathered dinosaurs with similar traits have been found, predominantly in China, that indicate that *Archaeopteryx* has no unique characteristics shared with birds that cannot be found in dinosaurs.

The flight capability and habits of *Archaeopteryx* have long been controversial. The latest specimens show that the extent of primary feathers along the bones of the arms was more limited than first thought, thereby decreasing the area available for a flight surface if used as a wing. Additionally, the lack of certain structures in the shoulder girdle combine to rule out powered flight, although limited flapping and gliding may have been possible. The first toe, called a hallux, is not fully reversed so as to specialize in grasping onto branches as in arboreal dwelling birds. And the second toe had a hyperextensible claw, similar to dromaeosaurid theropod dinosaurs but not modern birds. Collectively these suggest that *Archaeopteryx* retained the predominantly ground-dwelling habits of its forerunners and could not sustain powered flight.

Archaeopteryx was therefore not so much a bird as it was essentially a feathered dinosaur. Although most likely not a powered flyer, *Archaeopteryx* displayed the first feathers suitable for flight. It has been speculated that these originated as useful for insulation or to assist grip and changes of direction when pursuing prey, before being co-opted to develop novel aerodynamic capabilities such as gliding or flying short distances.

The remains of *Archaeopteryx* are among the most significant and famous of all fossils. The discovery of an apparent transitional form between reptile and bird catapulted *Archaeopteryx* onto the world stage just as Western society was hotly debating Charles Darwin's new concept of evolution. To some, the beautiful form of this "dinosaur-bird" supplanted historical images of Creation; it provided clear evidence that each species descended from its precursors and that these changes could be traced in the fossil record. Its fossils continue to provide an iconic example of life's mutability over time.

Mark James Thompson

See also Dinosaurs; Evolution, Organic; Extinction; Extinction and Evolution; Fossil Record; Fossils, Interpretations of; Ginkgo Trees; Stromatolites; Trilobites

Further Readings

Chambers, P. (2002). *Bones of contention: The fossil that shook science.* London: John Murray.

Chiappe, L. (2007). *Glorified dinosaurs: The origin and evolution of birds.* New York: Wiley.

Dingus, L., & Rowe, T. (1997). *The mistaken extinction: Dinosaur evolution and the origin of birds.* New York: Freeman.

Aristotle (384–322 BCE)

For the Greek philosopher Aristotle, the most prominent disciple of Plato and founder of the so-called Peripatetic School, time is one of the fundamental constituents of reality. In his *Categories* he refers to time—without further discussing it here—as one out of ten "kinds of being," as "when" (*pote*). As a continuous quantity next to place and line, surface and body, time, for Aristotle, pertains to the category of quantity (*poson*). In *Physics,* however, he uses the concept of time in juxtaposition with the concepts of nature (*physis*), motion (*kinesis*), place (*topos*), infinity (*apeiron*), continuum (*syneches*), and emptiness (*kenon*) as a fundamental concept of his philosophy of nature. And although in the logic founded by him, time is of no concern to Aristotle (a "temporal logic" still being a far cry), it is the implicit horizon of human decisions and actions in his ethics. Unlike in modern philosophy, in which it figures as an eminent subject, time, for Aristotle, is merely an "accident" of reality, inasmuch as this latter is grouped around the concept of substance (*ousia*). Thus, on the one hand, all categories outside of the substance number among the accidents. On the other, just as motion and quiet, the number—and with it time—belongs to that which is "generally perceptible" (*koina aistheta*) in the phenomena, that is to say to that which is not restricted to a specific sense such as smelling or hearing but that belongs to all perceptions in general. Although they are, as a matter of consequence, universal constituents of humans' experience of reality, these categories exist in themselves merely as accidental qualities of a substance in motion.

Nevertheless, Aristotle's treatise on time in *Physics* (IV 10–14) is indubitably one of the most elaborate and influential contributions to the clarification of the essence of time. It evidently does not allow the inclusion of time in a metaphysical system, as that was later accomplished by the founder of Neoplatonism, Plotinus. Already the early critics such as the pre-Christian Peripatetics and the Neoplatonic commentators of Aristotle therefore object less to his phenomenological analyses than both to the fundamental lack of clarity with regard to the metaphysical status of time—that is, more precisely, of its definition as number and measure—and to the function performed by the soul in measuring and perceiving time. The judgment passed on Aristotle's analysis of time by modern critics has to be seen, for the most part, in the light of their own theories of time, some of which take their origin from the *aporiae* of the Aristotelian text. For Henri

Bergson, Aristotle is the first philosopher to have spatialized time and to whose concept of time Bergson opposes his concept of duration (*durée*). Martin Heidegger, on the foil of his existential-ontological concept of temporality (*Zeitlichkeit*), regards Aristotle as the exponent of a "vulgar" concept of time whose characteristics are timekeeping, the use of clocks, and the "uninterrupted and unbroken succession of the now" (Heidegger, 1988, §19). Modern characterizations of Aristotle's theory of time range from "the first philosophical theory of measuring time" (Janich, 1985) to "the phenomenology of the ordinary conception of time" (Wieland, 1992, p. 334; translation by entry author).

Taking his definition of time as "number of motion with respect to before-and-afterness" (Phys. IV 11, 219b1–2) as a starting point, this entry discusses Aristotle's theory of time with respect to six different topics: time and movement, time as number and measure, time and the "now," time and the soul, the use of clocks and the measurement of time, and time and eternity.

Time and Movement

A central problem of time is the question of its existence, for time is that which "exists either not at all or only hardly and vaguely so"; it is composed of what is past and future, both of which are nonexistent: the one being no more, the other not yet. Therefore it seems that time "does not participate in the substance"; that is, it does not exist as a substantial but only as an accidental being. The being of time is dependent upon movement that is itself, just as time, only of accidental being, inasmuch as it concerns processes that affect a temporal substance in motion. With respect to the relationship between time and movement, Aristotle distinguishes two views, both of which he opposes: Time is (1) the movement of the universe and (2) the celestial sphere itself. Although he does not assign these positions to anyone, the first can be related to Plato (as is done, according to Simplicius, by Eudemos, Theophrast, and Alexander of Aphrodisias). In the *Timaios,* Plato describes time as the "moving image of eternity" and ties its measurement up with the heavenly spheres and the planetary orbits. The second position is presumably Pythagorean. Archytas, for instance, is supposed to have called time the "expansion of nature as a whole." Despite the fact that Aristotle rejects both positions as insufficient, he adopts their assumption that time and movement are linked with one another. In doing so, he brings out two aporiae: (1) While movement is always the movement of a thing that is being moved, related exclusively to this thing and the place of its movement, time universally encompasses all things. (2) Movement can be faster and slower, whereas time passes steadily and thus serves as a measure, not of itself, but of the velocity of movement. It follows that time is not identical with movement, yet also not independent of it.

To prove that the relationship between time and movement is one of reciprocity, Aristotle puts forward the argument of the "Sardinian sleepers," a myth according to which there are men in Sardinia who, lying next to the heroes there, fell into a sleep devoid of all memory. Philoponos regarded this sleep as a 5-day healing sleep, and Simplikios identified it as the legend of the Heraclidae who had died after the colonization of Sardinia and whose bodies, as though they were fallen asleep, had outlasted time; to sleep in their vicinity was said to induce momentous dreams. Aristotle's philosophical point in referring to this myth is that the Sardinian sleepers miss the time during which they were sleeping because they connect the now perceived before falling asleep with the now perceived when waking up again and, leaving out the time that has passed meanwhile, experience it as a continuity. As time is always limited by two nows, no time seems to have elapsed when we perceive—or believe to perceive—one and the same now. From the fact that our perception of time is tied up with the perception of a movement—and be it but the soul's inner perception of itself—it follows that time and movement mutually imply one another. And although this relationship is one of mutual implication and one might first analyze movement with regard to time, Aristotle begins his systematic enquiry into the essence of time with the question of what time is with regard to movement—for the methodical reason that, within the framework of *Physics,* movement has already been discussed, whereas time has not and is still unknown.

Time as Number and Measure

Time is not identical with movement but with one of its aspects: "that by which movement can be numerically estimated." The number, in the sense in which Aristotle is using the term, is first and foremost the number of things we count, mathematical numbers being the result of an abstraction (*aphairesis*) from the numbers of things we have counted. Aristotle therefore criticizes the Platonic philosophers for reclaiming their ideal numbers from the numbers of things counted and for treating these ideal numbers as substances. Hence, "number," for Aristotle, is an equivocal concept that, on the one hand, designates the "countable" number (i.e., the number of the things that are being counted) and, on the other, the number "by which we count" (i.e., the mathematical, abstract number). The counted number refers to a quantity of things of the same kind. Because each of these things is understood as one indivisible whole, every specific area has a unifying measure of its own: harmony, for instance, the quarter note, or, when we want to count horses, the single horse. Again, the mathematical number (that by which we count) can be understood either as an abstract sequence of numbers that we apply to concrete things when we count (Ross, 1936, p. 598), or as the abstraction from the number of things counted, one of which, when we count them up, we use as unit (Wieland, 1992, pp. 318–322). Accordingly, the number by which we count serves as unit: "We measure the 'number' of anything we count by the units we count it in—the number of horses, for example, by taking one horse as our unit. For when we are told the number of horses, we know how many there are in the troop; and by counting how many there are, horse by horse, we know their number." Because one (*monas*), the first principle of all numbers, is "in every respect" and per se indivisible, the number as the "plurality of (discrete) unities" (*plethos monadon*) is the measure with the highest precision, whereas continuous quantities are measured by units that, to our perception, seem to be simple and indivisible. As noted by Richard Sorabji (1983), seeing that Aristotle considers time not only as "number" but also as "measure of motion," one can say that he is obviously not using these concepts synonymously (pp. 86–89). Julia Annas (1975) points out that, as a matter of consequence, Aristotle's language with regard to time either lacks unity or, more likely, what we really count, when we think we count different nows, are simply the periods of time limited by these nows (pp. 97–113).

Time, defined as "the number of motion with respect to before-and-afterness," is for Aristotle part of the counted number, not of the number by which we count. Hence, as both Wieland (1992, p. 327) and Sorabji (1983, pp. 86–89) note, the unit by which we count is not time itself, but, first, a now posited sooner or later and, second, a certain period of motion that we take as a unit in order to count up, and measure, a number of movements of the same kind. Time and motion mutually imply one another when it comes to measuring them: "For by time we measure movement, and by movement, time." By defining a particular motion as a unit of time we consequently attain a first unit of time with which we can measure other motions ("number of motion," after all, refers in the first place to such temporal units as day, year, or season of year). As a matter of consequence, the thing that is being counted has two aspects: On the one hand, we measure time by counting particular movements of the same kind that we have defined beforehand; on the other, we count the now or the number of nows: "And just as motion is now this motion and now another, so is time; but at any given moment, time is the same everywhere, for the 'now' itself is identical in its essence, but the relations into which it enters differ in different connexions, and it is the 'now' that marks off time as before and after." Just like a point in a line, the now functions as a limit between two periods of time, not primarily in that it is the end of a past and simultaneously the beginning of a future—if it were, the now would be a standstill and as such incapable of time and motion—but rather like the outmost points of a line that serve to demarcate a certain lapse of time. The smallest number of a unit of time is two or one, two with respect to the two nows that delimit time (the former and the latter now), in particular the two nows that constitute a certain period as a unit for measuring time; and it is one with respect to the unity of the now that, as the principal measure of time, serves both as a dividing and an integrating factor. Aristotle's definition of time as "number of motion with respect to before-and-afterness" combines these two aspects of the number, for what counts is not the former and the latter now, but both of them taken together in their capacity to limit a particular motion and the time it lasts, thus serving as a counted number that measures motion with respect to its temporal boundaries.

Time and the Now

The reality of time is a problem that Aristotle solves by way of the now: "In time there is nothing else to take except a 'now.'" As between time and movement, also the relationship between time and the now is one of mutual implication: "It is evident, too, that neither would time be if there were no 'now,' nor would 'now' be if there were no time." The now is not a part of time but the boundary between two periods: past and future. Thus, contrary to what is imputed to him by Heidegger (1988, §19), time for Aristotle is not a succession of nows. Nevertheless, the aporia remains as to whether the now is always one and the same or always new. Each of the two suppositions entails a dilemma. (1) The now cannot always be a new one, not only because nows that are not different from one another are capable of a simultaneous coexistence, but also because the way in which a former now disappears cannot be explained; neither can it have disappeared all by itself (seeing that it once was) nor can it have transformed itself into a later now, for then there would be an infinite number of nows between itself and subsequent nows, which is impossible. (2) The now cannot always be one and the same, because then completely different periods of time would be marked off from one another by the self-same boundary; moreover, all points of time past and future would then coincide with one another in a single now. For Aristotle, the solution to this aporia lies in the fact that the now has two aspects: On the hand, the now, understood as the potential division within the continuous flux of a movement and of time, is essentially always new, capable of actualizing itself as a boundary between "sooner" and "later" and of being perceived as an indivisible whole. On the other hand, the now is always the same. As such, the now is the first principle of, and yet different from, time.

An objection that was raised against Aristotle's definition of time (e.g., by Strato of Lampsacos, a Peripatetic of the 3rd century BCE) is that time is per se continuous, whereas both number and now are discrete, a criticism that is inaccurate, because for Aristotle time is the countable aspect of motion: In counting continuous periods of time and motion, we mark these off from one another by discrete nows. Time, thus, has passed, if we perceive "before" and "after" (*aisthesin labomen*) with regard to motion, that is, when we take the self-same now for two nows, one earlier, the other later, and think (*noesomen*) of its two limits as distinct from the interim that they contain. No time has elapsed, however, when we perceive the now as one and the same, that is, when there is no sooner or later with regard to motion. "Before-and-afterness" is what results if the soul is counting the nows and inserts them into the sequence of numbers. It is the successive order of this sequence, and not an inner sense of time, that is decisive for the irreversibility of the nows. Otherwise, seeing that "before" and "after" are temporal expressions, the definition of time as "number of motion with respect to before-and-afterness" would be circular and the essence of time would depend on the activity of the counting soul. Thus, although it is itself discrete, the now establishes, as a first principle, the continuity of time, for in marking off now the one, now the other period, it divides time as a limit (*peras*) and is itself always different, yet in remaining always the same, holds time continuously together. The now herein resembles the point when it divides a line. On the one hand, it is always the same, for it always performs the same function of dividing the line; on the other hand, it is not the same inasmuch as it always divides the line in a different place. And, as Wieland (1992) notes, because it is in the nature of noetic thinking to be capable only of thinking of indivisible and discrete contents, it (i.e., the noetic thinking) attains continuity only by the successive positing of discrete marks, immediate continuity being a prerogative of the perception (p. 326).

Aristotle regards the now as a nonexpanding limit, that is, as the beginning or the end of a period of time. In some places, he considers the now as a presence of minimal extension, which, as an integral part of time, overlaps with past and future, for example, the now in the sense of "today." In his analysis of time, however, he does not work with such a concept of now but uses the concept of a nonexpanding limit. Among scholars there is disagreement whether one can reformulate Aristotle's theory of time in the terms of the static "earlier, simultaneous, later" as opposed to the dynamic "past, present, future"; some have noted that Aristotle does not clearly distinguish between a static and a dynamic terminology (e.g., Sorabji, 1983, pp. 46–51). On the whole, one could say, as Wieland (1992) does, that Aristotle has a rather static concept of time, using it as an "operative concept of experience" rather than seeing it as the continuous flux it is for modern philosophy (p. 326).

Aristotle precludes the likely objection that his definition of time suffers from circularity by inducing "before" and "after" as spatial concepts: The thing that is being moved can be perceived in different places in a room, first in one, then in another. The continuity of time is directly grounded on the continuity of motion and indirectly on the continuity of magnitude (*megethos*). Inasmuch as things are different from one another according to their respective position (*thesei*), "before" and "after" have their origin in spatial dimensions, that is, in the hierarchical order of the different elements that are the principles of place (e.g., earth below, fire above) and in relation to which the position of other substances can be determined as lying closer (*enguteron*) or farther away (*porroteron*). This concept can be transferred to anywhere; for example, when we determine the starting and the finishing line in a race or when we say that the upper arm is farther away from the hand than the forearm. Temporally, "before" and "after" are determined with regard to their respective distance from the present now. Analogous to their respective position in space, they are also determined with regard to motion and time.

One can therefore not really accuse Aristotle, as did Henri Bergson, of a spatialization of time. On the contrary, his theory of time provides an epistemological foundation developed from the recurring discrimination between what is "before" for us (*proteron hemin*) and what is "before" objectively (*proteron physei*). Like Koriscos walking from the marketplace to the Lyceum, "before-and-afterness" is what motion is at any one time (*ho pote on*). This, however, is not yet in accordance with the Aristotelian definition of motion itself, namely, that it is the "progress of the realizing of a potentiality, qua potentiality." And it is "before-and-afterness" that constitutes the extension of time, whereas time is in itself defined as "that which is determined either way by a 'now'" and as "the number of motion with respect to before-and-afterness." Ontologically, it is impossible to reduce time and motion to spatial dimensions, seeing these are static and reversible, whereas motion and time are dynamic and irreversible. The sole purpose that their reduction to spatial dimensions serves is that it makes the temporal correlations that can be grasped only intellectually and the nonfixable locomotion more comprehensible. If time and movement agree with spatial magnitude with regard to the latter's quantity, continuity, and divisibility, then the importance of this magnitude is merely one *for us,* helping us to understand the quantity, continuity, and divisibility of movement and time. Time and movement are only accidentally quantitative and continuous, namely, inasmuch as that thing, which they are affections of, is itself divisible. This is the magnitude of extension and not the substance in motion itself (for this is divisible only with respect to its form and matter) that enables us to perceive motion. Thus, not only time and motion but also motion and spatial magnitude can be measured with mutual regard to one another. Motion and continuity of the magnitude of extension, on the other hand, are merely products of the mathematician's abstraction, that is, of his or her disregard for all other sensual qualities of the object. In other words, the mathematic fixation, both of locomotion (understood as the distance covered by the object) and of time as the numerical aspect of motion, is to facilitate the methodical description of a phenomenon that is per se unfixable and therefore indescribable. Contrary to what is occasionally asserted, time and motion are not per se identical with their respective measurement. Rather, they are determined by their ontological relation to the body that is being moved, a relation that can be described gradually as accidentality or nonbeing.

Analogous with time, motion, and line, as well as the relationship among their respective unifying principles, the now, the thing that is being moved, and the point, is one of epistemological foundation. Being for themselves always identical with themselves, they are the origin of unity. But in being subject to change according to different circumstances, they are also the origin of difference—and this is precisely the essence of their being principles: the now as that in which the beginning and the end of a period originate, the thing that is being moved as the principle in which the beginning and the end of a movement originate, and the point as the principle in which the limits of the line originate. The way in which the point functions as the origin of the line is principally the same as that in which the now and the thing that is being moved function as the origin of time and motion, respectively. The point divides the line in marking off the two sections of the line, the beginning of one from the end of another. But whereas the point fulfills a double function with regard to the line, the now and the thing that is being moved are, with regard to time and motion, respectively, always different from themselves, because they never come to a standstill. What all three relationships have in common is the fact that the continuum cannot be the sum of the discrete elements. Neither is the line made up of a number of points, nor motion composed of the different sections of movement the thing that is being moved has traveled through, nor yet time merely a succession of nows. The whole point of Aristotle's theory of the continuum is that while the continuum in itself is actually undivided, it is potentially capable of an infinite number of subdivisions. Thus, as a temporal limit, the now simultaneously is the end of a past and the beginning of a future, with every single period being potentially capable of numberless further subdivisions, that is, of numberless further nows as limits between past and future. Actually, each of these nows functions as the unity and the first principle of the continuity of time, namely, in that it links up the numberless periods of time divided into past and future both with itself and with one other.

The thing that is being moved is the ontological foundation of the now. The thing that is being moved is this particular something (*tode ti*), that is, a something that belongs either to the category of substance (*ousia*) or to that of the what (*ti*). Although the essence of "this particular something," which is deictically proven to be one identical and unmistakable same, can be determined in general terms, it is at the same time, namely, in being qualified as "this particular," only comprehensible on condition that changing circumstances exist in which this "something" does remain the same. Only the thing that is being moved, and not motion itself, is now characterized as "this particular something." Aristotle defines quantity as that which can be subdivided into parts, each of which is a single unity and a "this particular something." Number, understood as a quantity of discrete and countable unities, is based on the unity of the concrete substance, whereas measure, understood as that which determines the dimensions of a continuum, is based on the perceptible quantitative moments of this substance. And just as motion and the thing that is being moved occur simultaneously, also the number of motion, time, and the number of things that are being moved, the different nows, always coexist with one another. The thing that is being moved is a concrete substance, and while motion, inasmuch as it is merely an accident of this substance, borrows such properties as quantity, continuity, and divisibility accidentally from the magnitude of extension it runs through, it borrows these properties per se from the substance that is being moved. It is always Koriscos, who at some point covered the distance between the marketplace and the Lyceum, describing a succession that is not merely the connection of its disjointed members and that can be explained as a unit only because it has a beginning and an end.

Time and the Soul

In the last chapter of his treatise on time, Aristotle takes up the question whether without the soul time could exist, the intellect in the soul being understood as the only faculty in nature that is endowed with counting. Inasmuch as time had heretofore been linked with the outside, in other words, the physical world, this question seems to entail the aporia whether time, for Aristotle, is objective or subjective. Aristotle furnishes evidence for both interpretations when he remarks that, if there were no soul, time could but exist in the form of a temporal substratum (*ho pote on ho chronos*), that is, in the form of motion and the order pattern of "before-and-afterness" involved in it, which is time only on condition that it is countable. The Peripatetics were the first philosophers to discuss this aporia: Kritolaos (2nd century BCE), for instance, argued that time did not exist as an independent reality in its own right (*hypostasis*), but merely as an object of thought (*noema*),whereas Boethos of Sidon (1st century BCE) thought that time existed independently of the soul's counting. Plotinus objected that time as a quantitative magnitude would be as extensive as it is, even if there were nobody to measure it. Saint Thomas Aquinas's solution to the aporia, which he gives in his commentary on Aristotle's *Physics*, is that time as well as motion exist independently of perception and that the number and that which is countable only potentially, not actually, stand in need of someone counting. Thus, whereas the essence of time depends on the soul as on that which is capable of counting, time understood as the temporal substratum is independent of the soul as that which is potentially counting and, both with regard to its essence and as temporal substratum, completely independent of the soul that is actually counting. For a phenomenological interpretation that does not take the ontological difference between the essence and the substratum of time into account, the meaning of the aporia is the constitution of time. According to this interpretation, time does not exist within the soul, for instance, as the latter's inherent order pattern, but the soul is the necessary yet not sufficient condition for the existence of time in the world. Thus, as in Wieland (1992), "Time is neither *through* the soul, nor *in* it; it is only *not without* the soul's activity" (p. 316; translation by entry author). Time as number bears an immediate relation only to the movement of things, whereas to the things in themselves it bears an indirect relation. The soul is being presupposed only insofar as it counts the different nows that mark off the different periods of motion and of time. The measure it uses in doing so is not its own but the product of its comparing a particular movement or period of time (which has been taken as the respective unit of measure) with the movement or period of time to be measured. The soul is consequently not the origin of time understood as subjective time, nor does it simply state the objective time of the outside physical world, but, as Franco Volpi (1988) notes, it manifests and constitutes time as "the phenomenological form of Becoming [. . .] for the human experience of the natural world" (p. 58; translation by entry author). What the Aristotelian analysis of time does not take into account, however, is the question Heidegger (1988, §19) tries to answer in his exaggerated interpretation of Aristotle as to how far the objective experience of time is the manifestation of the soul's own temporality.

The Use of Clocks and the Measurement of Time

Having realized that time and movement mutually imply one another, Aristotle considers the notion—known to us from Einstein's theory of relativity—of measuring time relatively. Seeing that any coherent movement can be measured numerically, he argues for the possibility of a simultaneous coexistence of several times, analogous with different movements parallel to one another. However, in order to measure the respective duration of these relative times, there has to be an absolute first temporal measure from which their simultaneity can be determined, "just as if there were dogs and horses, seven of each, the number would be the same, but the units numbered differently." Thus, with regard to the measurement of time there is a difference neither between the different forms of movement (apart from local motion, Aristotle also mentions the change of qualities and of quantity and the genesis and disappearance of the substances) nor between the different velocities of movement. The uniform rotation of the heavens is the "first measure," because the number of its orbits, for example, days, months, and years, is the easiest to discern; it is with regard to this rotation that other, less uniform movements are measured. The only methods people in Aristotle's days had at their disposal when they wanted to measure temporal units inferior to the day were sundials and, independently of celestial rotation, water clocks. And although the principle of modern clocks—that is, the uniform circular movement capable of being subdivided into units of equal size—had not yet been invented, one could say, with Friedrich Solmsen (1960, pp. 149–150), that Aristotle's analysis of time anticipated the theoretic fundamentals of the clocks that were developed much later.

The measurement of time can take the form of either counting periods or measuring spatial distances that involve nonperiodic processes, both of which involve two procedures. The first consists of two movements, one periodic the other irreversible, and is best illustrated with regard to the pendulum clock, where the periodic movement is marked by the pendulum and the irreversible one by the cogwheel mechanism that causes the hands to move clockwise. The second method consists of measuring a given distance by comparing it to a distinct distance. Aristotle is familiar with both forms of measuring: The rotation of the heavens is a periodically recurring process whose different orbits, in their relation to one another, generate the numerical units of day, month, and year. Both our perception of time, namely, in that it enables us to distinguish "before-and-afterness" and the sequence of numbers by way of which earlier and later periods are marked off, can be seen as the corresponding irreversible processes. Whereas the periodic rotation of the heavens furnishes the actual measure of time, the act of measuring involves the comparison of different movements. Time measures movement "by determining a certain unit of movement which shall serve to measure off the whole movement (as the cubit serves to measure length by being fixed upon as a unit of magnitude which will serve to measure off the whole length)." Or: "It is by the movement-determined-by-time that the quantity both of movement and time is measured." It follows that the measurement of time is based on a comparison of movements transferred to a spatial distance. In Aristotle's theory of time, the measuring of periods and that of distances thus complement one another.

Time and Eternity

Contrary to Plato's theory of time, according to which time is the "moving image of eternity," in Aristotle's analysis of time there is neither a mention of eternity nor an attempt to establish a relation between the temporal number associated with movement, on the one hand, and the unity Plato associated with eternity, on the other. Rather, unity in Aristotle is reduced to the unifying measure of that period of movement that has been chosen as the measure of time. The importance and dignity that Plato attributes to the celestial bodies with regard to the concept of time are, in Aristotle, reduced to the idea that the rotation of the heavens, on account of its easy discernibleness, is an excellent, yet not the only, measure of time. What is certain also to Aristotle is the perennial being of time, and the reasons he gives for this are the following: (1) Every now is always the end of a past and the beginning of a future period; an ultimate temporal unit would therefore find its end in a now that, being a limit, is always also the beginning of a future; that is, time is what always is. And, according to this argument, just as time is perennial, so is movement. (2) Seeing that they have always existed and that, without time, there would be no "before-and-afterness," it is impossible for both movement and time to come into being or to disappear. The ultimate guarantor for the perennial being of time, however, is God, Aristotle's Prime Mover, who, being himself timeless and unchanging, guarantees, through the medium of the ever-revolving heavens, the unity, perpetuity, and ubiquity of time. The only characteristic Aristotle attributes to that which is "perennial" is that it is "not in time," that is, that its essence cannot be measured by time. In contradistinction to the traditional idea, the passing and disappearing of things is, for Aristotle, not caused by time but by movement. And although he admits that time depends on the periodical rotation of the heavens, for him the cyclical notion of time that the Presocratic philosophers and even Plato still adhered to, is irrelevant to Aristotle.

Michael Schramm

See also Aquinas, Saint Thomas; Aristotle and Plato; Avicenna; Causality; Cosmogony; Darwin and Aristotle; Eternity; Ethics; Metaphysics; Ontology; Plato; Presocratic Age; Teleology; Time, Measurements of

Further Readings

Annas, J. (1975). Aristotle, number and time. *Philosophical Quarterly, 25,* 97–113.

Heidegger, M. (1988). *The basic problems of phenomenology* (Rev. ed.; A. Hofstadter, Ed. & Trans.). Bloomington: Indiana University Press.

Janich, P. (1985). *Protophysics of time: Constructive foundation and history of time measurement.* Dordrecht, The Netherlands: Reidel.

Ross, W. D. (1936). *Aristotle's* Physics. *A revised text with introduction and commentary* (Vol. 2). Oxford, UK: Clarendon Press.

Solmsen, F. (1960). *Aristotle's system of the physical world*. Ithaca, NY: Cornell University Press.

Sorabji, R. (1983). *Time, creation and the continuum: Theories in antiquity and the early Middle Ages*. London: Duckworth.

Volpi, F. (1988). Chronos und Psyche. Die aristotelische Aporie von Physik IV, 14, 223a16–29. In E. Rudolph (Ed.), *Zeit, Bewegung, Handlung. Studien zur Zeitabhandlung des Aristoteles* (pp. 26–62). Stuttgart, Germany: Klett-Cotta.

Wieland, W. (1992). *Die aristotelische Physik. Untersuchungen über die Grundlegung der Naturwissenschaft und die sprachlichen Bedingungen der Prinzipienforschung bei Aristoteles*. Göttingen, Germany: Vandenhoeck & Ruprecht.

Aristotle and Plato

Aristotle's conception of time essentially relies on Plato's speculations on this subject. This is apparent from Aristotle's definition of time: "number of motion in respect of 'before' and 'after.'" Time and movement are also closely related in Plato's *Timaeus*, where it is said that time is "a moving image of eternity" that moves "according to number." According to Plato, time is in its very nature measurable, as before the heavens came into being there was no time. The planets were created to mark off and to "stand guard over the numbers of time," which implies that they define the units with which we measure time.

Even though according to Aristotle time is measurable and the primary measure of time is the movement of the celestial spheres, which is the fastest regular movement, this is not the core of his definition of time. First, time is a kind of number, with which we do not count, but it is something that is countable. Consequently, the second essential feature of time is its continuous nature, since the numbers with which we count are a discrete plurality, but the numbers with which we count are continuous and therefore so is time.

Additionally, time is a number in the sense that it consists of a series of "nows," which are countable. Due to the fact that time is a number, composed of countable units, it is fundamentally ordered in the way that the "before" and "after" order in which numbers stand, reflects the earlier and after nows, the earlier and after times.

The chain of nows is so arranged that each now presupposes always something before and after the given now. Although according to Plato movements and changes are inevitable and orderly (they must be regularly repeated in order to be measured), order is not defined by Plato as a before-and-after order, as Aristotle holds.

The second aspect in which Aristotle follows Plato in order to depart from him is the question of the relation between time and eternity, namely, between what is in time and what is outside of time. Plato distinguishes between two senses of lasting forever (*aidios*). One sense of everlasting is lasting as long as time does. The heavens are *aidios* in that way, because they were created along with time and they are indestructible. The other sense of *aidios* is having no beginning and no end. In contrast to the celestial bodies, which last throughout time and move constantly, the eternal being exists outside of time, and it is never subject to any change whatsoever. Therefore, it is only appropriate to ascribe an "is" to the eternal being and never a "was" or "will be"; in other words, it is always present and never past or future.

Following Plato, Aristotle considers that the entities that do not have beginning or end are outside of time. Aristotle, however, rejects Plato's view that time is created, which is supported by two arguments. The first argument begins with the claim that there has always been motion or change, which is made plausible by the claim that any beginnings of motion or change must be initiated by earlier motion or change. The second argument relies on the assumption that each now is a beginning and an end of time, from which follows that there is no first now. Aristotle's refutation of the view that time is created has serious implications for his own conception of time and its relation to eternity.

The most significant consequence is that for Aristotle the class of the entities that are outside of time is bigger than Plato thought, and it includes the things that exist throughout time. Namely, because time is beginningless, there is no difference between the entities that last as long as time does and entities that have no beginning. All of them are outside of time.

Aristotle refers to two criteria for determining what is "being in time." According to the first criterion, being in time is being surrounded by time, and something is surrounded by time if there is time before and after it. Because time has no beginning or end, the duration of the entities surrounded by time is finite. According to the second criterion, the entities are in time if their being is measured by time, or they are outside of time if their being is not measured by time.

In contrast to Plato, Aristotle holds that heavenly bodies, although mobile, are somehow outside of time, for the reason that their being cannot be measured by time. As these bodies are in everlasting movement, there is no total period of time within which they are moving, and consequently their existence cannot be measured in terms of time. According to Aristotle, from the fact that the celestial bodies are, in a sense, outside of time, it does not follow that they do not stand in temporal relations. They can be successively past, present, and future, but they endure unalterably through all time. Aristotle held that the stars, the planet Earth, and all species (including our own) are eternally fixed in nature. There is no creation, no evolution, and no extinction in his thought.

Apart from the heavens, nonexistent "things" that necessarily do not exist are not in time, such as the diagonal of a square's being commensurable with its side. Their opposites—in this case the diagonal's being incommensurable with its side—always are. In Aristotle's view the "things outside the heavens," such as God, are, in a more radical sense, outside of time. God is primarily eternal, an "absolutely immobile and perfectly active" being. Even though the heavenly spheres are not subject to generation and destruction, they are "being moved" by the first "unmoved mover," and therefore in principle they are capable of being otherwise, while God, the first mover himself, is unavoidably what he is—the perfect and eternal activity.

Irina Deretic

See also Aristotle; Cosmogony; Darwin and Aristotle; Eternity; Plato; Time, Measurements of

Further Readings

Barnes, J. (Ed.). (1991). *Complete works of Aristotle* (Rev. Oxford Trans., Vol. 1–2). Princeton, NJ: Princeton University Press.

Coope, U. (2005). *Time for Aristotle.* Oxford, UK: Oxford University Press.

Cooper, J. M., & Hutchinson, D. S. (Eds.). (1997). *Plato: Complete works.* Indianapolis, IN: Hackett.

von Leyden, W. (1977). Time, number, and eternity in Plato and Aristotle. *Philosophical Quarterly, 14*(54), 35–52.

Armageddon

The word *Armageddon* appears in the Bible only in the New Testament Book of Revelation 16:16. It is mentioned in the context of the sixth bowl of judgment (Rev 16:12–16) as the place where the kings of the whole world will gather for battle "on the great day of God the Almighty" (v. 14), which refers to the Parousia of Christ. In the Book of Revelation, it is the penultimate battle of history; the final battle will occur 1,000 years later at "the beloved city" of Jerusalem (Rev 20:7–10). Some interpreters think that the two descriptions of battles actually refer to the same event in different ways. Later Christian theologians used Armageddon as the name for the final battle of history during which the opponents of God and his church will be destroyed by Christ at his coming. Also, the image has been commonly used in Western culture to refer to a final battle or cataclysm that will bring the world to an end. In Christian theology and popular conceptions, the image of Armageddon relates to time as a future event associated with the end of history.

Interpreters have disagreed over the identification of the place. Revelation 16:16 indicates that the name is derived from Hebrew, so interpreters have offered at least six explanations of its Hebrew meaning. First, it is a combination of the Hebrew word *har* ("mountain") and the name Megiddo. Megiddo, a city located beside the Jezreel Valley near the intersection of several trade routes, was occupied from 7000 to 500 BCE. At least 34 battles have occurred there throughout history, including the first battle of recorded history. Thirteen of those battles had occurred by the time Revelation was written. Although Megiddo is a 70-foot-high tell, no mountain is located near the site. Second, if *ar* is derived from '*ir* (the Hebrew word for "city"), then it refers to the city of Megiddo.

Third, it refers to Mount Carmel, which is located 5 miles northwest of Megiddo. Mount Carmel was the place where, in the Hebrew Bible, the prophet Elijah defeated the prophets of Baal (1 Kgs 18:20–46). Fourth, the Hebrew phrase is constructed from *har* ("mountain") and *mo'ed* ("assembly"). This interpretation assumes that the Greek *gamma* transliterates the Hebrew *ayin.* The Mount of Assembly is referred to in Isaiah 14:13 as the heavenly court where the king of Babylon would seek to exalt himself above God. As Mount Zion was viewed as the earthly counterpart of the heavenly throne room (Ps 48:2), Armageddon refers to the attack on Jerusalem by end-time Babylon. Fifth, *magedon* is derived from the Hebrew *gadad,* which means "to cut" or "to gash." Therefore, the name means "marauding mountain" or "mountain of slaughter," the place where the armies of the earth are gathered together to be exterminated. Sixth, it combines *har* and *migdo* ("fruitful"), referring to Jerusalem. Revelation 14:14–20 and 20:7–10 also associate the last battle with Jerusalem.

Because of the difficulties in specifying the origin of the name, many interpreters believe that the author of the Book of Revelation was not thinking of a physical locality but was using the association of Megiddo with warfare as a theological symbol of the rebellion of evil against God and God's final defeat of evil. Armageddon would then be the culmination and epitome of all previous rebellions against God that have occurred throughout history. The author may be alluding to Zechariah 12:11 to express the idea that the nations that stand against God will mourn as they face God's judgment.

Revelation 16 never describes an actual battle. During the seventh bowl judgment (Rev 16:17–21), a voice from the heavenly temple declares, "It is done." In association with the end of the world, a great earthquake destroys Babylon and huge hailstones from heaven torment people. The reason that no actual battle takes place is because, in the view of the author of Revelation, Christ has already defeated the forces of evil in his death and resurrection.

The description of Christ's Parousia in Revelation 19:11–21 appears to be another description of Armageddon, although the term is not used in that context. There the kings of the earth have gathered their armies together to make war against the rider on the white horse, but they are destroyed before the battle even begins.

Gregory Linton

See also Apocalypse; Bible and Time; Christianity; Ecclesiastes, Book of; End-Time, Beliefs in; Eschatology; History, End of; Last Judgment; Parousia; Revelation, Book of; Time, End of

Further Readings

Cline, E. H. (2000). *The battles of Armageddon: Megiddo and the Jezreel Valley from the Bronze Age to the nuclear age.* Ann Arbor: University of Michigan Press.

Day, J. (1997). The origin of Armageddon: Revelation 16:16 as an interpretation of Zechariah 12:11. In S. E. Porter, P. Joyce, & D. E. Orton (Eds.), *Crossing the boundaries: Essays in biblical interpretation in honour of Michael D. Goulder* (pp. 315–26). Leiden, The Netherlands: Brill.

Kline, M. G. (1996). Har Magedon: The end of the millennium. *Journal of the Evangelical Theological Society, 39*(2), 207–222.

Asimov, Isaac (1920–1992)

Isaac Asimov was a famous American author and scientist whose work helped to popularize science in American culture. He wrote or edited more than 500 fiction and nonfiction books, making him one of the most prolific writers of all time. Asimov was deeply interested in the concept of time, which he addressed throughout his work.

Asimov is widely regarded as one of the masters of science fiction, along with Arthur C. Clarke and Robert A. Heinlein. His publications are wide-ranging and include topics as varied as astronomy, Shakespeare, Greek mythology, and Bible studies.

Asimov was born in Petrovichi, Russia, on January 2, 1920. His family immigrated to the United States and settled in Brooklyn, New York, when he was 3 years old. As a youth he developed an interest in reading science-fiction magazines and writing short stories. During World War II he served in the U.S. Naval Air Experimental Station and later in the U.S. Army. Following the war, Asimov attended Columbia University, where in 1948 he received a Ph.D. in biochemistry. In 1949, he joined the staff of the Boston University Medical School and remained there throughout his career.

His most popular works of fiction include *I, Robot* (1950), which was adapted into a film version in 2004; *The Foundation Trilogy* (1951–1953), which describes the fall of the Galactic Empire; *The Caves of Steel* (1954); *The End of Eternity* (1955); and *The Gods Themselves*. Asimov also wrote nonfiction works, including *The Intelligent Man's Guide to Science* (1960), *Asimov's Guide to the Bible* (1968–1969), and *Asimov's Guide to Shakespeare* (1970).

A self-proclaimed humanist, Asimov emphasized science and rationalism throughout his work. His fiction explores the role of humankind in the universe, extending back in time to the origins of life. He was deeply concerned with the concept of time and development in history. Although generally written for entertainment, Asimov's fictional work often addressed problems and troubles that humankind has faced in the past or may face in the future. Fascinated by technology and the potential of human intellect, he included robots and other futuristic inventions in his stories. His nonfiction is celebrated for making complex ideas in science clear to the common public. His books were written for both children and adults.

Asimov was given numerous awards and honors during his lifetime.

He was also a member of the American Humanist Association, for which he served as president from 1985 to 1992. In later years Asimov wrote three volumes of autobiography: *In Memory Yet Green* (1979), *In Joy Still Felt* (1980), and *I. Asimov: A Memoir* (1994, posthumously).

Asimov died on April 6, 1992. Ten years after his death his family revealed that he had died from complications due to AIDS, which he contracted from a blood transfusion during heart bypass surgery. His doctors advised the family to withhold the cause of death from the public due to stigma associated with the AIDS virus at that time.

James P. Bonanno

See also Bradbury, Ray; Clarke, Arthur C.; Futurology; Novels, Time in; Verne, Jules; Wells, H. G.

Further Readings

Asimov, I. (1994). *I. Asimov: A memoir.* New York: Doubleday.

Asimov, I. (2002). *Isaac Asimov: It's been a good life* (J. J. Asimov, Ed.). Amherst, NY: Prometheus.

White, M. (1994). *Asimov: The unauthorized life.* London: Millennium.

Astrolabes

The term *astrolabe* designates several related observational instruments used primarily for astronomical and navigational calculations, the most common and historically significant of which is the planispheric astrolabe. Others include the rare linear and spherical astrolabes and the simplified mariner's astrolabe. The astrolabe's basic function was observing the angular distance between objects, such as between a star and the horizon. Planispheric astrolabes were also designed to make calculations and predictions based on a rotating planar projection of the celestial sphere, which enabled the user to, among other things, tell time. These astrolabes illustrated the annual path of the sun and the daily rotation of the stars, which could be related to the current time or predicted for any specific time. Thus, the planispheric astrolabe was, in some sense, an observational tool, a calculator, a clock, and a calendar all in one. In fact, it was the design of the planispheric astrolabe, with its two-dimensional depiction of the celestial rotation, that inspired the familiar circular face of the mechanical clocks that began to emerge in the 14th century. On astronomical clocks, popular in the 15th and 16th centuries, the planispheric projection used on the astrolabe was retained inside the center of a 24-hour clock face.

Although the exact origin of the astrolabe is unknown, it is thought to have developed in Greek antiquity, perhaps as early as Hipparchus but at least by the time of Ptolemy in the 2nd century CE. Although the astrolabe fell out of use in the West during the latter portion of the 1st millennium CE, its popularity flourished in Arabic culture for centuries. Particularly noteworthy is the work of 10th-century Islamic astronomer Abd al-Rahman al-Sufi, who is said to have described some 1,000 uses of the astrolabe. The instrument reentered Western astronomy

Astrolabes were used by early astronomers and navigators to measure the altitude of stars and planets. This is a replica of a small astrolabe, about 45 milimeters in diameter.

Source: Norbert Speicher/iStockphoto.

during the 11th century through contact with Islamic culture, alongside the rediscovery and translation of classical texts. Hermann the Cripple (1015–1054), a Benedictine monk, wrote of the astrolabe in Latin around this time; Geoffrey Chaucer wrote the first English treatise on the subject 3 centuries later.

Planispheric astrolabes are similar in shape to modern pocket watches. Typically made of brass or other metals, the instrument is built around a circular base plate called a *mater.* The back of the astrolabe is engraved around the outside of the mater with a scale of degrees for measuring angles, as well as other scales to indicate the position of the sun on the ecliptic. Attached to the center is a rotating sighted bar called an *alidade,* which is used for measuring angles in the sky. Such observations can be taken by holding the astrolabe vertically by an attached ring, moving the alidade to align a celestial object with both sights, and reading the degrees indicated by the alidade on the scale. The front of the astrolabe is used for representing the observed rotation of the heavens in a planispheric projection. The top layer of the front consists of the *rete,* a skeletal rotating plate that represents the positions of the stars and the ecliptic path of the sun. Beneath the rete is a detachable plate marked with celestial coordinates that can match the position of the rete to the altitudes observed with the alidade. These plates are necessarily specific to particular latitudes; hence most astrolabes were provided with multiple interchangeable plates. The front of the astrolabe typically also included a scale of hours around the outside and a pivoting ruler to aid in measurements. The mariner's astrolabe was a simplified version of this instrument used only for observing celestial altitudes at sea.

The versatility and ingenuity of the astrolabe made it popular among astronomers from antiquity until the beginnings of modernity. A sighting instrument, a calculator, a star map, a clock, or a calendar, the astrolabe had numerous applications to astronomy and navigation as well as astrology. Because it recreates and measures the rotation of the heavens, the astrolabe has also much connection with the measurement of time. Astrolabes could be marked to indicate both uneven and even hours of the day and could relate the time of year based on the sun's position in the ecliptic. A notable symbol of classical and medieval astronomy, the astrolabe is also the primary precedent for the circular clock format used around the world today.

Adam L. Bean

See also Chaucer, Geoffrey; Clocks, Mechanical; Time, Measurements of

Further Readings

Bennett, J. A. (1987). *The divided circle: A history of instruments for astronomy, navigation and surveying.* Oxford, UK: Phaidon.

Gunther, R. T. G. (1976). *Astrolabes of the world* (2 vols.). London: Holland Press.

Hoskin, M. A. (Ed.). (1997). *The Cambridge illustrated history of astronomy.* Cambridge, UK: Cambridge University Press.

ATHEISM

See NIETZSCHE, FRIEDRICH

ATTILA THE HUN (C. 400–453)

Prior to Attila's rule, the West had not experienced such a threat from a single, fearsome leader born of a nomadic people. His conquests gave the Huns control of a region extending from the Danube River to the Baltic Sea, and from the Rhine River to the Caspian Sea. In terms of impact on the course of history, there would not be another conqueror such as Attila until the rise of Genghis Khan 750 years later.

The Huns, excellent equestrians especially during battles, migrated from Central Asia and settled in Central Europe north of the Roman Empire in the late 300s. Little of Attila's early life is known, including the exact year of his birth. He and his elder brother, Bleda, inherited the Hunnish kingdom from their uncle, King Ruga, when he died in 434.

The Treaty of Margum of 435 required the Eastern Empire to pay an annual fee to Attila and was the first of many humiliating agreements. From 435 to 439, Attila campaigned to consolidate control of Hunnic provinces in the Caucasus and trans-Volga regions. In 443, the First Peace of Anatolius between Attila and the Eastern Romans further humbled the empire. Bleda died a year later, leaving Attila as sole ruler. Historians debate whether his death was a murder or an accident.

Here Attila, King of the Huns, points at storks leaving the city of Aquileja and predicts that it is a sure sign of a Hun victory, 452. Attila was a fierce warrior on the battlefield, and through his aggression he posed an extreme threat to the Romans and nearly conquered Rome itself.

Source: Kean Collection/Getty Images.

In 447, Attila's army conquered the Balkan territories, destroying many cities in their wake. They reached Constantinople but did not succeed in taking it. The Second Peace of Anatolius was imposed on the Eastern Romans. It called for an increased annual fee, repatriation of former Huns, and for the Romans to evacuate all the territories south of the Danube River. Two years later, an assassination attempt on Attila on the orders of the Eastern Roman emperor, Theodosius II, was foiled, and the emperor was once again embarrassed.

In 451, Attila invaded France (Gaul) in hopes of conquering the Western Roman Empire. A combined army of Germanic and Roman forces stopped him in the Battle of Chalons-sur-Marne, near Troyes. It has been described as one of the 15 decisive battles of world history. Approximately 100,000 people were killed. Attila invaded northern Italy and conquered 12 cities in 452. A papal delegation led by Pope Leo I persuaded Attila to leave in return for a large sum of money and the right to launch another invasion. In 453, on the night of his wedding to the last of several wives, he died as a result of a suffocating nosebleed probably induced by intoxication. His sons divided his empire, but internal strife soon destroyed the power of the Huns. Eventually they were absorbed into the people of the Balkans. During Attila's lifetime he was a major threat to the Roman Empire, but his challenge did not outlive him. Nevertheless, he is well remembered in history, drama, and literature.

Suzanne Colligan

See also Alexander the Great; Caesar, Gaius Julius; Genghis Khan; Nevsky, Saint Alexander; Rameses II; Rome, Ancient

Further Readings

Howarth, P. (2001). *Attila, king of the Huns: Man and myth*. New York: Carroll & Graf.

Thompson, E. A. (1996). *The Huns*. Oxford, UK: Oxford University Press.

ATTOSECOND AND NANOSECOND

Humans live on a timescale measured by minutes and seconds, whereas atoms and molecules exist on a timescale measured by femtoseconds and attoseconds. A nanosecond is roughly one billionth of a second (1×10^{-9}). An attosecond is one billionth of a nanosecond, or a quintillionth of a second (1×10^{-18} seconds). Throughout the 1990s, scientists had no way of measuring on an attosecond timescale and were using a femtosecond timescale to view the movements of atoms. A femtosecond (1×10^{-15} seconds) is one quadrillionth of a second, much faster than a nanosecond and only 1,000 times slower than an attosecond, yet enough to make a difference. According to Niels Bohr's model of the hydrogen atom, electrons take about 150 attoseconds to orbit the nucleus. From a human perspective, a single second in comparison to this electron's orbital revolution is roughly the same as 200 million years.

In 1954, Manfred Eigen noted chemical reactions that transpired in nanoseconds, introducing the world to a whole new field of chemistry. Prior to Eigen, these reactions were invisible to human observations.

To view atomic and molecular activities requires rapid strobes of laser light beyond the speed of nanoseconds. The overall movement of these atoms can be seen when viewed at femtoseconds; however, to view the activities of the electrons, these pulses need to be short and quick enough to capture attoseconds. Paul Corkum created the first idea of how to measure an attosecond, and the first recorded measurement of an attosecond in 2002 is attributed to a group of scientists in Vienna led by Ferenc Krausz.

The process of viewing electrons on an attosecond timescale requires the rapid, repetitive pulsation of a laser through one of the noble gases, such as neon. This results in the collision of an atom's nuclei with its electrons, creating attosecond bursts of X-ray energy. These X-ray bursts can then be focused and redirected to create attosecond pulsations. These attosecond pulses can then be turned toward an atom to track the motion of an electron. One such activity that scientists were able to map was that of the Auger process, the rearrangement of an atom's electrons to fill a gap created by the loss of an inner shell electron. After knocking an inner shell electron out of its orbit around an atom's nucleus, scientists have been able to view the movements of the electrons to fill in the gap and the resulting expulsion of another electron, the Auger electron.

Despite the advancements made in the studies of attoscience, scientists are still far from discovering the smallest amount of time, known as Planck time (1×10^{-43}). Planck time is the amount of time it takes light to travel across the smallest unit of measurement, Planck length. Beyond these measurements, the traditional spacetime continuum and gravity begin to break down and quantum mechanics needs to be taken into consideration.

Mat T. Wilson

See also Chemical Reactions; Light, Speed of; Planck Time; Time, Measurements of

Further Readings

Drescher, M., Hentschel, M., Kienberger, R., Uiberacker, M., Yakovlev, V., Scrinzi, A., et al. (2002). Time resolved inner-shell spectroscopy. *Nature, 419,* 803–807.

Giles, J. (2002). Attosecond science: The fast show. *Nature, 420,* 737.

Hentschel, M., Kienberger, R., Spielmann, C., Reider, G. A., Milosevic, N., Brabec, T., et al. (2001). Attosecond metrology. *Nature, 414,* 509–513.

AUGUSTINE OF HIPPO, SAINT (354–430)

Born Aurelius Augustinus at Thagaste in Roman North Africa (today's Algeria) of a pagan father and Christian mother, Saint Augustine of Hippo was formally educated as a rhetorician, but sought pagan, Manichaean, and Neoplatonic answers to questions about reality. After his conversion to Christianity, he became a monk, and in the year 396 was appointed bishop of Hippo Regius in North Africa. He wrote sermons, devotions, prayers, letters, polemical writings (against Manichaeans, Donatists, and Pelagians), and doctrinal treatises (e.g., *On Christian Doctrine* and *On the Trinity*). He is best known for his autobiography of his conversion, *The Confessions,* and his apologetic of divine providence, *The City of God.*

Saint Augustine, 1480, fresco, Ognissanti, Florence: Saint Augustine of Hippo is regarded as one of the great fathers of the early Christian church. He was converted to Christianity in 386 and became the bishop of Hippo, in North Africa, in 396.

Augustine helped to develop the Christian view of time, particularly in the following writings: *On Music, The Immortality of the Soul, The Literal Meaning of Genesis,* and chiefly in *The Confessions,* his account of his early life up to his conversion to Catholic Christianity and his decision to enter service to the church. The first ten books contain this story, and the final three contemplate God and Creation. In Book 11, amid a discussion on the creation of the cosmos, Saint Augustine enters into a meditation on time. The bishop of Hippo does not give us a scholastic argument, but in humility, an extended prayer and dialogue on time and eternity, in which he asks God to reveal to him the mystery of time, "this most intricate enigma."

Saint Augustine first asks about God in relationship to time. He notes that God is eternal and changeless and, as time means change, then time is not eternity. Time is a creature, a creation of God; thus God is exempt from the relation of time. Eternity is fixed and time is never fixed: "No time is all at once present." Before creation, there was no time—no past and no future: "Before all times God is: neither in any time was time not."

Next, Augustine discusses humanity in relation to time: for Saint Augustine, it is always present and never past or future. Using images of time, motion, age, and words, he discusses the extent of the present and our perception of intervals of time. Although we recognize a past in memories (as in our childhood) and future (as in contemplating our next action), they are not present. He then proposes three categories of time: "a present of things past, a present of things present, and a present of things future," all perceived by memory (present past), sight (present present), and expectation (present future).

After addressing humanity in relation to time, Saint Augustine discusses the measurement of time. Humans measure time in space, in that we perceive time as an extension or distention a stretching of our humanness. Yet not only do humans measure time as a movement in space but we also measure time even when things are standing still. So time, then, is not the motion of a body. Time is measured by long time and short time, "a protraction," though we do not measure the past, present, and future. It is in the human mind that times are measured in proportion as they pass by in short or long. So, the human mind expects, considers, and remembers time: "that is that which it expects, through that which it considers, passes into that which it remembers."

Finally, Saint Augustine sees time as a distention, a distraction in life (*ecce distentio est vita mea*). He concludes that time, needing the human mind to consider it, cannot exist outside of creation and is not eternal. Therefore, God is eternal as are all those things that are co-eternal with God (the Word and the Spirit).

For Saint Augustine, while time is inscrutable, time is a mutable creation of God. Time is always present and measurable only in proportion to that present. Because time is measured by human beings, it is human beings that have the sensation of time stretching and spreading each human in the journey of time.

Anthony J. Springer

See also Aquinas, Saint Thomas; Aquinas and Augustine; Bible and Time; Christianity; Eternity; God and Time; God as Creator; Time, Sacred

Further Readings

Flasch, K. (1993). *What is time? St. Augustine of Hippo. The confessions, Book XI.* Frankfurt, Germany: Klostermann.

George, T. (2005). St. Augustine and the mystery of time. In H. L. Poe & J. S. Mattson (Eds.), *What God knows: Time, eternity, and divine knowledge.* Waco, TX: Baylor University Press.

Jackelén, A. (2005). *Time and eternity.* Philadelphia: Templeton Foundation.

Aurora Borealis

> The Valkyrior are warlike virgins, mounted upon horses and armed with helmets and spears. When they ride forth on their errand, their armour sheds a strange flickering light, which flashes up over the northern skies, making what men call the aurora borealis, or Northern Lights.
>
> Bulfinch's *Mythology,* 1855

Throughout time, humans have gazed at the sky to behold the splendor of the universe and contemplate the unknown. Certain times of the year, at the polar zones of Earth, there is a majestic show of lights and colors that occurs in the night sky. The lights that are viewed from the north skies are called *aurora borealis,* a combination of the name of the Roman goddess of the dawn, Aurora, and the Greek name for north wind, Boreas. The aurora borealis is visible only in the northern skies and is thus also known as the northern lights. This phenomenon also occurs in the southern skies; the counterpart is known as the *aurora australis,* with the name being derived from the Latin word for "of the South."

The cause of these great lights starts far away from Earth, at the center of our solar system. The solar corona is the outermost portion of the sun and also the portion that produces temperatures that range in the millions of degrees. This corona, at times, ejects a rarefied flow of hot plasma (a gas consisting of both free and positive electrons) into outer space. This ejection of plasma is known as the solar wind. The solar wind travels through space until it nears Earth.

Earth's magnetosphere consists of the area dominated by its magnetic field. Extending far beyond Earth's atmosphere into outer space, the magnetosphere blocks much of the solar wind and causes it to disperse. Solar winds contribute energy and material to the magnetosphere, causing the electrons and ions present in the magnetosphere to become energized. Once energized, these particles move along the magnetic field lines toward the polar regions of the atmosphere. The light is emitted shortly after this transfer occurs and is usually dominated by a greenish glow, produced by emissions of atomic energy, and also a dark-red glow, especially at high altitudes and lower energy levels. These two colors represent transitions of electrons and atomic energy, in absence of newer collisions, which continue for extended periods of time and account for the fading and brightening that occur. Other colors, such as purple and blue, can be seen when atomic energy and molecular nitrogen interact, but these displays tend to be of shorter duration.

The aurora borealis, or northern lights, shines above Bear Lake, Alaska. The lights are the result of solar particles colliding with gases in Earth's atmosphere. Early Eskimos and Indians believed different legends about the northern lights, such as they were the souls of animals dancing in the sky or the souls of fallen enemies trying to rise again.

Source: U.S. Air Force photo by Senior Airman Joshua Strang.

The best place to see the aurora is near Earth's magnetic poles. It can, however, be seen in temperate latitudes during times of heavy magnetic storms. These storms relate directly to the 11-year sunspot cycle and are strongest during the peak. These strong storms can continue to occur for up to 3 years following the peak. In September 1859, one of these strong magnetic storms occurred and produced what is thought to be the most spectacular aurora ever witnessed in recorded history. The aurora was the result of the Carrington-Hodgson white light solar flare, which was emitted on September 1, 1859. This flare was one of the most intense coronal mass ejections in recorded history. The aurora was seen across the United States, Japan, Australia, and Europe. It was this aurora that allowed the link to be seen between auroral activity and electricity. Many of the telegraph lines that were in use across North America and Canada encountered interference during this aurora. Several other telegraph lines had been powered down but, nevertheless, they picked up a geomagnetically induced current through the lines and allowed the telegraph operators to continue communicating. Since then, the phenomenon of the aurora has continued to intrigue many people. In the future, scientific research in outer space may shed more light on the aurora phenomenon.

Christopher T. Bacon

See also Light, Speed of; Seasons, Change of

Further Readings

Jago, L. (2001). *The northern lights.* New York: Knopf.

Petrie, W. (1963). *Keoeeit: The story of the aurora borealis.* New York: Pergamon Press.

AVICENNA (980–1037)

Avicenna is the Latin name of Abū Alī al-Husayn ibn Abd Allāh ibn Sīnā, an Islamic Persian philosopher and physician, who was born in Afsana near Bukhara and died in 1037 in Hamadan, both located in Persia.

After education in all the known sciences by teachers in his father's house, Avicenna worked as physician and advisor to the local sovereign. In 999 the Samanid house was defeated by a Turkish dynasty and his father died—two reasons for Avicenna to flee from his hometown. During the following years Avicenna served as physician and scientist under several rulers in different regions until his death at the age of 57. His works became famous and were used in the education of students in European universities until the 17th century.

Avicenna's philosophy is based on his study of Aristotle. As he did not understand Greek, he studied Arabic and Persian translations of the texts. Avicenna's main works are *The Canon of Medicine,* which sums up the knowledge of healing in his time, and *The Book of Healing,* which is meant to be a paraphrase of the works of Aristotle.

As does Aristotle himself, Avicenna believes God to be the first cause of all things. God is the first existent and as such not influenced by the workings of time. Time begins only with the creation of the world. God is not interested in single incidents but is the mover of all things, the moving principle.

According to Avicenna, prior to their creation in the material world, all things already exist in the intellect of God. Only after they have been created can they also be perceived by the human intellect.

According to Avicenna's philosophy, the continuity of time is broken within each human soul. Any act of the soul divides time into a "before" and an "after," into past and future. The present exists in the moment of action. Soul and body are two separate substances: Whereas the body is mortal, the soul stays immortal. As a consequence, resurrection of the human body does not exist.

Avicenna's thinking exerted considerable influence not only in the Islamic world but also over European philosophy in the Middle Ages, especially on Albertus Magnus and Saint Thomas Aquinas.

Markus Peuckert

See also Albertus Magnus; Aquinas, Saint Thomas; Aristotle; God and Time; God as Creator; Islam; Time, Sacred

Further Readings

Goodman, L. E. (1992). *Avicenna.* New York: Routledge.

Gutas, D. (1988). *Avicenna and the Aristotelian tradition.* Boston: Brill.

B

Baer, Karl Ernst Ritter von (1792–1876)

Karl Ernst Ritter von Baer was the modern founder of embryology and comparative embryology, as well as an accomplished zoologist and biologist. No longer a familiar name, Baer was in his time a genius acknowledged by his greatest contemporaries in science.

Baer was born in Landgut-Piep, Estonia, on February 17, 1792, into a rather wealthy aristocratic German-speaking family. At that time, Estonia was part of Russia, and Baer was a patriotic Russian.

The young nobleman studied medicine at Tartu, Estonia, and then Würzburg, Berlin, and Vienna, from 1810 to 1814. Only 3 years later he became director of the zoological museum at Königsberg, Germany. Baer's scientific genius went beyond anything wealth and privilege alone could supply, however.

He wrote a treatise in Latin on mammalian eggs and human origins in 1827; in fact, Baer had discovered a mammalian egg in the Graafian follicle, settling specific questions about human procreation. Baer also discovered the notochord in early vertebrate embryos.

The rest of his published works were in German. A preeminent man of science in Germany, Alexander von Humboldt, presented Baer with a medal from the French Academy. Much later, Albert Einstein wrote a short piece on Baer's law. Baer's law states that erosion is greater on the right bank of rivers in the northern hemisphere and greater on the left bank in the southern hemisphere, a law that perhaps occurred to him as he studied the fishes of the Caspian and Baltic seas.

Yet Karl Ernst von Baer "led two entirely different scientific lives, the first in Prussia, the second in Czarist Russia," as Jane Oppenheimer described his career.

In 1834 Baer became Professor of Zoology and Anatomy at St. Petersburg in the Russian Empire.

Not an evolutionist, he criticized the ideas of Charles Darwin. Baer favored instead his own notion of "developmental history" (*Entwicklungsgeschichte*). Baer discovered that the stages of embryonic development of higher animals resemble the stages of embryonic development of lower animals. Embryos of one species may be indistinguishable from the embryo of a much higher creature. This notion of developmental stages proved important for the rise of evolutionary theory.

He worked on his major project on the developmental history of the animal kingdom, *Üeber Entwicklungsgeschichte der Tiere,* from 1828 to 1837. Like Aristotle long before him, Baer studied chick embryos. And like Aristotle, Baer endorsed the notion of epigenesis (that the embryo becomes progressively more complex).

He also studied fishes and wrote in particular of his investigations into their developmental histories in a separate work in 1835. Baer showed that vertebrate organs derived from germ layers by differentiation, an important scientific discovery. He also demonstrated that embryos of higher animals share analogous features in embryonic development, the so-called biogenetic law. Embryos of higher animals develop through stages analogous to those of lower animals; that is, features specific to the specimen appear only after more general features have developed. Or, in the developmental history of the organism, general traits develop first.

Baer's fame spread beyond Prussia and the Russian Empire. He became a member of the French Academy of Scientists in 1858 and received the Copley medal from the Royal Society 9 years later.

Charles Darwin, in "An Historical Sketch of the Progress of Opinion on the Origin of the Species," wrote, "Von Baer, towards whom all zoologists feel so profound a respect, expressed about the year 1858 . . . his conviction, chiefly grounded on the laws of geographical distribution, that forms now perfectly distinct have descended from a single parent-form." In *Descent of Man,* Darwin referred to him as "the illustrious Von Baer" and commended Baer's observation that "the wings and feet of birds, no less than the hands and feet of man, all arise from the same fundamental form." Darwin gave his critic high praise, indeed: "Von Baer has defined advancement or progress in the organic scale better than anyone else, as resting on the amount of differentiation and specialization of the several parts of a being—when arrived at maturity, as I should be inclined to add" (*Festrede*, 1862).

Obviously, Baer's ideas contributed to evolutionary thought without his having accepted Darwin's theory.

Vladimir Vernadsky credited von Baer with developing the ideas of carbon and nitrogen cycles.

Late in life, Baer wrote his autobiography and published a series of speeches and short essays on widely varied subjects. He was a respected man of science until the end. Karl Ernst Ritter von Baer died November 16, 1876, in Dorpat, Estonia.

Baer on Time

Baer published a speech connecting the *perception of time* with the *rate of pulse* in mammals. His scientific paper "*Welche Auffassung der lebenden Natur ist die richtige? Und wie ist diese Auffassung auf die Entomologie anzuwenden?*" was delivered as the commemorative address to the opening of the Russian Entomological Society in October 1860. It raised the following questions: Which conception of living nature is the correct one? And how is this conception to be applied in entomology? To answer the first question, Baer found it necessary to discuss the ultimate grounds of nature: time and space.

Absolute Nonpersistence in Nature

Concerning time, the constant alteration found in nature is nothing less than a continual development, a continual evolution. Persistence of substance does not occur over time. What humans take to be persistent existence is due entirely to the human scale of time, which is far too short. If we compare this scale of time to the grand relations in nature, we discover that humans cannot take themselves to be the measure for space and time. For measurement of space, humans have taken their various body parts as standard units. Although such units may well suffice for the immediate environs, or even for the earth's surface, they shrink and disappear in contrast to the spaces of the universe and even then only to those expanses visible to the human eye. When astronomers contemplate vast astronomical distances, they use units of measurement that are more comprehensible; the distance from the earth to the sun, for example. Yet this distance is some 92 million miles, a distance very hard to grasp. Baer noted that light travels so fast that it covers this distance in only 8 minutes. If we expand our scale to the distance light travels in a year, then the distances involved in measuring the cosmos go beyond human intuition and can be expressed only in scientific notation.

To measure time, humans have adopted regularly recurring physical natural phenomena to mark units of time, whether it be the day, month, or year.

Baer considered it indubitable that the standard brief unit of time, the second, was taken from the human pulse rate, as it remains fairly steady within the individual from second to second. This is a measure of time derived from our own biological processes, but we can do no other, observed Baer. Far shorter would be the time required to become aware of a sensory impression. Such measurement of time according to a sensation has been used by all peoples, said Baer. The German word *Augenblick,* which means "moment," is literally the "blink of an eye." Such examples can be adduced at length. And yet, because lively impressions are registered quickly and dull ones slowly, there can be no generally valid measure of the duration of a sensory impression, though Baer estimated it to be between 1/6 and 1/10 of a second. The speed of the faculty of perception is, for Baer, the true and natural unit of measurement for life. "In general, it appears that the pulse stands in a definite relationship with the rapidity of sensation and movement. The pulse of rabbits is twice as fast as that of man, and children only half as fast [as adult human beings]" (p. 258). But as rabbits perceive more quickly than do children, rabbits apparently experience much more in the same amount of time. Thus the speed of the faculty of perception sets the standard of "objective" time for a species.

In his address to the Russian Entomological Society, Baer wanted to make clear that "the inner life of a human being or animal can pass more quickly or more slowly, in the same amount of objective time, and that this inner life is the standard with which we measure time in the observation of nature" (p. 258). It is only because this fundamental standard is so small that we presume an animal that we observe in nature maintains a unified size and structure. In fact the animal has changed, if ever so slightly, due to breathing and blood circulation. It has undergone countless minute changes at the cellular level in its intestines, and so on. If we observed it not for an instant, but for a day or longer, we would notice some changes in the animal.

Baer's First Thought Experiment Concerning Time

To his audience in St. Petersburg, Baer posed a fascinating thought experiment. "If we imagine for a moment that the pace of life in man were to pass much faster or much slower, then we would soon discover that, for him, all the relations of nature would appear entirely differently" (p. 259). If we can take 80 years as an advanced age, then the life duration of such a man would be 29,200 days and as many nights. Now imagine that such a long life were condensed a thousandfold. After 29 days, he would already have reached invalidity. To ensure that none of his inner experience is lost, however, his pulse rate would have to be multiplied a thousandfold, so that he would still experience 6 to 10 sensory impressions per pulse beat. Baer observed first that such a man—Baer called him the "man of a month" (*Monaten-Mensch*)—would see many things that a normal man would not. He would see cannon balls streak by, which we would not be able to see because they change position too fast for us to perceive. A man of months would see the moon go through its cycle only once and so might well infer that it began as a crescent, grew larger and fuller, until it disappeared altogether. Such a man would, though, have no conception of seasons and would be flabbergasted to know that his environs would be covered with snow, that water would freeze in winter, for example. Similarly, due to our small time horizons, we find it difficult to imagine Earth during the Ice Age or to realize that the poles were once covered with rain forest or that our nation was once covered deep in a glacier for millennia.

Baer noted, secondly, the supposition of 29 days as a life span, and the compression of years a thousandfold, to be rather arbitrary. Indeed, the compression could have been much greater, as many life forms complete their life cycle in less than 29 days. Mushrooms, protozoa, and many insects complete their life cycles in but a few days.

Suppose, then, that we shorten human life. Instead of living 80 years, let us take a man who lives but 40 years, with an additional compression of a thousandfold; then man would live only 21 minutes. Nature would look very different to such a man, whom Baer called the "man of minutes" (*Minuten-Mensch*). He would form no concept of day and night (at least by direct experience) and would see the sun sink only slightly over his entire existence, and the stars and moon would not appear to change at all. Further, what would such a man know of changes in vegetation and the organic world generally? If he spent half his life watching a bud bloom in 20 minutes, he would still not know the full developmental course of the bud. Thus, for the man of minutes, flowers, grass, and trees would seem to be unalterable entities. Even the movements of animals would not be seen by him, because their limbs would be moving far too slow for his rapid eyesight to be seen. If he lived under the night sky, the man of minutes would conclude that the stars rise from the horizon for a short period. He would be justified in concluding—because he would not be able to see the full course of the stars repeatedly or even once—that the stars only go so far above the horizon and then set again, or that they cease motion or behave in ways that stars do not in fact behave. Or he might conclude that the stars do not move, but only Earth's horizon. He would never be able to verify which possibility is true after only 20 minutes of observation. The entire organic world would appear lifeless to the man of minutes. If he lived under the day sky, he would have no reason to believe that the sun sets completely and night occurs, or that the sun would ever appear again on a new day. All the sounds that we hear would be inaudible for the man of minutes; he, in turn, might hear sounds that we could not, assuming that his ears are configured the same as ours. Our ears hear sounds only between 14 and 48,000 vibrations per second. Faster or slower vibrations we cannot perceive at all. Indeed, Baer hypothesized, the man of minutes would only *hear,* and not *see,* light.

As if this astounding thought experiment were not enough, Baer posed a further experiment to his audience. Let us take a man, whose senses remain structurally human. Let us speed up his perceptions not only a thousandfold, but instead a millionfold. But let all the rest of nature remain as it exists. Baer inferred that such a man of milliseconds would perceive the vibrations of "aether," which he hypothesized was several hundred billion vibrations per second, and which he hypothesized we see as color and light, would actually become audible, given that his sensory apparatus had such capacities. Aside from the later rejection of aether as a scientific hypothesis, Baer's point seems rational: Anything vibrating in the range of hundreds of billions per second would become audible to the man of milliseconds. Likewise, perhaps some ranges of vibration are perceived by human beings as sound, which the man of milliseconds would perceive as color and light. Based on recent experiments, Baer suggested that radiant heat consists of vibrations. Though he lived before the discovery of X-rays and radio waves, Baer went on to suggest that there might be many phenomena around us that we perceive as nothing at all. He considered the notion not at all counterintuitive, and modern science is replete with examples that validate his idea. Baer's ideas reached a sort of blend of science and poetry when he suggested that the planets might make a harmony of the spheres "for ears other than our own." But in case his audience thought him flip about his line of inference, Baer said he very sincerely wanted to "prove that, had our innate sense of time been otherwise, nature would present itself to us differently, not merely shorter or longer in her processes and narrower or wider in her effects, but rather as something entirely different" (p. 264).

Baer's Second Thought Experiment Concerning Time

Having completed his first thought experiment, Baer posed a second thought experiment to what must have been an audience in rapt attention.

> We have, previous to this point, shortened the human life in relation to the external world. . . . Let us now, conversely, lengthen it. Imagine, then, that our pulse were to go 1/1000th as slow as it actually goes. And we allow the time required for sensation to be a thousandfold increased over what we require now. If we assumed the same amount of experience, then the life time of such a person would reach a "ripe old age" at approximately 80,000 years. With such an altered standard, which we take from our own life processes, the entire picture would look otherwise. A year would seem like 8.75 hours. We would lose our ability to watch ice melt, to feel earthquakes, to watch trees sprout leaves, slowly bear fruit and then shed leaves. (*Festrede*)

Such a man would truly be able to *see* change in the enormity of a mountain range being born. We would no longer notice the lifetimes of mushrooms or lesser animals such as insects. We would be able to see flowers only once already bloomed, and then only to disappear. Only the great trees would attain our notice and gain some meaning for us in their slower aging, Baer conjectured. The sun would probably appear to leave a tail in its wake, similar to the tail of a comet or the tracer from a cannonball.

As if this thought experiment were not enough, Baer finally asked his audience to imagine this 80-millennial human lifespan multiplied a thousandfold. That is, imagine a man living 80 million years in Earth time, but who would have only

189 perceptions in an entire Earth year. So every perception would require almost 48 hours to complete. Only 31.5 pulse beats would occur in the body in an entire Earth year. "If we increase the magnitude of the man's life, which has already been slowed a thousandfold, by another thousandfold, he would experience external nature completely differently again." Such an 80-million-year man would not perceive the sun as a discreet circle but would see it as a glowing solar ecliptic, somewhat less bright in winter. The change of seasons would be a whirlwind: For only 10 pulse beats of the year, Earth would be snow and ice; for 1.5 pulses the melting snow would drench the land in spring; and for another 10 pulses, Earth would turn green.

Conclusions From the Experiments

With this observation Baer ended his second thought experiment concerning time. He was at pains to point out to his audience that these experiments in thought had not presupposed any new senses for man in order to experience different relations of time in nature. He observed that other animals have perceptions not accessible to man. So an alteration in man's senses would give humankind an entirely different picture of the world.

> We have taken man quite simply as he is [said Baer] and only asked how the entirety of nature would appear to him, if he carried inside himself a different standard of time.—It is indubitable that man can measure nature, both space and time, only according to himself, because an absolute standard does not exist. Earth's surface seems very large to him, because he can see across only a very small portion of it. But the same is only very small in relation to the Sun or to the universe. If man had the size of only a microscopic monad, even if he were to retain the entire sharpness of his intellect, a pond would appear as immense as an ocean.—It cannot be otherwise with his standard of time, by which we measure the effectiveness of nature, because we can measure only extension by standards of space. In fact, we have seen that the narrower we take man's innate measure of time to be, the more rigid and lifeless the entirety of nature appears to be, until finally, due to the brevity of life, the passage from day to night would not be observable whatsoever. (p. 267)

Baer's thought experiments concerning time have proven his grand metaphysical claim at the beginning of his address to the Russian Entomological Society. Because the physical forces that are inherent in water, heat, and light wear away everything in nature, the audience may no longer doubt that all apparent persistence is only transitory.

With a resonance of the metaphysics of Heraclitus, Baer grandly concluded that " all *persistence* is only an *appearance. Becoming,* in the form of development, is the *true* and *persisting* thing, through which all individual things are created in passing" (pp. 268–269). Baer's ideas went well beyond entomology into physics and beyond physics to infer what is ultimately real. "Matter in itself (*Stoff an sich*) and force in itself (*Kraft an sich*) exist only in the mental faculties. They are mere abstractions of our understanding. In reality no matter exists without properties (powers), just as we know no force which does not work from matter. Both are transitory, however, and the laws of nature are the remaining necessities by which they alter each other" (p. 269).

Thus we find in Baer's vision a world of relational forces and a set of natural laws by which the forces work. The organism measures time according to endogenous processes, primarily pulse rate, and for each organism, time begins and ends with the stages of its own developmental history.

Greg Whitlock

See also Darwin, Charles; DNA; Evolution, Organic; Experiments, Thought; Gestation Period; Haeckel, Ernst; Time, Perspectives of; Time, Relativity of

Further Readings

Appleman, P. (Ed.). (1979). *The descent of man: Darwin* (2nd ed.). New York: Norton.

Baer, K. E. R. von. (1862). *Festrede zur Eroffnung der russischen entomologischen Gesellschaft im Mai 1860*. Berlin.

Oppenheimer, J. P. (1990). Science and nationality: The case of Karl Ernst von Baer (1792–1876). *Proceedings of the American Philosophical Society, 134*(2), 75–82.

Bakhtin, Mikhail Mikhailovich (1895–1975)

Mikhail Mikhailovich Bakhtin was a Russian literary and language theorist as well as a cultural philosopher. Though his ideas and concepts were diverse and complex, the search for the unity within differences and various interrelations ruled his work. Bakhtin was interested in time and space throughout his life and had developed his literary concept by the 1920s. Two decades later he clearly enunciated his considerations about the *chronotope* and adapted Einstein's physical category of time–space for the aesthetics. He favored relativity theory for the purpose of relational meanings but refused relativism. In his later works Bakhtin introduced the concept of *carnival,* a feast with the unique sense of time and space.

Bakhtin was born in Orel, south of Moscow, on November 17, 1895. Beginning in 1919 he published several works on the history and theory of literature, language, psychology, and culture, occasionally under the names of friends. He studied philology in Odessa and St. Petersburg. Owing to his religious activities during the political rule of Stalin, he was sentenced in 1929 to exile in Kazakhstan. Together with problems with the Soviet government and the suppression or loss of several publications, Bakhtin also suffered from a bone disease, which caused him pain and eventually resulted in the amputation of his right leg. Bakhtin spent his last years in Moscow, where he died on March 7, 1975. In his early years Bakhtin convened the so-called Bakhtin circle, a group of intellectuals who were interested in diverse subjects such as German literature and philosophy, religion, and politics. Bakhtin's reading of the German classic philosophers, including Kant and Hegel, and the advances made by contemporary physicists such as Einstein and Planck influenced his wide range of ethical, aesthetic, and epistemological issues.

His concerns with ethical problems led him from the act to rhetoric and communication. In the early composed and posthumously published *Toward a Philosophy of the Act* (1986) he rejects the theoretical concepts of traditional formalism and substitutes for them his phenomenological or descriptive concept of dialogue. By recognizing the similarities between the act and the word, he exchanges the abstract system of language of the traditional disciplines for the metalinguistic concept of communication, in which the utterance, the context, and its interrelations are essential elements. To describe dialogic interrelations Bakhtin introduces the concepts of *carnival, heteroglossia,* and *polyphony.* In his first and influential paper "Problems of Dostoevsky's Work" (1929), Bakhtin uncovers the polyphonic novel as a new kind of novel. In a creative and active process the author enters dialogic relations with its characters and the recipient as well. When his seminal paper was translated into English, Bakhtin added a chapter on his concept of carnival and redefined the book in *Problems of Dostoevsky's Poetics* (1963). In *Rabelais and His World* (1965) Bakhtin deepens his idea of carnival and introduces the concept of the grotesque. During the feast of carnival, people live in a concrete imaginary or utopia, whose foundation is laughter, by turning the world upside down. The collection *The Dialogic Imagination: Four Essays* (1975) includes one of Bakhtin's most important analyses of the novel, as well as treatises on heteroglossia, dialogism, and the chronotope.

Franziska Kümmerling

See also Bible and Time; Chronotopes; Dostoevsky, Fyodor M.; Einstein, Albert; Ethics; Hegel, Georg Wilhelm Friedrich; Kant, Immanuel; Planck Time; Time, Relativity of; Utopia and Dystopia

Further Readings

Clark, K., & Holquist, M. (1984). *Mikhail Bakhtin.* Cambridge, MA: Harvard University Press.

Gardiner, M. (2003). *Mikhail Bakhtin.* London: Sage.

Barth, Karl (1886–1955)

Karl Barth was a Swiss Reformed theologian whose paradigm-shifting critique of theological liberalism made him perhaps the most influential theologian of the 20th century. In the course of his critique Barth introduced a novel conception of time that made a valuable contribution to discussions of the relationship between time and the God of Christian faith. Though Barth's ideas about time evolved throughout his career, this entry concentrates on his mature thought as spelled out most explicitly in *Church Dogmatics* II.1 and III.2.

To understand Barth's position on any topic one must remember three convictions that undergirded his work: (1) All attempts to discern truth must begin with God; (2) knowledge of God is properly derived only from God's self-revelation; and (3) God has revealed himself most definitively in Jesus Christ. These convictions are operative in how Barth did and did not talk about time. For instance, Barth did not begin with an analysis of the scientific community's latest insights about the origin of the universe or the human race. Though Barth was neither ignorant of, nor inimical to, such theories as evolution, he regarded them of no use to theology because they begin with human observation, not divine revelation. This should not be taken, however, as a naive rejection of science on Barth's part. Rather, Barth refused to pit science against theology out of his conviction that these fields of inquiry had such disparate objects that any comparison would be futile.

Because Barth refused to discuss the nature of time independent of God, his discussion of divine eternity served as a convenient entry point. Though Barth affirmed the classical Christian conviction that God is eternal, he warned against trying to define eternity by beginning from purely human terms, whether positive or negative. He was particularly averse to formulations that equate eternity with timelessness, tie eternity to the world's process of becoming, or infinitely extend time forward and backward. Instead, he rooted divine eternity in, and compared it to, God's Trinitarian nature. According to Barth, as the three persons of the Godhead (Father, Son, and Holy Spirit) constitute one being manifest in three modes that are held together by a perpetual interrelationship of love, so divine eternality is the mutual interrelationship of three distinct but not separate temporal forms (past, present, and future) that comprise one undivided duration.

Thus, in his limitless eternity, God also experiences temporality, but in a categorically distinct way that is beyond human comprehension. To the extent that humans experience time as lack of unity, constancy, and simplicity, God can have nothing to do with it. Yet God's unique temporality serves as the basis of his free choice to enter limited human time on behalf of humanity. Through Jesus, God has taken temporal time into his own eternal being and brought about its healing and renewal. By becoming contemporary with humans, Jesus opened the possibility that humans may enjoy fellowship with him and share in the new time inaugurated when he reconciled the world to himself. Barth's view of time—like his view of most topics—ultimately points to God's free decision to save humanity through Christ.

John C. Nugent

See also Bible and Time; Christianity; Eternity; God and Time

Further Readings

Busch, E. (2004). *The great passion: An introduction to Karl Barth's theology* (G. W. Bromiley, Trans.). Grand Rapids, MI: Eerdmans.

Hunsinger, G. (2004). *Mysterium trinitatis:* Barth's conception of eternity. In G. Hunsinger (Ed.), *For the sake of the world: Karl Barth and the future of ecclesial theology.* Grand Rapids, MI: Eerdmans.

Baxter, Stephen (1957–)

Stephen Baxter, a British engineer and science fiction writer, collaborated with Sir Arthur C. Clarke on two novels in the series *A Time Odyssey*, which explores the nature of time. In the first novel, *Time's Eye*, powerful alien beings (the Firstborn) are experimenting with humans by taking different time slices from human history and creating a patchwork in which these various slices are loosely woven together. Cosmonauts and UN peacekeepers from the year 2037 are brought into contact with a British army unit from 1885 that includes Rudyard Kipling and later encounters Alexander the Great's army, which must confront Genghis Khan's horde. When the displacement first occurred, a temporal and a spatial shift occurred: The sun was at its zenith in 2037, and then it moves across the sky to a position of late afternoon; it was as if the process of time had altered its history. The various characters in the story are "castaways in time," in a new world they call Mir.

A Spacetime Tapestry

One of the interesting conundrums that arises is that those from 2037 know of Rudyard Kipling, in this time slice a young man, and what he will go on to do. How much of his future should they tell him? And how much of what they tell him influences what he is to become? Or if (when) he dies in Mir, is there a Rudyard Kipling in England in 1900 who will still write his books? They also discover a discontinuity from horizon to horizon at one point where the time slices have been stitched together, which is explained by tectonic shifts over the thousands of years difference in the time slices. The rips in the "tapestry" of spacetime were sewn together piecemeal to create this new reality, so the Firstborn could observe (through great "eyes" in the sky) how these humans would behave in these disjointed circumstances. One of the time-displaced travelers, Bisea, is sent "home" to 2037 by the Firstborn because she asks them to do so (through the Eye).

This is where the second book, *Sunstorm*, picks up Bisea's story. She comes home to a gigantic disruption of all electrical and communication signals by geomagnetically induced currents prompted by an unusual sunspot. Research following this event revealed that a much more devastating occurrence would strike Earth, from the sun, in less than 5 years, a sunstorm that would destroy Earth. Scientists build a kind of shield in space to deflect as much of the sun's eruption as possible, and it is roughly 90% successful. Three superintelligent computers, Thales, Aristotle, and Athena, play a major role in saving Earth. What the humans discover, through Bisea's insight from her time in Mir, is that the Firstborn had caused the sunstorm deliberately, to stop the wasting of useful energy by humans on Earth. As this plan had failed, surely they would try again.

Parallel Corridors of History

An earlier book by Baxter, *The Time Ships*, delved even more deeply into time and time travel. Baxter's story purports to pick up where H. G. Wells's *The Time Machine* had left off. The Time Traveler goes on a new journey, but not as far forward in time as before (to 657,208 CE). He is captured by Morlocks, but these are very different from those he met before—civilized, very technologically advanced. One of them, Nebogipfel, takes an interest in him and concludes that the Time Traveler himself had caused a Divergence of Histories by relating to friends the details of his last journey. One of the friends, the Writer, had written it down, and it served as a warning. The population had avoided the conflict of that other history, had continued to grow, and had harnessed the power of the sun.

The Time Traveler learns of the work of Kurt Gödel in the 1930s, whose incompleteness proof showed that the quest for knowledge could never be completed; the Morlocks had taken on the task of accumulating knowledge, an infinite task. The Time Traveler, whose real intent was to go back to his own time to destroy his original time machine, convinced Nebogipfel to go with him on the pretense that it would be a quest for more knowledge. Nebogipfel explained to him another theory of Gödel's, of rotating universes that explained the existence of parallel corridors of history and the possibility of journeys forward or back in time and to other parallel histories. (This theory can, in fact, be found in Gödel's work.)

The Time Traveler visits himself as a slightly younger man (one of the paradoxes of time travel) to try to convince him not to build the Time Machine, a destroyer of worlds. His earlier self points out the logical difficulty of the Time Traveler being there to persuade him not to build the Time Machine as if the machine had never been built. A juggernaut from 1938 appears (another time anomaly) to protect the development of the science of the Time Machine and carry the Time Traveler and his earlier self forward to a London at war with the Germans. The Time Traveler and his earlier self meet and talk with theorist Kurt Gödel, who had deduced the existence of multiple histories. They have to flee a serious bombing attack in a new Time Car, and travel *back* in time roughly 50 million years. Their Time Car is wrecked in the landing, and they begin slowly reconstructing it. They are found by a British expedition from 1944 that has come back in time to find time-traveling Germans and keep them from altering history to suit their own evil purposes. When the British find the Germans, the Germans drop a bomb and the British must flee because of the dangers of the residual radiation. The British set up a colony safely removed from the bomb site and begin raising children.

The Next Stage of Evolution

Nebogipfel finishes rebuilding the Time Car, and then the Time Traveler and his earlier self travel forward into an unknown future. They find a colonized moon and a set of inhabited space stations, and then (by 1891) they find an Earth abandoned for travel farther out into space, leaving an Earth where the environmental equilibrium had been destroyed. They are about to die in this ice-world, but they are rescued by pyramid-like machines, the Universal Constructors, who have repaired the damage done to their bodies. These "machines," as Nebogipfel points out, are really "alive"—they reproduce and have memories, and they are conscious. They are the descendants of humans. They inhabit a Sea of Information, and they will not die out as a species, as humankind had. Day after day, Nebogipfel tapped into the information sea of the Constructors, and discovered that the Constructors intended to build huge Time Ships to go deep into the past. They want the Time Traveler to go with them, to the beginning of time. The project might take a million years, so Nebogipfel proposes that they go forward a million years in their Time Car to join the expedition. They do so, then begin (disembodied, absorbed into the information sea) the journey back through time. Near the end they travel through "cosmic shrapnel" and Nebogipfel tells the Time Traveler that space is folding on itself, that space and time are twisted until they are indistinguishable, a One. He and the Constructors (their consciousnesses) begin passing forward in the time of a new universe, one that was best ("optimal") for the Constructors. The Time Traveler is returned to his body and his original Time Machine and, along with Nebogipfel, to his home in England, where he gives the Plattnerite (the substance that powered the Time Machine) to his younger self. He then remounts the Time Machine and takes it forward to 802,701 CE, a day before the time when he had lost his beloved Weena on his first time voyage (back in one history, among the many); this time he manages to save her.

Thus Baxter mingles science fantasy with science truth and science speculation to expand the limits of our thought about time.

Stacey L. Edgar

See also Bradbury, Ray; Clarke, Arthur C.; Gödel, Kurt; Novels, Time in; Time Machine; Time Travel; Verne, Jules; Wells, H. G.

Further Readings

Baxter, S. (1995). *The time ships.* New York: HarperCollins.

Clarke, A. C., & Baxter, S. (2005). *Time's eye.* New York: Del Rey.

Clarke, A. C., & Baxter, S. (2006). *Sunstorm.* New York: Del Rey.

Wells, H. G. (1968). *The time machine.* New York: Fawcett. (Original work published 1895)

Becoming and Being

A quality that distinguishes philosophers and scientists from the rest of humanity is a willingness to confront and systematically explore issues and ideas that, for most people, seem so fundamental as to be unworthy of attention. Basic to philosophical thinking and discussion is the effort to define the very terms of reality, including *becoming* and *being* and their relationship to time. This becomes clear in an overview of Plato's idea of being and the thoughts of other major philosophers, including Aristotle, Gottfried Leibniz, Henri Bergson, and Alfred North Whitehead, and their divergence from being with their own ideas of becoming and how this connects with ideas of time. Plato held that the notion of *being* was what constituted absolute reality. Being holds that true reality is fixed in nature, unchanging regardless of time and space, whereas a changing reality is the false reality of perception. Opposed to being is the thought of *becoming,* where reality takes on a process or a change in order to create the reality we perceive, often termed *process philosophy*.

Plato

Reality is different for everyone, in the sense that to some degree we all perceive things differently.

Perceptions can also change for an individual from day to day: Either the perceived entity has taken on a different form, or the person perceiving the entity has changed in some way—in terms of experience, knowledge, values, and ideas. Plato (c. 427–c. 347 BCE) held a dualistic view of reality: the perceived world of dynamic, unfixed, and fluctuating perceptual reality, or *becoming;* and the unchanging, fixed, absolute reality, or *being*. Plato claims that because humans perceive their reality through the senses, the reality they know is skewed. This is because the senses are inaccurate, making the knowledge of this reality erroneous. By Plato's logic, true reality can be perceived only by the soul, or conceptual thought, and not the bodily functions that often alter a fixed reality. Plato refers to this fixed reality, which is perceived only by the soul, as the Idea or the Universal. The true reality of an object exists outside of the perceptions we gather from it through our senses. To Plato, the things that the senses perceive come out of a movement between the senses and the things perceived. Both are in a state of change, and where these changes meet, there is perception.

Becoming is subject to space and time. Our perceptions are rooted in time, as we see things change throughout time and perceive them differently throughout different periods within time. What we perceive are only particulars of an Idea; they can only represent an Idea, but are not the Idea itself. For example, when you see a horse you are seeing a perception of the Idea of a horse, and the "horseness" or Idea is separate from the particular horse that we have a sensory perception of. Being is not bound by time. It is fixed and unchanging for all eternity, thus making it absolute reality. According to Plato, this absolute and true reality is unchangeable and eternal. Time exists only as a moving representation of the eternal. Plato believes that when the heavens were created, so was this moving representation of them that we are able to perceive. Time has been around since the beginning, but it exists only in the perceptual world, as the eternal unchanging world is not subject to time. The past and the future are parts within the perceived time, that we understand the eternal to be within, but which it is not. The eternal simply "is" and never "was" or never will "be" as we understand our temporal space. The eternal is fixed and unchanging, not subject to the motion and change of time.

Process Philosophy

Major philosophers have since diverged from this Platonic way of thinking in terms of an absolutely fixed reality. The more commonly held view of today is that the world is a dynamic place and continually changing as things are becoming, not simply being. This becoming is also referred to as process philosophy. Process philosophy branches from metaphysical philosophies. Metaphysics is the study of reality and how we experience it in this world. Process philosophy offers a take on reality that claims that reality can be described in terms of processes and not things. It focuses upon the changes we perceive happening, rather than the unchanging or fixed. For a process philosopher, any type of change or process characterizes reality. Any type of change, whether it is physical, organic, or psychological, is made up of numerous phases. It flows from one thing to the next, rather then remaining stagnant or fixed within time.

Aristotle

Aristotle (384–322 BCE) was one of the first major thinkers to move away from the idea of being or fixed entities. Aristotle rejected Plato's dualistic approach to Ideas and particulars. He did not agree that our senses show us a world full of copies or representations of the real universal Ideas. Aristotle claimed that Ideas and particulars, or forms, relied on one another for existence. He held that the form we see is the reality of an object within the matter of that object. The form to Aristotle is the same as the Idea of an object is to Plato. It underlies what the object itself is and not the perception we have of the object. The difference is that Aristotle claimed the forms and matter of an object rely heavily on one another, whereas Plato believed they are separate from one another. For Aristotle, forms are able to change, but we can still acquire a reality from them. Although these changes take place, Aristotle taught that one part of an object's matter always remains the same. The part that remains the same is the matter of an object, and the part that we perceive as changing is the form of an object. Thus, change can take place, with an object still remaining what it is, as its matter is still unchanged. Aristotle held that when a change takes place, the original form of an object does not change the object; rather, a new form will instigate the change. This "new" form was always present; it just reacted on the matter to create what we perceive to be a change. Forms or matter cannot be destroyed. Matter can be changed only by many different qualities or forms, depending on what is present in its environment.

For Aristotle, these forms that we perceive are becoming or changing. Aristotle held that this change and time are linked, and time does not exist without change or motion. Aristotle related time to motion, or that which can be referred to as change, as in every instance of motion there is a change occurring. Time and change are perceived together, even if our physical senses do not perceive a change; a thought that enters the mind makes us think that a period of time has elapsed no matter how brief. Although time may measure changes, it is not change. It cannot be a change because it is everywhere and with everything. Time is a constant, and change can be faster or slower; thus they are not one and the same. Aristotle claimed that time is perceived in the present but, for the present to be there, there must have been a before and an after (even if we do not perceive these points in time). He claimed that some things that are not affected by time are not in time. These are the things that are eternal, such as heavenly bodies, which exist with time but are not a part of it. These eternal things are not affected by the before and after as the finite things are. The things that are in time are those that are changing or have motion and are finite.

Gottfried Wilhelm von Leibniz

Leibniz (1646–1716) believed that we are able to perceive the ever-evolving reality and that it is a true reality to us. He went further to claim that if perceivers can see no contradictions in the reality they perceive, then it is in fact conceivable and therefore real. To Leibniz, the concept that something that creates no contradictions is real opposes the Platonic thought that perceived things are not real. Leibniz claimed that by an object's uncontradictory nature, if that is what it has, we are able to understand it, thus making it real or conceivable to ourselves. He makes an important distinction that these things must have some basis in reality; for if they do not, then they become imaginary. This realm of possibility exists within what Leibniz terms a *region of Ideas*. This region of Ideas is what Leibniz related directly to God, claiming that it is God who makes things perceivable to us in our world. Humans, being rational, are able to perceive a divine representation of things, thus having knowledge of them.

Leibniz maintained that reality resides within centers of force, all of which are different from one another. Leibniz termed these centers of force *monads*. Monads are in everything and cannot be destroyed; therefore they are eternal. They are each individual and can come together to make up larger things. Changes within monads themselves happen irrespective of other monads, because they change internally. According to Leibniz, the monad becomes what it was always meant to be, that is, as God meant it to become. The changes that continually occur within a monad are simply allowing it to reach its full potential; that is, what it was always meant to become. Monads are present in different levels of a hierarchy, God being the highest monad. This hierarchy is determined by the degree to which something can perceive the truth. Monads reflect the universe, with differing degrees of clarity, depending on where they fall within the hierarchy. The higher the form is, the more Godlike it is, and the lower the form is, the more mirror-like it is. The lowest form of a monad has unconscious perceptions and no memory. A monad that is more highly developed will possess a memory and has conscious awareness and perceptions. A higher monad, or one that is God-like, will contain all the aspects of the lower monads as well as self-consciousness and reason.

For Leibniz, time is an illusion because it does not exist as a dimension itself outside of a particular monad. He does not think that time is only a series of moments strung together to create continuity. Leibniz's explanation of time derives from his theory of sufficient reason: Everything that occurs has a reason for its occurrence, that reason being that it is the way God intended it to change and become. As monads go through change internally, so too is time internal to a monad. As Leibniz divided his monads, he also divided time into three respective categories. The first category is atemporal, free from any limitations of time, or God. The second category is a continuous change within the monad or a realization of actuality, as God intended. The third category, is an external framework of sequential order, or the "now."

Henri Bergson

Bergson (1859–1941) termed reality as the *élan vital,* or a vital force, which is rooted in consciousness. He taught that there is change and evolution in everything at every time; nothing simply exists. Everything to Bergson was continually changing, including consciousness. We know our reality through consciousness and experience, not through scientific reasoning. Our consciousness constructs reality from past experiences and is continually moving and evolving forward. Experiences are never repeated, as they are unique to situations and time. Becoming is varied, and no experience is the exact same as another. To Bergson, becoming can be perceived as qualitative, evolutionary, and extensive. However, although it may appear to fit into one of these categories, each instance of becoming is the same regardless of how we perceive and categorize it. The real instance of becoming resides at the back of our knowledge centers and we only recreate it through our perceptions—we do not see its true essence. Bergson compared knowledge to cinematographic perceptions. That is to say, we perceive things in static "snapshots" and put them together like a moving picture to create a reality.

For Bergson, this cinematographic approach addresses time. The approach takes instances within time and makes them presentable in frames, which we can view singularly or as a stream coming together. This approach includes duration, through which a series of images is perceived by the observer and understood only by our imagination and not through our real knowledge. The imagination allows us to experience real duration or time, as time itself is immeasurable because it is constantly in motion. Bergson held that we do not perceive time as a fluid movement but rather as these glimpses of static occurrences. Perception allows us to view a progression through time rather than seeing time directly within our perceptions.

Alfred North Whitehead

Whitehead (1861–1947) placed the temporal world into *occasions of experience,* meaning that what we perceive are simply multitudes of instances grouped together to form our perceptions of them. These experiences can be placed into groups to create an interpretation of something. This line of thinking would in essence allow an occasion to be broken into a series of smaller experiences. Everything is broken into experiences, including our minds. Therefore, for Whitehead, there is no separation between the mind and the body. They are interconnected through process. These occasions of experience rely on experiences or processes that have happened before them, and they influence those that will come after them. This presents the idea that progress and duration and occurrences do not simply happen but rely on occurrences that have already taken place. These experiences are subject to free will, as each experience requires an understanding and then a reaction in order to create the next experience.

For Whitehead, the past experiences are not determined through our senses. Whitehead terms these past experiences *pastness,* and they are present behind all the experiences we have in the present. Our reaction to these experiences creates our future. For Whitehead, things are continually moving and evolving. Our current perceptions emerge from what has come before them; they emerge and become. Each occasion is forever evolving and changing in order to reach self-completion. Whitehead claimed that each of these occurrences is not determined, but each happens in relation to another occurrence that directs the occurrence toward a future. Occurrences are continually flowing into one another through a process. By this process, we perceive occurrences as the mind views them and turns them into perceptions for our physical selves to understand.

Whitehead held that we view occurrences as separate from one another, not occupying the same space within time. For Whitehead, however, this is a false view. Instead, he claimed that for us to understand occurrences, we must relate them to past occurrences. Whitehead maintained that things do not exist separately within space and time. Time, space, and occurrences are related to one another; none can exist on its own, for the process universe is becoming within time.

Jennifer Goul

See also Aristotle; Bergson, Henri; Hegel, Georg Wilhelm Friedrich; Heraclitus; Leibniz, Gottfried Wilhelm von; Metaphysics; Nietzsche, Friedrich; Plato; Teilhard de Chardin, Pierre; Theology, Process; Whitehead, Alfred North

Further Readings

Browning, D. (1965). *Philosophers of process.* New York: Random House.

Eastman, T. E., & Keeton, H. (2004). *Physics and Whitehead: Quantum, process, and experience.* Albany: State University of New York Press.

Gale, R. M. (1967). *The philosophy of time: A collection of essays.* Garden City, NY: Anchor Books.

Grosz, E. A. (2004). *The nick of time: Politics, evolution, and the untimely.* Durham, NC: Duke University Press.

Kalkavage, P. (2001). *Plato's* Timaeus. Newburyport, MA: Focus.

Krishnananda, S. (2008). *Studies in comparative philosophy.* Rishikesh, India: The Divine Life Society.

Robinson, T. A. (1995). *Aristotle in outline.* Indianapolis, IN: Hackett.

Rutherford, D. (1997). *Leibniz and the rational order of nature.* New York: Cambridge University Press.

Sarkar, A., & Kumar, A. (1974). *Whitehead's four principles from West-East perspectives: Ways and prospects of process philosophy.* San Francisco: California Institute of Asian Studies.

Bede the Venerable, Saint (c. 672–735)

Often called the father of English history, the Venerable Bede (Latin: Baeda), born in Northumbria, recorded the history of early medieval England, supported the reunification of the Celtic churches with the Roman Church, and popularized the term *anno Domini* (AD) in calendar dating. Bede's histories and chronicles became a model of historical writing and the standard reference works in Europe, especially during the Carolingian Renaissance, being copied multiple times and circulated throughout Europe. The Venerable Bede's literary works cover a variety of topics: biblical commentaries, hagiography, homilies and liturgical works, historical texts (*Ecclesiastical History of the English People, History of the Abbots of Wearmouth and Jarrow*), and scientific works (*On Nature, On Time, On the Computation of Time*).

In Bede's *Ecclesiastical History of the English People* (*EH*), completed in 731, Bede informs the readers that he was born in the territory of the monasteries of Saint Peter and Saint Paul at Wearmouth and Jarrow (founded in 674 and 680). At the age of 7, Bede's "kinsmen" entrusted him to the care of the abbots Biscop (also called Benedict) and Ceolfirth at these monasteries for his education. Bede lived a disciplined life within the monastic rule, receiving ordination as deacon at the age of 19 and priest at the age of 30. Although Bede did not travel far from Northumbria, he acquired an understanding of geography, providing place names and physical features; he recognized the various societal groups in England and Ireland and recorded the accounts of influential individuals. Bede's histories, chronicles, and letters reveal his awareness of the chronology of past events, as well as a grasp of current facts (e.g., the state of kingdoms and well-being of his community and neighbors).

Under the direction of Abbot Biscop, the sister monasteries at Wearmouth and Jarrow stood out as a center for the arts and scholarship, welcoming Continental artists, liturgical directors, and scholars. These two monasteries worked together, sharing resources and an extensive and impressive library. The Northumbrian monks and their library and archives provided Bede with an example of historical study, meticulous record keeping, and adequate sources.

Historians strongly emphasize the significance of Bede's *Ecclesiastical History of the English People.* This work provides the most accurate and detailed account of Christianity in Britain and Ireland from the late 200s to the mid-700s, recording biographies (e.g., Oswald, Columba, Aidan, Cuthbert) and crucial events. During the so-called Dark Ages, this history also explains the daily life of early medieval England and encouraged the spread of education, literacy, and a growing sense of national identity. Therefore, it appropriately became one of the earliest national histories and another important regional history of Christianity.

The Venerable Bede supported the moral benefit of history, saying, "Should history tell of good men and their good estate, the thoughtful listener is spurred on to imitate the good; should it record the evil ends of wicked men, no less effectually the devout and earnest listener or reader is kindled to eschew what is harmful and perverse, and himself with greater care pursue those things which he has learned to be good and pleasing in the sight of God" (Preface, *EH*). Although the *EH* possesses historical value, Bede primarily wrote to show the spread of Christianity in England, hoping to convert others to the Christian faith.

One hundred and fifty medieval copies of the *EH* survive (proving its immediate importance), and this work became the first English history book to be printed for the public (proving its long-term influence and historical significance). The Venerable Bede carefully chose his sources (e.g., documents, testimonies, correspondence) and explained his methodology of research and writing; the *EH* became a model for future historical accounts, particularly influencing the scholarship of the Carolingian Renaissance. In terms of church history, the *EH* resembled Eusebius of Caesarea's history of the church and also drew from the works of Jerome, Saint Augustine of Hippo, and Gregory the Great.

Works

Bede's works (e.g., *Ecclesiastical History, On Nature, On Time,* and *On the Computation of Time*) reflect his interest in and exploration of the world of natural science, astronomy, and ecclesiastical computation or calendrical calculations. Bede contributed to the medieval understanding of the calendar in two ways. First, the *EH* popularized the use of the Latin term *anno Domini* (or AD, meaning "in the year of our Lord"). The Scythian-born monk Dionysius Exiguus (c. 500–540) invented the AD system, which is an altered Alexandrian calendar consisting of a 19-year Paschal cycle. Dionysius Exiguus also dated the birth of Christ at 753 *ab urbe condita* (or AUC, meaning "from the foundation of the city [Rome]"). Although this calendar was believed to be the most accurate, it still possessed weaknesses (e.g., Christ was born during the reign of Herod the Great, around 750 AUC, instead of 753 AUC). Bede recognized Dionysius's errors but continued to use the system in all of his writings. The calendrical debate arose throughout Europe over the correct dating of Easter. From the *EH,* Bede explains that the Celtic churches followed an older calendar, which had long disappeared from Continental Christianity. Bede enthusiastically supported the Roman Church and encouraged the Celtic churches to adopt Roman practice (e.g., the dating of Easter). Historians usually recognize the submission of Celtic Christianity to the Roman Church at the Synod of Whitby in 664.

Second, Bede authored two world chronicles: *On Time* (or the *Lesser Chronicle,* 703) and *On the Computation of Time* (or the *Greater Chronicle,* 725). In these works, Bede examines the divisions of time, from the study of hours, days, weeks, and years to an explanation of the six ages of Christianity (as outlined in Saint Augustine's writings). The six ages are listed as (1) Adam to the Flood, (2) Noah to Abraham, (3) Abraham to David, (4) David to the captivity, (5) the captivity to the birth of Christ, and (6) the present age until the return of Christ. In the *Lesser Chronicle,* Bede does not place a specific amount of time on the sixth age and calculates that 3,952 years passed from the time of Adam's birth to Christ's birth. Accused of heresy for suggesting these new calculations, the venerable monk modified his chronologies and published his larger work, the *Greater Chronicle.* These two works followed Dionysius Exiguus's Alexandrian calendar, becoming the standard method of time keeping and recognizing seasonal changes and annual holidays in medieval Europe. Bede's experience with the orderly monastic life and observation of the environment in which he lived (e.g., ocean tides, agriculture) gave him plenty of reason to study the passing of time. This literary genre became a popular style of writing and influenced the production of similar manuscripts.

The Northumbrian community revered Bede as a scholar, teacher, priest, and fellow monk, calling him "Bede the Venerable." Tradition holds that the monks buried Bede at the monastery of St. Paul at Jarrow. To protect the grave from Viking invasions during the late 700s to early 800s, the monks moved his body to Durham Cathedral, where his grave remains today. Historians and scholars are indebted to the work of Bede; without his *Ecclesiastical History* little would be known of early medieval Britain and the spread of Christianity in England and Ireland. Most importantly, the Venerable Bede helped to clarify the ecclesiastical computus and popularized the use of the term *anno Domini* in calendar dating.

Leslie A. Mattingly

See also Augustine of Hippo, Saint; Bible and Time; Christianity; Ecclesiastes, Book of; Evil and Time

Further Readings

Bede. (1999). *The ecclesiastical history of the English people; The greater chronicle; Bede's letter to Egbert* (J. McClure & R. Collins, Eds.). Oxford: Oxford University Press.

Blair, P. H. (1990). *The world of Bede.* Cambridge, UK: Cambridge University Press.

Orme, J. (2005). *An annotated bibliography of the works by and on the Venerable Bede.* Unpublished thesis, Lincoln Christian Seminary, Lincoln, IL.

Ward, B. (1998). *The Venerable Bede.* New York: Continuum.

Beowulf

Beowulf is the name of an epic Anglo-Saxon poem written in Old English, named after the protagonist. It was composed probably around 1010 CE and is known from only a single manuscript, called the Nowell Codex after the name of its earliest (16th-century) known owner, Lawrence Nowell. It is a matter of debate whether the manuscript was the written version of an older oral tradition or the literary composition of the scribes, most likely monks, who put it into writing. What is known is that two scribes were responsible. The action of the poem takes place in what is now Denmark and southwestern Sweden in the late 5th century CE. Although the characters are all pagan, the Christian authors inject references to God and the Old Testament and occasionally comment about the unenlightened nature of the characters.

The poem begins by relating the funeral of the legendary founder of the Scylding (Danish) royal family, Scyld Scefing, whose great-grandson Hrothgar now rules. Hrothgar is a wise old king who successfully ruled his people for 30 years before his troubles began. When he was prosperous, Hrothgar built a great mead hall, called Heorot, where his thanes and warriors celebrate nightly. One night, a vicious ogre named Grendel, who lives in a nearby cave in a swamp, attacks the mead hall and slaughters a number of Hrothgar's men. It turns out that Grendel is a descendant of the biblical Cain, as are all monsters, and being an outcast, the ogre hates humankind for its joys and accomplishments. Hearing the celebrations in Heorot angers him, and he makes nightly raids upon it for 12 years. Beowulf, a young Geat (from Geatland in southwestern Sweden) warrior of surpassing size and strength, arrives at Hrothgar's kingdom with 14 handpicked companions to rid the land of Grendel. Beowulf's father had been sheltered from danger by Hrothgar years earlier, and Beowulf wishes to repay this debt, as well as earn riches and fame. That night, while the Scyldings sleep elsewhere, Beowulf and his men stay in Heorot to await the ogre's arrival. When Grendel comes, he kills and eats one of the men, then attacks Beowulf. The two fight furiously, almost destroying the building, until Beowulf tears Grendel's arm from its socket, mortally wounding him. Grendel retreats to his cave in the swamp to die, and Beowulf proudly presents the severed arm to Hrothgar, who hangs it from the roof of Heorot. Beowulf is richly rewarded and celebrated.

Later that night, Grendel's mother, an ogress of almost as much strength as her son, attacks Heorot and abducts one of the men in revenge. Beowulf sets out the next day with his men to kill her, and they find the severed head of her victim awaiting them. Beowulf is given a mighty sword by one of Hrothgar's thanes, Unferth, who previously had insulted Beowulf but now respects him. Beowulf dives into the swamp and confronts Grendel's mother. He is unable to kill her with his weapon; she gains the upper hand until the hero spots a miraculous great sword in her lair and uses it to kill her. A miraculous light illuminates the cave, which is full of treasure and also contains the body of Grendel. Beowulf uses the magical sword to cut off Grendel's head. The sword's blade then melts, and Beowulf takes his trophy and the remaining hilt back to Hrothgar. He is again rewarded and celebrated, and Hrothgar warns Beowulf of the dangers of pride and the vicissitudes of time. Beowulf returns to Geatland where his uncle, Hygelac, is king. Hygelac is later killed in battle, and when Beowulf is offered the throne, he declines it, opting instead to serve Hygelac's son Heardred, who is also killed in battle. Beowulf then becomes king and reigns well for 50 years. Disaster then strikes in the form of an outraged dragon that ravages the countryside in revenge for the theft, by a Geat fugitive, of a goblet from his treasure hoard. The hoard is 300 years old, the original property of a fallen tribe of warriors, and is cursed as well, making it of no use either to the dragon that guards it or to anyone else. The old Beowulf sets out in pursuit with a band of 11 loyal men. He challenges the dragon and they fight. Beowulf's weapons fail to harm the monster, and all but one of his men abandons him. The one true man, Wiglaf, stays to help and wounds the dragon enough so that Beowulf can kill it. Beowulf himself is mortally wounded and dies, leaving his kingdom to Wiglaf. He is buried underneath a great barrow together with the cursed treasure.

Like other epic poems such as the *Iliad* and the *Odyssey*, both composed more than a thousand years earlier, *Beowulf* continues to fascinate scholars and the reading public alike. Apart from the heroic action and adventure that the poem narrates, its timeless themes include the virtues of loyalty, reputation, generosity, and hospitality, as well as the dangers of envy and revenge. Although the character of Beowulf is larger than life, he is still a human being, a mortal man, subject to aging and the ill fortune that eventually befalls him. However, because of his great virtues—such as the loyalty to his lords that drove him to great deeds, his generosity to them and to those who served him, and his reputation as a great and noble fighter—he is remembered as the very model of a warrior king.

Robert Bollt

See also Homer; Novels, Historical; Novels, Time in; Poetry; Shakespeare's Sonnets

Further Readings

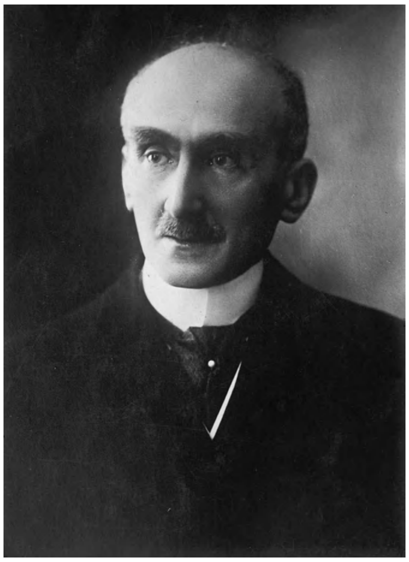
Alexander, M. (Trans.). (1995). *Beowulf: Old English edition.* London: Penguin.

Alexander, M. (Trans.). (2003). *Beowulf: A verse translation* (Rev. ed.). London: Penguin.

Bergson, Henri (1859–1941)

The philosopher Henri Bergson was born in Paris and studied at the École Normale Supérieure. Following graduation he taught philosophy at various *lycées* (secondary schools) in Provence, after which he taught at the Collège de France. He received his doctoral degree in philosophy in 1889 and was awarded the Nobel Prize for literature in 1928. His background in psychology is most easily recognizable in his early writings. Over his long career, he developed ever more into a metaphysician. Key among his ideas is the distinction between the mechanized clock time of scientific thinking and the way time is actually experienced.

The experiencing of time as a quantity, as a countable element of a time continuum, differs for Bergson at a basic level from the qualitative experiencing of a duration. The duration is something pure and is not expressed in quantities. It is equivalent to the immediate experience of totality. A melody or a symphony is to be experienced only as a whole. Its wholeness possesses an immediacy that cannot be broken up into its elements without losing its qualitative characteristics. Its temporal



According to French philosopher Henri Bergson, real time cannot be analyzed mathematically, and to measure time is to try to create a break or disruption in time.

Source: Library of Congress, Prints & Photographs Division, LC-DIG-ggbain-38388.

extension is *pure duration*. According to Bergson, the completely pure duration is the form that the succession of our perceptual processes assumes as our "I" yields itself to life, when it refuses to separate the present and past states. The tones of the melody fuse together, its different parts infusing each other simultaneously. Furthermore, if a melody is deconstructed into its components, then time, the medium in which one counts and differentiates, is nothing more than space.

The *pure duration* is fundamentally different from countable time. To Bergson, it was impossible to construct a synthesis of quantitative and qualitative elements. The experience of a duration is the experiencing of a quality that is immeasurable. Pure duration is an indistinguishable, qualitative manifold, which is in no way similar to numbers. It is a mistake on the part of the natural sciences not to carefully separate qualitative and quantitative characteristics. The uniformly flowing time of the natural sciences is a physical–astronomical construction. This time is seen as a line whose points represent successive moments. Admittedly, time may be mathematically expressed in such a way, but this is not really time itself. Real time is the immediately experienced time, and this is duration (*durée*). In the analysis of the experiencing of space, psychologists have stopped studying space in exchange for our perceptions, through which we achieve meaning or understanding of the concept of space. Perceptions have a qualitative character because they are not themselves extended, but their synthesis causes extension. Space is created out of mental activity, which, with one stroke, contains the different perceptions and also orders them next to each other. In this respect, space is that which allows us to differentiate multiple identical and simultaneous perceptions from one another. Humans are able to conceive of space without quality. Thus, two different realities exist for humans: the reality of sense qualities, which is heterogeneous, and the reality of space, which is homogeneous. The reality of space allows us to implement exact differentiations, to count and to abstract.

If the unlimited medium of space, which is completely without quality, is defined as homogeneous, then time, which is also defined as homogeneous, must be space, because there are no differentiating characteristics between different homogeneities. Nonetheless, people agree that time is to be seen as an unlimited medium, which is different from space and yet still homogeneous. The homogeneity thus exhibits a doubled guise according to whether it is seen to be a coexistent or a sequence. We steal time from duration by observing states of consciousness all at once and next to one another, projecting them into space. Time as a homogeneous medium is space. Duration is then to be thought of as the extension of an episode of time, taking the form of a constant line. As soon as duration is seen as homogeneous, one has imperceptibly allowed the concept of space. Bergson does not accept the true duration to be a quantity. It has a qualitative size, which has an intense character. It becomes possible to experience true duration when one becomes entirely entranced by something, for example, when hearing a melody or when one leaves the area of experience of space, for example, in a dream.

Through time measurements, duration is projected into space. Pure duration thus loses its qualitative character and is reduced to a quantitative size. Time measurements are not measurements of duration but rather the counting of simultaneities. A simultaneous process of the permeation of the occurrences of perception takes place inside of us through our memory, which is what actually creates true duration. Through an act of memory, we can compare equal positions of a periodic movement; in other words, an oscillation. Without memory we would have only one position of the pendulum or the sun, namely the present position, and thus no duration. Without periodic processes, we could not deconstruct duration into space and would have only pure duration.

Even if the measurement of time really is the projection of duration into space, it is not space that is considered here but rather duration, which is expressed with the help of space. Although time can be graphically represented using the fourth dimension of space, time is, as a phenomenon, still very different from space. In the analysis of the relationship between space and duration, Bergson comes to the conclusion that there is real space without duration, in which phenomena appear and disappear simultaneously with our states of consciousness. There is also the reality of duration, whose heterogeneous moments penetrate each other. In the outside world, there is a moment corresponding to every state; each and every moment and state must appear simultaneously, and each moment can be isolated from the others through this correspondence. A symbolic conception of duration based on space has emerged out of the comparison of both realities. This conception assumes the form of a homogeneous medium. That which connects space and duration is simultaneity, which one could define as the point of intersection between time and space. According to Bergson, the natural sciences have concerned themselves only with the symbolic conception of reality.

There would not be two kinds of recognition—one philosophical, the other scientific—if the experience would not allow us on the one hand to sequence and measure this experience in the form of facts externally ordered next to each other, and yet on the other hand would present itself in the form of mutual permeation, which is pure duration, remaining inaccessible to both law and measurement. In both cases, experience means consciousness. But in the first case, the consciousness unfolds in the direction of the external by perceiving external things. In the other case, this consciousness retreats by realizing and understanding itself. Bergson has drawn a line between the external and internal of the consciousness. The external of the consciousness is the immediately given world, which is measurable through physical processes. The internal of the consciousness is the present of the complete collection of experiences; this present completely dedicates its attention to one fact of the world and therewith pure duration, constituting a closed act. The experience is a part of the internal consciousness.

Duration and Motion

When analyzing the concept of motion as the living symbol of a seemingly homogeneous duration, Bergson ascribes to the consciousness the fusing of quantitative elements with qualitative ones, which seems to be withheld from the consciousness when analyzing duration. The motion that is observed as a transition from one point to the next is a mental synthesis, a psychological process and therefore unextended. In space there are only points in space, and regardless at which point the object in motion finds itself, an object has only one position in space. If the consciousness perceives something other than points in space, this is, according to Bergson, due to the consciousness remembering the successive positions and building a synthesis out of these. But how does it actually create such a synthesis? Obviously not through the deploying of the same positions in a homogeneous medium; this would require a new synthesis to bring the positions into connection with each other and so on into eternity. There is a qualitative synthesis at work here, a step-by-step organization of our successive perceptions among each other, a unit within the analogy of a melodic phrase.

Bergson differentiates between the extensive conception of the traversed space and the intensive perception of motion. This is the differentiation between the successive positions of a movement and its synthesis, the act of traversing. Naturally, a movement deconstructed in terms of its position in space has nothing more in common with the intensive perception of movement. A movement is not the sum of the points of its path. This insight led Bergson to the solving of Zeno of Elea's paradox. Zeno wanted, through his famous thought experiment about the race of Achilles with the turtle, to give precedence to the being of things when juxtaposed with changes in the world. The turtle asked Achilles for a head start, as Achilles was the faster runner. The only problem was that after the race had started, Achilles first had to run to the turtle's starting point; however, the turtle had already moved on by this time. Each time Achilles reached the turtle's last starting point, he had to race to the next point on which the turtle at that exact moment was located. But the turtle had already moved on. This process would allow itself to be extended into eternity without Achilles ever being able to catch up to and pass the turtle. Achilles' every step is a simple, indivisible act. Zeno's mistake was, however, that he identified this progression of indivisible acts with the homogeneous space underlying them. Achilles passed the turtle because one of Achilles' steps and one turtle step are each indivisible acts of varying lengths. Zeno does not see that space allows only a random, arbitrary process of de- and re-composition and in this way mingles space and motion. Science concerns itself, according to Bergson's point of view, not with motion and time per se but rather solely with their respective projections into space. Science deals with time and motion only after the previous elimination of its basic and qualitative element, namely, duration, in terms of time, and mobility, in terms of motion. For this reason Bergson's *duration* may be seen not as the attempt to mediate between scientific and phenomenological views of the world but rather as a separation stemming from the consideration that the experienced reality is more than can be displayed in the natural sciences, which means that scientific recognitions rest upon a reduction of reality.

James and Bergson

Comparing the concepts of time used by Bergson and the American psychologist William James is instructive, since the method used by both thinkers is based on psychology, and their concepts thus resemble each other. Bergson broke with the scientific view of the world by radically rejecting the concept of space and time presiding within the natural sciences. James, on the other hand, evaded the totality of our experience when he tried to measure the length of the *specious present* in order to determine which time spans we are able to understand or measure at one time.

The difference between James and Bergson lies in their differing evaluation of the past and its relationship to the present. Both reject the concept of a dimensionless, punctiform present, which advances like a mathematical point along a geometric line into the future. They came to this conclusion through introspection into the immediately given, the flowing of the thoughts. In addition, Bergson's distrust of graphical symbols played a role, as he believed they destroy the true nature of time through their static character. Bergson insisted that time cannot be represented in the form of a straight line as the fourth dimension of space. A straight line is a timeless object implying that its parts are simultaneously present. Only after we have radically freed our conceptualizations from our visual customs and geometric symbols are we able to understand the nature of time. Bergson avoided every kind of visual metaphor for the description of the structure of duration. When we have finally left behind us the symbolic representation of time as a straight line, we will no longer represent its parts geometrically as points. The moments of time are not punctiform moments; time is not endlessly divisible. Bergson's analysis of pure duration has a deeper meaning than a merely psychological one. He wanted to examine the nature of time in general, not time as only the "stream of thoughts." In the *Principles of Psychology* James argued for the conception that the qualitative and heterogeneous "stream of thoughts" covers and hides the underlying Newtonian homogeneous time, the original container of all changes, including those taking place in the brain. Due to James's having limited his analysis of time exclusively to the area of psychology and having en bloc accepted classical physics, he had difficulties in recognizing the true character of duration. Bergson stood, despite his anti-intellectual attitude, within the Cartesian tradition, whereas James argued out of the tradition of the British empiricists. James limited himself to the empirical, immediately given psychological data. Bergson tried to rationalize the given structure of the immediately given and to see the logical connections between the varying aspects. He found that the most disastrous and troublesome effect in understanding time is caused by the visual and geometric symbolizing of the temporal reality. This helped him to reject, in general, the concept of homogeneity and the mathematical concept of continuity.

James and Bergson were both temporalists, but whereas James elevated the character of constant change, Bergson emphasized the lingering just as strongly as the flowing. Bergson saw both aspects as complementary; he elevated the conservation of the past. When we hear a symphony, its theme is present during the entire performance such that we may recognize it over and over again. Within the melody the tones fuse together into the whole. Bergson assigned the past a special status while believing that James could not entirely free himself from visual conceptions. He observed the present as a duration with a certain length. Therewith he imagined time to be tiny pieces of time occurring one after the next. Accordingly, time would be a process constantly separating itself, which is not, as in Bergson's conception, a reality that is gradually becoming richer and growing together in the progression of duration. That life continues means that it exists in a continual flowing within which nothing is lost, but rather in which everything continues to grow, like a rolling snowball, so that everything to come is, in part, determined and infused from that which has already been. Whereas James's model has a purely linear character, Bergson's conception of time is characterized by an increasing complexity, which contains all past states and is gradually growing.

Joachim Klose

See also Becoming and Being; Consciousness; Creativity; Duration; Epistemology; Evolution, Organic; Hartshorne, Charles; Intuition; Memory; Metaphysics; Time, Subjective Flow of; Whitehead, Alfred North; Zeno of Elea

Further Readings

Bergson, H. (2001). *Time and free will.* Mineola, NY: Dover.

Bergson, H. (1990). *Matter and memory.* Cambridge, UK: Zone Books.

Capek, M. (1991). *The new aspects of time—Its continuity and novelties.* Dordrecht, Netherlands: Kluwer.

Berkeley, George (1685–1753)

George Berkeley was one of the great thinkers of the post-Descartes period of European modern philosophy. An important critic of the philosophers René Descartes and John Locke, he developed and defended a form of philosophical *idealism,* the view that only minds and their ideas are real. He had significant influence on David Hume and Immanuel Kant, and his work is still taught regularly in contemporary modern philosophy courses.

George Berkeley was born near Kilkenny, Ireland. At age 15, after some years studying at Kilkenny College, he entered Trinity College in Dublin. He became a fellow of Trinity College in 1707 and soon after was ordained in the Anglican Church. At Trinity College, Berkeley's philosophical idealism began to emerge in response to his study of figures like Descartes, Locke, Nicolas Malebranche, Isaac Newton, and Thomas Hobbes.

Berkeley's most important works were published while he was in his 20s: *An Essay Towards a New Theory of Vision* (1709); *Treatise Concerning the Principles of Human Knowledge* (1710); and *Three Dialogues Between Hylas and Philonous* (1713).

In his 30s he spent a 4-year tour in Europe as tutor to a young man. His resumption of his position at Trinity led to his appointment as Dean of Derry in 1724. At about this time he began to prepare to launch a college in Bermuda. In 1728, with his new bride, Anne Forster, he left for America (Newport, Rhode Island) to wait for British Parliament funds for this project. The money never materialized, and he was forced to return to Britain in 1731. In 1734 he was appointed Bishop of Cloyne, and thus he returned to Ireland. Here he wrote his last philosophical work, *Siris* (1744), which became a best-seller, on the medicinal and religious power of tar-water (a liquid prepared by letting pine tar stand in water). Berkeley died in 1753, shortly after moving to Oxford to supervise the education of one of his three surviving sons, George.

Berkeley's two great works of philosophy (the *Treatise* and *Dialogues*) are primarily a defense of idealism. A key part of this defense rests on a systematic attack on "materialism," namely, the view that material things exist. By material things Berkeley meant things that can exist independently *of minds*. Such independent existence had been held prominently by Descartes and Locke (who were dualists). Berkeley, argued that no mind-independent physical objects are possible. On the contrary, for Berkeley, to exist is to be perceived or to perceive—*esse est percipi (aut percipere)*.

Consistent with his idealism, Berkeley did not view time as existing independently of its being perceived by minds. Along with Gottfried Wilhelm von Leibniz, he denied Newton's idea of a fixed frame of reference for the motion of objects—namely, absolute time (and absolute space). For Berkeley, because to be is to be perceived, and absolute time itself cannot be perceived, absolute time is not real. Time for Berkeley is merely "the succession of ideas." To remove the train of ideas that minds experience is to remove any notion of time.

Carlo Filice

See also Descartes, René; Hume, David; Idealism; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Newton, Isaac; Ontology; Perception

Further Readings

Jessop, T. E. (1973). *A bibliography of George Berkeley.* The Hague, Netherlands: M. Nijhoff.

Turbayne, C. (Ed.). (1982). *Berkeley: Critical and interpretive essays.* Minneapolis: University of Minnesota Press.
Winkler, K. P. (1989). *Berkeley: An interpretation.* Oxford, UK: Clarendon Press.

Bible and Time

A comparison of the Hebrew Bible (in Christianity, the Old Testament) and the Christian Bible, or New Testament, reveals differences in how the concept of time came to be understood in the Jewish and Christian traditions, respectively. The Christian viewpoint regarding time is linear; that is, the universe had a beginning and will have an end (in Greek, the *eschaton*), which will occur when Jesus Christ returns to Earth in the Second Coming to judge both the living and the dead. His arrival will be the fulfilling of a promise he made to his apostles and will be consummation of the world and time. The first mention of this concept was by Saint Augustine of Hippo in his seminal *City of God,* written during the 5th century. In 410 CE, the Visigoths sacked Rome, with many Roman citizens blaming Christianity. It was in this atmosphere that Augustine set out to provide a consolation of Christianity, writing that it was the City of God that would ultimately triumph—at the end of time. Such a view was vastly different from the view of the Hebrews.

Time in the Hebrew Bible

The Hebrew concept of time, as it had developed at that juncture in history, was concerned with the quality of time as it related to seasonal events like the rain in summer or an early autumn. In addition, the Hebrew calendar was based on the lunar cycle. The Hebrew day was one rotation of the earth on its axis; the month was one lunar cycle, or revolution of the moon around the earth; and the year was 12 lunar months, approximately the time required for the earth to travel around the sun. The Hebrew Bible divides the Jewish year according to each season of an agrarian society, such as when the women Naomi and Ruth traveled to Bethlehem to attend the barley harvest. Likewise, the concept of time centered on the hallowed events of God intervening in the Israelites' history. Time was related to an event that occurred in the natural world and how it was possibly linked to divine acts.

For the ancient Hebrews, time was concrete and real, not an abstraction. There is no evidence that they engaged in the sort of abstract philosophical speculation that is the hallmark of the ancient Greeks. Rather, the Hebrews would likely say, "The passage of time is a sequence of God's saving acts." That is, real events occurred, and humanity measured and marked life by its relationships to those events. Ancient Hebrew culture cared little for discussions regarding whether time was real or whether it was a human invention. In fact, nowhere in the Hebrew Bible is there a general word for "time" (at least, not in an abstract sense); it also has no special terms for past, present, or future. The most common or everyday expressions of time concerned the point at which some event occurred or will occur. The matter of precision in defining such moments, however, can seem vague or elusive. For example, First Kings 11:4 refers to the time "when Solomon was old," but at no point does the author refer to a specific period when Solomon began becoming old, or at what point he became old, as though he were not old the previous day and then suddenly he was old.

Ancient Hebrew culture seems to have lacked a concept of eternity, an idea developed in the West by the Greeks. For the Hebrews, a conception of whether someone could be alive without the passage of time would have been meaningless. For them, the existence of life was itself proof that time existed. There was no time where there were no life events and no life events where there was no time.

Modern society views time as chronological (60 seconds make up 1 minute, 60 minutes make up 1 hour, 24 hours make up 1 day, etc.), whereas the ancient Hebrews' sense of time was qualitative. Throughout the Old Testament, specific happenings and individuals were distinguished and then arranged in order, not by location in terms of chronological sequence but, rather, according to the impact of their occurrence. The Hebrews were awed by the importance or meaning of things and people, not by measured time. Scholars of Judaic culture have observed that for the Hebrews, events separated in time could be perceived as contemporaneous. For instance, a worshiper might experience a past act of salvation, such as the Exodus from Egypt, and experience it as if it were happening right then, even if the Exodus had occurred in the past.

For the Hebrews, the conception of time centered on one's exertions and accomplishments; likewise, they were interested in how individuals carried on in their daily lives—how they wrote, played, traveled, slept, dreamed, performed ceremonies, went to war, and prayed. God's actions were also present in time. The passage of time was a story concerning God's behavior; thus time did not exist outside of Yahweh. To spend time profitably probably meant living one's life so that others could mark their lives and tell their stories in reference to one's actions. In the Hebrew worldview, the important question was not "What should I do that makes *efficient* use of time?" but "How can I best make use of my life in this present moment?"

In the Torah, it is written that the righteous dead will be resurrected in the "messianic age" with the coming of the messiah. At that moment, each individual will be given immortality in a sin-free, perfect place. On the other hand, the wicked dead will not be resurrected at all; rather, they face complete oblivion. By contrast, in Christianity the wicked dead will face an eternity of torment in hell—not oblivion. This is not the only Judaic belief about the afterlife; some contemporary Jews believe in some version of hell. The Torah is not specific about the afterlife, nor are there any specifics about the timeline.

Time in Christianity

The New Testament states that the universe was created for humans—in science this is called the anthropic principle (meaning that everything is "just right" for life to exist). According to the Christian doctrine of *creatio ex nihilo,* the universe was created at a specific point in time. This idea has received support from secular philosophers arguing against the idea that the universe is eternal, as well as from scientific evidence indicating the reality of the "big bang." If the universe began to exist at a specific time during the past, is the Bible correct in stating that time had a beginning? In essence, if time existed apart from everything else, then the biblical use of time lacks real meaning. On the other hand, if the Bible is correct that the universe began with an act of creation, then time does not exist away from events occurring throughout the universe; thus the beginning also entailed a beginning of time.

Saint Augustine of Hippo felt that because time exists in our universe, then God must exist outside of time. God lives in an eternal present, with no past or future—hence time has no meaning to God. One need not be a believing Christian (or a believer in any deity) to accept this concept regarding eternity. Many atheists and agnostics feel that mathematics exists outside of time and is, in some sense, eternal. The Bible states unequivocally that God is eternal, meaning that he did not "begin" and will never experience an "end." How this is understood depends on which definition of eternity a Christian uses, as there are several. One might state that God exists in eternity, which is nothing less than a belief that all aspects of time (past, present, and future) have no meaning. God has existed in eternity at all times and should be expected to "live" there forever. Many individuals think that human beings can never grasp the ramifications of eternity, because it is either an infinity of what we already know (eternity is nothing more than the passage of time) or is something completely different from what we can imagine.

Related to the idea of eternal existence regarding God as Creator is the assumption that Yahweh is dependent upon no one or no thing; it was he who created everything else. If this premise is true, then the Bible's conception of his timelessness is essentially correct—God is independent of the universe, has always existed and always will, and would continue even if God obliterated all space and time.

Throughout the New Testament, the view concerning time in heaven is that it is beyond anything we can comprehend. For example, in the Book of Revelation, John saw scenes taking place on Earth in human history and scenes in heaven occurring at the same time. Time in heaven moves in the forward direction as it does on Earth. For example, Revelation 8:1 describes a period of silence in heaven lasting "about half an hour," although the meaning of time in heaven is different from what we know. For instance, one occurrence in eternity is found in the Gospels: One episode concerns Jesus standing on Mount Mizar, where he was transfigured before his disciples, Peter, James, and John. Appearing with him (c. 30 CE) were Moses (from c. 1400 BCE) and Elijah, who, according to tradition, was carried into heaven without seeing death (c. 850 BCE). All three appeared to be alive, as if they had known each other for many years, unmindful of the decades that separated them, at least in the manner that we judge time.

New Testament writers stated that time was calculated using two methods: *chronos* and *kairos* (times and seasons). These Greek words for times and seasons added immeasurably to scholars' comprehension concerning how time works throughout our universe. Chronos refers to the quantification of time and its length, how each second follows one after the other, and/or seeing time as being bounded. To grasp the significance of the word, one should read where it was used in the New Testament, including Matthew 2:7; Luke 4:5, 8:27, 20:9; Acts 20:18; Romans 16:25; and Mark 2:19. Kairos, on the other hand, refers to the value of time, how an era is known by its unique events, the crucial worth of happening, and a favorable moment. In the Bible, humanity is depicted as having a distinct beginning, a history that accurately recorded the Creator, and the drawing closer of a day of judgment when all people, regardless of wealth, prestige, or accomplishments, will be evaluated justly by God.

Time in the Work of Karl Barth

Karl Barth, the great German theologian killed by the Nazis in 1944, looked at time differently. In his opinion, the end of time (the coming of God's Kingdom) is not a future goal at the end of linear time or a process that takes place within time; rather, it is the eternal, existential test for each individual "in time." In other words, it is God's intervention in the world at any given moment. Barth did not think that having a horizontal understanding of time was efficacious, and thus he formulated an existential conception. In its more radical versions, this view conceives of time as an aspect of human self-consciousness: One's mode of existence is moored in the present, and this temporality of the present time is elemental to the human existence in the world. Hence, time is not an objective linear entity with a given past, present, and future. The past is definitively over and the future has yet to be, so only the present has being in any real sense. Theologically speaking, this means that God's word has neither a past nor future and is fully independent of humanity, though it greatly influences the present, in an existential and qualitative fashion.

With Christ's resurrection, humanity saw that God inhabited a dominion known only to God. Human understanding of the past, our place within it, and the influence of human corporeality is confirmed using this concept of time. Barth distinguished two temporal dimensions—human time and divine time. Human time is intertwined tightly with a grasp of what the past, present, and future are and is a fixture of God's creation. Humanity has a historico-corporeal reality only in the sense of how we view time; that is, the individual that gives up his or her time also gives of himself or herself. Any statement that may be said regarding one's life or death is subject to humanity's irrevocable temporal sequence. The human person is one with his or her life history.

In the New Testament, God took unto himself time, human time, and created time—all through Jesus. It was indeed real time with the triadic division into no-more, here-and-now, and not-yet. But in the risen Christ this division does not signify the transitoriness that belongs to human life inasmuch as in his Lordship over time he is present in terms of what he was (the past), of what was previously hoped for (the prophetic past perfect), and as he who will come again (the future). It could be said, then, that God has "time." This is not to say, however, that God's time is indistinguishable from ours; rather, God inhabits an eternal present that encompasses what is, what was, and what is to come.

Cary Stacy Smith and Li-Ching Hung

See also Adam, Creation of; Augustine of Hippo, Saint; Barth, Karl; Christianity; Ecclesiastes, Book of; Evil and Time; God and Time; God as Creator; Judaism; Last Judgment; Luther, Martin; Moses; Noah; Parousia; Revelation, Book of; Satan and Time; Time, Sacred

Further Readings

Barth, K. (2000). *Evangelical theology: An introduction.* Grand Rapids, MI: Eerdmans.

Boman, T. (2002). *Hebrew thought compared with Greek*. New York: Norton.

Craig, W. L. (2001). *Time and eternity: Exploring God's relationship to time.* Wheaton, IL: Crossway Books.
Ganssle, G. E. (2001). *God & time.* Downers Grove, IL: InterVarsity Press.
Hasker, W. (1998). *God, time, and knowledge.* Ithaca, NY: Cornell University Press.
Holy Bible. (1984). New international version. I Kings 11:4; Matthew 2:7; Mark 2:19; Luke 4:5, 8:27, 20:9; Romans 16:25; Acts 20:18; Revelation 8:1. Colorado Springs, CO: International Bible Society.
Littlejohn, R. (2000, Winter). Time and God. *Biblical Illustrator,* pp. 53–56.
McGrath, A. E. (2001). *Christian theology: An introduction* (3rd ed.). Boston: Blackwell.
Whitrow, G. J. (1961). *The natural philosophy of time.* London: Thomas Nelson & Sons.

Big Bang Theory

Today, it has become widely accepted that our universe originated with the so-called big bang. This event marks the beginning of time and the further evolution of our universe. In the standard model of cosmology, this origin arises in a spacetime singularity. The question what was "before" the big bang cannot be answered, because no physical description is available. More accurately, with reference to the singularity the concepts of time and space lose their meaning, as the scales involved (called Planck time and Planck length) are so incredibly small that spacetime can no longer be considered a continuum. Quantum gravitational effects come into play, and no consistent quantum gravitational theory has yet been developed. Physical description and understanding are therefore possible only after this period, which is called the Planck era. It is generally held that the big bang occurred about 15 billion years ago.

The idea of the big bang goes back to the Belgian mathematician Georges Édouard Lemaître (1894–1966). Many of its predictions are supported by astrophysical observations. The theory predicts that one fourth of all baryonic material should be made out of helium. Here, baryonic matter means mass consisting of "normal" nonexotic particles, like hydrogen, helium, and other nuclei, together with electrons. Observations of metal-poor objects in the universe indicate that this is indeed the case: Their chemical composition yields a helium amount of about 24%. By using this measured abundance of helium, it is possible to derive the different kinds of *neutrinos* (electrically neutral particles). It was theorized that three different kinds should exist, and this has since been confirmed by accelerator experiments.

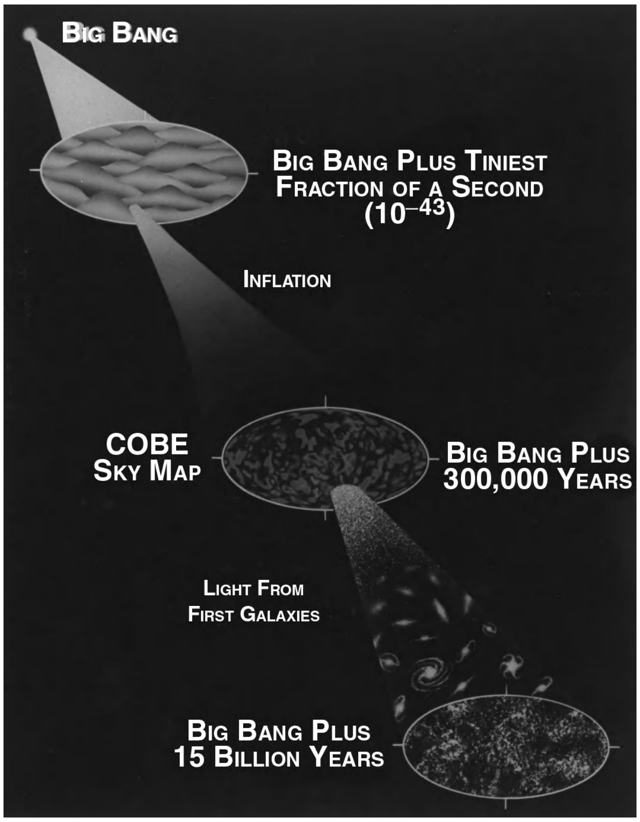
Another important hint was the detection of the cosmic microwave background (CMB) by Arno Penzias and Robert Wilson in the 1960s. The astrophysicist George Gamow predicted this thermal blackbody radiation in 1946. Actual measurements by the satellites COBE and WMAP confirm this exact blackbody spectrum. Due to the expansion of the universe the temperature of the CMB has decreased from 3000 Kelvin (i.e., 2726.85 degrees celsius) to a value of about 2.73 Kelvin (–270.42 degrees celsius). Yet one more important point refers to the structures in the universe we observe today. They originate from small fluctuations in the density. These fluctuations should be imprinted on the CMB as fluctuations in temperature, which have been detected by COBE and WMAP. Altogether, the theory of the big bang is very promising.

Briefly after its birth, our universe underwent several different epochs. It is assumed that in the beginning, all natural forces were united into one elementary force.

The expansion of the universe led to a decrease in temperature and therefore shortly to the decoupling of the forces into the four basic forces: the gravitational force, the strong force, the weak force, and the electromagnetic force. Following the Planck era, the first one that split from the rest was gravitation. The remaining forces comprise the so-called GUT force. (GUT stands for grand unified theory.) The continued decrease in temperature then led to the separation of the others, starting with the strong force (which acts between the protons and neutrons in atomic nuclei), followed by the electroweak force, which divides into the electromagnetic force (describing the behavior of magnetic and electric fields) and the weak force (which acts between electrons and light particles). This happens after a time span of about only 10^{-12}) seconds!

After the decoupling, the building blocks of the atoms, quarks, and electrons were mixed up together with the photons and other exotic particles within a hot soup. The ongoing expansion led to the gradual cooling of this soup and eventually to the condensation of the quarks into hadrons (protons and neutrons) with a slight excess over their antiparticles. The permanent decrease in temperature finally led to the building of atomic nuclei at T = 3,000 K. The primordial nucleosynthesis, as this event is called, describes the development of helium, deuterium, lithium, and beryllium. The other, heavier elements we measure today come from supernova explosions, which set free these elements from the interior of the stars, where they have been produced.

At a temperature of about T = 3,000 K, the first atoms formed. The universe cooled down enough so that was transparent for the photons, which means that interaction with other atoms was marginal. They decoupled and thereby resulted in the



Microwave Sky Map (©). This microwave sky map was made from 1 year of data taken by COBE (Cosmic Background Explorer) differential microwave radiometer (DMR) used in artist's concept depicting the crucial periods in the development of the universe after the big bang.

Source: Time & Life Pictures/Getty Images.

cosmic microwave radiation discussed earlier in this entry.

To summarize, the predictions of the big bang theory coincide well with subsequent observations. It has become an important foundation of the description of the universe.

Veronika Junk

See also Big Crunch Theory; Black Holes; Cosmogony; Cosmology, Cyclic; Gamow, George; Hawking, Stephen; Lemaître, Georges Edouard; Singularities; Universe, Age of; Universe, Evolving; Universe, Origin of; White Holes; Wormholes

Further Readings

Guth, A. H. (1997). *The inflationary universe: The quest for a new theory of cosmic origins.* Cambridge, MA: Perseus.

Lidsey, J. E. (2000). *The bigger bang.* Cambridge, UK: Cambridge University Press.

Singh, S. (2004). *Big bang: The origin of the universe.* New York: Harper Perennial.

Smoot, G., & Davidson, K. (2007). *Wrinkles in time: Witness to the birth of the universe.* New York: Harper Perennial.

Big Crunch Theory

The universe began with a turbulently charged explosion from a minuscule core, thrusting rapidly toward its outside limits; thus, the life cycle of the cosmos commenced. This cycle continues today. The three possibilities of this expanding universe are that the universe is "open," "flat," or "closed." An open universe means that the universe will continue to expand at an ever-increasing rate forever. If the universe is flat, then the expansion rate will slow down, but the universe will never collapse. Instead, all movement will end in an eternal frozen waste. If the universe is closed, then it will expand only until it reaches a certain point, at which the process will be reversed and the universe will shrink until it collapses.

In the universe, dark energy overwhelms everyday gravity and outweighs the visible universe by a factor of 10 to 1. If the big bang model of the universe is right, the universe is expanding, and if there is enough mass in the universe, at some point the expansion will halt and gravitational forces will cause the universe to collapse on itself. However, if there is insufficient matter, the universe will expand forever and will eventually cool off completely to die a slow death. This would be the end point of a closed universe. If, and only if, there is sufficient mass to halt the expansion, or Hubble flow, movement will be reversed. Instead of galaxies moving rapidly outward, they would move back toward the center. If the existing diffusion velocity of the universe, in units of kilometers per second per mega parsec, slows in relation to the apparent velocity of recession of a galaxy to its distance from the Milky Way, this would mean the universe is aging. If this end result occurs, the big crunch would create the conditions for a new big bang.

It had been postulated that the universe began about 15 billion years ago with a big bang, starting from an infinitesimally small point of "not anything at all" in the empty space of "nothing" in which matter and time did not exist. A very small point of matter appeared and then exploded and began expanding outward at an ever-increasing tempo. This was only the beginning, and it is still expanding today. As the universe expands, more and more matter is shaped into more complex forms. If the universe is a flat universe, then everything will stop and die in cold empty darkness. If it is a closed universe, then it will collapse in on itself.

The big crunch theory, as outlined by Alexander Friedmann (1888–1925), states that if the density of matter in the universe is sufficiently large, gravitational forces between the matter will eventually cause the universe to stop expanding; then it will start falling back in. It will eventually end in a second cataclysmic event such as the big bang. The big crunch theory is completely dependent upon whether or not matter is dense enough in the universe. If astronomers correctly calculated the quantity of matter in all visible stars and galaxies, this would be too little to stop expansion, let alone start contraction.

According to the theory, if there is enough matter in the universe, then the gravitational forces of all this matter will stop expanding and begin to collapse. Ultimately, this will lead to a new big bang after enough energy is trapped in an infinitesimally small point. This theory requires that enough dense matter exists in the universe. Unless a very large amount of dark matter is discovered, the big crunch will not happen.

It appears that the light from stars is in fact bending around what may be blackbodies. These might be the dark matter necessary for contraction. There may also be billions of loose stars between galaxies. There are billions of galaxies in galaxy clusters and billions of these clusters in strings of clusters, all in a tiny envelope in empty space. Each galaxy has not only visible matter but dark matter as well. The question is, in what quantity? Dark matter may also comprise most of the universe, but all we can detect is the light matter.

When the expansion of the universe ceases, many strange things will happen. Because of gravity, galaxies will begin crashing into one another. The red shifts of expansion, first noted by astronomer Edwin Hubble, will be replaced by blue shifts of contraction. The spaces between photons will be condensed. Wavelengths will also be shortened. The result will be an overall increase in temperatures of radiation fields.

Temperatures will average at least 300 Kelvin (K). Galaxies will increasingly crowd the night sky until there is no difference between night and day. Temperatures will continue to rise until the average temperatures will reach 1010 K, just seconds before the big crunch. All the matter in the universe will be concentrated into a point of singularity so tiny that a new big bang will soon follow.

The countdown is on for this phenomenon. If the big crunch theory is correct, the universe will come to a standstill in about 750 quadrillion (7.5×10^{17}) years. About the same amount of time will pass, maybe a little longer, before the final collapse.

Wild as it may seem, it is no more outrageous a theory than the other two major competing theories of the end of the universe. With all the combined matter of the universe, the expansion would tend to slow down considerably. If the drag on this expansion is sufficiently powerful, expansion will stop and all motion will cease. If there is enough mass, then the expansion will reverse itself and will collapse. Only if mass is insufficient will the cosmos continue getting bigger, exactly for an eternity, if not longer.

Michael Joseph Francisconi

See also Big Bang Theory; Cosmology, Cyclic; Singularities; Universe, Closed or Open; Universe, Contracting or Expanding; Universe, End of

Further Readings

Castelvecchi, D. (2006). A view of the universe before the big bang. *New Scientist, 190,* 15.

Corwin, M., & Wachowiak, D. (1985). Discovering the expanding universe. *Astronomy, 13,* 18–22.

Craps, B. (2006). *Big bang models in string theory.* Philadelphia: Institute of Physics Publishing.

Gallmeier, J., Grilley, D., & Oston, D. W. (1996). How old is the universe? *Sky and Telescope, 91,* 92–95.

Goodstein, D. (1994, September 19). *The big crunch.* Paper presented at the 48th NCAR (National Center for Atmospheric Research) Symposium, Portland, OR. Retrieved September 1, 2008, from http://www.its.caltech.edu/~dg/crunch_art.html

Ikin, K., Sietzen, F., & Smith, P. (2003). Crunch time for runaway universe. *Ad Astra, 15*(1), 10. Retrieved June 24, 2008, from http://www.nss.org/adastra/volume15/v15n1/contents/miscv15n1.htm.htm

Maddox, J. (1995) Virtue in now-antiquated textbooks: Tolman's relativity, thermodynamics and cosmology. *Nature, 375*(653), 445.

Martinec, E. J., Robbins, D., & Savdeep, S. (2006). Toward the end of time. *Journal of High Energy Physics, 8*, 25.

Tolman, R. C. (1987). *Relativity, thermodynamics and cosmology.* New York: Dover.

Trefil, J., & Kruesi, L. (2006). Where is the universe heading? *Astronomy, 34*(7), 36–43.

Biodiversity

See Evolution, Organic

Biotechnology

See Cybertaxonomy

Birth Order

Birth order, also referred to as position in the family, is the timing of an individual's birth within the family structure. The effect of birth order on personality development has been the subject of increasing social science research from the late 20th century to the present. While factors such as gender, age span between siblings, cultural practice, parenting styles, and genetic makeup affect personality traits, statistical studies show that birth order also may play an influential role in the shaping of behavioral patterns lasting into adulthood.

One of the first to examine the dynamics of family structure was Austrian psychologist Alfred Adler (1870–1937), founder of the school of individual psychology. Adler believed that the relationship with siblings often foreshadowed later individual outcomes. His general hypothesis purported that oldest borns suffer from a degree of neuroticism stemming from the arrival of the second child, which diverts attention from the first. Later borns, he believed, are overindulged, and the middle borns are most likely to develop successfully. However, he produced no long-term scientific research to support this theory.

Common anecdotal wisdom has often emphasized stereotypical negative traits based on sibling order, describing the oldest as domineering, the middle as neglected, the youngest as spoiled, and only children as selfish. However, research based on long-range data contradicts these widely held but unsupported beliefs and demonstrates a complex cause-and-effect association. Comprehensive research has sought to discover a correlation between birth order and a wide array of social factors, including personality type, career choice, success in marriage, and receptiveness to new ideas.

Of particular interest to mid-20th-century investigators was the discovery of factors leading individuals to succeed in certain career fields, especially those requiring decision making under pressure. Such high-profile positions examined included U.S. presidents and astronauts participating in the early stages of the U.S. space program. Data reveal that 52% of American presidents have been first- or older borns and 21 of NASA's 23 first astronauts who flew into space were either the oldest or only children; all 7 of the original Mercury astronauts were also firstborns. Other studies show that prominent television newscasters and talk show hosts are often firstborns or only children. These data have led to conclusions linking older borns and only children with a high potential for achievement and leadership as well as possessing a desire for approval. Higher-than-average scores on verbal performance by only children and firstborns have also been attributed to a greater amount of time spent in the company of adults.

Research led by psychologist Frank Toman studied the impact of birth order on marriage, friendship, and gender roles, with emphasis on the variables of the sex of the siblings and birth spacing. Toman and his colleagues surveyed mid-20th-century European families to determine the success of marriages based on birth order of partners and the sex of their siblings. Their findings concluded that marriages were most likely to succeed between the older brother of a sister and the younger sister of a brother (or the reverse). These he called complementary sibling roles, which prepared the partners for a similar role in the marriage relationship. Persons who married a counterpart—such as the oldest in the family with same-sex siblings—were more likely to divorce, because the partners compete to play the same role rather than complement one another. Toman's theory is widely recognized in marriage and family counseling and has been used as one of a number of tools to measure compatibility.

Researcher Frank Sulloway's studies, based on contemporary and historical data, find a correlation between birth order and "openness to experience," even when factoring in other influences such as sex, social class, family size, race, and age. Later borns, he describes, are historically more likely to support causes that challenge the status quo, from the Protestant Reformation to the American abolitionist movement. He cites examples such as Mahatma Gandhi, Martin Luther King Jr., Fidel Castro, Ho Chi Minh, Susan B. Anthony, and Malcolm X as such later borns. On the other had, firstborns, he contends, are often more likely to defend traditional order.

If older borns and only children are apt to be high achievers, does it hold that those lower in the birth order are less successful? Sociologist Howard M. Bahr found this was not the case in his study of New York City adult men in rehabilitation centers. His study was comprised of adult males who were not taking responsibility for themselves or others and might be described as social "failures." He found that birth order did not appear to play a statistical role, except in the case of only children, who were overrepresented. Bahr speculated that high parental expectations, which often result in the success of children, may also account, in some cases, for a withdrawal from the unreasonable pressures often placed on an only child.

Birthrate Cycles and Family Structure

The timing of an individual's birth may shape personality, not only within the family structure but also in the broader historical context. Global social and economic conditions have a significant effect on birthrates and, therefore, family size. From 1800 to 1900, family size in the United States dropped from an average of 7 children to 3.5, reflecting the move from an agrarian to an industrialized society. During the worldwide Depression of the 1930s, the average American family produced 2.5 children, with a low of 2.3 in 1933, resulting in what some sociologists have described as the adult "silent generation" of the 1950s that largely supported traditional values and held conservative political and economic views.

The post–World War II surge in the U.S. birthrate peaked in 1957 with an average of 3.7 children per family. Improved contraception methods, introduced widely in the 1960s, coupled with social and environmental concerns, encouraged a smaller family size; in 1972 average family had 2 children. Current UN statistics show that Europe, Canada, Australia, and China show declining birthrates (less than replacement of 2 children per family). The United States and large parts of South America show a stable birthrate averaging 2 children per family, and the most rapidly growing population is occurring in countries of sub-Saharan Africa.

These birthrate cycles impact the family structure and therefore birth order patterns, with implications for society as a whole. These trends produce, in industrialized nations, smaller families with more only children and fewer middle children, possibly creating what some experts call a society of leaders and followers with fewer middle children as mediators.

Concluding Remarks

Research continues in the study of birth order and its effect on personality development and long-lasting behavioral patterns. Theorists in general have found a consistently high correlation between birth order and certain personality traits, together with gender, and other time-related factors such as spacing between siblings, and historical circumstance. Results generally describe firstborns as responsible, goal oriented, and supporters of the status quo; middle borns as flexible, competitive, and diplomatic; later borns as outgoing, creative, and tending to question authority; and only children as often exhibiting magnified traits of both the older and later borns. It would appear that the timing of an individual's birth is one of several factors to consider in personality analysis, and birth order may have a significant effect on the way in which individuals see themselves and how they respond to those around them. In turn, family size and the resulting characteristics attributed to birth order may have an impact on society as a whole.

Linda Mohr Iwamoto

See also Birthrates, Human; Fertility Cycle; Longevity

Further Readings

Leman, K. (1984). *The new birth order book: Why you are the way you are.* Old Tappan, NJ: Revell.
Sulloway, F. (1996). *Born to rebel: Birth order, family dynamics, and creative lives.* New York: Pantheon.
Toman, W. (1976). *Family constellation: Its effects on personality and social behavior.* New York: Springer.

Birthrates, Human

This entry discusses the human birthrate in the context of the historical past, contemporary, and future trends of human population. Human birthrate is at the heart of the challenges surrounding the population explosion worldwide and the divide that exists between industrial and developing nations. Birthrate is also a vital subject in light of the growing concern over environmental issues, security, and development. Meaningful discussion of the human birthrate naturally requires a consideration of time factors because historical, contemporary, and future trends of the birthrate are interpreted in terms of periods of human fertility. Furthermore, spacing, delay, and postponement of childbirth, as well as overall rates of birth, are of course measured through time.

Notions and Measures of Birthrate

Birthrate, the rate of fertility of the human population, can be determined in various ways. One way of understanding birthrate is by considering childbirths per 1,000 people per year. This is a crude estimate of birthrate. As of 2007, accordingly, the average birthrate worldwide was 20.3 per year per 1,000 total population, and thus, for the total world population of about 6.6 billion, the average birthrate was 134 million babies per year.

Another method of determining birthrate is referred to as total fertility rate, which is the average number of children a woman gives birth to during her entire life. This is a better indicator compared with the crude birthrate because it is not affected by the age distribution of the population. A total fertility rate is a measure of the fertility of an imaginary woman who passes the age-specific fertility rates of women in the childbearing-age range. Thus total fertility rate is neither the number of children counted nor the fertility of an actual group of women. It is rather the average number of children born to a woman on condition that she is subjected to all age-specific fertility rates for ages of 15 to 49 of a given population in a given year. A third method of measuring birthrate is called general fertility rate, and this method measures the number of births per 1,000 women with the age range of 15 to 49. Standard birthrate, on the other hand, compares the age–sex structure to a hypothetical standard population.

Historical Development and Trends

Birthrates and death rates were closely even and high until the 19th century. Thus population growth was slow. But with the advancement of medicine and of living standards generally, death rates started to decline, leading to a growth in population size. In addition, whenever the fertility level rises above the replacement level, it contributes to the growth of population size.

Leon Bouvier and Jane Bertrand note that the 20th century, particularly its first half, experienced an increase in birthrates. The growth rate continued in the 1960s with an average birthrate of six children in the developing nations of Africa, Asia, and Latin America. UN reports indicate that there were some declines in fertility up to the end the century. Accordingly, the birthrate fell to 3.3 children among the developing countries during the years 1990 to 1995. Nonetheless there are wide disparities in birthrates even among these countries. In this regard, the rate of fertility for sub-Saharan Africa is 5.9, whereas it is 1.9 in East Asia. The historical development and current trend both show a state of an overall decline of birthrate worldwide, even though there is a wide gap between the developed world and the developing nations.

A low level of fertility is marked at 2.5 births per woman or below. John Bongaarts and Rodolfo Bulatao remark that this level applies to most of the demographically advanced developing and industrial countries. Fifty percent of the world population lives in these countries, whereas 15% of the world population lives in countries where fertility is below 1.8 births per woman. These countries were able to achieve low fertility by getting away from higher-order births. The higher-order births are the third births, fourth births, and more. The trend appears to be a lowering in numbers of births as family styles change from larger to smaller ones. Thus, the high fertility of the developing world will continue to decline until it reaches 2 children per woman. It is a rare occurrence for a fertility rate to rise once it reaches the rate of 2 children per woman. Accordingly, based on the observed experiences of the past decades, low-fertility countries tend not to return to a fertility rate well above the 2 children per woman.

Bongaarts believes that the future trends for rates of birth can be further affected by the factors of technology and science that have relevance to childbirth. Improved methods of contraception, technologies in the areas of hormone therapy and sexual enhancement medications, techniques of sex selection of offspring, selective abortions, and genetic selection of the characteristics of the babies to be born are possible factors to influence the future trends of birthrates.

Factors of Birthrates

Bongaarts and Bulatao explain that birthrate is a function of many factors. Socioeconomic changes that compete with motherhood—such as delayed marriages, failing marriages, separation and divorce, postponement of births to later ages, increase in the size of the aging population, and changes in reproductive behaviors—are among the factors that contribute to low numbers of births. Public policies are also factors that affect birthrates. The trend toward fewer births among families in some developed nations can be reversed to a replacement level by government policies providing educational and career development support to women of childbearing age. Other factors that affect birthrates include abortion, age–sex structure, social and religious beliefs, literacy levels of females, overall economic prosperity, poverty level, infant mortality rate, and urbanization.

Socioeconomic conditions help explain fertility rates. Harsh economic conditions can delay marriage and childbirth. Similarly, high rates of unemployment and inflation can contribute to the low rate of fertility due to delayed marriages and childbirth. The conditions in which people think that they cannot afford the expenses of childrearing contribute to the tendency to postpone childbirth. The notion of the human child as economic strain adds to the possibility of low birthrates. The cost of education and other needs associated with childrearing will influence parents' decisions as to the number of children they will have. In the industrial countries, the desire for a low birthrate can be strengthened further by easy access to birth control and a low rate of child mortality.

The situation in some developing countries, however, appears to assume a different scenario. The high level of poverty and illiteracy, coupled with other social and religious factors, contribute to a high rate of birth. Due to the perceived possible economic incentive for having children both in the short term and in planning for one's old age, having more higher-order births is a natural way of coping with the reality of economic hardships. Under such circumstances, therefore, economic hardship contributes to an increased fertility rate, whereas among relatively more literate societies, economic hardship (such as unemployment and inflation) delays marriages as well as childbirth. Lower levels of education among women, lack of contraception, and the limited role of women outside the performance of household duties contribute to the high-order birthrates in the developing countries.

Events such as wars have a major impact on birthrates. According to Bongaarts and Bulatao, major conflicts like World Wars I and II have had a significant impact on fertility rates in the United States and other nations. The baby boom generation that followed the end of World War II illustrates the impact of war on fertility rates. Major socioeconomic and political changes also bring about changes in fertility rates. In this regard, the changes in Eastern Europe in the late 1980s affected birthrates in those societies, which are now considered to be low.

Institutional factors such as marriage play key roles in determining the state of birthrates in societies. The trend is a delay in marriage and an increasing rate of divorce. Postponement of marriage and failure of marriages in the forms of separation and divorce contribute to the low rate of birth in terms of both the tempo and quantity of childbirth. As part of the changes in the socioeconomic and political dynamics of societies, changes in gender roles have a bearing on birthrates. Over the last four decades, the changes in the roles of women have led to a tendency toward low order of birth. Due to an increased level of education and opportunities for woman, childbirth delays and in some cases childlessness have become societal phenomena. These developments are among the factors that contribute to the low rate of childbirth.

Replacement Level

Fertility at replacement level occurs when each generation of women exactly replaces its predecessor. This is a situation whereby each woman gives birth to just one daughter. Replacement level of birthrate is a fertility rate at which women give birth to not more children than are needed to replace the parents. Other factors being constant, replacement level of fertility maintains nil population growth. Replacement levels vary across nations. While the replacement level in developing countries equals 2.4 births per woman, it is 2.1 for the industrial world. UN reports reveal that the level remains above replacement in developing regions, while it is below in some industrial nations. During the second half of the 1990s, the average birthrates were reported to be 5.1 in Africa, 3.4 in South Asia, and 2.7 in Latin America. On the other hand, the figures are below replacement level in the developed world: 1.4 in Europe, 1.9 in North America, and 1.8 in East Asia.

Challenges and Prospects: The Case of Ethiopia

Population growth due to high rate of birth has negative consequences given the low level of economic progress to support it in the case of developing nations. This is the situation in sub-Saharan countries such as Ethiopia. Ethiopia is becoming the second most populous country in Africa, with the addition of two million people every year. At the same time, economic and social developments are declining with minimal industrial and agricultural output. The country is thus highly dependent on foreign aid. Over half of the population is economically unproductive, either too young or too old to work, and consequently supported by few working members of the society. The Ethiopian Economic Association reports indicate that the country's main economic sector is agriculture, which is becoming less productive due to overcrowding, overuse of resources, lack of modern practices, erosion, deforestation, and heavy reliance on rainfall. As the result of such crises, shortage of food and drought are becoming common phenomena in Ethiopia. Unchecked population growth in Ethiopia affects the environmental balance as well. Assefa Hailemariam argues that the densely populated areas are overcultivated apart from deforestation, which leads to erosion and land degradation.

Countries like Ethiopia need to check their population growth so that they may achieve sustainable development. The strategies that can help counter population explosion include educating young women, in general, and educating the entire population about harmful cultural practices such as early marriage and early childbearing. The education of girls can contribute to active involvement of women in the economy, late marriage, delayed birth, and active decision making with regard to reproductive issues such as spacing and delay of births. The use of contraceptive methods is a typical example: Educated women are more likely to use them than those who are uneducated. The investment in the education sector is an important factor in achieving the goal of curbing rapid population growth by maintaining low-order birthrates.

According to Sahlu Haile, traditional practices of marriage, family life, and childbirth in developing countries contribute significantly to a high rate of birth. In Ethiopia, the average age of marriage is 17, and a significant percentage of those married at this age become mothers within a few years, contributing to the high birthrate in the country, which is 5.9. Thus, delaying marriage would contribute to the delay in childbirth. To combat harmful practices, Haile recommends educating the public through formal as well as informal venues. The role of the mass media and public policies is also vital; family planning, including counseling and the provision of contraceptive methods, is crucial. Such strategies delay marriages and childbirth while also contributing to the improvement of maternal and child health. International assistance is also helpful to complement local efforts and governments' commitments in developing nations.

Concluding Remarks

The future of our planet is greatly affected by human birthrates, which have direct bearing on population size. A state of controlled birthrate growth will contribute to the stability and maintenance of a sustainable environment that can support people's fundamental needs. Conversely, unchecked birthrates will contribute to the complications of challenges in the areas of environmental crises, famine, drought, massive immigration, conflict, insecurity, and political instability worldwide. Uncontrolled level of replacement, which in the industrial world may continue to be below replacement level, will lead to scarcity of labor in the industry and even in the military forces. Likewise, uncontrolled rates of birth above the replacement level among developing nations will add to the worsening of the scarcity of resources and depletion of the environment, adding to human suffering worldwide.

Belete K. Mebratu

See also Fertility Cycle; Malthus, Thomas; Mortality

Further Readings

Bengtsson, T., & Saito, O. (Eds.). (2000). *Population and economy: From hunger to modern economic growth.* New York: Oxford University Press.

Bongaarts, J. (1997). The role of family planning programs in contemporary fertility transitions. In G. W. Jones, J. C. Caldwall, R. M. Douglas, & R. M. D'Souza (Eds.), *The continuing demographic transition.* Oxford, UK: Oxford University Press.

Bongaarts, J., & Bulatao, R. (2000). *Beyond six billion: Forecasting the world's population.* Washington, DC: National Academies Press.

Bouvier, L., & Bertrand, J. (1999). *World population: Challenges for the 21st century.* Santa Ana, CA: Seven Locks Press.

Brown, L., & Gardner, G. (1999). *Beyond Malthus: Nineteen dimensions of the population challenge.* Washington, DC: Worldwatch Institute.

Ethiopian Economic Association. (2002). *Second annual report on the Ethiopian economy: Vol. 2. 2000/2001.* Addis Ababa, Ethiopia: Author.

Lutz, W., Sanderson, W., & Scherbov, S. (Eds.). (2004). *The end of world population growth in the 21st century. New challenges for human capital formation and sustainable development.* London: Earthscam.

Meadows, D., Randers, J., & Meadows, D. (2004). *Limits to growth: The 30-year update.* White River Junction, VT: Chelsea Breen.

Black Holes

A black hole is a gravitationally dense astronomical object with such strength that no form of energy can escape its influence. A black hole creates a warp, or gravity well, on the space it occupies. From the point of approach, a black hole exhibits a visibly flat structure that contains the condensed matter pulled into the black hole: the *accretion disk*. The size of an accretion disk is dependent on how large the black hole is. Additionally, a black hole may exhibit plumes of gas, called *jets,* perpendicular to the accretion disk. Neither accretion disks nor gas jets are proof of a black hole, as other objects such as neutron stars and quasars have the same characteristics.

Typically, a black hole forms by the collapse of a massive object, such as a star. A star needs to be at least 20 solar masses, a neutron star, or a white dwarf to have enough influence to bend space. When a star nears the end of its fuel supply, it swells to a red giant. Once the star has burned its remaining gases, the shell of the star collapses in on itself and shrinks to a white dwarf. Given time, the pressure and mass may be so intense that the star will continue to degrade and collapse inward. The gravitational signature of the star becomes a singularity, and a black hole forms.

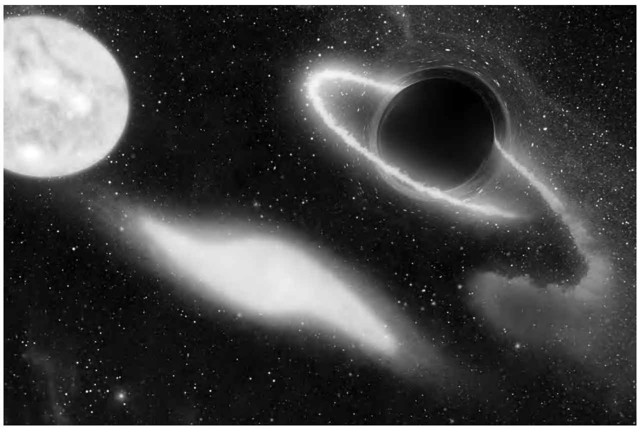
Cosmological Studies

Upon approach to the black hole, the effects of the gravitational well begin at the event horizon, or the boundary between normal space and the black hole itself. Here, the velocity needed to escape the influence of the black hole is equivalent to the speed of light. Studies of the event horizon are called *black hole thermodynamics*. In theory, time itself is affected at the event horizon; however, only theory can explain what happens once an object crosses. At the very center of the black hole lies the only physical part of a black hole, a singularity. The singularity is the point source of the gravitational anomaly; it is what remains of the former object that created the black hole.

The quantum physics leading up to a black hole are quite discernable, from Albert Einstein's theory of relativity to Stephen Hawking's theory of radiation emission. However, once the event horizon is breached, modern quantum physics no longer applies. As Einstein noted, the curvature of gravity around a collapsing star pulls other particles with it, and continues to do so even as acceleration reaches a constant state.

Types of Black Holes

There are four types of black holes, each derived from two components: charge and rotation. Electric charge influences the black hole near its singularity, while a massive spinning object, such as a pulsar, causes the rotation of a black hole. These types of black holes are listed in Table 1. In 1963, New Zealand mathematician Roy Kerr additionally suggested that these black holes may also be gateways to parallel universes. Kerr was the first mathematician to solve and apply Einstein's general relativity theory to a rotational star. Since then, additional theories suggest that the existence of an object opposite to a black hole must exist, as the matter pulled in must be pushed out. This is called a *white hole* and would then be connected to the black hole via a "wormhole." However, until many black holes are studied in closer detail, no concrete evidence exists to support the existence of white holes.



An artist's rendering of a super massive black hole at center of remote galaxy digesting the remnants of a star. The area around the black hole appears warped because the gravity of the black hole acts like a lens, twisting and distorting light.

Source: NASA Jet Propulsion Laboratory (NASA-JPL).

Table 1 Types of Black Holes

Type	*Rotation*	*Charge*
Schwarzchild	No	No
Reissner-Nordström	No	Yes
Kerr	Yes	No
Karr-Newmann	Yes	Yes

Several physicists have attempted to describe the many processes that lead up to the event horizon. Einstein's relativity theory states that as an observer approaches a black hole, the very warping of space itself will cause time to warp too and, in effect, slow down until it "freezes" at the event horizon. However, time at the vantage point of the observer's origin will remain constant, and if the observer never breaches the event horizon, the point of origin will have advanced into a much distant future.

Classic Paradox

If a probe were sent to investigate a black hole, clocks on board the probe would act as normal, even though the probe had begun to enter the region of the event horizon. If the probe were commanded to return, it would simply just turn around and eventually be away from the influence of the gravity well. After approximately 1 minute of clock time to the probe, the probe would be on its way again through the "normal" universe.

However, back at the International Space Station, the probe would appear to slow down and freeze as though no longer moving. The simple act of sending a reverse command would take very little time to transmit but would take much longer to execute as the probe experiences the warp. Although it never fully crossed the event horizon and managed to climb out of the black hole region, it will have taken thousands of years to do so. When the probe returns to "normal" space, it may be thousands of years later for Earth, but just mere moments for the probe. The two clocks would then be asynchronous.

Hawking determined that black holes emit radiation due to quantum effects and, as such, allow the black holes to lose mass. A loss of mass suggests that the black hole is capable of losing mass and therefore dissipating given time. Because time does not apply within the black hole, though, it is unknown how this effect would occur.

The First Findings

In 1971, Tom Bolton of the David Dunlap Observatory at the University of Toronto, Canada, noted a star in the constellation Cygnus whose binary companion was causing the main star (called HDE 226868) to exhibit anomalous behavior. Too massive to be a mere neutron star, this area, known as Cygnus X-1, became the first object named a black hole. Since then, many more stellar regions have been found exhibiting similar peculiarities. Even now, there is a controversy surrounding the definition of a black hole and what should and should not be included as aspects in defining a region as a black hole. Although Hawking originally denied that this particular region was a black hole, he has since conceded that there is now enough evidence to support the theory.

Recent Findings

In 1994, NASA scientists working with the Hubble Space Telescope suggested that a super massive black hole exists at the center of the elliptical galaxy M87. This was the first evidence that black holes may be at the center of all galaxies. On February 29, 2000, astronomers using the Chandra X-Ray Observatory (an orbiting X-ray telescope) discovered what appeared to be a massive object at the center of the Milky Way galaxy, which the Keck observatory confirmed shortly afterward. Scientists reduced the size of the accretion disk of the central black hole in 2004 to less than the distance between the earth and the sun using the Very Long Baseline Array of radio telescopes. Many universities and individual astronomers maintain several Internet sites devoted to lists of black holes, found by utilizing a search engine.

Timothy D. Collins

See also Big Bang Theory; Big Crunch Theory; Cosmogony; Cosmology, Inflationary; Einstein, Albert; Entropy; Hawking, Stephen; Light, Speed of; Pulsars and Quasars; Quantum Mechanics; Relativity, General Theory of; Relativity, Special Theory of; Singularities; Spacetime, Curvature of; Stars, Evolution of; Time Warps; Universe, Origin of; White Holes; Wormholes

Further Readings

Abramowicz, M. A., Bjornsson, G., & Pringle, J. E. (1998). *Theory of black hole accretion discs.* New York: Cambridge University Press.

Bruce, C. (1997). *The Einstein paradox and other science mysteries solved by Sherlock Holmes.* New York: Basic Books.

Hawking, S. W. (1974). Black hole explosions. *Nature 248*(1), 30–31.

Melia, F. (2003). *The black hole at the center of our galaxy.* Princeton, NJ: Princeton University Press.

Boethius, Anicius (c. 480–c. 524)

Anicius Manlius Boethius was the most important Latin philosopher in late Antiquity. The Neoplatonist and Christian is traditionally called "the last Roman and the first scholastic." This is because his works conserved essential ideas of the ancient Neoplatonic philosophy in a Roman encyclopedic manner and became fundamental for the Christian scholastic education in the Middle Ages in Western Europe. His works on Aristotelian logic and mathematics, partly translations of Greek tractates on philosophy and theology, were standard school books in the Middle Ages.

Boethius was born circa 480 CE and received an excellent education in Latin and Greek literature and philosophy. He became extremely successful in his public career very early on. He was consul in Rome in 510 CE, and his two sons were consuls in 522 CE. According to his own statement, this was the high point of his life. However, his successful and happy life was cut short by a radical change: Boethius became involved in political intrigues, was fired by King Theodoric, imprisoned at Pavia, and finally executed around 524 CE. This catastrophe is the background of Boethius's most famous book, the *Consolation of Philosophy,* in which the Lady Philosophy consoles him with Neoplatonic arguments by showing him the true nature of happiness, with God as its highest source.

The final part of the *Consolation,* the famous Books IV and V, focuses on the problem of the reconciliation of human free will and God's providence. It aims at avoiding determinism. The discussion of this topic includes a theory of time, because God and humans have different ways of knowing distinguished by time and eternity. God knows all at once. His thinking is beyond time, because his eternity (*aeternitas*) is the source of time but not time itself. Eternity is defined as the total and perfect possession of endless life at once. Therefore in God's providence all the uncountable past and future happenings are present. Eternity is regarded as a "pure present" or a divine "now."

Contrasting eternity, Boethius mentioned the Aristotelian doctrine of the infinity of the created world (everlastingness—*sempiternitas, perpetuitas*) that has neither a beginning nor an end of time. In doing so Boethius touched on a cardinal philosophical and theological problem of his times. Christians believed in the creation of the world and of time by God as recorded in the Book of Genesis and as stated by Boethius in "About the Catholic Faith." Others thought that, according to Plato, the created world is coeternal to its creator. In the *Consolation,* Boethius explicitly rejected the latter interpretation and followed Plato's (and Aristotle's) view that the world is not eternal but perpetual.

Whereas the everlasting world imitates God's timeless eternity by being unlimited in duration, human beings are even more deficient. Humans think and act within the limits of time (*tempus*) that has a beginning and an end, a past and a future. Human knowledge, therefore, covers only particular aspects of the whole seen and unseen Creation but not the whole, neither one part of it after the other nor at once. Because of this restricted perspective, humans cannot adequately understand God's providence and their own fate evolving from providence.

The distinction between eternity, everlastingness, and time goes back to complex philosophical speculations of Neoplatonic and Christian thinkers—namely Plotinus and Saint Augustine of Hippo, mainly reflecting Plato's *Timaios*—and was fundamental for the scholastic theories of time in the Middle Ages and later on.

Anja Heilmann

See also Aristotle; Augustine of Hippo, Saint; Bible and Time; Christianity; Eternity; God and Time; Plato; Rome, Ancient; Time, Sacred

Further Readings

Sorabji, R. (1983). *Time, creation and the continuum: Theories in antiquity and the early Middle Ages.* London: Duckworth.

Bohm, David (1917–1992)

The American theoretical physicist David Bohm is widely regarded as one of the 20th century's most original thinkers. Over the course of a distinguished career that spanned more than 50 years of teaching and writing, Bohm participated vigorously in the international scientific debates surrounding the overthrow of classical physics by the twin but apparently irreconcilable theories of relativity and quantum mechanics. Along the way he made important contributions to the study of the basic properties of the physical world, such as the theory of the plasma, a fourth state of matter in addition to the solid, liquid, and gaseous states. Eventually the reach of Bohm's ideas went beyond the traditional boundaries of physics and cosmology and came to influence the fields of philosophy, language studies, psychology, and the arts. In his later years he became convinced that the phenomenal world, including time and space, is no more than the surface appearance of something much deeper, the ultimate ground of being in which even the distinction between mind and matter could be resolved. As Bohm observed, not only had Einstein's theory of relativity shown that a sharp distinction between space and time cannot be maintained, but also quantum theory implies that elements separated in space and moments separated in time are noncausally related projections of a higher-dimensional reality, a reality that is, moreover, enfolded in consciousness. The universe, according to Bohm, is an unbroken, flowing, unified whole.

Born in the coal-mining town of Wilkes-Barre, Pennsylvania, where his father owned a small furniture store, David Bohm later recalled his first encounter, at age 10, with a science fiction magazine, which fired his imagination with tales of space travel and distant planets. An absorbing interest in science led to his serious study of physics as an undergraduate at Pennsylvania State University. Following a year of graduate study at the California Institute of Technology (Caltech) in Pasadena, Bohm arranged to meet with J. Robert Oppenheimer, founder of a school of theoretical physics at the University of California, Berkeley, that was attracting many of the brightest young scholars in the nation. Evidently impressed, Oppenheimer invited Bohm to join his team of research students, and in 1941 Bohm moved to Berkeley and entered the vanguard of nuclear physics, where his creativity began to flourish. Against the background of World War II, however, the implications of basic research into the nature of the atom had taken an ominous turn. By the end of the 1930s scientists in both Europe and the United States had recognized the possibility of constructing a nuclear weapon, and in 1942 the U.S. government secretly enlisted Oppenheimer to head an international group of top physicists in developing an atomic bomb. The code name for their efforts was the Manhattan Project, and the extreme concern with security surrounding their work was to have a profound effect on the future of many of the scientists affiliated with the Radiation Laboratory at Berkeley.

Although Bohm was not directly involved with the Manhattan Project and in fact was ignorant of its very existence, his sympathy with socialism and his association with members of the American Communist Party placed him, and other scientists who held similar views, under a cloud of suspicion; Oppenheimer himself was under close surveillance. The fear that the Soviet Union, then a U.S. ally in the war against Germany, would succeed in developing a nuclear weapon before the United States generated an atmosphere of mistrust that lasted long after American warplanes had dropped atom bombs on the cities of Hiroshima and Nagasaki.

Awarded his Ph.D. in 1943, Bohm was invited after the war's end to join the faculty of Princeton University in New Jersey, where he became friends with Albert Einstein, at that time a Fellow of Princeton's Institute for Advanced Study. At Princeton, Bohm wrote his first major work, *Quantum Theory,* which upon publication became a widely adopted textbook for physics students. Although acceptance of quantum theory had become all but universal among physicists, Einstein maintained strong reservations about the theory's insistence that, at the smallest scale, chance and probability were absolute and irreducible properties of the physical world. Taking Einstein's objections seriously, Bohm began formulating his concept of the "quantum potential," which would allow even the more bizarre aspects of quantum reality to be explained causally and as manifestations of the holistic nature of the universe. The implications of this idea would occupy Bohm's imagination in various ways for the rest of his life.

Meanwhile, the cold war with the Soviet Union had given rise to near-hysterical fears of communist domestic subversion. The House Committee on Un-American Activities had launched investigations of scientists formerly associated with the Radiation Laboratory at Berkeley, and David Bohm, among others, was called to testify. Indicted but subsequently acquitted of all charges of wrongdoing, Bohm was nevertheless denied a renewal of his contract by Princeton, which had come under political pressure to "put its house in order." Now unsure of his prospects for academic employment in the United States, Bohm applied to the physics department of the university in São Paulo, Brazil, with recommendations from both Einstein and Oppenheimer, and in October 1951 he began a period of voluntary exile that lasted, except for periodic visits, until his death.

Later, Bohm taught at the Israel Institute of Technology (Technion) and then in England, first at the University of Bristol and then at Birkbeck College, London, where he remained until his retirement as professor emeritus. Throughout these years, he continued to develop, expand, refine, and publish his ideas, some of which deeply influenced others, such as John Bell, whose eponymous theorem established the essentially nonlocal character of the quantum world. Among those with whom Bohm maintained collegial and personal relationships were Einstein, Oppenheimer, Niels Bohr, Richard Feynman, and the philosopher of science Karl Popper; his many correspondents included Werner Heisenberg, Louis de Broglie, Wolfgang Pauli, Maurice Wilkins, and the historian of science Thomas Kuhn. He also maintained friendships with several notable figures outside the realm of science, such as the Dalai Lama and the philosopher Jidda Krishnamurti.

Near the end of his life, Bohm's growing conviction that the material world and consciousness together form an unbroken whole was given full expression in his theory of the implicate order; namely, that what we take to be reality (the *explicate order*), in which separate and distinct particles are observed to interact, is an abstraction derived from a deeper, *implicate order* in which time and space are no longer the dominant factors that determine relationships of dependence or independence of separate elements. Physicists' efforts to reveal the ultimate "building blocks" of the universe by analyzing it into ever-smaller constituents fail to address this issue. And yet, not only has the mechanistic view of reality already been superseded but, according to Bohm, both relativity and quantum mechanics are likely to be revealed in the future as abstractions from still more general laws. To illustrate how the implicate order may be enfolded within the explicate, Bohm uses various metaphors, including that of the hologram: Just as each point in a holographic image encodes information about the whole image, so is the entire universe enfolded within any given point in spacetime. As for consciousness, Bohm's intuition was that, far from being purely local, merely an epiphenomenon of electrochemical processes in the brain, mind is a universal quality and that, at the deepest level, matter and consciousness cannot be separated.

Sanford Robinson

See also Becoming and Being; Consciousness; Einstein, Albert; Kuhn, Thomas S.; Popper, Karl R.; Quantum Mechanics; Relativity, General Theory of; Relativity, Special Theory of; Spacetime Continuum; Time, Relativity of

Further Readings

Bohm, D. (1951). *Quantum theory.* New York: Prentice Hall.

Bohm, D. (1957). *Causality and chance in modern physics.* Princeton, NJ: Van Nostrand.

Bohm, D. (1980). *Wholeness and the implicate order.* London: Routledge.

Bohm, D., & Hiley, B. (1993). *The undivided universe: An ontological interpretation of quantum theory.* London: Routledge.

Bohm, D., & Peat, F. D. (1987*). Science, order, and creativity.* New York: Bantam.

Peat, F. D. (1997). *Infinite potential: The life and times of David Bohm.* New York: Basic Books.

Bonaparte, Napoleon (1769–1821)

Napoleon I, born Napoleone di Buonaparte, is among the most renowned figures in modern European history. He rose to prominence during the French Revolution (1789–1799) to become first consul of the French Republic, and then emperor of France. He conquered much of Europe militarily and instituted a series of liberal political reforms, including the *Code Napoléon,* making him one of history's most contradictory rulers.

Napoleon's extraordinary military and political career was evident enough to his contemporaries, who often likened him to Alexander, Caesar, or Hannibal. The art and literature of the period are littered with such imagery. Napoleon was deeply conscious of his place in time and carefully cultivated his image as a "great man" of history. He embraced the French Revolution and became its foremost beneficiary. He consolidated many of the reforms of the revolution and spread them across Europe, coupled with much violence in doing so. Napoleon crowned himself emperor of the French before Pope Pius VII, in conscious imitation of Charlemagne a thousand years earlier. He made his son the king of Rome, linking his name to the legacy of the so-called Eternal City. Napoleon's epic battles, such as those at Austerlitz and Waterloo, are among the most consequential in history. Taken together, the French Revolution and Napoleonic period represent a transitional moment from the *ancien régime* to modern Europe.

Napoleon was born at Ajaccio, Corsica, soon after the island became a French possession. His parents, Carlo and Letizia Buonaparte, sent the young Napoleon to study in Paris where he graduated from the military academy in 1785. An admirer of Rousseau and Voltaire, Napoleon supported the French Revolution that erupted in 1789 and joined the revolutionary Jacobin Club. Patronage and prodigious service as an artillery commander won him promotion in the French army. Following highly publicized campaigns in Italy and Egypt, he returned to Paris and took part in the coup d'état of 18 Brumaire. He held the position of first consul until 1804, by which time he had consolidated enough power to declare himself emperor in a grand ceremony at the Notre Dame de Paris. Napoleon's insatiable appetite for power and glory brought France into conflict with the other states of Europe, which formed a series of alliances led by Great Britain. At its height, the Napoleonic Empire included nations across Europe, to which many reforms of the French Revolution were extended, as well as much exploitation.

Napoleon's disastrous invasion of Russia in 1812, immortalized in Leo Tolstoy's novel *War and Peace,* demonstrated that the emperor could be defeated. Napoleon abdicated in 1814 following additional defeats and was exiled by the Allies to the tiny island of Elba. He escaped the following year and marched on Paris, gaining followers along the way. The so-called Hundred Days of rule ended abruptly with Napoleon's legendary defeat at Waterloo on June 18, 1815. The Allies exiled Napoleon this time to the island of St. Helena off of the coast of West Africa, where he died on May 5, 1821, at the age of 51. Today, Napoleon I is entombed at Les Invalides in Paris.

The period denoting the rise and fall of Napoleon is often referred to as the Napoleonic period or the Age of Napoleon, a designation reserved for few figures in world history. Napoleon's legacy remains controversial; he has been both celebrated and vilified perhaps more than any other figure of his time. His self-destructive ambition drove Europe into years of brutal warfare that has been described as the first total war. Moreover, his sweeping changes to the political map of Europe gave impetus to national unification movements, such as in Italy and Germany.

James P. Bonanno

See also Alexander the Great; Caesar, Gaius Julius; Hitler, Adolf; Nevsky, Saint Alexander; Stalin, Joseph; Tolstoy, Leo Nikolaevich

Further Readings

Alexander, R. S. (2001). *Napoleon.* New York: Oxford University Press.

Durant, W., & Durant, A. (1975). *The story of civilization: Vol. 11. The Age of Napoleon. A history of European civilization from 1789–1815.* New York: Simon & Schuster.

Dwyer, P. G. (2003). *Napoleon and Europe.* London: Longman.

Boscovich, Roger Joseph (1711–1787)

Roger Joseph Boscovich (Rudjer Josef Boşković, or Ruggiero Giuseppe Boscovich) was born on September 18, 1711, in Ragusa (Dubrovnik), Dalmatia, to a large Catholic family. He finished his principal work, *Theoria Philosophiæ Naturalis Redacta ad Unicam Legem Virium in Natura Existentium* (A Theory of Natural Philosophy Reduced to a Single Law of the Actions Existing in Nature), in Vienna in 1758, and a definitive edition in Latin and English appeared in 1763. Boscovich's scientific accomplishments were so extensive that they cannot be listed here. He published about 100 scientific treatises (most in Latin) and during his lifetime had an academic scientific reputation in France and Italy, England and the United States, as well as in the Slavic world.

Yet the rest of his exceptional life was eclipsed by the fact that Boscovich was the undisputed founder of one of the three families of atomic theory. Boscovich's considerable scientific reputation today is based largely on the theory of matter that he formulated in his *Theoria*. This work helped shape modern conceptions both of matter and of the force field. For example, Michael Faraday and James Clerk Maxwell adapted their theories of the electromagnetic field to ideas based on Boscovich's theory of natural philosophy.

His *Theoria* consists of a great many topics in physics, which may be skipped over by the reader interested primarily in his theory of time. Supplements I and II of the *Theoria* contain Boscovich's mature theory of time, space, and matter. Upon reading his entire magnum opus, though, the modern nature of Boscovich's system becomes apparent. His theory of point particles (*puncta*) includes kinematics, along with a relational and structural understanding of particles. In the case of high-speed particles, Boscovich foresaw the penetrability of matter.

Though his father was of purely Serbian lineage and his mother of Slavonic-Italian origins, Boscovich always insisted he was a Dalmatian nationalist. He died on February 13, 1787, of an extended lung ailment.

Boscovich's Relation to Zeno, Newton, and Leibniz

To understand Boscovich's notion of time, it is best to summarize his own place in the history of Western reflections on time. Even at the beginning of Boscovich's career, the paradoxes of motion posed by Zeno of Elea in the long-past Presocratic period still confounded science.

One paradox assumes two columns of soldiers marching past each other at the same speed and in front of columns of stationary soldiers. Zeno demonstrated that the soldiers would be moving at both half-speed and double-speed relative to the other marchers. He considered this absurd, dismissing, in a sort of reductio ad absurdum argument, the assumption of *real time*. His paradox of motion, then, was a conceptual problem for all serious thinkers.

In reply to Zeno, Aristotle had argued that instead of using multidimensional objects, such as columns of soldiers, unextended points should be employed. In agreement with Aristotle, Boscovich embraced zero-dimensional points as the basis of his notions of time and space.

But this led to another conundrum that still baffled thinkers at the time of Boscovich; using only such unextended points, it is impossible to construct continuous space. This is true because either the points touch, in which case they "compenetrate" and become one point, or they do not touch, in which case a *continuous* space or time cannot be constructed. Boscovich solved the remaining problem by rejecting the validity of the law of continuity as applied to space and time, whereas the law of continuity holds true (only) for motion. Thus he founded one of three primary families of atomic theory: point-particle atomism.

Though a great genius in his own right, Boscovich was eclipsed by two near contemporaries, Sir Isaac Newton and G. W. F. Leibniz. Independent of Newton, Leibniz had also discovered the calculus of infinitesimals, solving Zeno's paradox at a mathematical level. The latter had also adopted zero-dimensional points in his physics and metaphysics, which he called "monads." While Newton's "atoms" were extended and substantial, Leibniz's monads and Boscovich's "force-point particles" were without extension or substance. Unlike Leibniz, however, Boscovich did not attempt to build a continuum from such zero-dimensional points. Rather, he argued that a continuum is the motion of one point. He supposed that any two points never have direct contact, an event that the metaphysics of Leibniz allowed.

By modifying Leibniz's monadology, and by rejecting Newton's corpuscular theory, Boscovich forged his own path. In this way, Boscovich was able to "avoid a mighty rock, upon which both of these others [Zeno and Leibniz] have come to grief." Behind their misconceptions was the "imperfect idea of a sort of round globule having two surfaces distinct from one another, an idea they have acquired through the senses; although, if they were asked if they had made this supposition, they would deny that they had done so."

Perhaps the most striking and counterintuitive postulate of Boscovich's theory was that *there is no universal time, only local time*. At the level of force-points, there is only local time relative to two points. *Time in the context of a single force-point does not exist,* for Boscovich's theory. Time is a strictly relative feature of localities between at least two points, and in the case of sensory objects, great masses of points.

The same is true for space, which Boscovich considered highly analogous to time. Spatially, a solid rod, measuring two precise and distinct points, cannot be rotated in space to measure the same distance between two new points, as it cannot be proven, without circular reasoning, that the rod has not been bent during its rotation. Just as there is a space only relative to the rod, there can be no absolute measure of time, without circular reasoning.

There is no actual space or actual time but only "real local modes." While these force-points are objective and real, and are the only references of "time," they are not centers of time awareness (or sensation generally), at least not for the author of the *Theoria.* Above all, what Boscovich wanted to say about time is that it is not a *continuum consisting of many points;* rather, it is *a relation between two or more discrete force points.* Thus the smallest particle of time is not a time atom (an indivisible length of time) but instead a "tempescule," a "continuous progressive movement in which some intervals are parts of other intervals," since there is a potential to insert an infinite number of points between any two points, no matter how close the time points are together. Space extends in three directions between points of space, whereas time has but one direction. The apparently continuous line of time actually consists in the progressive movement of the present.

Without saying so directly, Boscovich accused his critics and fellows of a "fallacy of division." They had reasoned that what is true of macroscopic objects is true of their most basic constituents. Namely, because larger composite objects are extended, solid, impenetrable, and in contact with each other, elemental objects must also be extended, solid, impenetrable, and in contact with each other. This transfer of properties from whole to part, with only the senses (especially the tactile sensation of solidity) as evidence, was logically illicit.

Similarly, the elemental nature of time and space cannot be arrived at by the senses, according to Boscovich. The ultimate nature of the force-points can never be fully comprehended. The senses cannot be the ultimate jury of reality, as the case of Copernicus had shown. Likewise, the nature of the force-points cannot be deduced from properties of macroscopic objects. What seems certain to the senses may be overthrown by science.

Thus Boscovich founded the point-particle family of atomism. Even for readers in the 21st century, such relativity may be appreciated for its precociousness.

Boscovich and Spinoza's Metaphysics of Substance

Almost every intellectual pursuit during Boscovich's lifetime revolved around the perceived cultural twin threats of Spinoza and Newton (determinism and materialism, respectively). To Boscovich's disadvantage, it has been almost completely overlooked that Boscovich's theory of force-points rejected both Spinoza's concept of "substance" and Newton's corpuscular atomism, the roots of both being traceable to Descartes. At one fell swoop Boscovich rid the general literate public of its twin threats but did so by completely overturning the testimony of the five senses.

Ironically, among the reading public, a growing concern became Boscovich's own theory: Even though the author insisted that his force-points were not centers of spirit, conation, emotion, cognition, or any of the like, many among his readers and the general public worried that some future thinker would modify the theory in precisely that manner. Though Boscovich was an ardent and committed Christian and an outstanding member of the Society of Jesus, his theories were atheist–scientific in interpretation.

In the Appendix on Mind and God to the *Theoria,* Boscovich argued that force-points cannot be construed as *spirits* and that *time is linear, not circular.* First, spirits are immaterial and cannot be spatially or temporally locatable, as must be force-points. Second, because the number of force-points is infinite, there is no mathematical necessity for time to eternally recur. To avoid a version of the theory now called "eternal recurrence," Boscovich argued that there is no definite number of force-points, that instead their number is infinite.

For the reader of the *Theoria,* these rebuttals are unconvincing. In the first case, readers knew quite well that consciousness (and with it the soul) might easily become only another sort of wavelength in Boscovich's physics. This would reject the Cartesian dualism in concert with Christianity, to the advantage of a monism of a universal singular force in no way identifiable as the traditional God. Here Boscovich introduced something of a deus ex machina into his physics, as his theory of force accounted for all physical relations as properties of force-points at varying distances. In the second case, readers remembered that Boscovich's law of force postulated that *there are no actual infinities in nature*. By introducing an actual infinity of points, he violated his own theory. Further, Boscovich introduced another deus ex machina into his physics by arguing that an "infinite determinator" would choose against eternal recurrence, in any case, because an infinite determinator would want linear, not circular, time. To the careful reader of the *Theoria,* however, these rebuttals by Boscovich rang hollow before the specter of soul, time, and God being reduced to sets of force-points.

Boscovich in Relation to Kant and Schelling

The relation of Boscovich to Kant is exceptionally complex, and it must suffice here to remark that both Boscovich and Kant sought to occupy a position situated between Newton and Leibniz, but without repeating their mistakes. There the similarities largely end, though, for the paths of discovery followed by Boscovich and Kant diverged for decades.

The elder Boscovich knew of Kant's arguments against his point-particle atomism and was not convinced. In fact, Boscovich drew nothing from the young Kant into the original *Theoria* and mentioned the objection from Kant (not by name) in a later edition only to include a summary of arguments against his own position.

In his Supplements I and II, Boscovich drew a distinction between "space and time" and "space and time as we know them." Significantly, though, he did so adopting neither a cumbersome metaphysic of faculties nor a distinction between noumena and phenomena. Thus Boscovich's theory would have been a valuable asset to Johann Gottfried von Herder, an opponent of Kant's metaphysics, who did not know of the former. Moses Mendelssohn, another critic of Kant who knew of Boscovich's theory, found Boscovich's theory worthy of public endorsement.

Within the rather alien German Idealist tradition, oddly, Boscovich found another adherent. In his philosophy of nature, Friedrich W. J. Schelling employed Boscovich's *Theoria* precisely to avoid the metaphysics of both Spinoza and Newton (along with that of Leibniz). Almost certainly, Schelling would have come into contact with the ideas of the *Theoria* while Kant's student at Königsberg. At that time, the young Kant was working out a theory of force, which would occupy him off and on until his last works. In his dissertation, Kant had reviewed and modified the theories of force from a wide range of naturalists and physicists. The exclusion of Boscovich is remarkable; apparently Kant was not yet settled in his own mind about the *Theoria*.

Kant certainly knew of Boscovich and his cultural "danger": Moses Mendelssohn had made that obvious to the German literate public. In his last years, Kant still wrestled with Boscovich in *Metaphysics of the Groundwork of Natural Sciences* around the ancient questions of motion and direct contact. As was his wont in this case, Kant never explicitly mentioned Boscovich. But identifiable ideas in Kant's thinking were originally and uniquely from Boscovich. In *Metaphysics of the Groundwork of Natural Sciences,* Kant's final word was a theory of force based on force-points much closer to that of Boscovich than to the theory of Leibniz.

After Schelling, the overt influence of Boscovich on German thought would come primarily with Friedrich Nietzsche's *Beyond Good and Evil,* in which the author lauded Boscovich as another Copernicus in usurping the world of sense-driven appearances (by destroying the last remnant of solid, extended matter). Nietzsche employed the force-points of Boscovich not only as centers of physical force but also of conation and sensation, even of temporal registry. This evolved quickly into Nietzsche's own theory of will to power. An early and foundational note from 1873, the "time atomism fragment," sketched precisely these modifications of Boscovich's point-particle theory into Nietzsche's own theory of force-points. Yet the influence of the *Theoria* on Nietzsche's philosophy went unnoticed except for a crucial study (in German) by scholar Karl Schlechta and physicist Anni Anders in the 1960s. Since the 1990s, though, awareness of Boscovich's role in Nietzsche's work has become widespread. Although Boscovich was one of a large number of scientific influences on Nietzsche, his theory of force was by far more central than the others.

In any case, Boscovich will be remembered as a point-particle theorist and as a philosopher of nature.

Greg Whitlock

See also God and Time; Herder, Johann Gottfried von; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Materialism; Metaphysics; Newton, Isaac; Nietzsche, Friedrich; Spinoza, Baruch de; Spacetime Continuum; Time, Relativity of; Zeno of Elea

Further Readings

Boscovich, R. J. (1966). *A theory of natural philosophy.* Cambridge: MIT Press.

Hesse, M. B. (1962). *Forces and fields: The concept of action at a distance in the history of physics.* Westport, CT: Greenwood Press.

Whitlock, G. (1998). Examining Nietzsche's "Time atom theory" fragment from 1873. *Nietzsche-Studien. Internationales Jahrbuch für Nietzsche Forschung, 26.* Berlin: de Gruyter.

Whitlock, G. (1998). Reexamining Nietzsche's relation to Roger Joseph Boscovich. In B. E. Babich & R. S. Cohen (Eds.), *Nietzsche's writings in epistemology and philosophy of science, Vols. 1 & 2.* Boston: Kluwer Academic.

Whitlock, G. (2003). Moses Mendelssohn and the German reception of Roger Boscovich's *Theoria. Pli: Warwick Journal of Philosophy 14,* 106–128.

Boucher de Perthes, Jacques (1788–1868)

Jacques Boucher de Perthes was a French archaeologist and writer who revolutionized archaeology by pioneering the notion of prehistory. He discovered evidence that humans had existed far earlier in time than had been previously thought.

Boucher de Perthes was a French customs official by profession and a geologist by hobby when he made his groundbreaking discovery. During the 1830s and 1840s he explored and excavated sites in the Somme Valley near Abbeville, France. At a site named Moulin-Quignon he found humanmade tools and pottery alongside extinct elephant and rhinoceros remains. He concluded that because the tools and bones lay together in the same layer of the earth, they were most likely from the same period of time. Perthes collected and studied the tools, which included bifaced "hand-axes." In 1847 he published the first volume of his three-volume work, *Celtic and Diluvian Antiquities,* in which he detailed his findings along with illustrations. Perthes claimed that the tools were made by Celts before the cataclysm of the biblical flood. Scientists did not take Boucher de Perthes's discoveries seriously at the time. It was not until the late 1850s that notable geologists, including Sir Charles Lyell and members of the Geological Society of London, visited his excavations and verified the discovery.

Jacques Boucher de Crèvecœur de Perthes was born into an aristocratic French family that claimed descent from the family of Joan of Arc on his mother's side. Born to wealth, he was able to devote much free time to study and writing on a variety of subjects, including literature and politics. He also wrote plays that never sold. Perthes traveled extensively and was a social activist for the poor throughout his life. In 1825 he was appointed director of the Abbeville customs office, a position formerly held by his father.

Boucher de Perthes's discovery had immense implications for humans' perception of time. He refuted the long-held notion that humanity was created only 6,000 years earlier, or 4004 BCE, a date notably argued by Archbishop Ussher. He established the concept that humanity, and the earth itself, dated far earlier in time than had been previously believed. Gradually he was acknowledged as the founder of prehistoric archaeology. Boucher de Perthes's assertions were largely reinforced with the publication of Charles Darwin's *On the Origins of Species* in 1859. Darwin famously established that organisms evolve over a very long period of time through the process of natural selection.

In 1863, a human jaw was found by a worker at the excavation site known as Moulin-Quignon in France. After careful examination by French and British anthropologists, the jaw was authenticated and appeared to further vindicate Boucher de Perthes. However the "Moulin-Quignon jaw" proved to be a fraud arranged by a worker who was motivated by a reward of 200 francs. The hoax did not damage Boucher de Perthes's reputation. In 1864 Napoleon III honored him with the medal of Officier de la Légion d' Honneur for his contributions to science. Boucher de Perthes died in Abbeville, France, in 1868.

James P. Bonanno

See also Anthropology; Archaeology; Darwin, Charles; Fossils and Artifacts; Geology; Lyell, Charles; Paleontology

Further Readings

Brodrick, A. (1963). *Father of prehistory: The Abbe Henri Breuil.* New York: Morrow.

MacCurdy, G. G. (1924). *Human origins.* New York: D. Appleton and Company.

Van Riper, A. B. (1993). *Men among the mammoths: Victorian science and the discovery of human prehistory.* Chicago: University of Chicago Press.

Bradbury, Ray (1920–)

Ray Bradbury's published writings include a vast array of science fiction and fantasy short stories, some of which are inspired by his fascination with time machines and time travel. Bradbury has created lasting images of a futuristic world in which people visit the past. His stories often focus more on the concern with the moral aptitude of people who are given the opportunity to experience scientific advances, rather than on the scientific advances in and of themselves. Born in Waukegan, Illinois, Bradbury moved with his family to Los Angeles, where he graduated from high school in 1938. Bradbury first published his short story "Hollerbochen's Dilemma" (1938) in a Los Angeles Science Fiction League's fanzine *Imagination!* In 1941, he broke into the professional market when he published the short story "Pendulum" in *Super Science Stories.*

Bradbury began writing full time in 1943, emerging first as a science fiction author and later moving into fantasy, mystery, nonfiction essays, children's literature, and even comic books. Over the course of a long career he has written over 500 works, including short stories, poems, novels, and plays for theater and television.

Many of Bradbury's short stories depict time travel and time machines. In "A Sound of Thunder," first published in *Collier's* magazine in 1952 and reprinted in his collection *The Golden Apples of the Sun* (1953), Bradbury uses time travel to emphasize the profound effect actions occurring in the past can have on the future, when present-day Earth unravels after hunters inadvertently kill a prehistoric butterfly when on their safari expedition.

In "The Fox and The Forest" (*The Illustrated Man,* 1951) Bradbury wrote about a married couple living in a dismal and dehumanizing future overrun with war and bomb-building efforts. They attempt to flee their world by taking a time travel holiday in Mexico, circa 1938. In "Forever and the Earth" (*Long After Midnight,* 1976), Bradbury uses a time machine to transport Thomas Wolfe from his deathbed into the future. Concepts of time travel also exist in his children's book *The Halloween Tree* (1972). Another story that deals with time machines or concepts of time travel is "Last Rites" (*Quicker Than the Eye,* 1996).

In his novel *Dandelion Wine* (1946), he told of a human time-machine, Colonel Freeleigh, who could transport other people back in time by his ability to tell stories. Bradbury republished this story as "The Time Machine," in *Golden Apples of the Sun.*

"The Kilimanjaro Device," first published in *Life* magazine as "The Kilimanjaro Machine" and later reprinted in *I Sing the Body Electric* (1969), is about an encounter with Ernest Hemingway. *Ahmed and the Oblivion Machine* (1998) is a children's fable about a young boy gifted to travel through time and experience life's sorrows and joys.

It is not only his concepts of time travel that made for fantastic stories. Bradbury often tells tales with futuristic vision, not only of what life would be like but how humankind would take advantage of, or misuse, future technological advances because of moral lapses, greed, neglect, and corruption.

Debra Lucas

See also Clarke, Arthur C.; Futurology; Novels, Time in; Time Travel

Further Readings

Bradbury, R. (1980). *The stories of Ray Bradbury.* New York: Knopf.

Weller, S. (2005). *Bradbury chronicles: The life of Ray Bradbury.* New York: Morrow.

Bruno, Giordano (1548–1600)

During the Italian Renaissance, the self-unfrocked and controversial Dominican monk Giordano Bruno emerged as its most important philosopher. To a significant degree, this reputation is due to his daring conception of time within a bold cosmology. Bruno challenged all earlier models of our universe, from the geostatic and geocentric viewpoint of the Aristotelian perspective to the God-embraced and Christ-centered worldview of Nicholas of Cusa. As a result of his rejection of previous ideas in astronomy, philosophy, and theology, Bruno presented a new and astounding cosmology that foreshadowed, in a general way, our modern conception of time in terms of physical relativity and the present interpretation of this material universe in terms of ongoing evolution.

This bronze statue of Giordano Bruno on the Piazza Campo de Fiori, Rome was erected on the place where the Dominican friar and philosopher from Nola (southern Italy) died at the stake February 17,1600, after he was tried and condemned to death for heresy by the Inquisition's court.

Source: AFP/Getty Images.

Dissatisfied with empirical evidence and personal experience, Bruno used thought experiments, rational speculation, and his own powerful imagination to envision the essential characteristics of this dynamic universe. He rejected both Aristotelian philosophy and Thomistic theology. Likewise, he was not content with the models of reality that were presented by Nicolaus Copernicus, Johannes Kepler, and Galileo Galilei. Going beyond all earlier models of a finite and closed universe, Bruno argued that the cosmos is eternal in time, infinite in space, and endlessly changing. For him, time had no beginning and will have no end in the flux of nature; it stretches forever into the past and forever into the future. Consequently, in such a universe, there is no fixed or privileged point of reference.

Rejecting the biblical account of Creation as having taken place over 6 days, Bruno saw cosmic creation as an endless process throughout eternal time. For him, there is no static or absolute framework within which to judge the passing of events to be long or short compared with other events; the length of time is relative to an arbitrary temporal framework within the eternity of time. Throughout cosmic history, the universe has created an infinite number of stars, comets, planets, moons, galaxies, and island universes. In fact, there has even been time for life forms and intelligent beings to emerge on countless other planets strewn throughout the universe. Therefore, our own species occupies neither a special place nor a central position within cosmic reality. In Bruno's sweeping and liberating vision, our human species is merely a fleeting speck in the incomprehensible vastness of sidereal history.

For Bruno, God is nature. Therefore, God is eternal, infinite, and endlessly creating new objects, events, and relationships throughout cosmic history. Ultimately, the Brunian cosmology is grounded in a mysticism that unites, in a divine reality, eternal time and infinite space. In 1600, Bruno was a victim of both religious and political intolerance. Having been found guilty of infidelity and heresy, he was burned alive at the stake in the Campo dei Fiori of central Rome. Today, an impressive statue of this iconoclastic thinker stands on the very spot where he died. He is best remembered for his perspective on time and unorthodox insights into the composition of our universe.

H. James Birx

See also Bruno and Nicholas of Cusa; Eternity; God and Time; Infinity; Mysticism; Nicholas of Cusa (Cusanus); Spinoza, Baruch de; Xenophanes

Further Readings

Bruno, G. (1964). *Cause, principle, and unity.* New York: International Publishers.

Greenberg, S. (1950). *The infinite in Giordano Bruno.* New York: Kings Crown Press.

Mendoza, R. G. (1995). *The acentric labyrinth: Giordano Bruno's prelude to contemporary cosmology.* Shraftsbury, UK: Element Books.

Michel, P. H. (1973). *The cosmology of Giordano Bruno.* Ithaca, NY: Cornell University Press.

Roland, I. D. (2008). *Giordano Bruno: Philosopher/Heretic.* New York: Farrar, Straus and Giroux.

Bruno and Nicholas of Cusa

Giordano Bruno (1548–1600) and Nicholas of Cusa (1401–1464) provided a unique interpretation of God and the universe within their conceptual framework of time. Although some influences of Nicholas of Cusa upon Bruno's ideas are often ignored or misconstrued, together they reflect both the theological and philosophical turmoil that faced the Catholic Church in the 15th and 16th centuries. Advancements in science, philosophy, and the desire for freedom from dogmatic thought had brought serious consequences to these dynamic thinkers. Accusations ranging from heresy, apostasies, blasphemy, to the critical responses from known scientists and their accepted theories had brought periodic censure to Nicholas of Cusa and condemned Bruno to death. The commonalities and differences that can be seen in the fate of these two philosopher-theologians are due to the ideas within their embodied views.

The influence of Platonic and Neoplatonic thought found throughout the views of both Nicholas of Cusa and Bruno are expressed in the shared commonalities regarding the spatiotemporal nature of God and the universe. Infinite and eternal, the cosmos emanates and is constituted from the One (Absolute) in a materialistic interpretation of God. Mysticism, mathematics, and the unity of contradictions provided a comprehensive account of the diversity or plurality found in nature and was associated with the very nature of God; albeit, humankind can never fully understand God. In their theological and philosophical perspectives, not only is God constituted in the material of the known universe (monistic and pantheistic), but also God is indivisible.

Although such views are intriguing, at least from a philosophical perspective, these postulations regarding God, the universe, and humankind's place in nature directly challenged the philosophical underpinnings of Catholic theology and other theological denominations. As for the Catholic Church, the Christian interpretation of Aristotle as presented by Saint Thomas Aquinas (1225–1274) was dogmatically pervasive during this time, as it is today. The postulated views of Nicholas of Cusa and Bruno proved to negate basic church doctrine, especially the conceptual framework of time as represented in the church's divine revelation by God. Further implications regarding holy scripture, Christology, the Holy Trinity, and salvation and redemption are apparent. In regarding these issues, the differences between Nicholas of Cusa and Bruno become evident.

In the intellectual timeline, Nicholas of Cusa was a link between Aristotle and Bruno. He held that humankind is in a state of "learned ignorance" and is incapable of understanding the unity and infinity of the Absolute Maximum and Absolute Minimum of the One or from Absolute Necessity, that is, God within the conceptual framework of the Trinity. Within this framework, the coincidence of contradictions and opposites are united and embodied as One, which humankind can only perceive as separate and distinct. Infinity regarding these concepts was represented by analogies drawn from the mathematical properties of lines, triangles, circles, and spheres, and even motion. It is these analogies of mathematics that allow humankind to arrive at and differentiate divine truth and the infinity of truth.

The cosmos (which includes humankind), by its very nature, is only a "contracted" maximum, a reflection or mere copy of the Absolute Maximum. In this regard, the cosmos had a distinct beginning. The infinity and the eternal nature of the cosmos become the only significant link with the Absolute Maximum. For Nicholas of Cusa, Christianity was unique and paramount within the unification of the Absolute Maximum and Absolute Minimum within the contracted universe, for Christ Incarnate became a focal point within unity as depicted in the Trinity. Just as God is constituted and contrasted with humankind, Christ embodied both perspectives simultaneously. Christ's nature was both Absolute Maximum and Absolute Minimum within the contracted nature of the cosmos. This allowed Christ to transcend death and enabled humankind to know God. The mysteries of faith steeped in mysticism seek to provide individuals the path, via Christian love, toward the Church. This union of individuals, such as is expressed by the congregation, becomes united with Jesus Christ on whose existence humankind depends.

Bruno provided a different view of the cosmos and humankind's place within it. For Bruno, the spatiotemporal universe—form and matter—not only had no beginning and is infinite in nature, but also is in a constant state of flux. In this manner, time becomes relative. This relativity confers upon it a sense of individuality, for example, as depicted by motion or life, and that which is juxtaposed as eternity. Individualistic concepts of time are not singular in nature; rather, the time of each individual is irrevocably linked to others within the universe. This dynamic and diverse plurality of the monadic universe is united and one within nature, ultimately equating God with nature. Bruno postulated that within this infinite universe there are numerous planets, stars, and galaxies, some of which contain life within their relative conceptual framework of time. Consequently, in a universe that is full of life and has no center or periphery, humankind's place in the cosmos is without a hierarchy. The life of our species is one among many within the inconceivable stretch of the cosmos.

Bruno speculated that, in the process of understanding humankind's nature, our species will discover the nature of divinity within ourselves. This divinity can be expressed throughout human cultures and their respective religious–mystical perspective. A combination of mysticism and rationality results in a sense of universalism, as depicted in ancient religions and magic, which is reflective of the divinity within the human species. If the Brunian idea of humankind's nature and relationship with the divine is taken seriously, differences among religious practitioners are negated. A sense of utopia, peace, and harmony would be an eternal goal that could be realized. Although human life is finite, perhaps in a Brunian sense our species' existence and "divine" nature are infinite and peace is possible when compared to humankind's history and life on other worlds.

Bruno's ideas of time, the universe, and the nature of divinity had resulted in severe repercussions. His anti-Aristotelian stance, rejection of Ptolemy and acceptance of Copernicus (based on mysticism), rejection of traditional religions, and critical judgment of orthodox Christianity had not endeared him to authorities. Bruno's view, considered more art than science, attempted to unify and expand the human perspective beyond the confines of many geocentric and anthropocentric lines of thought. In contrast to the philosophical and theological positions of Nicholas of Cusa, these contrary and conflicting views resulted in his trial and execution in 1600.

The concept of time, as with the universe, pushes the human intellect to the fringes of reality. The concepts as depicted by Giordano Bruno and Nicholas of Cusa are representative of many perspectives encountered within humankind's desire to understand itself in terms of nature and its relationship to the cosmos. Human evolution, as with speculations on the evolution of life on other planets, is intertwined within the fabric of time and space. Subjective and elusive, the infinity of time and space remain central to human existence, even though it is neither central nor critical to the universe or cosmos. For Nicholas of Cusa, learned ignorance aids humankind in the epistemological fulfillment of the universe and the understanding of our species' relation to the divine. Bruno, on the other hand, postulated a more humanistic approach. Ultimately, time is relative in a chaotic universe filled with life on planets throughout the cosmos. Together, Bruno and Nicholas of Cusa provide a unique perspective that still resonates today.

David Alexander Lukaszek

See also Bruno, Giordano; Cosmogony; Eternity; Infinity; Nicholas of Cusa (Cusanus); Time, Relativity of

Further Readings

Bruno, G. (1998). *Giordano Bruno: Cause, principle, and unity: And essays on magic* (R. de Luca & R. J. Blackwell, Eds. & Trans.). New York: Cambridge University Press.

Michel, P. H. (1973). *The cosmology of Giordano Bruno*. Ithaca, NY: Cornell University Press.
Nicholas of Cusa, Cardinal. (1962). *Unity and reform: Selected writings of Nicholas de Cusa* (J. P. Dolan, Ed.). Notre Dame, IN: University of Notre Dame Press.
Nicholas of Cusa, Cardinal. (1997). *Nicholas de Cusa: Selected spiritual writings*. New York: Paulist Press.
Roland, I. D. (2008). *Giordano Bruno: Philosopher/Heretic*. New York: Farrar, Straus and Giroux.

Buddhism, Mahayana

Buddhism was divided into two schools because of a schism that gained increasing momentum between the 1st century BCE and 2nd century CE. The new school of Buddhism called itself "the greater vehicle," or Mahayana, as it had reinterpreted the teachings of Siddhartha Gautama (563–483 BCE) to accommodate a greater number of people. The Mahayanists distinguished themselves from the old mainstream Buddhism by referring to it as "the lesser vehicle," or Hinayana. Because there is a derogatory connotation to the epithet *Hinayana*, contemporary scholars tend to shun the term in favor of *Theravada* or *Theravada Buddhism*. Among the philosophical differences between the two schools is a new conceptualization of temporality that defies the traditional division of past, present, and future and bridges the conceptualization of time in the realms of relative and absolute order.

Major Characteristics

Both schools of Buddhism subscribe to a common set of basic teachings attributed to Gautama Buddha (also known as Shakyamuni or Sakyamuni). Among these teachings are the Four Noble Truths, the Noble Eightfold Path, the theory of *karma,* and the cosmology of impermanence, or *dukkha*. Differences arose from the way that the two schools made sense of the teachings. Whereas the Theravadins insisted on a rigorous adherence to the Buddha's original teachings, the Mahayanists championed a more liberal, dynamic, and esoteric interpretation. As a result, Mahayana Buddhism developed a number of innovative shifts in emphasis.

The Bodhisattva Ideal

The most important Mahayana innovation was perhaps the *bodhisattva* ideal. Literally "awakened being," the bodhisattva is a Buddha-in-waiting, who vows to postpone entry into *nirvana* (freedom from desire or attachment) until all living beings are saved. This voluntary sacrifice for the sake of others presents a sharp contrast to the Theravada ideal of the *arahant,* or "worthy one." The latter is also enlightened, but attends to his or her own pursuit of sainthood and seeks nirvana just for him- or herself. What the bodhisattva wants is universal salvation. Much as the bodhisattva merits nirvana, he or she chooses to remain in the realm of *samsara* (endless cycle of birth and rebirth) to help people awaken to the impermanence of human existence, transcend the temptation of desires and wants, and be relieved of sufferings.

Central to the bodhisattva ideal are wisdom and compassion. In addition, the bodhisattva vow involves a pledge of commitment to the perfections of morality, patience, vigor, and meditation. The bodhisattva is the name for a group of celestial beings who perform acts of incredible generosity, bring hope to lay as well as monastic Buddhists, and are worshipped alongside the Buddha.

Trikaya, or Threefold Nature

Another Mahayana innovation was the notion that the Buddha had *trikaya,* or three bodies: a Manifest Body (*Nirmanakaya*), a Body of Bliss (*Sambhogakaya*), and a Body of Dharma (*Dharmakaya*). According to this doctrine, the historical Siddhartha Gautama was only the Manifest Body of a universal, spiritual being known as the Buddha. Underneath his external manifestation, the Buddha is at once eternal with his Body of Bliss and absolute with his Body of Dharma.

Out of the three-body doctrine grew the notion of a deity: The Buddha is divine and has transcendent power. His Body of Dharma is that which provides the universal ground of being and, therefore, constitutes the Absolute. His Body of Bliss is capable of assuming various transformations, including Maitreya (Buddha of Future) and the five cosmic Buddhas: Vairocana, Aksobhya, Ratnasambhava, Amitabha, and Amoghasiddhi. Indeed, Mahayana Buddhism embraces a pantheon of Buddhas, whereas Theravada Buddhism professes faith in the teachings of Gautama Buddha solely.

Sunyata, or Void

The Mahayana doctrine of *sunyata* (emptiness) stresses the void nature of all things, including their components. The whole external world is no more than an illusion projected by thought. All phenomena in the world are ultimately unreal, as are the sufferings of endless birth and rebirth. Furthermore, the ultimate void is true of the Absolute as well, which is empty in the sense that it is totally devoid of the distinctions, limitations, and delusion imposed by thought.

The concept of sunyata has its philosophical roots in the *Madhyamaka,* or Middle Path tradition founded by Acharya Nāgārjuna during the 2nd century. It employs dialectic oppositions to account for the relationship between the realms of samsara and nirvana. Ignorance of the ultimate void condemns one to the realm of samsara, whereas knowledge of the ultimate void elevates one into the realm of nirvana. The Mahayana goal, however, is to transcend these opposites in enlightenment. This is possible because nirvana can be found in the transience of ordinary life. Samsara is nirvana, and one does not have to follow a path of monastic withdrawal from the world in order to realize the bliss of nirvana. Ultimately, nirvana is samsara correctly understood.

Universalism of Buddha Nature

Mahayana Buddhism universalizes Buddha nature. Within the Theravada, there is a divide between samsara and nirvana. One can attain nirvana only through the dissolution of one's individuality, hence the doctrine of *anatman* or "no-self." In contrast, Mahayana Buddhism posits a connection between the two realms. All sentient beings are reflections of the Buddha, and Buddha nature is inherent in all living beings. Humans and animals alike have the seeds of Buddha nature within them, so any sentient being can gain Buddhahood.

In its spiritual quest, the Mahayana school advocates the transformation of one's relationship with the world rather than severing oneself from ordinary life. By stressing that spiritual assistance is possible from the Buddha, bodhisattva, and one's own Buddha nature, this school offers more hope of enlightenment in a single lifetime for both lay people and monastic Buddhists. Proceeding from a broader interpretation of the Buddhist tenets, Mahayana Buddhism not only incorporates the monastic principles and practices of the old school but also calls attention to the importance of faith, prayer, chanting, offering, and revelation through meditation in attaining enlightenment.

The Mahayanists did not see themselves as creating a new start for Buddhism. They claimed rather to have recovered the true spirit and message of the Buddha's teachings. In modern times, new research has led some scholars to suggest that Mahayana Buddhism does not hold closely to the teachings of Gautama because it may have evolved from a religious system that was ignored or opposed by the early Buddhists.

Mahayana Schools

Under the broad umbrella of Mahayana Buddhism, a number of different traditions came to flourish, including such schools or sects as Pure Land, Tiantai, Vijnanavada, Chan (Zen, in Japanese), and Tantric Buddhism.

Pure Land Buddhism

Pure Land Buddhism was introduced into China as a devotional society during the 4th century by a Chinese scholar, Huiyuan. Based on the first-century Sukhavativyuha Sutra (Pure Land Sutra), this school provided devotees with a simplified way to obtain salvation—repeating the name of the Buddha Amitabha (Buddha of Infinite Light) faithfully in order to be reborn in his heavenly Pure Land in the west. It was a paradise where everyone was enlightened and headed for the bliss of nirvana. Deliverance to this paradise depended on devoting oneself in chanting to Amitabha and reading the Pure Land Sutra. Not only did Amitabha (Amida in Japanese) hearken to prayers and respond to invocations, but the Buddha delighted in offerings. This Mahayana sect had a great appeal to the laity and spread far and wide in China, Korea, Japan, and Vietnam.

Tiantai Buddhism

Tiantai Buddhism represented the first Chinese attempt to found an eclectic school of Buddhism. It had a place for all the Buddhist scriptures, which were seen as the true words of the Buddha speaking to an audience who understood his message better and better over time. Founded in the 6th century CE by its first patriarch Zhiyi, the Tiantai (Tendai in Japanese) school assigned central importance to the Saddharmapundarika Sutra (Lotus Sutra). Its basic position is very much in the Madhyamika (Middle Path) tradition. Tiantai Buddhism teaches that because there is no noumenon besides phenomenon and phenomenon itself is noumenon, all things have no reality and, therefore, are void. Furthermore, all beings are of the same Buddha nature, and all are to attain Buddhahood eventually. Tiantai Buddhism became very influential in China, Korea, Japan, and Vietnam.

Vijnanavada Buddhism

Parallel to the Madhyamika (Middle Path) tradition is the Vijnanavada (Consciousness Only) tradition, which arose in India during the 4th century CE. According to this tradition, nothing exists outside of the mind, and only consciousness is real. Its works were taken to China two centuries later by Xuanzang, a Chinese monk who rendered the Vijnanavada compendium into Chinese and is remembered as the greatest of all pilgrim-scholars. His disciple Dosho introduced Vijnanavada Buddhism into Japan. The 7th century saw an indigenous Chinese school grow out of the Vijnanavada tradition in general and the *Avatamsaka Sutra* (Garland Sutra) in particular. Established by a master monk, Dushun, in the late 6th century CE, this Mahayana sect was known as Huayan (Flower Garland), and it primarily worshipped the Buddha Vairocana (Primordial Buddha; Rulai in Chinese and Dainichi in Japanese). Huayan Buddhism quickly found its way into Korea and Japan in the 7th century.

Chan Buddhism

Chan Buddhism was a form of Mahayana that underwent extensive cross-breeding with Daoism after it was brought to China in 520 CE by an Indian monk, Bodhidharma. Chan (Zen in Japanese) is the Chinese transliteration of *dhyana,* which is the Sanskrit word for "meditation." Indeed, meditation is a centerpiece of Chan Buddhism. It features an individual quest for spiritual insight, which is also typical of the approach of Theravada Buddhism. For Chan adepts, however, enlightenment is an awakening to the sunyata, or emptiness of reality. Chan apprenticeship is primarily informed by "wordless teaching," which is characteristically Daoist. This Mahayana school also has a rather "this-worldly" character. In addition to meditation, Chan adepts can be engaged in manual work (gardening, wood-chopping, etc.) as much as in cultural pursuits (e.g., calligraphy, painting, poetry writing). It is important that they look within ordinary life for inspirations, which, integrated into spiritual insights from meditation, can culminate in sudden enlightenment. Chan Buddhism spread to Vietnam in the 6th century CE, became dominant in Korea during the 10th century, and led to the rise of the Rinzai and Soto sects in Japan between the 12th and 13th centuries.

Tantric Buddhism

The earliest texts of Tantric Buddhism date back to the 4th century. Often known as Vajrayana Buddhism, this school teaches attainment of enlightenment by the bodhisattva path. Sutras important in Mahayana Buddhism are generally important in Tantric Buddhism as well. What makes Tantric Buddhism distinctive is its adoption of esoteric tantra techniques to expedite enlightenment. Such techniques usually employ mantras, mandalas, and even sexual activities as aids to meditation. Mantras are sacred words with mystic power, whereas mandalas are artworks of religious symbolism that depict deities, holy landscape, and other-worldly vision. Following a reformed Madhyamika tradition, Tantric Buddhism identifies knowledge on three levels of consciousness: the commonsense level that is illusory, the relative level that recognizes the temporary existence of components, and the true level that brings about an awareness of the ultimate void. Enlightenment comes with the realization of wisdom on the true level, and Tantric Buddhism claims to provide an accelerated path toward that goal. Tantra techniques are synonymous with Vajrayana practices or the Vajrayana. Sometimes called "the diamond vehicle," the

Vajrayana constitutes a dominant part of Buddhism in Tibet and Shingon Buddhism in Japan.

Today Buddhism is a thing of the past in its country of origin, and the most complete Mahayana canon exists in classical Chinese. Unlike the Pali canon, which was compiled by the Theravadins, the Mahayana scriptures were written in Sanskrit and, in some cases, classical Chinese. Because many of the Sanskrit texts are lost, they have to be recovered from the Chinese translations that have survived the vicissitudes of time.

Reality, Time, and Temporality

The Buddhist cosmology identifies samsara with the relative order of reality and nirvana with the absolute order of reality. The former is conditioned, whereas the latter is unconditioned. *The* Nirvana Sutra says, "Buddha (*Tathagāta*) is permanent with no change at all." In contrast, time is "becoming," namely, change. To stress the ever-changing nature of time, Mahayana Buddhism sees time as a flow of events and a process.

A process has an "arising," a "duration," and a "dissolution." Nothing lasts forever, but the process is due to happen all over again. In line with this view, emphasis is on time as "becoming" rather than "being." Moreover, time is cyclic in the sense that the process of birth and rebirth recurs endlessly. It sends one into the misery of an afterlife based on one's karma that is carried over from this life. The doctrine of karma dictates that whatever one does has an impact on one's reincarnation. The uninitiated, however, are ignorant of the karmic effects of time. Rather than redeeming themselves from false desire and attachment, they choose to seek moments of pleasure and live in momentariness, thus the cyclic return of samsara.

The absolute reality is timeless. Not only is it immutable and eternal, but, according to the Lotus Sutra, it comes from nowhere and goes to nowhere. Time as becoming belongs in the realm of samsara. Nonetheless, that time is ever-changing is unchanged, so there is room for an enlightened mental process that parallels the perception of temporality in its true nature.

The Mahayana sense of temporality is based on an awareness of relational organization, not the ontological past, present, and future. A case in point is the factors and conditions that shape the process when salt is poured into water. At the moment of pouring, saline water is a thing of the future but has its making in the present. Once the ingredient is being dissolved, both salt and water are becoming things of the past. What happens is an interlocking of stages ("arising," "duration," and "dissolution"). As the past and future are very much in the present, the tripartite ontology of time is of little use. Attention to relational organization will reveal how a coming-together of causative factors and conditions leads to their formation of a special relationship and interaction to produce a result. An understanding of the relational organization of processes is possible in the realms of samsara and nirvana.

Zhiming Zhao

See also Buddhism, Theravada; Buddhism, Zen

Further Readings

Conze, E., & Waley, A. (1975). *Buddhism: Its essence and development.* New York: Harper & Row.

Harvey, P. (2001). *Buddhism.* New York: Continuum.

Suzuki, D. T. (1963). *Outlines of Mahayana Buddhism.* New York: Schocken.

Buddhism, Theravada

Theravada Buddhism is a school that grew out of the teachings attributed to Siddhartha Gautama (563–483 BCE) and was recorded in the Pali language around the 1st century BCE. Literally meaning the "school of the elders," Theravada Buddhism represents the old orthodoxy of Buddhism. At its core is a set of doctrines that are common to all Buddhist sects and designed to promote the deliverance of individual humans from the suffering of life. Featuring a monastic life of austerity, Theravada Buddhism is followed primarily in Sri Lanka, Burma, Thailand, Cambodia, Laos, and parts of Vietnam, Malaysia, China, and Bangladesh. Despite its asocial nature, this school has a sense of historical time, and it developed a conceptualization of temporality that is dualistic, pertaining to the phenomenal and ultimate reality respectively.

Theravada Buddhism is sometimes referred to as *Hinayana Buddhism*, a term that is no longer used in informed circles. Its problem lies in the derogatory meaning that *hina* assumes in Sanskrit texts when it appears in contrast to *good* or in juxtaposition with terms such as *ignoble* and *harmful*. Rather than denoting "lesser vehicle," *Hinayana* can be taken to mean "vehicle of despicable quality." Consequently the World Federation of Buddhists recommends that it be avoided.

Gautama, the Buddha

Siddhartha Gautama was born to King Suddhodana Gautama and Queen Maya in Lumbini (now in Nepal). The young prince applied himself assiduously to the ascetic practices of Hinduism and Jainism. In addition, he sought out some of the most famous spiritual and philosophical teachers of his time. Years later, however, it occurred to him that neither the traditional religions and philosophies nor asceticism had brought him closer to true wisdom.

The king was determined to do everything within his power to stop the prince from choosing a spiritual life over the throne. However, at the age of 29, Siddhartha renounced the world of luxury and embarked on a long journey to seek the true nature of reality through the eyes of a wanderer. On the night of his 35th birthday, he entered into the deepest of meditations under a tree in Gaya, India, and was able to attain enlightenment after persevering through the most excruciating temptations. It marked the birth of Gautama, the Buddha (Enlightened One). He spent the next 45 years traveling from place to place to preach and spread the doctrines of Buddhism. Parallel to his preaching was the way of life he led: Walking barefooted, he held an alms-bowl in one hand and a walking stick in the other, with his head shaven clean of hair and his body wrapped in a plain robe of saffron. The Buddha died at the age of 80 in Kusinara, India. Virtuous and wise, the Gautama Buddha was also known as *Sakyamuni* or *Shakyamuni* (sage of the Sakyas kingdom).

Fundamental Teachings of Buddhism

The essence of the Buddhist teachings is stated in the Four Noble Truths. This doctrine runs as follows: Human existence is suffering (*dukkha*); suffering is caused by desire and attachment (*trishna*); the cessation of suffering comes with the removal of desire and attachment (*nirvana*); and the way to the cessation of suffering is the Noble Eightfold Path, which serves to bring about the extinction of desire and attachment.

To pursue the Noble Eightfold Path is to cultivate right understanding, right thought, right speech, right action, right livelihood, right effort, right mindfulness, and right concentration. This model of spiritual cultivation has three prongs: *Sali,* or physical activities (right speech, action, livelihood); *Samadhi,* or mental cultivation (right effort, mindfulness, and concentration); and *Panna,* or development of wisdom (right understanding and thought). Together they define the Buddhist ideal of a virtuous and moral life.

Buddhism stresses the impermanence of life. According the Buddhist philosophy, what we call a "being" is no more than a combination of the Five Aggregates of Attachment: matter, sensations, perceptions, mental formations, and consciousness. Each of these aggregates is an ever-changing force that arises out of conditions and operates in a conditioned state. There is no unchanging substance in a "being" or "self" or "soul," all of which are false ideas. As our physical and mental being has no immutable and independent existence, life is transitory and impermanent. Moreover, Buddhism sees a parallel between impermanence and suffering, as was stated by the Gautama Buddha himself: "What is impermanent is *dukkha.*"

A major form of suffering is *samsara* (circle of continuity), in which living beings are trapped in a continual cycle of birth and rebirth. The momentum to rebirth is shaped by the volitional activities of one's previous life, which have karmic effects. The theory of karma is a theory of cause and effect. Moral intention and behavior yield good karma that impacts one's next life positively, whereas immoral intention and behavior yield bad karma that affects one's next life negatively, including condemnation to the misery of a nonhuman creature. The main spiritual goal of Buddhism, however, is to seek total liberation from samsara, the endless cycle of birth and rebirth. To this end, one must awaken to the true nature of reality and transcend false desire and attachment.

The Pali Canon

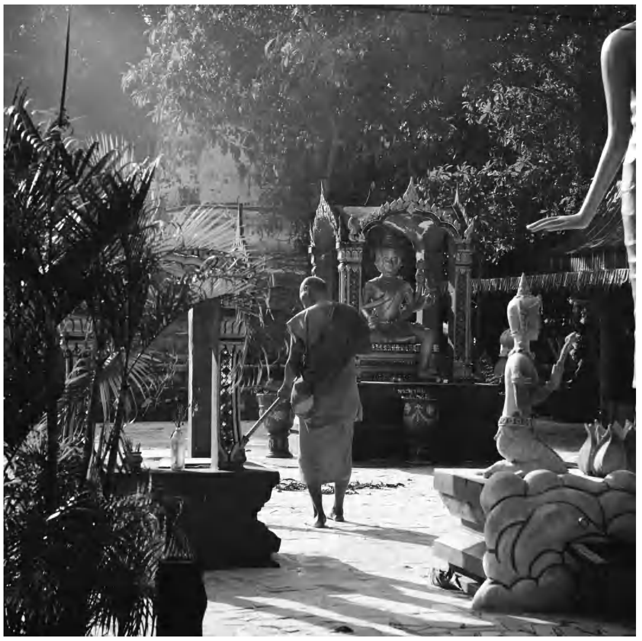
The earliest scriptures of Buddhism are represented by the Tripitaka (three baskets of law). Written in Pali and compiled from an oral tradition, the Tripitaka did not take shape until some 400 years after the death of Siddhartha Gautama. There were conflicting memories with regard to what Gautama Buddha had actually said and meant. As it is, the text tends to reflect the memories and views of those who were close to the Buddha, such as his prominent disciples Kayshapa and Ananda. As the most important of all Buddhist scriptures, the Pripitaka comprises three books: Rules of Conduct (*Vinaya Pitaka*), Discourse (*Sutta Pitaka*), and Analysis of Doctrine (*Abhidhamma*).

The various sects of early Buddhism were founded on a relatively literary interpretation of the Pali canonical tradition. One of these sects was named *Theravada* and is held to be representative of the orthodoxy of early Buddhism. The Theravadins were found mostly in Sri Lanka rather than India by the time Buddhism was bifurcated into two major schools of thought: old and new. The new one was named *Mahayana*, whereas the old one came to be known as *Theravada* or *Hinayana*, a coinage attributed to the Mahayanists.

The Theravada Tradition

Early Buddhism, as represented by the Theravada sect, arose in rejection of the Brahmanical tradition, vedic ritual, and caste theology of Hinduism. It maintained that all human beings were equal but vulnerable to the suffering of life. Only in Buddhism could one find an ultimate solution to such suffering and misery. In prescribing this "ultimate solution," Theravada Buddhism stresses the importance of following the original teachings of the Pali canon. More specifically, it professes devotion to taking refuge in the Buddha, the Dharma, and the Sangha (order of monks)—the Three Jewels of Buddhism.

The Theravada school of thought held that the Buddha was a human being, and that he owed his attainment of nirvana to human endeavors and intelligence rather than inspiration from any external power or god. There is a noticeable absence of metaphysical statements about the Buddha in Theravada Buddhism. For its followers, the Buddha is a teacher par excellence, who sees reality in its true form and achieves the perfect wisdom. To take refuge in the Buddha is to follow the teachings and example he left behind.



A Buddhist monk sweeps around a temple (Wat Pranang Sang) in Thailand. Buddhism stresses the impermanence of life. According to the Buddhist philosophy, what we call a "being" is no more than a combination of the Five Aggregates of Attachment: matter, sensations, perceptions, mental formations, and consciousness.

The teachings expounded by the Buddha are known as the Dharma. It sheds light on the true nature of reality and provides impersonal laws in place of God. Ignorance is the root cause of all evil, and it is to be overcome by taking refuge in the Dharma. Devotion to the Dharma is devotion to the Buddha Gautama. It means rigorous adherence to his original teachings and adamant opposition to reinterpreting them liberally.

Following the Buddha's example, Theravada practitioners see the attainment of nirvana as their immediate goal. It is their final exit from the world. But such liberation is entirely personal, and no assistance from outside is possible. Enlightenment can be achieved only through one's own effort—by leading a monastic life of austerity and taking refuge in the Sangha in addition to the Buddha and the Dharma. Literally meaning “group” or “community,” the Sangha serves to awaken human intelligence and initiate one into the quest of individual enlightenment.

Such is the attitude of Theravada Buddhism toward the Buddha, the Dharma, and the Sangha. Just as noteworthy is its interpretation of dukkha. While the Buddhist philosophy stresses the impermanence of entity (i.e., being), it emphasizes the persistence of processes (i.e., samsara). In the Theravada tradition, dukkha is very real, whether it denotes “impermanence” or “change” or “suffering.” As a process, it contrasts sharply with entities such as desire and attachment, which are illusory.

Historical Awareness and Time Concept

Legend has it that the historical Gautama started his spiritual journey after he had seen an old man, a sick man, a dead man, and a recluse. These four signs turned his mind away from the world into the wilderness. If this legend were any indicator, then the goal of Theravada Buddhism was to seek liberation from the grip of change and becoming by way of enlightenment. It appeared asocial and ahistorical of Theravada Buddhism to urge a complete severance from the phenomenal world in quest of enlightenment. Nonetheless, this school developed a historical awareness in order to relate the biography of Gautama, chronicle the events in his life, and discuss the intellectual heritage of its saints. The concept of historical time is necessary for learning hagiologies and convincing the faithful. Temporality, however, was perceived differently in relation to the two different orders of reality: relative and ultimate.

Theravada Buddhism does not subscribe to the theory of *sunyata,* or total emptiness of reality. Although time is only a successive flow of components and aggregates, it is not unreal. In the relative or phenomenal order of reality, the operations of time are characterized by momentariness and cyclicity. Human existence is like a fleeting bubble. Between birth and death, sentient beings live in moments, because nothing is free from change, and its long-lasting duration is merely illusory. Burdened with desires and wants, human existence is condemned to an endless cycle of birth and rebirth, which is the doing of karma.

Cyclic time, in turn, is the manifestation of *dhamantā,* which is the law of the universe. Literally “rule” or “norm,” dhamantā dictates an iron chain of causality. There is, however, more than simple recurrence in the workings of dhamantā, for the causation of recurrence is multilateral. It involves a concatenation of several causative factors activated together situationally. As a result, each living being is unique and different from what it was in a previous life. Theravada Buddhism denies that any sentient being exists or perishes eternally in the phenomenal world.

Cyclic time is to be measured in terms of cyclic becoming. Although there is no single cause in becoming, karmic effects are decisive. This makes sentient beings the arbitrator of their own becoming. By will and volition, one can choose to accumulate good karma in order to eventually rise above cyclic becoming.

In the ultimate or transcendental order of reality, historical time is irrelevant; so are the momentariness and cyclicity of time. There is no past or future. What is left is an eternal present, in which wisdom of eternal laws and rules prevails. Time is cumulative and no longer measured in terms of cyclic becoming. It is divided into great units called the *kappas* (eons), each represented by the appearance of a Buddha. Notably, the Buddha Gautama is said to have refused to speculate whether the world is eternal or not, probably because it contains more than one order of existence: animal, human, and divine.

Zhiming Zhao

See also Buddhism, Mahayana; Buddhism, Zen

Further Readings

Gombrich, R. (1988). *Theravada Buddhism.* New York: Routledge.

Hoffman, F. J., & Deegalle, M. (1996). *Pali Buddhism.* Richmond, UK: Curzon Press.

Rahula, W. S. (1974). *What the Buddha taught* (2nd ed.). New York: Grove Weidenfeld.

Buddhism, Zen

Zen is a form of Japanese Buddhism that developed from the Chinese Mahayana school of

Buddhism known as Chan. The core of Zen practice involves using seated meditation to achieve enlightenment. In Zen, one sees and accepts the world just as it is and is aware of the impermanence of everything; one should fully focus on each moment, not what has been or what will be. The medieval Zen master Dogen developed a complex view of the stationary aspects of time to account for the apparently stable sequential order of the passage of moments. His theory substantiated his claim that the Buddhist ideal could be realized only through continuous practice. By focusing on and living fully in the moment, an individual can achieve *satori,* the intuitive understanding of the underlying unity of all existence.

History

Zen first emerged as a distinct school of Buddhism in China in the 7th century CE. From China, Zen spread southward to Vietnam and eastward to Korea and Japan by the 13th century. In the late 19th and early 20th centuries, Zen also established a distinct presence in North America and Europe. The two main sects of Zen were brought to Japan by Japanese monks who studied in China. The Buddhist monk Eisai (1141–1215) introduced Rinzai Zen in 1191, and the Buddhist monk Dogen (1200–1253) introduced Soto Zen in 1227. Both sects still flourish today, along with some smaller movements.

Because of a worldview that lives in the moment, Zen has had a strong influence on Far Eastern arts and crafts. Haiku poetry, ceremonial tea drinking, painting, calligraphy, gardening, and architecture were all influenced by the practice of Zen. Mountains, birds, plants, rocks, and other natural subjects were ideally suited to a point of view that reflects immediate direct vision (like a window) rather than an interpretation of a subject (like a mirror).

It is difficult to trace when the Western world became aware of Zen, but a Japanese Zen monk named Soyen Shaku did attend the World Parliament of Religions in Chicago in 1893. In Europe, Expressionist and Dada movements in the art world of the early 20th century shared many themes with Zen. The British-American philosopher Alan Watts took a close interest in Zen Buddhism and lectured on it extensively through the 1950s. Jack Kerouac published a book in 1959 titled *The Dharma Bums,* illustrating how a fascination with Buddhism, and Zen in particular, was being absorbed into bohemian lifestyles, especially along the western coast of the United States. In the decades since that time, schools in the mainstream forms of Zen have been established around the world.

Zen Practice

In other forms of Buddhism, an individual achieves enlightenment through a combination of training, meditation, and the study of religious texts. Zen, in contrast, focuses solely on seated meditation (*zazen*) as the means of gaining enlightenment. Meditation practices differ in Zen schools. Soto Zen teaches *shikantaza,* which is strictly sitting in a state of alert attention completely free of thought. In practicing shikantaza over time, insight is gradually achieved. Rinzai Zen uses koans during meditation to achieve enlightenment in a sudden flash. Koans are riddles with no solutions or paradoxical anecdotes or questions that demonstrate the uselessness of logical reasoning, such as "What is the sound of one hand clapping?" Zen tradition emphasizes direct communication over the study of scripture, so the Zen teacher plays an important role. The Zen teacher is a person ordained in any Zen school to teach the Dharma (teachings of the Buddha) and to guide students in meditation. Zen is a way of life that has paradoxically produced a large body of literature.

Time in Zen Buddhism

There have been many writings on time in the history of Buddhism, but Dogen of the Soto Zen school has gone farther than most in attempting to organize the experience of time into a system of thought. Dogen wrote an essay titled "Uji" in the year 1240 when he was 41 years old. *Uji* is the philosophy of time (U = existence, and ji = time). Basically, he wrote that time is existence and all existence is time. The word *Uji* refers to a specific time taken from an infinite continuity. Dogen says: "Uji arises, free from desire. It materializes now here, now there. Even the king of heaven and his retainers are not separated from uji manifested. Other beings on land and in water also arise from uji. All things in darkness and light arise from uji. These manifestations become the time process. Without time, nothing can arise." Dogen's view is that all existences are linked and ultimately become time. From one point of view, each moment of time is isolated and disconnected from the past and future. From another point of view, time manifests new time each moment, connecting the past and future. Dogen speaks both to the continuity and discontinuity of time.

Zen Buddhism emphasizes the transience of the phenomenal world. A great emphasis is placed on concrete events being intuitively understood through contemplation rather than the study of theory or scripture. Through meditation, one hopefully becomes enlightened, or achieves Buddhahood. Buddhahood is time. Dogen states that those who want to know Buddhahood may know it by knowing time as it is revealed to us. Because we are already immersed in time, Buddhahood is not something to achieve in the future but something that "is" now, and we just have to realize it.

Jill M. Church

See also Buddhism, Mahayana; Buddhism, Theravada

Further Readings

Heine, S., & Wright, D. S. (Eds.). (2006). *Zen classics: Formative texts in the history of Zen Buddhism.* New York: Oxford University Press.

Kapleau, P. (1965). *The three pillars of Zen.* New York: Weatherhill.

Katagiri, D. (2007). *Each moment is the universe: Zen and the way of being time.* Boston: Shambhala.

Leighton, T. D. (2007). *Visions of awakening space and time: Dogen and the Lotus sutra.* Oxford, UK: Oxford University Press.

Suzuki, D. T. (1996). *Zen Buddhism.* New York: Doubleday.

C

Caesar, Gaius Julius (100–44 BCE)

Gaius Julius Caesar was a brilliant Roman general and statesmen whose actions truly changed history and altered its course. Had he never existed, the world today might be a very different one. He was born a patrician and claimed descent from the Trojan hero Aeneas and ultimately the goddess Venus—a distinguished, if fanciful, lineage that stretched back thousands of years.

Caesar became the head of his family at age 16, following the death of his father. He joined the army and served with distinction until his return to Rome in 78 BCE. He then pursued a legal career and thrived as an orator. He was on his way to Rhodes in 75 BCE to study under a respected master of oratory when his ship was seized by Silician pirates and he himself was captured and held for ransom. After it was paid he hunted down the pirates and had them all executed, which he had promised them while he was still in captivity.

Upon Caesar's return to Rome a number of promotions followed. He was elected first tribune, then quaestor, then successfully ran for the office of pontifex maximus (high priest of the state religion) in 63 BCE; this office permitted him the right to reform the Roman calendar to what we call the Julian calendar, a variation of which (the Gregorian) we now use today. Caesar thus influenced the way the Western world conceives the passage of time. Caesar was then appointed governor of Outer Iberia (in Spain), where he led troops to several victories. He returned to Rome and was elected consul (together with two other statesmen) in 59 BCE. He then formed a political alliance known as the First Triumvirate with the wealthy statesmen and generals Crassus and Pompey. Caesar was then appointed governor of northern Italy, the western Balkans, and then southern France. He proceeded to conquer and annex additional provinces of Gaul (France) that had previously been beyond Rome's scope. In 55 and 54 BCE he led two campaigns into Britain with reasonable success, and then returned to Gaul, where he continued to secure the unstable regions for the next few years. Caesar had thus succeeded in Romanizing a greater portion of Europe than had ever been done before.

In the meantime, Caesar's former ally, Pompey, who was head of the Senate (as Crassus had been killed in battle), ordered Caesar to return to Rome, as his proconsul term had expired. Caesar knew that he would have to enter the city as a private citizen and without his army, leaving him open to certain legal prosecution for his actions as proconsul. He decided to ignore this and effectively declared war on his former friend (and son-in-law, as Pompey had been married to Caesar's daughter until her untimely death). Caesar declared his intentions when he crossed the river Rubicon in 49 BCE. Civil war erupted, and Caesar spent around a year defeating his rival Pompey's legions across Europe, finally pursuing him as far as Alexandria in Egypt, where Pompey was murdered by the Egyptian court.

Caesar in the meantime was appointed dictator of Rome, and began to interfere in a civil war in Egypt between Ptolemy XIII and his sister Cleopatra VII. He began a love affair with the queen and defeated her brother in battle. He then traveled to the Near East for additional campaigns, and to Africa to defeat the last of Pompey's supporters. He returned to Rome in 45 BCE and named his grand-nephew Gaius Octavius (the future Emperor Augustus) his heir. The Senate named Caesar Dictator Perpetuus (dictator for life), and many feared that he would become king; this led to an assassination plot led by Caesar's friend, Marcus Junius Brutus and his brother-in-law, Cassius. On March 15 (the Ides of March) in 44 BCE the assassins struck, stabbing Caesar 23 times on his way to a Senate meeting. Unfortunately, what the assassins had tried to prevent was exactly what they precipitated: the end of the Republic and the beginning of a hereditary monarchy. Mark Antony and Octavian joined forces with Caesar's cavalry commander Lepidus (to form the Second Triumvirate) and waged war against the armies of Brutus and Cassius, defeating them at Philippi in Greece. Mark Antony and Octavian then came to blows, with Mark Antony forming a legal and amorous alliance with Cleopatra. Antony and Cleopatra were defeated and committed suicide, and Lepidus went into exile, leaving Octavian free to be declared the first Roman Emperor.

The Roman Empire, which Caesar had effectively created, continued to dominate the Western world for centuries; its influence is still felt in modern language, culture, science, technology, and religion. We can only speculate as to what our world might have become had Caesar himself never existed, or if his life had taken an alternate course.

Robert Bollt

See also Alexander the Great; Attila the Hun; Charlemagne; Genghis Khan; Rameses II; Rome, Ancient

Further Readings

Caesar, Gaius Julius. (1999). *The Gallic war.* Oxford, UK: Oxford World Classics. (Original work c. 45 BCE)

Goldsworthy, A. (2008) *Caesar: Life of a colossus.* New Haven, CT: Yale University Press.

Suetonius. (2003). *The twelve Caesars.* London: Penguin Classics. (Original work published 121 CE)

Calendar, Astronomical

A human invention, the calendar was created to measure and record the passage of time. For our early ancestors, survival depended on observing changes in the sky. The moon's changing shape and position were easy to see, which is why most ancient calendars used the synodic period or lunation, the interval between successive full moons, as an intermediate measure between the solar day and the solar year. Herein lies one of the primary difficulties with calendar design.

Lunar months vary between 29 and 30 days, and the number of lunations fluctuates between 12 and 13, resulting in a calendar year of varying lengths. When to begin a new year was another concern. The oldest calendar, first used around 4236 BCE, is that of predynastic Egypt. The beginning of this 365-day calendar, divided into 12 months of 30 days and 5 extra days, was marked by the rising of the brightest star. Because the tropical year, the interval between successive equinoxes, is slightly longer, at approximately 365.25 days, this calendar gradually drifted into error.

The earliest Roman calendar, 735 BCE, began in March. Composed of 6 months of 30 days and 4 of 31, it resulted in a 304-day year. The remaining days, which fell in winter, were uncounted until Numa Pompilius, the second king of Rome, hoping to collect more taxes, added 2 months (Januarius and Febrarius), thereby lengthening the year to 354 days. With their names based on Latin numerals, the seventh, eighth, ninth, and tenth months became our September, October, November, and December.

Following the advice of the astronomer Sosigenes, Julius Caesar abandoned the republican calendar and began reforming the old Egyptian one, lengthening the year to 365.25 days, and arranging the months according to the solar year. Their lengths were either 30 or 31 days; February had 28, with an additional day inserted every 4 years. July, named after Julius Caesar, had 31 days. Augustus Caesar, unhappy that August had only 30, ordered that it be changed to 31, which would have meant three consecutive 31-day months. To avoid this, the rest of the months were rearranged, hence the rhyme, "Thirty days hath September. . . ." In order to realign the calendar with the seasons, Julius Caesar ruled that 46 BCE, known at the time as "the year of confusion," would have 445 days.

Although used widely for more than 1,500 years, the Julian calendar was about 11 minutes and 14 seconds too long, the tropical year being 365.24219879 days long, not 365.25. By 1580, the resurrection of Christ, tied as it is to the spring equinox, fell on March 11, which was 10 days too early. Pope Gregory XIII ordered that October 5, 1582, became October 15, 1582. He further decreed that February would have one extra day in years divisible by 400, resulting in an average year of 365.2425 days. By modern day calculations the Gregorian calendar, in use today, is about 26 seconds too long. Alternate calendaring systems continue to be proposed and their merits examined and debated. However accurate, none are really viable in the long run. As noted in 1878 by the American astronomer Simon Newcomb, the years are slowly decreasing by about a half a second each century. From time to time, future generations will find adjustments are necessary.

Jocelyn Phillips

See also Calendar, Egyptian; Calendar, Roman; Comets; Meteors and Meteorites; Observatories; Planetariums; Time, Galactic; Time, Measurements of; Time, Sidereal

Further Readings

Holford-Strevens, L. (2005). *The history of time: A very short introduction.* New York: Oxford University Press.

Richards, E. G. (1998). *Mapping time: The calendar and its history.* New York: Oxford University Press.

Calendar, Aztec

The Aztec calendar is a timekeeping system that was used in the Mesoamerican Aztec culture and by other peoples of the pre-Columbian era in Central America. The calendar is sometimes referred to as the Sun Stone, due to the imagery depicted on the carved basalt. The original name that was used historically by the Aztecs, however, is *cuauhxicalli* ("eagle bowl"). The original Aztec calendar was carved into a slab of basalt weighing more than 22 metric tons, and was found in 1790 in the main square in Mexico City. The carving is currently housed in the National Museum of Anthropology and History in Chapultepec Park in Mexico City.

The Aztec calendar was a complex counting of days and years that involved two cycles: one consisting of 365 days based on the solar year, and the other consisting of 260 days, which may be based upon the Aztecs' obsession with numerology. Together, when all the combinations of the cycles were exhausted and formed a 52-year "century," the combined cycle culminated with an elaborate ritual by the Aztecs known as the New Fire Ceremony, which helped stave off the end of the world.

The 365-day count (*xiuhpohualli* in Nahuatl) consisted of 18 months divided into 20-day periods, with the remaining 5 days known as *Nemontemi*. The days in *Nemontemi* were considered unlucky, and were filled by fasting, in the belief that nothing good would come by attempting anything productive. Whether the Aztecs placed these 5 days at the end of the calendar year, throughout the year, or at the beginning is unknown, but it is certain they were there.

Each month in the *xiuhpohualli* had a name and corresponded to a deity in Aztec mythology. Because human sacrifice and ritualized warfare were a religious necessity in Aztec culture, many of the months are characterized by the types of human sacrifices and actions performed. These sacrifices would be performed on the Sun Stone itself. For example, in the month of *Hueytozoztli* (great vigil), the patron deities Centeotl and Chicomecacoatl were appeased with virgin sacrifices. At this time of the year occurred the blessing of the maize, with which both Chicomecacoatl and Centeotl were associated.

The 260-day count (*tonalpohualli*) consisted of 20 periods of 13 days (*trecenas*), each given a particular sign. These included, in order: caiman, wind, house, lizard, serpent, death's head, deer, rabbit, water, dog, monkey, grass, reed, jaguar, eagle, vulture, motion, flint knife, rain, and flower. The periods would begin sequentially, assigning a number to each symbol (i.e., 1 caiman, 2 wind, etc.), until after the 13th day, when the beginning of a new trecena would be marked 1, with whatever symbol with which it was associated.

The *tonalpohualli* is very important for the Aztec mindset. Not only does it serve as a divinatory tool, but it also serves as a time division for a particular deity. The Aztecs believed in an equilibrium that pervaded the cosmos. It was their duty to maintain that equilibrium. Since the deities of the Aztecs are always battling for power, everything needs to be divided up among them (including time) to prevent the disruption of the equilibrium.

In order to prevent confusion of years, the Aztecs named a new year with the symbol of the last day of the last month of the year. These 4 days could be represented only by the glyphs for reed, flint knife, house, and rabbit. Subsequently, in the 52-year century, the numbers 1–13 would apply to each of these four glyphs, depending on the year count (i.e., if the previous year was 1 reed, the next would be 2 flint knife). This would continue until the 13th year, and then a new glyph would be assigned to the year as 1 (in the above cycle it would be 1 flint knife). In order to avoid confusion with days, the date would be written with the year boxed in. An Aztec day would be represented as its *tonalpohualli* counterpart (e.g., 1 caiman) in its year (e.g., 1 reed). At the end of the 52-year cycle, the process would begin anew, with the year reverting to 1 reed.

The Aztec calendar, as it has come to be known, remains significant to many scholars interested in mathematics, anthropology, archaeology, and cosmology. It offers insights into both the religious and the agricultural life of not only the Aztecs, but also other Nahuatl peoples who used a similar system. Though it remains under a museum's custody, the calendar still keeps its count, endlessly repeating its 52-year cycle.

Dustin B. Hummel

See also Calendar, Mayan; Time, Measurements of

Further Readings

Graeber, R. B., & Jimenez, R. C. (2006). *The Aztec calendar handbook* (4th ed.). Saratoga, CA: Historical Science Publishing.

Holmer, R. (2005). *The Aztec book of destiny.* North Charleston, SC: BookSurge Publishing.

Calendar, Egyptian

An old Arab proverb states that "man fears time, but time fears the pyramids." Indeed the pyramids of Giza are perhaps the most famous and recognizable structures to have ever existed, built beginning around 2500 BCE. The Egyptian civilization was not only concerned with grand projects like monumental architecture, or ethereal ones dealing with deities, mummification, and the afterlife, but also with more worldly matters such as mathematics, medicine, and keeping exact track of the day, month, and year. Until the end of the Old Kingdom (ca. 2181 BCE), the Egyptians numbered years according to a biennial census. By the end of the Old Kingdom a different system was employed that was very straightforward. Since the weather is largely unchanged throughout the year, the Egyptians reckoned time according to the inundation of the Nile, the most important event in their lives. The annual inundation renewed the fertility of the land, and it was an event for which the king himself was considered responsible in his capacity as the nearest living relation to the gods.

There were three seasons of 4 months each. The first began around mid-July, when the annual inundation began, and lasted until mid-November, when it ceased. This season was named *Akhet,* meaning "inundation." Following this was *Peret,* meaning "rowing," which lasted until mid-March, and finally *Shomu,* meaning "harvest," until mid-July and the next inundation. Each of the seasons was divided into 4 months, which also had names (rarely used), each with 30 days. Most monumental inscriptions begin with the date. This is written according to a standard formula. First comes the word for year (*hezbet* or *renpet-hezbet*), followed by a number. This signified in what year of the current king's reign it was written. Then comes the sign for month, followed by a number, then the season, then the sign for day followed by a number. Finally, a phrase that goes something like "under (the reign) of the King of Upper and Lower Egypt . . ." ends the formula.

A variation occurs when the month is the first of the four within a season; this can be written using only the word for "first." Another variation commonly occurs when it was the last (30th) day of the month, in which case the word for "last" replaced the sign for day and the following number 30. The Egyptian calendar also took into account the remaining 5 days left over after the 360 counted within the system, by adding 5 extra days after the end of the year (the last day of the harvest season). These are known as *epagomenal* (added) days, each representing the birthday of a different god: Osiris, Horus, Seth, Isis, and Nephthys. The first day of the year was called the "Birth of Re." As the Egyptians had no leap years, their calendar lost a day every 4 years.

The Coptic calendar, still in use today, is based on the ancient Egyptian one. Ptolemy III attempted to introduce a 6th epagomenal day every 4 years to avoid the loss, but the idea met opposition from the priests. This reformation was not put into use until Roman Emperor Augustus synchronized the Egyptian calendar to the Roman, Julian one in 25 BCE. This became known as the Coptic calendar, which is still in use today by the Coptic Church. Egyptian farmers still think in terms of the harvest season for obvious reasons.

Translating Egyptian dates into our calendar system is problematic for Egyptologists. We do not know how many years every king ruled, and sometimes there were two kings at once. However, scholars are helped a little by Egyptian astronomical calculations, most importantly the annual rising of Sirius at the start of the inundation season. Given the loss of 1 day every 4 years, if the rising of Sirius is recorded (only three such examples exist) the year (BCE) can be calculated to within a 4-year time frame, for example 1317–1320 BCE. Otherwise, there are different systems of establishing a margin of error; from the Middle Kingdom (c. 2050–1800 BCE) it is about 30 years, and accuracy increases with the passing centuries. By the 6th century BCE, the margin of error virtually vanishes.

The Egyptians also divided their days into 24 hours, with the day beginning at sunrise (about 6 a.m.). The day and night were composed of 12 hours each. In astronomical texts each hour has a name, but in ordinary accounts they are simply numbered.

The Egyptians regarded time as not only linear, as we do nowadays, but as cyclical as well. Each day, week, month, year, and reign was regarded as newly created, hence the reason they calculated years according to the current king. Egyptian has two words for *eternity: djet* and *neheh. Djet* represents linear time, which refers to an unchanging flow of existence. *Neheh* signifies cyclical time, viewed daily by the rising and setting of the sun, the seasons, the inundation of the Nile, birth, death, and the reign of a new king. In other words, the Egyptians saw themselves as passing through a single time continuum, albeit in a cyclical fashion. A typical Egyptian formula goes *djet neheh,* usually translated as "for ever and ever" or "for ever and eternity," used, for example, when wishing eternal life upon a king. The Egyptian calendar thus not only calculates the day, month, and year of a given event, but also summarizes a great deal about the Egyptian cosmology and how they viewed time itself—the very time that man fears, the time that fears the pyramids.

Robert Bollt

See also Calendar, Roman; Time, Measurements of

Further Readings

Allen, J. P. (1999). *Middle Egyptian: An introduction to the language and culture of hieroglyphs.* Cambridge, UK: Cambridge University Press.

Collier, M., & Manley, B. (2003). *How to read Egyptian hieroglyphs.* Berkeley: University of California Press.

Gardiner, A. H. (1957). *Egyptian grammar: Being an introduction to the study of hieroglyphs.* Oxford, UK: Griffith Institute.

Calendar, Ethiopian

Ethiopia is located in the Horn of Africa, neighboring Sudan, Kenya, Somalia, and Djibouti. It is one of the oldest countries of the world, with diverse ethnicity, languages, cultures, religions, and traditions. Ethiopia was under the rule of monarchs for decades, if not centuries; from 1974 to 1991 it was under military rule. Beginning in

1991, Ethiopia instituted a federal system of government with some forms of democratization. Unlike most nations in Africa, Ethiopia maintained its independence from colonialism. This nation has its own calendar, and it recently celebrated the end of the second millennium on September 12, 2007. This date marks New Year's Day 2000 on the Ethiopian calendar.

The Ethiopian calendar divides the year into 13 months with 12 months of 30 days and one month of 5 or 6 days (see Table 1). The 13th month is an intercalary month called *Paguemain;* it has 5 days that become 6 days every 4 leap years on a leap year. Ethiopia is known for having a 13-month calendar; it has become part of a slogan to attract tourists: Ethiopia, 13 months of sunshine. The table, adapted from Aberra Molla, presents the names of the months in Amharic and English, and their starting dates in the Gregorian calendar, including the variations of the starting dates during leap years.

The Ethiopian New Year begins on September 11 of the Gregorian calendar and on September 12 in leap years. The New Year falls in September, right after the end of the rainy season. After 3 months of clouds, fog, cold, and rain, September brings a joyous season of sunshine and blossoming flowers. It also brings the start of the school year for children, with the big feast of the New Year holiday called *Enkutatash*—the mark of the beginning of the year. Another holiday, *Meskel,* follows a fortnight later and celebrates the discovery of the True Cross (*Meskel*). September brings the beauty of greenery and flowers, relief from the darkness of the rainy months, and a fresh start for another year.

The year 2007/2008 in the Gregorian calendar is the year 2000 in the Ethiopian calendar. It marks the end of the second millennium and the beginning of the third millennium. The Ethiopian calendar falls behind the Gregorian calendar by 7 or 8 years. The 7 years' difference ranges from September to December, and it becomes 8 years beginning from January up to August. For example, the 7-year difference between the two calendars in the month of December becomes a difference of 8 years in January after the New Year of the Gregorian calendar, whereas it comes back to 7 years in September again, right after the Ethiopian New Year. This is, as Aberra Molla notes, because of the difference between the Ethiopian Orthodox Church and the Roman Catholic Church regarding the determination of the date of the creation of the world. According to the Ethiopian Orthodox Church, the world was created 5,500 years before the birth of Jesus Christ. Accordingly, it is now 2,000 years since Jesus Christ was born while it is 7,500 years since the creation of the world.

The Ethiopian calendar is similar to the Coptic calendar. According to Molla, it has its origin in the Coptic Church of Egypt. The difference between the Ethiopian and Coptic calendars is the saints' days and their observance time. According to the Ethiopian calendar, Ethiopian Christmas and

Table 1 The Ethiopian calendar versus the Gregorian calendar

Month	*Start Date*	*(During Leap Year)*
Meskerem/September	11 September	(12 September)
Thikimt/October	11 October	(12 October)
Hidar/November	10 November	(11 November)
Tahsas/December	10 December	(11 December)
Tir/January	9 January	(10 January)
Yekatit/February	8 February	(9 February)
Megabit/March	10 March	
Miazia/April	9 April	
Ginbot/May	9 May	
Senie/June	9 June	
Hamlie/July	8 July	
Nehasie/August	7 August	
Puagmain—the intercalary month	6 September	

Epiphany are celebrated on January 7 and January 19, respectively.

The Ethiopian calendar has 4-year cycles. The years are named after the evangelists Matthew, Luke, Mark, and John. The year is divided into the four seasons of autumn, winter, spring, and summer. The week in the Ethiopic calendar has seven days with 24 hours in each day; 12 hours of day and 12 hours of night. The days are *Ehud* (Sunday), *Segno* (Monday), *Maksegno* (Tuesday), *Rebu* (Wednesday), *Hamus* (Thursday), *Arb* (Friday), and *Kidame* (Saturday).

According to the Ethiopic calendar, the day starts with the rising of the sun in the morning and ends at sunset, followed by the beginning of the night. In the morning, the day starts with the first hour as 1 o'clock (7 a.m. local time) and the day ends at 12 o'clock (6 p.m. local time). The night starts at 1 o'clock (7 p.m. local time) and ends at 12 o'clock at sunrise (6 a.m. local time). The Ethiopic calendar divides the 24 hour day into even equal hours of 12 hours of daytime and 12 hours of nighttime. The hour-count in the Ethiopian calendar indicates the number of hours since the beginning of daytime or nighttime. So, 5 o'clock (11 a.m. local time) is the fifth hour of daytime, whereas 5 o'clock at night (11 p.m.) is the fifth hour since the onset of nighttime. Ethiopia is located at 45 degrees longitude, thus midnight in London is 3 a.m. in Ethiopia or the ninth hour of nighttime. Traditionally, people have understood the day to start in the morning and end at the sunset, with the next day starting with sunrise. The 12 hours in between are nighttime. It appears people conceive of one day as being those 12 hours of daylight. This, however, is not the case with the official version of the day, which is in fact 24 hours of both daytime and nighttime taken together.

Government offices and businesses use both the Ethiopian and Gregorian calendars side by side. Some institutions, however, prefer the Gregorian to the Ethiopian calendar. The use of the two calendars simultaneously sometimes causes confusion and inconvenience. Confusing the dates, year, and hours of the day of one calendar with the other can have serious consequences. For instance, in higher education institutions where the Gregorian calendar is used for academic schedules, a freshman student may confuse the time for an 8 a.m. examination to mean 8 o'clock (2 p.m. local time) and miss the morning examination while waiting for 8 o'clock (2 p.m.) after lunchtime—a very serious problem for the poor freshman student who could receive a failing grade and dismissal from school. The Gregorian calendar is also used for Ethiopia's interactions with the outside world in commerce and other sectors. The growing trend toward global interdependence seems to mandate wider usage of the Gregorian calendar in Ethiopia. Ethiopia is proud of its traditional calendar and is determined to keep it, while it also attempts to communicate with the rest of the world by embracing the Western calendar.

The 2000 Ethiopian Millennium, which was launched officially on September 12, 2007, was a yearlong celebration. It was recognized by the United Nations and the African Union. The event was attended by signatories and heads of state, with speeches and music performances and a series of special events. Controversy surrounded the celebration, however. Some critics of the government oppose extravaganzas while millions of Ethiopians are still suffering from poverty. The government and its supporters, however, argued that the millennium celebration could be a renaissance to mobilize the people and generate commitment and momentum to eradicate poverty and attain development in Ethiopia.

Belete K. Mebratu

See also Calendar, Gregorian; Time, Measurements of

Further Readings

Beckingham, C. F., & Huntingford, G. W. B. (1961). The Ethiopian calendar. *The Prester John of the Indies* (Appendix IV). Cambridge, UK: Hackluyt Society.

Molla, A. (1994). *The Ethiopic calendar.* Retrieved November 8, 2007, from http://www.ethiopic.com/Calender/ethiopic.html

Calendar, Gregorian

The Gregorian calendar is the world's most widely used calendar today. A calendar is a system of organizing units of time and of reckoning time in advance in order to satisfy the needs of a specific society. It serves practical purposes, providing the basis for recording and calculating dates over extended periods, and for planning and maintaining cycles of civil and religious events. Therefore, a calendar can provide a sense of understanding and controlling time, linking humankind and the cosmos. Because the principles on which a calendar is based are shared by the whole society that adopts it, it can be considered a specific form of social contract, a source of social order and cultural identity.

A calendar is constructed on astronomical cycles: The principal ones are the year (which is based on the revolution of the earth around the sun), the month (which is based on the revolution of the moon around the earth), and the day (which is based on the rotation of the earth on its axis). Yet these cycles do not synchronize perfectly: The average periods of sun and moon do not comprise an integral number of days, nor are they exactly commensurable with each other and with the length of a day. Moreover, the irrational ratios between the fundamental time units (year, month, day) are not constant in the long run.

Therefore, calendar years and months, which have an integral number of days, cannot be synchronized exactly with respect to the astronomical year and to the cycle of lunar phases. Thus, each calendar tries to surmount the problems that arise from this incommensurability through rational approximations. For instance, the Julian calendar, which reformed the Roman calendar in 45 BCE, added a leap day to February every 4 years. In this way the average length of the calendar year became quite congruous with the length of the astronomical year.

Furthermore, each calendar fixes a specific date for beginning the year, and most calendars choose an initial epoch for counting years: a historical or legendary event is adopted as starting point of the year count in order to maintain a consistent chronology. For instance, the foundation of Rome was adopted as the initial epoch of the ancient Roman calendar, the birth of Christ as the initial epoch of the Christian calendar.

History of the Gregorian Calendar

The Gregorian calendar was developed by the end of the 16th century by the astronomers Aloysius Lilius and Christophorus Clavius in order to resolve the problems arising from the desynchronization between the Julian calendar and the astronomical data. As the mean Julian calendar was slightly too long, the astronomical equinox, which should be on March 21, had regressed to a date earlier in the month. Consequently, the calendrical equinox drifted forward, causing difficulties in determining the correct date of Easter. Indeed, in 325 the Council of Nicaea had determined to celebrate Easter on the first Sunday after the ecclesiastical full moon, which falls on or shortly after March 21, the date calculated for the vernal equinox. Over the centuries, the shifting forward of the calendrical equinox caused Easter to drift away from its correct date, losing its position in springtime and its relation with the Jewish Passover.

As early as the 13th century, scholars had realized that the method of calculating the date of Easter had to be reformed. Several attempts were made to find a solution to this question, but no consensus was reached. By the 16th century the astronomical equinox was occurring 10 days before the calendrical equinox, and astronomical full moons were occurring 4 days before ecclesiastical full moons. Therefore, in 1563, the Council of Trent established that the date of the vernal equinox had to be restored to March 21 and required the outlining of a new calendar in order to correct present errors and prevent future ones. Consequently, Pope Pius V introduced corrections to the lunar tables and the leap-year system (1568–1570).

In 1572 Pope Gregory XIII succeeded Pope Pius V; aiming to optimize the measures taken by his predecessor, he commissioned a study for a general reform of the calendar. The astronomer Aloysius Lilius designed a project for calendar restoration; it was worked out in detail by his colleague Christophorus Clavius. The project was forwarded by Pope Gregory XIII to many Christian princes and university professors, gaining consensus and agreement.

On February 24, 1582, Pope Gregory XIII published the bull *Inter gravissimas,* whose specific aim was the reform of the calendar. This reform corrected the length of the solar year, changing the previous value of 365.25 days to the new value of 365.2425 days. In order to obtain this average length, the number of leap years was corrected from 100 in 400 years to 97 in 400 years. To achieve this result, the leap year system of the Julian calendar, which fixed every 4th year as leap year, was maintained, making corrections only at the turn of centuries: The bull determined that secular years divisible by 100 but not by 400 should be considered common years. Moreover, the error accumulated over the centuries since the Council of Nicaea was corrected by the removal of 10 days: the day after October 4, 1582, was designated October 15, 1582.

The order of the months and number of days per month of the Julian calendar were confirmed: January 31 days, February 28 (in leap years 29), March 31, April 30, May 31, June 30, July 31, August 31, September 30, October 31, November 30, and December 31.

Although Pope Gregory XIII recommended in his bull to defer by 10 days the expiration of any payment, many people strongly opposed the adoption of the new calendar, fearing it could conceal a deception. Nevertheless, the Gregorian calendar was adopted in 1582 in Spain, Portugal, and their colonies, in the Polish-Lithuanian Commonwealth, and by most of Italy, France, Holland, and Zeeland; in 1700 in Denmark, Norway, and the Protestant states of Germany; in 1753 in the British Empire; in 1918 in Russia and in 1923 in Greece; and by the end of the 19th century it had been adopted in Japan and Korea and at the beginning of the 20th century in China.

The Gregorian calendar is quite accurate, accumulating an error of one day in about 3,300 years. Yet it also shows some weaknesses: Because of its unequal units, it cannot be divided into equal halves or quarters, and years and months may begin on any day of the week, making it difficult to predict the date of movable feasts.

Alessandra Padula

See also Calendar, Astronomical; Calendar, Julian; Earth, Revolution of; Equinoxes; Leap Years; Time, Measurements of

Further Readings

Coyne, G. V., Hoskin, M. A., & Pedersen, O. (Eds.). (1983). *Gregorian reform of the calendar: Proceedings of the Vatican Conference to Commemorate Its 400th Anniversary, 1582–1982.* Cittá del Vaticano, Europe: Pontificia Academia Scientiarum; Specola Vaticana.

Vardi, I. (1991). *Computational recreations in mathematica.* Reading, MA: Addison-Wesley Professional.

Calendar, Islamic

The Islamic or *Hijri* calendar has 354 days in a year, divided into 12 lunar months of either 29 or 30 days (29.5 days is the time taken by the moon to complete a full circle around the earth). This calendar is used in many Islamic countries as the primary way to date events, and by all devout Muslims to track the observance of Islamic holy days. The Hijri calendar is named for the year 622 CE, when the *Hijra* occurred—the emigration of the Prophet Muhammad and some of his followers from Mecca to Medina to escape their enemies. Islamic years are labeled as AH (from the Latin phrase *anno Hegirae,* or "in the year of the Hijra"); for example, the Gregorian year 2008 CE corresponds to 1429 AH in the Islamic calendar. The Hijri calendar first came into use in 638 CE, when it was introduced in Medina by Caliph Umar ibn al-Khattab, a close companion of Muhammad.

Because the lunar year is shorter than the solar year (the time taken by the earth to complete a full circle around the sun), fixed events or celebrations in the Islamic calendar fall 11 days earlier with each successive solar year, taking 33 years to move through the entire cycle of the solar calendar. The calendar used in Arabia prior to the introduction of the Islamic calendar was a lunisolar calendar that used lunar months, but that occasionally had an additional intercalary month inserted in order to keep the calendar in alignment with the natural seasons arising from the sun's annual peregrinations. The Qur'an forbids this practice in Surah 9, verses 36–37, which state that God has ordained a fixed number of months (12) each year, and that transposing of additional months is arbitrary and is an act of Unbelief.

The first day of each Hijri year is called Ras as-Sana ("head of the year"), and the names of the 12 months of the year reflect their origins in more ancient systems for marking the solar seasons. The months are *Muharram* (the sacred month), *Safar* (the month that is void), *Rabi' al-awwal* (the first spring), *Rabi' al-than* (the second spring), *Jumada al-awwa* (the first month of dryness), *Jumada al-thani* (the second month of dryness), *Rajab* (the revered month), *Sha'aban* (the month of division), *Ramadan* (the month of great heat), *Shawwal* (the month of hunting), *Dhu al-Qi'dah* (the month of rest), and *Dhu-al-Hijjah* (the month of pilgrimage). Four of these months (*Dhu al-Qi'dah, Dhu-al-Hijjah, Muharram,* and *Rajab*) are considered sacred, because fighting was traditionally forbidden during them, and sins and good deeds carried more weight at these times than during the rest of the year. Ramadan is the month when Muslims focus on the moral and spiritual elements of life, fulfilling the fourth pillar of Islam (*sawm* or fasting) by practicing abstinence and fasting each day from sunrise until sunset, and by engaging in self-reflection and acts of kindness and generosity. During the month of Dhu-al-Hijjah, devout Muslims fulfill the fifth pillar of Islamic religious obligation (*hajj*) by making a pilgrimage to Mecca in Saudi Arabia. Two major festivals are universally celebrated by all Muslims; these are *Id al-Adha* (the Festival of Sacrifice), and *Id al-Fatir* (the Festival of Breaking of the Fast). Id al-Adha occurs on the tenth day of the month of Dhu-al-Hijjah, signaling the official end of the hajj pilgrimage with communal prayer and the sacrifice of animals. Id al-Fatir is celebrated for 3 days at the end of Ramadan; it marks the end of a full month of fasting with acts that honor God's benevolence, including feasting, gift-giving, visiting friends and family, and helping the poor.

The Islamic weekly calendar is derived from the Jewish Abrahamic tradition, with each day beginning at sunset. The days of the week are called *yaum al-ahad* (meaning "first day," and corresponding to Sunday in the Christian calendar), *yaum al-ithnayn* (second day), *yaum ath-thulaathaa'* (third day), *yaum al-arbia'aa'* (fourth day), *yaum al-khamis* (fifth day), *yaum-al-jumu'a* (gathering day), and *yaum as-sabt* (Sabbath day). At noon on *yaum-al-jumu'a* (Friday), Muslims gather at a mosque or *masjid* for worship.

Islamic months begin at sunset of the day when the *hilāl* or lunar crescent is first visually sighted. Although this method is still followed in India, Pakistan, and Jordan, visual observations can be inaccurate because of atmospheric conditions or because of the differences in the timing of moonrise across international time zones. Arithmetical astronomical calculations are therefore often used instead to set the calendar and to designate important holy days. In Saudi Arabia and most of the Gulf states, however, the *Umm al-Qura* calendar (based on precise observations of the new crescent moon in Riyadh) is used, causing holy days to be celebrated in that country several days in advance of other Muslim countries. To solve this problem, several prominent Islamic governance councils have since 1419 AH (1998–1999 CE) adopted an updated methodology for calculating the Umm al-Qura calendar that results in a uniform standard for determining Islamic days of observance. Another variant of the Islamic calendar, developed by early Muslim astronomers, is the *Fatamid* or tabular Islamic calendar, which uses arithmetic rules to set out a predictable 30-year cycle of years that has 19 years of 354 days and 11 leap years of 355 days. This calendar is accurate to within 1 day over a 2,500 year period, and is most often used as a way to date historical events or to convert dates between the Hegira and Gregorian calendars.

Helen Theresa Salmon

See also Calendar, Astronomical; Calendars, Asian; Islam; Moon, Phases of; Religions and Time; Time, Measurements of

Further Readings

Feener, M. R. (Ed.). (2004). *Islam in world cultures.* Santa Barbara, CA: ABC-Clio.

Glassé, C. (1991). *The concise encyclopedia of Islam.* San Francisco: HarperCollins.

Hewer, C. T .R. (2006). *Understanding Islam: An introduction.* Minneapolis: Fortress Press.

Kheirabadi, M. (2004). *Islam.* Philadelphia: Chelsea House.

Calendar, Julian

According to legend, the Roman calendar began with Romulus, cofounder of Rome, who had a calendar of 10 months, or 304 days. His successor, King Numa, added 2 months for a total of 354 days and then added another day to avoid the Roman superstition against even numbers. Still, this did not meet the accurate tropical year of 365.242 days.

To fix the inaccuracy, priests added an extra month every 2 years, which came to a total of 366.25 days a year. They also tried to add an intercalary month every 8 years, as a Greek version of the calendar did. This added up to roughly 365 days, but priests often forgot to add extra months when needed. The priests and aristocrats kept the calendar a secret so they could use it to their advantage, adding days or subtracting days to hasten or stall elections. In 304 BCE, Creius Flavius posted the codes to force the priests to publish the calendar as a public document, although the priests still held the power to add extra months.

Julius Caesar became pontifex maximus in 63 BCE, and undertook to reform the Roman calendar. While on campaign in Egypt, Caesar had seen the Egyptians' effective and simple calendar system. By the time he came to power, the republican calendar had drifted more than 3 months out of line. When elected, Caesar recruited Sosigenes and Alexandrian astronomers, along with many other philosophers and mathematicians, to aid in the task of calendar reform.

The first stage of reform began in 46 BCE by adding 2 extra months to bring the calendar back into alignment with the vernal equinox on March 25. In total, the year 46 BCE had 445 days, becoming known by some as the year of confusion, and by Caesar as the last year of confusion. The year 45 BCE then became the first year of the new system, and the date for the beginning of the year moved from March 1st to January 1st.

The length of the new calendar year included an extra 10 days, totaling 365 days instead of 355. The lengths of months were organized starting with January having 31 days and February having 29 days (except every 4th year, or leap year, when February had 30). From February on, months alternated between 31 and 30 days, beginning with March having 31 days. The dates of festivals and holidays stayed the same along with the old system of numbering days according to calends (1st day of the month), nones (5th/7th day), and ides (13th/15th day). Although most of the months kept their traditional names, the senate renamed the month *Quinctilis* as Julius (July) in Caesar's honor.

The calendar helped foster a middle class of traders, bureaucrats, soldiers, lawyers, money lenders, and craftsmen who now could measure time in the civic world of the empire. Because the new calendar was based on science, none could tamper with it for politics. With the new idea of a leap year, the calendar held 365.25 days compared with the actual tropical year of 365.242. This new calendar became the most accurate in the world and lasted until the Gregorian reform in 1582.

Alexandrian astronomers such as Hipparchus and Ptolemy later noticed that the calendar ran 6 hours slow. Roger Bacon also noted this at a later date. The Romans had no concept of a minute, so they could divide the day only into simple fractions for astronomical purposes. But for Caesar, a calendar year's being off by a few minutes or hours meant nothing compared with the former calendar's being off by days and months for the previous 2 centuries. After the death of Caesar, pontiffs began to confuse the leap year rule. Since Romans counted inclusively, they began adding a leap year every 3rd year instead of every 4th year.

To correct the leap year error in the calendar, Augustus Caesar left out all leap years between 8 BCE and 8 CE. To honor him, the senate renamed Sextilis as Augustus and took a day from February to add to his month so his would not be shorter than Julius Caesar's. They then adjusted the lengths of the remaining months by switching the lengths of September through December to maintain a constant alternation. As amended by Augustus, the calendar continued in use until the Gregorian reform.

Bethany Peer

See also Caesar, Gaius Julius; Calendar, Astronomical; Calendar, Egyptian; Calendar, Gregorian; Calendar, Roman; Rome, Ancient; Time, Measurements of

Further Readings

Bellenir, K. (1998). *Religious holidays and calendars.* Detroit, MI: Omnigraphics.

DeBourgoing, J. (2001). *Calendar: Humanity's epic struggle.* New York: Harry N. Abrams.

Duncan, D. E. (1998). *The calendar: History, lore, and legend.* New York: Avon.

Calendar, Mayan

The Mayan calendar, which originated as early as the 6th century BCE, was based in part on the traditions of earlier Central American cultures, including that of the Olmecs. The Mayans made careful observations of the moon, sun, and stars. From their astronomical studies they developed a complex calendar system that allowed them to perform calculations to determine what day of the week a future date would land on.

Despite lacking reliable instruments to establish accurate lengths of time, the Mayans used fixed reference points and matched multiples of lunations, calendar cycles, and eclipse intervals to discover the length of the tropical year and the lunar synodic month. Lacking a system for expressing fractions, they used multiples to express that the length of the tropical year as 365.242 days and the length of the lunar synodic month as 29.530864 days. Whereas the solar calendar used by Western nations such as Rome or Egypt disregarded the phases of the moon, the Mayan calendars included them. With the correlation of two different cycles, the Mayans determined dates of solstices and equinoxes to an accuracy of within one day.

The Mayan calendar system employed a complex correlation of two cycles, the *Haab* and *Tzolkin,* to make the Calendar Round. Each day and month had a name or number and a god associated with it to give the day fortune or misfortune. Mayan priests would weigh gods against one another, and their activities depended on whether or not the day would hold fortune or misfortune.

Haab

The Haab calendar, based on solar observation, structured the planting of agricultural crops. It consisted of 365 days, organized in 18 named months (*Pop, Uo, Zip, Zotz [Zodz], Zec [Tzec], Xul, Yaxkin, Mol, Chen [Ch'en], Yax, Zac, Ceh, Mac, Kankin, Muan, Pax, Kayab, Cumku*) with 20 days each plus *Uayeb,* a 5-day period. The name of each day began with a number from 1 through 20, followed by the name of the month. For example, the calendar would begin with 1 Pop, 2 Pop, 3 Pop, and continue until 20 Pop at which the next month would begin with 1 Uo, 2 Uo, 3 Uo, and continue on through the 18 month names. During the 5 days of Uayeb, considered phantom days or days of misfortune, all activity was avoided while the people waited for them to pass.

Although the Mayans knew the year was 364.25 days long, this calendar ignored that fact and drifted off 6 hours per year. Due to this, the New Year occurred at different times with different points recognized as the beginning. The Haab calendar consists of a circular view of time in which history repeats itself. In the case of the Haab, history repeated itself every 20 years. According to this, the past, present, and future blend together since all will eventually repeat.

Tzolkin

Mayans used the Tzolkin calendar ceremonially, setting the dates for feasts, when to wage war, and when to offer sacrifices. The Tzolkin consisted of 260 days, or 20 periods of 13 days. Days were labeled by using 20 named days and 13 numbers. The 20 named days consisted of *Imix, Ik, Akbal, Kan, Chicchan, Cimi, Manik, Lamat, Muluc, Oc, Chuen, Eb, Ben, Ix, Men, Lib, Caban, Ezznab (Adznab), Cauac, Ahau.* Each of the 260 days had its own unique name through keeping the named days in the same order and counting them off from 1 to 13. After 13, the numbers restart at 1 and the names later restart after Ahau, creating a cycle of new combinations. For example, the calendar would start with 1 Imix, 2 Ik, 3 Akbal, continue to 13 Ben, then the numbers would start over with 1 Ix, 2 Men, 3 Lib, and continue until the names repeated with 7 Ahau, 8 Imix, then continue until the numbers repeated again with 13 Cimi, 1 Manik, and 2 Lamat. This allowed for the calendar to have no official beginning or end until the end of the 260 days, following a cyclical view like the Haab.

The combination of the Tzolkin and the Haab was called the Calendar Round and consisted of 52 years. The day the year began was the year bearer and gave fortune or misfortune to the year. Only 4 days could be the year bearer: Kan the maize god and Muluc the rain god both predicted good years while Ix and Cauac both predicted bad years. Neither the Tzolkin nor the Haab counted the years, since a date in the combined Haab and

Tzolkin would not be repeated for 52 years (beyond the average life expectancy).

Long Count

The Long Count calendar held a linear view of time and allowed for the Mayans to record the time and events. This allowed for the recording of time and events every 20 years on carved stelae by using pictorial inscriptions that included dots and bars. The earliest stele known is correct up to a few hours (date 292 CE, stele no. 29). The calendar measured from the mythological beginning of time (in the Gregorian calendar, 3114 or 3113 BCE) to a then-distant point in the future (Gregorian calendar 2011 or 2012 CE). The 1-year difference in the Gregorian calendar is related to the question of the year 0 between 1 BCE and 1 CE.

Each day in the Long Count calendar is named in terms of two smaller cycles, a cycle of numbers from 1 through 13 and a cycle of 20 names used in a fixed order. The cycle's number system, based on 20, consists of 360 days (a *tun,* or a year). A *katun* equals 20 tun, and because of the layout, a katun could end only on the day of Ahau. Each katun had a ruling god that yielded the same powers each time a katun returned, but only three katuns held good prophecies.

A *baktun* consists of 20 katuns (400 years), and a complete cycle consists of 13 baktuns (5,200 years). The name of this cycle is based on Ahau, the date on which the katun ends. The cycle begins with 13 Ahau and drops 2 with every Katun until the cycle repeats itself (13–11–9–7–5–3–1–12–10–8–6–4–2–13). What is considered a Great Cycle is completed at the end of all 13 cycles; it's said that all things will then cease to exist (2011 or 2012 CE) and a new world will be ushered in with the next Great Cycle.

Bethany Peer

See also Calendar, Aztec; Calendar, Egyptian; Calendar, Roman; Eclipses; Moon, Phases of; Time, Measurements of

Further Readings

Aguiar, W. R. (1978). *Maya land in color.* New York: Hastings House.

Thompson, J. E. S. (1954). *Rise and fall of Maya civilization.* Norman: University of Oklahoma Press.

Calendar, Roman

The Roman calendar was a dating system purportedly enacted by Romulus, the cofounder of Rome, in the year 738 BCE. Originally, the calendar had 10 months and 304 total days. Six calendar months contained 30 days and 4 calendar months contained 31 days. The remaining 61 days that make up our current tropical calendar of 365 days were at that time ignored, falling into an uncounted winter season.

The 10 months of the Roman calendar were called Martinus, Aprilis, Maius, Janius, Quintilis, Sextiles, September, October, November, and December. Numa Pompilius, the second king of Rome, inserted the month of January at the beginning of the year and the month of February at the end of the year. In 452 BCE, February was relocated to its current calendar position between January and March.

Despite the addition of January and February, the calendar was still a full 10.25 days short of the current 365-day calendar year. This shortage caused confusion in seasons and lunar cycles, and time became endlessly out of sync. In an attempt to prevent further misalignment of the calendar and the seasons, an occasional intercalation was performed, allowing for the addition of a 27–28 day month every 2 years. This created an average of 366 days per year when extrapolated every 4 years, and it kept the seasons on track. This practice, also called Mercedonius, comes from the term *merces,* meaning wages, because workers were paid at this time of the year.

This intercalation method continued to cause confusion. Intercalation was an official duty of pontifices, and their reasons for timing of the intercalations often remained secret. Calendars were not public documents, and political tactics to lengthen or elongate the ruling terms of magistrates and other public officials confounded the problems.

In an effort to construct a more sound and incorruptible calendar system, Julius Caesar initiated a calendar reform. In 46 BCE, the Julian calendar was established; it was later modified into the Gregorian calendar now in general use.

Debra Lucas

See also Caesar, Gaius Julius; Calendar, Julian; Calendar, Gregorian; Time, Measurements of

Further Readings

Feeney, D. C. (2007). *Caesar's calendar: Ancient time and the beginnings of history.* Berkeley: University of California Press.

Michels, A. K. (1967). *The calendar of the Roman republic.* Princeton, NJ: Princeton University Press.

Calendars, Asian

In addition to the Gregorian calendar, the solar, or sun-based, standard international calendar of today, a variety of traditional calendars are in common use throughout Asia, depending on the country as well as the religion of the users. The lunar calendar is used mainly for cultural and astrological purposes. Characteristic of lunar calendars generally, the date that marks the beginning of a new year can vary. For those who live in an agricultural society, a solar-based calendar is best suited so that events occur at the same time each year according to planting/harvesting. Yet most calendars were based on the lunar year, which follows the cycles of the moon. The Chinese calendar, and subsequently others in use on the Asian continent, became a lunisolar calendar, one that follows both the sun and the moon, so that, for example, the solar calendar would number the months, while the lunar calendar would be useful for marking dates such as holidays.

Differences among Asian calendars also reflect how cyclical dating and chronology were tied historically to the reign of an emperor or ruling dynasty in that country. Thus, the numbering of a year meant different things in different traditions. Another difference is that the lunar calendar is based on where the moon rises and the time when it rises, leading to different starts of the month in various latitudes. Again, this can cause confusion when using the moon to determine the start of a day, a month, or even a year.

Some of the more common, or well-known, Asian calendars are the Chinese, Japanese, and Singaporean, as well as specific ones such as the Kali Yoga and Parasurama calendars used in Southeast Asia. Today, however, while cultures continue to use their traditional calendars for marking holidays and cultural events, the day-to-day dating of events is based on the Gregorian calendar to ensure that time is observed consistently across cultures.

The Chinese calendar has survived intact for nearly 5 millennia, partially because until the mid-1900s the calendar was considered sacred and thus one needed imperial authority to change it.

Over its long history, India has used many calendars and dating systems that can be split into two basic types—civil, which changed with each regime, and religious, as in the case of those maintained by the Hindus. Although each region had its own Hindu calendar (over 30 different ones), there are some common components. The earliest calendars in India began with a solar year of 360 days split into 12 lunar months, corrected by an intercalating month every 60 months. In 1200 CE, the Muslim calendar came into use for administrative purposes; it was replaced in 1757 with the Gregorian calendar by the British. Yet, throughout this time, each state maintained its own calendar used in daily interactions. Even when an Indigenous government took control in 1947, the difficulties of date interpretation throughout the country continued. Two general Hindu calendars remain in use: the Northern or the Vishnu calendar, which is based on the lunar month beginning with the full moon, while in the Southern calendar the lunar month begins with the new moon. In northern India, the lunar month begins with the full or waning moon, while Hindus in the south of India, the Siva, measure the month from the new or waxing moon. To help avoid some of the date interpretation problems, the two halves of the month are numbered separately, with each half being called a *paksha*.

The Jain calendar has many similarities to the version of the Hindu calendar observed in Northern India. The month begins at the full moon, and month names are the same, although spelling varies. The Jain concept of how time cycles through progressive and regressive eras also differs from that of the Hindus. Jains believe that a complete cycle of time consists of 12 separate units. Of these, 6 represent deteriorating conditions and 6 represent improving conditions. The 3rd and 4th units of both half-cycles represent times when neither extreme predominates.

The Sikh calendar is a lunar calendar that is based on the moon's movement from one zodiac sign into the next, rather than on the phase of the moon, though the dates of some festivals are based on the phase of the moon. The beginning of a new moon is called the *Sangrand.* Sikh festivals are marked on a special calendar called the Sikh Gurupurab Calendar, which begins in March or April. This intercalates an extra lunar month whenever 2 new moons occur within the same solar month. The Sikh lunar calendar is called *Birami* and is 12 months long, with each month averaging 29.25 days.

Buddhism originated from within Hinduism in much the same way that Christianity was derived from Judaism. Similarities between the two include lunar and astrological aspects. Buddhists and Hindus hold similar views on the cyclical character of time. Buddhists view time as an extension of the ever-repeating sequence in nature. Because Buddhist calendars are not associated with a specific civil calendar, the variances among geographical locations are even more pronounced than in Hindu calendars. For example, the method for determining the new year is not uniform; some begin with the full moon of Taurus, while the Tibetan Buddhists, whose calendar has been heavily influenced by the Chinese, begin their calendar at the full moon nearest the midpoint of Aquarius. In Vietnam, they begin at the new moon in Capricorn. As Buddhism spread outside of India, the two dominant traditions, Mahayana (in the West of India) and Theravada (in the East of India), became prominent in separate regions.

The structure of certain traditional calendars can also vary according to the needs of the culture, such as fishing or traveling for trade. The fishermen of Botel-Tobago Island (near Taiwan) had failed to observe the expected rising of the flying fish during a particular season. To solve the problem of keeping a calendar in step with both the moon and the seasons, they inserted an intercalary month when their own lunisolar calendar fell too far behind. Their fishing season was then postponed during this extra month.

Sara Marcus

See also Calendar, Islamic; Islam; Moon, Phases of; Time, Measurements of; Zodiac

Further Readings

Bellenir, K. (Ed.). (1988). *Religious holidays and calendars: An encyclopedic handbook* (2nd ed.). Detroit, MI: Omnigraphics.

Holford-Strevens, L. (2005). *The history of time.* Oxford, UK: Oxford University Press.

Richards, E. G. (1998). *Mapping time: The calendar and its history.* Oxford, UK: Oxford University Press.

Schendel, W. v., & Nordholt, H. S. (2001). *Time matters: Global and local time in Asian societies.* Amsterdam: VU University Press.

Welch, P. B. (1997). *Chinese new year.* Oxford, UK: Oxford University Press.

Zachary, H. (1957). *Wheel of time.* New York: Thomas Y. Crowell.

Calendars, Megalithic

Calendrical devices of a megalithic nature are found in many areas where early civilizations took root. These are exemplified by the huge stelae produced by the Mayan people of Mexico and Central America on which were recorded astronomical and mathematical data, such as the Long Count, that covered more than 4,000 years. Indeed, it appears that Mayan buildings even had astronomical orientations directed at celestial risings or settings on the horizon. Others were aligned so that shadows would cast images, such as the serpent on the Castillo at Chichen Itza. This pyramid also has four staircases of 91 steps that, with the top platform, combine to make 365—the number of days in the year. The Egyptian pyramids have remarkably accurate north/south—east/west alignments. Although these may not have been calendrical, they do seem to have been based upon either the rising and setting or vertical alignments of polar stars, and "star clocks" appear to have been painted upon the ceilings of some Egyptian tombs. Star paintings with astronomical alignments also have been found in megalithic tomb mounds in Japan. In China the Imperial Forbidden City is oriented on a north/south axis with the Temple of Heaven. The Emperor would follow this path on the winter solstice to perform rituals to guarantee the return of longer days. In Kenya a series of stone pillars called *Namoratunga* and bearing Sudanese Kushite engravings line up with conjunctions of the moon with various stars around 300 BCE. There are many other examples of archeoastronomy to be found, but not all are megalithic in nature. In recent decades, however, research has come to indicate that much more ancient megaliths found in western Europe, long believed by local peasantry to be petrified giants, giants' tables, beds of legendary heroes, or just ancient curiosities of unknown use to others, may have served as solar or lunar calendars to the prehistoric farming peoples of the Late Stone Age and Early Bronze Age.

In the most literal sense, *megalith* means very large stone (μεγα λιθος) in Ancient Greek. In the archeological sense, megalith refers to massive block-like stones that have been arranged into simple or complex architectural constructions, most often referent to the Neolithic (or "New Stone") and Bronze Ages of western Europe (although megalithic architecture is known from later periods, also, and is a worldwide phenomenon, as described above). The simplest type of megalith is the upright standing stone, or *menhir.* The name comes from the Welsh *maen,* meaning "stone," and *hir,* meaning "long," thus menhir means "long stone," and it is synonymous with the Breton *peulvan* (related to *pol* in Gaeilge, as in *Pol na Brone,* the Dolman of the Sorrows in the Burren of County Clare, Ireland). Sometimes menhirs are solitary objects; sometimes menhirs are arranged in groupings, or alignments, that range from just a few stones to more than a thousand, set in long rows, as at Carnac in Brittany and Callanish on the island of Lewis in the Scottish Hebrides, which are parts of gigantic alignments that may be calendrical in nature.

Ogham Stones

Ogham stones, found in Ireland, are megalithic menhirs that were incised in the Late Iron Age with horizontal or diagonal grooves on the corners in precise patterns that represent letters and numbers. It is believed possible that they also were done in (now decayed) wood, as the names preserved for the "letters" are those of tree species: The Ogham letter ├ corresponds to 'B' and is called *beith* in Irish, meaning 'birch,' ╞ corresponds to 'L' and is named for rowan (mountain ash); ┤ corresponds to H and is called after 'hawthorn;' ╡ corresponds to 'D' and is named after 'oak;' † stands for 'A' and represents 'pines/firs;' ǂ is 'O' and refers to gorse; and " corresponds to 'EA' and is called after 'aspens,' to give a few examples (the vertical line down the center of each symbol is the corner of the stone). The stones are believed to have been carved to commemorate people or events, mainly because most of the inscriptions are chiefs' names and dates. It is likely that the dates carved into these stones are not the dates of erection, however, as that would be anachronistic: the Late Iron Age dates are several millennia after the probably Neolithic times of construction.

Dolmans

A more complex type of structure is the *dolman,* or stone table (sometime called *cromlech*). These were burial chambers that consisted of upright megaliths covered by flat capstones, most likely sheltered within earthen mounds (*tumuli*) in antiquity, although most mounds have eroded away after 4 to 7 thousand years of weathering. Sometimes the chambers

Legananny Dolman in Ireland: Dolmans were burial chambers that consisted of upright megaliths covered by flat capstones, most likely sheltered within earthen mounds in antiquity, although most mounds have eroded away after 4 to 7 thousand years of weathering.

Source: PD Photo.org.

are elongated into galleries, and they may have small entry courtyards and transected internal vaults with corbelled ceilings as at Newgrange.

Druid Temples?

In 1648 English antiquarian John Aubrey (1626–1697) saw the megaliths around the British countryside as components of a massive prehistoric temple. He proceeded to conduct research at Avebury, Stonehenge, Wayland's Smithy, and other ancient sites that led him to describe them as *Templa Druidum,* or Druid temples. This view was seconded in the 18th century by fellow antiquarian William Stukeley (1687–1765) in two books, one about Avebury, the other about Stonehenge, published in the 1740s.

Despite Aubrey's and Stukeley's druidic provenance for megalithic constructions, and notwithstanding the popular French cartoon strip *Asterix,* in which an ancient Gaulish character, Obelix, frequently is shown to be transporting and erecting megaliths, the Celts were not responsible for the creation of the Western European megaliths. Celtic culture is archeologically accepted to have arisen in the first millennium BCE, and the megaliths of Western Europe are considerably older than that—some on the order of 4,000 to 5,000 years. Although the Celts and their priests, the Druids, did not build megalithic structures, according to some classical sources they did worship and sacrifice at them, just as do some modern people, who did not build the megaliths either. Although the people that we call the Celts did not build them, their ancestors may have, as modern DNA analysis has shown a continuous link between the peoples of Western Europe from the Stone Age to today.

Calendrical Hypothesis

In 1955 an engineer and amateur astronomer, Alexander Thom, presented a paper on his statistical analysis of 250 megalithic monuments, most of them in Scotland and Wales, that he believed showed considerable astronomical and geometric understanding on the part of their Neolithic builders. In addition to a celestial map that aligned the monuments with the horizon, Thom found what he believed to be a Middle Bronze Age solar calendar that was divided into 16 parts, or "months," that included four 22-day months, eleven 23-day months, and one 24-day month. This would divide the four annual quarters between the solstices and equinoxes into four yet smaller quarters per season. These four smaller quarters, or sixteenths, are Thom's "months." Although this idea was rubbished by archeologist V. Gordon Childe, it formed a springboard for further inquiry into the calendrical hypothesis.

Stonehenge

Perhaps the best-known megalithic site is also the one that best demonstrates the calendrical hypothesis: Stonehenge. Stonehenge is a truly impressive example of Late Neolithic/Early Bronze Age megalithic architecture. Although it began as a simple circular banked ditch in the late 4th millennium BCE when the entrance and the Heel Stone were erected, the bulk of what today is visible at Stonehenge was constructed from approximately 2000 BCE to 1500 BCE. Because Stonehenge was built by an agricultural society, knowledge of solar and lunar aspects is believed to have been considered vital to survival because it provided more or less reliable indicators of when to plow, plant, sow, and reap. The latitude on which Stonehenge rests is the one where the sun and moon form perpendicular aspects, a phenomenon reflected in the shape of the monuments and their surrounding fixtures. The Avenue from the great circle lines up with the 6-meter–high Heel Stone like the sites on a gun barrel, the target being the rising sun on the summer solstice.

During the second phase of construction a series of 56 holes ranging in size from 0.8 to 1.8 meters, called Aubrey Holes after John Aubrey's mention of them in his *Monumenta Britannica,* were cut in the chalk bordering the embankment to hold vertical timbers. In the third phase the bluestones, weighing between 1 and 1.5 tons, were brought to the site from the Prescelly Mountains of Wales 225 kilometers distant and raised in the center of the circle. The gigantic sarsen trilithons (sets of three stones estimated at about 30 tons each, forming huge upside down U's) were raised in the fourth phase of construction in the Early Bronze Age. The solar connection associated with Stonehenge is significant here in that it is in the Bronze Age that Welsh Celtic specialist Miranda Green sees the rise of a sun cult based upon solar symbols found on art and artifacts from this time.

In 1961, astronomy professor Gerald Hawkins used an IBM 704 computer to plot 120 pair of points against celestial positions to investigate what he believed to be the purpose of the monument: an astronomical computer to calculate, among other things, the solstices and lunar eclipses. Hawkins had expected to find solar alignments at Stonehenge, but the lunar alignments came as a surprise to him. Hawkins concluded that Stonehenge formed an astronomical observatory designed to predict lunar eclipses in a 56-year cycle that included two segments of 19 years and one of 18 years, based on the original Stonehenge's 56 Aubrey holes and the 19 bluestones of the horseshoe. The two smaller circles of holes, the Y and Z holes within the ring of Aubrey Holes, add up to 59 holes, or two lunar months of 29.5 days each. Continuing the 29.5-day lunar month theme, the ring of 30 Sarsen stones contains one that is quite a bit smaller than the rest, making the number essentially 29.5—once again a lunar month, and this pattern is repeated in the Bluestone Circle. Although some archeologists, notably Richard Atkinson, who was known for his work at Stonehenge, strongly disagreed with Hawkins, it is ironic that astronomers such as Fred Hoyle found his work to be the impetus for even further calculations. Brian M. Fagan argues that Stonehenge never was a device for calculating eclipses, but that it only *implies* the idea of time as reflected in the celestial cycles observable to its builders. To put it somewhat simplistically, following the publication of Hawkins's *Stonehenge Decoded,* the archeologists tended to side against him, while the astronomers tended to side with him.

Although it usually is the summer solstice sunrise above the Heel Stone that gets much of the commentary when discussing the astronomical nature of Stonehenge, Julian Richards argued on his BBC television archeology series, *Meet the Ancestors,* that it was the winter solstice, *not* the summer solstice, that may have been more important to the builders. According to Richards, the Avenue is just that—an avenue to the site from which to view the winter solstice, not a sight down which one would view the summer solstice sunrise. Rather than looking down the avenue to the Heel Stone, we should be looking in the opposite direction, through the largest trilithon, at the winter solstice sunrise when the image between the uprights is split like a window, and the sun rises through the upper part of the image as in the window, or Roof Box, at Newgrange in Ireland.

Newgrange

Newgrange, Knowth, and Dowth are the three megalithic passage tombs, or fairy mounds *(sidh),* found on Newgrange Farm in the Boyne valley, or *Brú na Bóinne* (Palace or Mansion of the Boyne), north of Dublin and about 8 kilometers west of the town of Drogheda, near Slane, in County Louth. At Knowth, one of the slabs is carved with an intricate scalloped design resembling a zodiac and is known as a "sundial." The best known of the three megalithic monuments is Newgrange, built in the late 4th millennium BCE. The massive mound covers an area of over one acre and is surrounded by 97 carved curb stones. The mound had eroded badly until it was reconstructed forensically through trial and error by its excavator, Michael J. O'Kelly, between 1962 and 1975. Surrounding the mound were a series of white quartz stones that were believed by some to have been a ceremonial road. O'Kelly noted their locations and, suspecting that they formed part of a wall, reconstructed the wall repeatedly, tearing it down each time until the stones fell into the positions where they were found to begin with. This, he decided, was the original design, which he then reconstructed.

Germane to the subject being discussed here, the great entry stone at Newgrange is carved with a number of spirals reminiscent of Vincent Van Gogh's painting *Starry Night,* and indeed this is known as a "celestial motif," although the spirals may represent the sun's passage across the heavens, not stars. Behind the stone is an entrance surmounted by a window, or "Roof Box." Normally the corbelled, cruciform vault at the end of the upward-sloping 19-meter–long passage is completely dark. However, for 2 days on either side of the winter solstice the interior is illuminated just before nine a.m. for about 17 minutes by a shaft of sunlight that enters the Roof Box and travels up the passage as far as the basin stone in the corbelled vault (a parallel phenomenon can be observed in the Sun Dagger at Chaco Canyon, New Mexico). Designs similar to Newgrange, complete with carved upright stones, can be observed at Loughcrew in County Meath, Ireland, and at Gavrinis in Brittany, France, built nearly a millennium earlier. Not far from Gavrinis is Carnac, an immense site in Brittany consisting of row upon parallel row of menhirs that seem to be aligned to both the sun and the moon, although whether or not they represent anything of a calendrical nature is unclear.

Michael J. Simonton

See also Anthropology; Archaeology; Chaco Canyon; Eclipses; Observatories; Solstices; Stonehenge; Time, Measurements of

Further Readings

Childe, V. G. (1980). *Prehistoric communities of the British Isles*. New York: Arno Press.

Daniel, G. (1963). *The Megalith builders of western Europe*. Baltimore, MD: Penguin.

Fagan, B. M. (2000). *Ancient lives: An introduction to archeology.* Saddle River, NJ: Prentice Hall.

Hawkins, G. S., & White, J. B. (1965). *Stonehenge decoded*. New York: Doubleday.

McMann, J. (1993). *Loughcrew: The cairns*. Ireland: After Hours Books.

Mohen, J.-P. (1999). *Megaliths: Stones of memory.* New York: Harry N. Abrams.

Piggott, S. (1965). *Ancient Europe: From the beginnings of agriculture to classical antiquity.* Chicago: Aldine.

Ruggles, C. (1999). *Astronomy in prehistoric Britain and Ireland*. New Haven, CT: Yale University Press.

Thom, A. (2003). *Megalithic sites in Britain*. Oxford, UK: Oxford University Press.

Wernick, R. (1973). *The monument builders*. New York: Time-Life Books.

Calendars, Tribal

The advancement of tribal peoples from rudimentary to scientific calendars reveals their intent to live a harmonious existence with the celestial bodies, and demonstrates the significance of stellar movements for tribal societies in forecasting seasons of harvesting, hunting, and fishing times, and ritual observances. These dedicated prehistoric observers of the sky were the precursors of modern astronomers.

Throughout the world, prehistoric astronomers reverently observed "the sacred sky"; their legends were affiliated with the stellar movements in concurrence with the changing seasons. Their attentive tracking guaranteed the precise timings of rituals and times of the year, which not only helped advance their societies toward the institution of accurate calendars but also gave rise to distinct cultures and customs, tribal lifestyles, and worldviews. In the beginning, oral tradition transmitted this knowledge from one generation to the next; the employment of simple measures progressed and diversified into complex and concrete means such as alignment fixtures and symbolic petroglyph recordings. A prestigious position was to monitor these devices and interpret their significance; this responsibility was accorded to a skilled and sanctioned authority, the shamans and priests. Among the Lakota, this was the Keeper of the Counts; among the Zuni, the Sun and Bow Priests; and in the Cherokee tribe, the Day Keeper.

Other planetary cycles were also observed: The Evenks of Siberia tracked the season of the Cosmic Hunt of Ursa Major, or the Great Bear; the Dogon tribe of West Africa kept observations of Sirius; the Pawnee monitored the "White Star Woman" or Venus; the Kahuna Priests of Hawai'i tracked the 223-month eclipse cycle. Daily measurements of time were overseen according to the available location: The Chacoans calculated the day's passing via shadow castings upon the pueblo terraces, while the Salish tribes gauged daily time by observing the ebb and flow of tidal fluctuations. The counting of winters appears to be the universal standard for yearly calculations, though some circumpolar peoples counted a winter year and a summer year.

Seasonal Documentation

Tribal astronomers have created artistic engravings and paintings as reminders of seasonal occurrences, such as the carved baton remnant discovered at Lorthet (Hautes-Pyrenees) bearing reindeer, jumping salmon, and two triangles that scholars theorize as seasonal indications; in Alaska, the season of salmon arriving in a thick blanket of fog is represented upon Tlingit totems and longhouses with "Fog Woman"; the Yakutia rock drawings of Siberia illustrate the Cosmic Elk constellation, which appears in March, foretelling the return of the sun. The Lakota used painted buffalo hides to record extraordinary astronomical occurrences. Also, star maps on cave ceilings from the Old and New Worlds depict stellar illustrations, circles within circles for the sun, or animals such as elk to represent constellations.

Knotted cords were frequently implemented to chronicle time; the Peruvians created the *quipu,* an intricate system consisting of a rope and attached cords with elaborate knot arrangements. In addition, methodical engravings of notches or drilled holes were universally employed for tallying days, months, and even years; such as the notches upon certain kiva walls in Chaco Canyon for lunar and equinox observances, allowing a sunbeam or moonbeam to glide over the markings to record significant days. Scored trees, for instance, were used by Papua New Guinea tribesmen to calculate lunar months; and the scoring of sticks was utilized by tribes like the Pawnee for makeshift calendars to record days, months, and years. Engraved bone artifacts from the European Upper Paleolithic cultures have been decoded by Alexander Marshack, who posits these markings to be lunar-phasing notations. The Indigenous tribes of the Nicobar Islands utilized chevron hatches and crosshatches for lunar calculations; while on Easter Island the Mamari illustrated tablet represents lunar phases. Winnebago calendar sticks have been used to calculate important dates, such as for planting and for ceremonies.

Cycles

The tribal concept of time concerning lunar phases can be seen in two devices: a 12-moon/month calendar that adds an intercalary moon when appropriate to balance the year; and a 13-moon calendar that removes a month when required. With continued observation of the sun and various constellations, a standard developed to track a more linear concept for a 365-day year. The Mayans' and the Chacoans' celestial concepts envisaged numerous cycles operating simultaneously; for example:

Moon's phase: 29.53 days

Tzolkin (Mayan): the sacred year (nine 28-day months of gestation) or 260 days

Calendar Round (Mayan): 18,980 days or 52 years

Lunar declination (Chacoan): 18.6 years

Months and Years

The nomenclatures of months (or moonths) tend to be epithets of natural occurrences. For the Tlingits, "when the black bear cubs are born"; for the Sioux, "Moon of Strawberries." Months were also named for activities: for example, among the Aleuts, "dried skins being eaten due to lack of food," and the "month of months" when their potlatch celebrations took place. The months were also named for the seasons: (Japanese) "Harmony—Happy Spring," or "Autumn Long Month"; the Japanese year also contained 24 *ki* or "solar terms." Many times, months or seasons overlapped one another.

The New Year was celebrated at various times by tribal people; many observed this occasion at spring. For the Tlingit, the initiation of the summer salmon run indicated a new year had begun; the New-Fire celebration in November hailed the new year for the Pueblo people; and the setting of the constellation Pleiades signified the new year for the Cherokee, with celebrations on the following new moon, near the beginning of November.

Archaeoastronomy and Megalithic Calendars

Mountains have been known to represent the cosmic womb for certain cultures. Some tribal homes were fashioned to look like a womb, with their doors facing eastward for the arrival of the sun. The Lakota tipi itself symbolizes the sun. Creating permanent structures to calculate time became the logical progression in astronomy. Rocks appear to be the first astronomical calendars, such as the Sahara Stonehenge of the Nabta culture, which anthropologist J. McKim Malville posits to be the oldest astronomical megalithic alignment. Megalithic circles such as the Lakota Medicine Wheels and the

Washington Skystone: Equinox line—center. Summer solstice—right. Winter solstice—left. North to South line—2nd right of equinox line.

Source: Photo by Jerry Hedlund.

British megalithic sites are known to have solar and lunar orientations; in addition, the numerous mounds and "earthworks" of Mesoamerica are also documented with solar and lunar alignments. Many of the archaeoastronomy pueblos or "Great Houses" at Chaco Canyon were constructed with solar, lunar, and planetary alignments; the geographical placement of each Great House is also postulated to have stellar relationships. A unique megalithic calendar in the state of Washington, named "Skystone" by astronomer Jerry Hedlund, utilizes grooves and indentations on the massive boulder to observe the solstices and the winter and summer rising of Sirius.

Pamela Rae Huteson

See also Anthropology; Calendar, Aztec; Calendar, Mayan; Chaco Canyon; Creation, Myths of; Mythology; Navajo; Pueblo; Religions and Time; Sandpainting; Time, Measurements of; Totem Poles

Further Readings

Brown, P. (1976). *Megaliths, myths & men.* New York: Taplinger.

Goodman, R. (1992). *Lakota star knowledge: Studies in Lakota stellar theology.* Rosebud, SD: Sinite Gleska University.

Hobden, H. J. (1985/1986). *Time before clocks. The captive moon—Part 2 as a timekeeper.* Retrieved August 30, 2008, from http://homepage.ntlworld.com/heather.hobden1/timebeforeclocks.htm

Siverts, H. (1995). Campesino time and space in Mesbilja, Chiapas. *Folk: Journal of the Danish Ethnographic Society, 36,* 91–107.

William, R. A. (1984). *Living the sky: The cosmos of the American Indian.* Boston: Houghton Mifflin.

Calvin, John (1504–1564)

The French-Swiss Christian theologian John Calvin was, like Martin Luther and Huldrych Zwingli, a major Protestant reformer. He was the founder of the so-called Calvinist mode of Protestantism, a precursor of modern Protestant Christianity not only in France but in the entire Western world. As ecclesiastical leader in Geneva for several decades, he shaped a very pious and stringent way of civic living. His theology of predestination strongly influenced religious conceptions of time in terms of human salvation.

Life and Works

Calvin was born as Jean Cauvin on July 10, 1509, in Noyon, in the Picardie region of France, as the son of an influential legal assistant to the bishop of Noyon. At the age of 14 he enrolled in the colleges De la Marche and Montaigu, both parts of the University of Paris. Though initially he intended to study theology after he had acquired basic knowledge in Latin and the liberal arts, he prevailed in his decision to study law in the central humanistic law schools Bourges and Orléans, from 1528 to 1531. In Orléans, he attained a doctoral degree. But after the death of his father, Calvin decided to give up jurisprudence and to attend the Royal College in Paris to study Greek and Hebrew languages and the history of antiquity. Here he authored his first published work, a comment on Seneca's *De clementia.*

After a Lutheran speech by a friend of his whom he was said to have influenced, Calvin was forced to flee from Paris in 1533. As a matter of principle he renounced the benefices of the Catholic Church in Noyon, arranged by his father. He had to escape a second time when the king authorized the prosecution of (Zwinglian) Protestants.

Upon his arrival in Basel in 1535, the highly intellectual Calvin began to study theology, already influenced by the spirit of Renaissance humanism as embodied in the work of Desiderius Erasmus and other leaders of the Reformation: Luther, Zwingli, and Philipp Melanchthon. Calvin began to write about theology, starting with a preamble to a translation of the Bible into French by his cousin Pierre R. Olivétan. The next year, Calvin himself set out to influence the whole Protestant movement by the release of a first version of his *Institutio Christianae Religionis* (Institutes of the Christian Religion) that, although somewhat immature, nonetheless attracted considerable attention. Within his *Institutes,* Calvin developed his ideas about predestination.

During 1536, the Protestant Reformer Guillaume Farel insistently asked and finally convinced Calvin to join his enterprise to encourage the Reformation in Geneva. After several months of religious teaching in the Cathedral, he became a priest and soon published a first *Catechism.* Because they proved to be too restrictive in their postulations in face of the governing council and in their parochial obligations to the citizens, Farel and Calvin were ejected from Geneva in 1538.

Until 1541, Calvin stayed in Strasbourg where the Reformist Martin Bucer had persuaded him to act as lecturer and preacher in a French fold. In 1540, he married the widow Idelette de Bure in defiance of the celibate habits of the clergy and published his *Comment on the Letter of Paul to the Romans*. In Strasbourg, he met Melanchthon.

Also in 1540, the town council invited Calvin to return to Geneva. Boosted by his meanwhile European-wide role as a major Reformist, Calvin did not accept until the council granted broad rights to him, in particular to impose his reforming but very strict constitution *Ecclesiastical Ordinances of the Church of Geneva* in 1541. A powerful Consistory was established and soon evoked the citizens' resistance. In the period until 1554, in which he released a second version of his *Catechism,* Calvin several times feared being banned again from Geneva because of his rigorously religious order. The constitution of the almighty clerical Consistory reflected Calvin's conviction of the prior authority of the clergy over any secular governance.

Calvin left a lastingly negative impression on many admirers of the Reformation by his betrayal of the Spanish preacher Michael Servetus when he passed through Geneva on his flight from Catholic persecution. Calvin paved the way for Servetus's conviction to death. This happened to occur in the turbulent year of 1553 when Geneva was struggling with masses of incoming religious refugees. After his election to the town council, Calvin's predominance was stabilized definitively, leading to and in turn strengthened by a massacre under the leaders of the opposition against his theocratic regime.

During the following years, Calvin concentrated on writing comments to nearly the entire New Testament and on corresponding with the other leading Reformists. Furthermore, he founded the Genevan Academy with the intention to teach young Protestant theologians according to Calvin's humanism and exegesis of the Bible. The Academy is considered very important in the success of the spread of the Reformation across Europe.

John Calvin died on May 27, 1564, in Geneva, after grave and chronic illness and was buried according to his own wish anonymously and without any ceremony.

Theology

The undoubted sovereignty of God and the authority of the Bible are central in Calvin's theology. Human existence arises solely from obedient belief, and humankind is ordained to live in devotion and modesty; with these principles Calvin shaped a source of Puritanism. By his appraisal of modesty and effort and in the belief that economic success shows the goodwill of God, Calvin influenced the economic motivation of Western societies to this day.

Calvin's doctrine of predestination maintains that some people are destined for salvation whereas others are not, and there is no way to interfere with this predestination. Humility, piety, expiation, and preparation for a spiritual rebirth for the sake of achieving a good future life should dominate the present pursuit of happiness. A sober abnegation of man's present estate is a consequence of Calvin's theology.

Matthias S. Hauser

See also Bible and Time; Christianity; Determinism; Last Judgment; Predestination; Predeterminism; Religions and Time

Further Readings

Calvin, J. (2000). *Concerning the eternal predestination of God*. London: James Clarke/New Impression. (Original work published 1552)

Parker, T. H. L. (2007). *John Calvin: A biography*. Louisville, KY: Westminster John Knox Press.

Reyburn, H. Y. (1914). *John Calvin: His life, letters, and work*. London: Hodder and Stoughton.

Thornton, J. F. (Ed.). (2006). *John Calvin: Steward of God's covenant: Selected writings*. Vancouver, BC, Canada: Vintage Books.

Campanella, Tommaso (1568–1639)

Born in 1568, in Stilo, Calabria (Southern Italy), Giovanni Domenico Campanella attracted attention and caused controversy as a Dominican monk, natural philosopher, political theorist, and utopian writer. Some of Campanella's most popular works include *Philosophy Proven by the Senses* (1591), *Selections* (poetry, 1622), *A Defense for Galileo* (1622), *The City of the Sun* (1623), *The Great Epilogue* (1623), and *Metaphysica* (1638). Showing a great fascination with natural science, astronomy, astrology, mathematics, and "natural" magic, Campanella worked these subjects into his writings on philosophy and theology. Campanella's concept of time is interwoven with his understanding of creation and eternity and their connection with God as creator.

Campanella entered the Dominican order in 1583 and adopted the name Tommaso in honor of Thomas Aquinas. In his studies, the young monk quickly disagreed with the traditionally accepted Aristotelian philosophy and began following the work of Bernardino Telesio (*On the Nature of Things*). Campanella wanted to strip away the writings of the popular Greek philosophers and examine the natural world through the human senses. The empiricism and beliefs that Campanella embraced, however, contained weaknesses and contradictions.

For Campanella, every human being, animal, and plant consists of three "primalities." As created beings, humans reflect the three-part nature of God, as Father, Son, and Holy Spirit, and consist of body, mind, and soul, as opposed to the Aristotelian dualist nature of body and soul. Therefore, Campanella's writings reflect the emerging Renaissance philosophy and contain themes of occultism, "natural" magic, animism, and pantheism. These philosophies and beliefs raised suspicions within the Roman Catholic Church about this Dominican monk's writings. Suspected of heresy and treason, Campanella underwent several Inquisition trials and periods of imprisonment from 1592 to 1626. Between his imprisonments, Campanella traveled throughout France and Italy and wrote voluminously. In 1597, authorities arrested Campanella for his association with and leadership of a political conspiracy to establish a new political order, following his utopian ideas (laid out in *The City of the Sun*), of a theocratic monarchy. Although Campanella spent 8 years in Rome following his imprisonments, he fled to Paris, France, in 1634, for safety and gained acceptance in the scholarly community until his death in 1639.

Although *Philosophy Proven by the Senses* and *City of the Sun* express and describe Campanella's philosophical and political framework, Campanella's *Great Epilogue* and *Compendium* provide the most in-depth look at time and eternity. In these works, Campanella defines time as "the successive duration of things." The Eternal God created time when he created the temporal universe, and the changes and mutations that occur in the world, such as the young becoming old, prove the succession of time. Campanella defines eternity as "the permanent duration of the Maker, without a before or after" (or a past or future). These two concepts contrast with Aristotelian thought, which says that time relates only to human activity and that the world exists as an eternal universe. Therefore, Campanella understood time as created with the world and representing the continual movement and flow of nature.

Campanella's literary contributions reflect the philosophy and ideas of the Renaissance and the Scientific Revolution, promote intellectual freedom, and support a political utopia of equality and ideal living conditions. The Dominican monk's works pertaining to time and eternity also presented challenges to traditional worldviews and incorporated theology and empiricism.

Leslie A. Mattingly

See also Aquinas, Saint Thomas; Bruno, Giordano; Eternity; Galilei, Galileo; God as Creator; Metaphysics; Nicholas of Cusa (Cusanus)

Further Readings

Blackwell, R. J., & Cro, S. (1999). Campanella, Tommaso. In *Encyclopedia of the renaissance, Vol. 1* (P. F. Grendler, Ed.). New York: Scribner.

Bonansea, B. (1969). *Tommaso Campanella: Renaissance pioneer of modern thought.* Washington, DC: Catholic University of America Press.

Ernst, G. (2005). Tommaso Campanella. *The Stanford encyclopedia of philosophy* (J. Kraye, Ed. & Trans.). Stanford, CA: Stanford University Press.

Headley, J. M. (1997). *Tommaso Campanella and the transformation of the world.* Princeton, NJ: Princeton University Press.

Ponzio, P. (2001). Tempus, aevum, aeternitas in the philosophy of Tommaso Campanella. In P. Porro (Ed.), *The medieval concept of time: Studies on the scholastic debate and its reception in early modern philosophy.* Boston: Brill.

Carroll, Lewis (1832–1898)

Lewis Carroll is the pseudonym of the Reverend Charles Lutwidge Dodson, an English writer and mathematician who is perhaps most famous for his much acclaimed books, *Alice's Adventures in Wonderland* and *Through the Looking Glass.* One of the most intriguing aspects of his writing is the relative suspension of time that occurs as is evident in how Alice and other characters continue to react to one another without consequence. In other words, there appears to be little attention to the temporal dimension of a cause-and-effect relationship. This is further evident in that little time actually passes in the time from when Alice begins her adventure to when she returns home.

From the beginning of *Alice's Adventures in Wonderland*, Carroll introduces a dimension of time. As Alice falls asleep and enters her dream, she observes an extraordinary white rabbit that she follows in part because she is curious about a rabbit who keeps time, especially with an oversized pocket watch. As she enters the rabbit hole and begins falling, she begins to question how long and how far she has fallen. She finally gives in and claims she will just see where she lands. Carroll's oblique commentary on Victorian society, and to some degree our own, is based on a cultural tendency to become preoccupied with how long a task takes instead of with the task itself and the end result.

Dream-induced stories offer us a fantasy and with that a suspension of how ordinal time is kept. Although Alice appears concerned with having to get back—her cat Dinah may miss her—she enters Wonderland by falling asleep with little awareness of how much time has passed. The timekeepers become integrated into the story in a way that offers the possibilities of traversing the time-space barrier. In the case of Alice, she is in a world where un-birthdays are celebrated, where tea time is any time, and where rabbits—creatures we would normally think of as devoid of time-related concerns—are timekeepers. The White Rabbit, as he is known, even carries a large pocket watch to continually remind him of his lateness.

Carroll recalls the afternoon that inspired this writing as one that spun on forever—as if he had lost track of time—"all in a golden afternoon." He continues, "the why of this book cannot and need not be put into words." It is arguable that Carroll wrote *Alice* to suspend his mind from his everyday work in mathematics. He kept these two worlds separate and reacted harshly whenever asked to comment on the other aspect of his life when not in that context.

Carroll dismissed many of the interpretations of his work, calling for children's minds and dreams to be the true interpreters of his work. Children have very little sense of time and rely on an innate sense of enjoyment to engage in their pastimes and activities. Yet elements of time are evident in how his characters come to life and often perform a satirical narrative of contemporary society. Culturally, we become socialized by the clock and rely on it as an instrument that ends up determining our pleasures and pastime activities. Carroll's readers enter a world where the opposite of what is expected occurs. For example, in *Through the*

Looking-Glass, Humpty Dumpty explains the idea of un-birthdays on 364 days of the year—allowing individuals not to have to wait a year between celebrations. Instead, time is not relevant for when celebrations can occur, opening up the option for celebrations to occur without anticipation of or waiting for a specific calendar event.

Given that Carroll neglected to embrace interpretations of his work, his writing remains a topic of interpretation among literary, political, cultural, social, and philosophical scholars. He opened up a world of intrigue by offering a realistic environment that exists in Alice's dreamlike state. As past and present generations have, future generations will continue to look on his work as wondrous literature that offers much for contemporary culture to interpret.

Erin E. Robinson-Caskie

See also Dreams; Novels, Time in; Rip Van Winkle, Tale of; Time, Relativity of

Further Readings

Carroll, L. (1865). *Alice's adventures underground.* London: Dover.

Carroll, L. (1995). *The complete, fully illustrated works.* New York: Gramercy Books.

Carroll, L., Gardner, M., & Tenniel, J. (1999). *The annotated Alice: The definitive edition.* New York: Norton.

Hudson, D. (1995). *Lewis Carroll.* London: Constable.

Cartan, Élie Joseph (1869–1951)

Élie Joseph Cartan was a French mathematician and physicist, outstanding especially in the area of differential geometry and group theory. He worked in various French universities, including in the period 1912–1942 as professor at the Sorbonne in Paris. He is among the principal architects of the modern rebuilding of differential geometry, which allows the expression of its concepts and laws without the use of coordinates. Among others, he introduced the general notion of differential form in the manner used up to the present day.

A significant contribution of Cartan to the theory of time is his geometric formulation of the Newtonian theory of gravity (1923). The Cartan theory is based on four-dimensional spacetime with Newtonian absolute time (see entries on Relativity) and with Euclidean geometry in the three-dimensional sections connecting simultaneous events in spacetime. Space—in contrast to time—is here not absolute, and the principle of relativity is extended to the arbitrary translatory motions of systems of reference. In Cartan's formulation, the functioning of gravity is expressed by help of some connection with the curvature of spacetime. Consequently, spacetime with gravity is curved by course of connection, and not by course of metrics.

The Cartan connection is bound to mass density in such a way that the validity of Newton's law of gravity is assured, and it is bound to space metrics and time metrics in such a way that the validity of Euclidean geometry of space and the existence of absolute time are assured. The necessary axioms form a somewhat complicated system (discussed in detail in the first volume of Charles W. Misner, Kip S. Thorne, and John A. Wheeler's monograph *Gravitation*). They make it possible to compare the essential features of Newton's and Einstein's gravity theories directly. Whereas Newton's theory is much simpler than that of Einstein in the mathematical language of the 19th century, the situation is quite opposite in modern geometric language.

The other contribution of Cartan to physics is presented by the *Einstein–Cartan theory.* It is a generalization of Einstein's general theory of relativity including in its equations not only the *curvature* but also the *torsion* of spacetime related to the *spin* (the inner angular momentum) of matter. It cannot be excluded that the ideas of this theory will find their use in anticipated unifying theories.

Jan Novotný

See also Einstein, Albert; Einstein and Newton; Newton, Isaac; Space; Spacetime, Curvature of; Time, Absolute

Further Readings

Misner, C. W., Thorne, K. S., & Wheeler, J. A. (1973). *Gravitation* (esp. pp. 289–302). San Francisco: W. H. Freeman.

Trautman, A. (1966). Comparison of Newtonian and relativistic theories. In B. Hoffmann (Ed.), *Perspectives in geometry and relativity: Essays in honor of Václav Hlavatý* (pp. 413–425). Bloomington: Indiana University Press.

Trautman, A. (2006). Einstein–Cartan theory. In J. P. Françoise et al. (Eds.), *Encyclopedia of mathematical physics* (pp. 189–195). London: Elsevier.

Catacombs

Catacombs are a series of connected subterranean rooms, tunnels, or galleries created for the interment of the dead. These burial places are most extensive in Rome, but can be found throughout the Mediterranean world, in Paris, France, other areas of Italy, Asia Minor, Egypt, Tunisia, and Malta. Individual rooms or recesses were dedicated to a single family, so relatives could return on important anniversaries to remember loved ones. They were places to gather for family worship and reflection over generations. Inscriptions and paintings in the catacombs provide historical information on an important time period, enabling us to see the evolution of religious thought during the earliest centuries of Christianity in Europe.

The term *catacomb* today is virtually synonymous with the Christian cemeteries established in Rome during the time of the Roman Empire, but catacombs actually originated in the Middle East about 6,000 years ago. These earliest burials were usually secondary burials—the bones of the dead were recovered, placed in ossuary containers, and interred in a cave or burial chamber. Over the following millennia, burials increased in complexity. By 1500 BCE, far more elaborate underground chambers were connected by galleries.

After the Roman Empire conquered Palestine, or Judea, many Jews migrated to Rome, bringing their burial practices with them. Romans cremated their dead, but the Jews continued to dig their resting places underground. Jewish catacombs were used strictly for burial and can be identified by simple inscriptions of the menorah, a seven-branched candelabrum.

Roman catacombs were carved into the soft volcanic tufa. The law did not allow for burial within the city limits, so the 60 or more catacombs lie in the immediate suburban area of that age, with entrances along the main roads leading into the city.

Early Christians in Rome were considered a Jewish sect, and their catacombs were modeled after those of the Jews. As the Christian community grew, new catacombs were created and existing ones expanded, though Christian catacombs were more than simply burial places. Religious and funeral services were held in them, and they provided temporary refuge for celebrating the Eucharist in times of persecution.

Structurally, the Christian catacombs of Rome form a labyrinth. Tunnels wind through the rock for miles. These galleries are lined with rectangular niches, called *loculi,* that hold the remains of one or more individuals. The earliest Christians were typically very poor. In imitation of Christ's simple burial, bodies were simply wrapped in a shroud and placed in a loculus. The opening was then sealed with mortar and tiles or a slab of marble. The name of the individual and a simple religious symbol were then inscribed on the tombstone.

As burials became more complex, other types of tombs developed. *Cubicula* were small rooms off a gallery that served as a family tomb. *Arcosolia,* large niches with an arch over the opening, were also used to inter families. Both cubicula and arcosolia were embellished with religious frescos and murals. *Forma* were individual tombs dug into the floor of a cubiculum or gallery. Forma were frequently dug near the tombs of the martyrs.

The catacombs were dug exclusively by a specialized guild of workers called *fossores*. They dug gallery after gallery by hand, carrying the debris out in baskets or bags. Periodically, shafts to the surface were created to provide light and air.

Roman law protected all burial sites and rendered them sacrosanct. Even slaves were entitled to a dignified burial. The Christian catacombs of Rome were used most heavily from the third century through the early 5th century when the Goths invaded. Repeated invasions in the succeeding centuries put an end to catacomb burial, as the invaders did not share the Roman restraint about plundering these sacred places. The remains of interred saints and martyrs were removed and housed more securely in churches around the city, and by the 12th century catacombs were completely forgotten.

In 1578, workers accidentally uncovered a catacomb under the Via Salaria while mining for stone, rekindling interest in these ancient burials. Catacombs have remained a curiosity and tourist attraction until the present day, though scientific excavation and analysis of the catacombs did not occur until the mid-1800s.

Catacombs were vital to early Christians. Serving primarily as resting places for the remains of the faithful, they provided a place for the living to spend time with their dead, recognize important anniversaries together, and wait with their loved ones for resurrection. The burial places of saints and martyrs provided the faithful with a physical location for pilgrimage.

Jill M. Church

See also Caesar, Gaius Julius; Christianity; Nero, Emperor of Rome; Religions and Time; Rome, Ancient

Further Readings

Davies, J. (1999). *Death, burial, and the rebirth in the religions of antiquity.* London: Routledge.

Della, P. I. (2000). *Subterranean Rome: Catacombs, baths, temples.* New York: Konemann.

Rutgers, C. V. (2000). *Subterranean Rome: In search of the roots of Christianity in the catacombs of the Eternal City.* Leuven, Belgium: Peeters Publishers.

Stevenson, J. (1978). *The catacombs: Rediscovered monuments of early Christianity.* London: Thames and Hudson.

Catastrophism

Catastrophism, an idea that emerged at the beginning of the 18th century, holds that the earth has been affected by a series of sudden, short-lived, violent events (such as land upheavals and floods that may have been worldwide in scope). These catastrophes, or "revolutions," shaped the earth's surface, forming mountains and valleys, and at the same time destroyed whole species of organisms, some specimens of which were preserved as fossils. After each catastrophe, entirely different life forms repopulated the earth, either by migration or because life emerged again, which would explain the differences in fossil forms encountered in successive stratigraphic levels. Initially, this could be a way to rationalize first field observations with an assumed short history of the earth and the decisively established organic origin of fossils as vestiges of ancient beings. However, a dynamics of paroxysm did not require catastrophists to hold to a limited geological time for the age of the earth. Many catastrophists believed that the earth was millions of years old and still concentrating its major changes on brief ruptures. The earth today was viewed as the result of an accumulation of catastrophic events, which articulate a directional history of the earth and life. Many scientists and historians regard directionalism more as a central theme than the dynamics of paroxysm and, consequently, some scholars redesignate catastrophism as a "directionalist synthesis."

Origins of Catastrophism

The Swiss naturalist Charles Bonnet (1720–1793) was the precursor of catastrophism. In his work *Principles of Catastrophism,* he suggested that all living things have been destroyed by catastrophes at periodic intervals throughout the earth's history and they themselves accounted for fossils. Bonnet was the first to use the term *evolution* in a biological sense. He believed that a new creation follows a catastrophic event in which new life forms could elevate one level in the Great Chain of Being (the influential concept that all of nature, from nonliving matter to sophisticated organisms to spiritual beings, is arranged in an unbroken physical and metaphysical series or hierarchy).

Catastrophism, however, is generally associated with the great French anatomist and paleontologist Baron Georges Cuvier (1769–1832). Cuvier is credited with applying his anatomical principle of the "correlation of parts" in the systematic study of fossil vertebrates to arrive at his most memorable discovery: that species of animals have indeed become extinct. Cuvier reconstructs the skeleton of fossil tetrapods (mainly large mammals) from isolated bones by gathering together and re-creating lost skeletal elements, given that the anatomical structure of every organ is functionally related to all other organs in the body of an animal because animals interact with their environment, resulting in the functional and structural characteristics of their organs. He concluded that these large terrestrial vertebrates had become extinct, based on the fact that their skeletons are very different from those of present-day species, which were very well known on all continents; and given the unlikelihood of discovering new ones. To explain the patterns of extinction and faunal succession in the fossil record and the alternations of marine and continental sedimentary strata that he himself had registered, Cuvier argued that sudden land upheavals and inundation of low-lying areas by the sea might have been responsible for the most recent extinctions in Eurasia. He viewed these revolutions as naturally recurring events, subsequent to long intervals of stability during the history of life on Earth, and this led him to enumerate successive ages down into the sequence of strata indicated by the fossil animals that they contain. Timewise, the history of the earth had been indefinitely long. At the same time, Cuvier expresses the directionality of geological history. Following the Wernerian system, he argues in favor of systematically changing mineralogy throughout time, and for a pattern of decreasing effect or intensity of catastrophes, as an original universal ocean gets smaller. Thus catastrophic dynamics and directionality are interconnected in a distinctive and comprehensive view.

Cuvier also affirms directionality when he remarks that fossils from successively older strata become increasingly more different from modern species, and thus ever more "primitive" by the conventional definition of progress. However, in Cuvier's view, species were immutable (fixed). Faced with bitter opposition to the evolutionary ideas of Jean-Baptiste Lamarck (1744–1829), his major argument was that mummified cats and ibises (brought to Paris by Napoleon's expedition to Egypt) showed that no transformations had taken place in 3,000 years. Cuvier also argued that each species is so well coordinated, both functionally and structurally, that it could not have survived significant change. Ironically, Cuvier's lifework is considered as marking a transition between the 18th-century view of nature and the view that emerged in the second half of the 19th century as a result of the doctrine of evolution. By rejecting the Chain of Being in favor of classifying animals in four separate groups (vertebrates, mollusks, articulates, and radiates), each of which had a special type of anatomical organization, he raised the key question of why animals were anatomically different.

Catastrophism Versus Uniformitarianism

Catastrophism was the dominant paradigm of geology until uniformitarianism became commonly accepted. Because catastrophism was more easily associated with religious doctrines, it greatly overshadowed the opposing uniformitarian ideas of James Hutton (1726–1797) that slow changes over long periods of time could explain the features of the earth. The dominant belief in many cultures about the creation and development of the world was essentially catastrophist. The finest example of these beliefs is the biblical account of the Great Flood, whose influence on scientific thinking persisted up to the threshold of the 19th century. Cuvier gave credence to his concept of catastrophism in 1812 in the essay "*Discours préliminaire*" (which he included in his "*Recherches sur les ossements fossiles de quadrupeds"*) as well as in the expansion of this essay into book form in 1825, "*Discours sur les révolutions de la surface du globe,*" the most important of all catastrophist texts. Cuvier's essay was very influential in England, where natural theology was dominant during the early 19th century. A group of geologists that included William Buckland (1784–1856) and Robert Jameson (1774–1854) misinterpreted Cuvier's ideas and explained catastrophism in a very different way. Jameson translated Cuvier's essay and published it under the title "Essay on the Theory of the Earth." He added extensive editorial notes to the translation that explicitly linked the latest of Cuvier's revolutions with the biblical flood, and the resulting text was extremely influential in the English-speaking world. Buckland spent much of his early career trying to demonstrate the reality of the Noachian flood with geological evidence, and he frequently cited Cuvier but misinterpreted his work. As a result of the influence of these and other advocates of natural theology, the 19th-century debate over catastrophism took on religious connotations in Britain that were not nearly as prominent elsewhere. Catastrophism became a bastion of ecclesiastical reactionaries in a vain effort to stem the inexorable advance of the natural sciences.

From around 1850 to 1980 most geologists endorsed uniformitarianism, thanks to the fact that it was clearly and concisely explained by Charles Lyell (1797–1875) but also because Lyell, a lawyer by profession, discredited catastrophism as a viable explanation of geological phenomena. Cuvier's catastrophism, which was widely spread by means of the distorted views of natural theology, was placed beyond the pale of scientific respectability by Lyell's rhetoric that falsely attributed to him two major charges that he had not made (and that still persist in recent textbooks). For Lyell, catastrophist geology became "a boundless field for speculation" that could "never rise to the rank of an exact science." Cuvier's essay, however, exposes all characteristic features of catastrophism as a science. It is an irony of history that Cuvier, one of the greatest intellectuals of 19th-century science and a champion of rationality, as well as other catastrophists, should become an object of ridicule without being read.

The Enlightenment and the intellectual climate of the Revolution influenced French thinkers and scientists, who, after a long period in which science was dominated by tradition, irrationality, and superstition believed that systematic thinking applied to all areas of knowledge could lead to the progress of ideas. Influenced by these ideas, Cuvier avoided religious or metaphysical speculation in his scientific writings, but he was also habituated to processes of dramatic and discontinuous upheaval by life experiences of The Reign of Terror (during the French Revolution). He made no reference to divine creation as the mechanism by which repopulation occurred following the extinction event. By contrast, he appointed the migration of surviving animals in isolated areas as the plausible mechanism. Nor did he make any explicit reference that the most recent revolution corresponded to the biblical flood. It is true that Cuvier paid special attention to the last revolution, concluding that it cannot be dated much farther back than 5 or 6 thousand years. He actually noted that no human fossils existed at all in the countries where the vertebrate fossil bones are discovered; however, as it is assumed that the last catastrophe occurred within human memory, he scanned the oldest records of all cultures and thus coordinated two sources of evidence, natural history for estimating the effect of ordinary causes since the last paroxysm and civil history. Since Western cultures recorded this event as Noah's Flood, and since Cuvier used the Bible as one source of legitimate historical information among many, posterity charged him with distorting geological facts to support religious traditionalism. However, his empirical hope was to understand catastrophes through a detailed study of the most recent event, the most suitable for this goal given the fragmentary nature of geological evidence and the tendency for such evidence to become more and more inadequate as we penetrated deeper into time.

Some textbooks have erroneously regarded Lyell as an empiricist who, by fieldwork and close attention to objective information, drove the dogmatism of catastrophists out of science. On the contrary, the catastrophists advocated empirical literalism as a fundamental approach to science. They interpreted what they observed as a true and accurate record of actual events and interpolated nothing. Early geologists and paleontologists noted that breaks or ruptures appeared frequently in the geological record when they studied the structure of the mountains. For instance, it is usually observed that deformed layers containing marine fossils may be truncated and overlain by other horizontal beds also containing marine fossils but that are entirely different from the previous ones. Applying the law of superposition and the principle of original horizontality, the defining principles of stratigraphy already established during the 17th century, these were interpreted by geologists as two rock masses or strata of different ages that appear separated by a surface indicating that sediment deposition was not continuous, the strata above the surface being younger than the strata below (unless the sequence has been overturned), and that folding and/or faulting of older strata occurred prior to deposition under the sea of the younger strata. This discontinuity evidences an event that catastrophists interpreted as paroxysmal to deform the original horizontal strata and eradicate the older fauna. Uniformitarian geology, however, interpreted the folding and/or faulting of older strata and their elevation above the sea as associated processes that occur so slowly that we cannot appreciate the changes within a human perspective. Equally, the surface between both rock masses was formed through subaerial exposure and erosion over a very long time, representing a gap in the record that could cover several millions of years. According to Lyell, catastrophists misinterpreted the massive lacunae as evidence for rapid change. Geological unconformities and local extinction look paroxysmal, but only because slow, daily changes rarely leave any evidentiary trace at all. In his view, the geological record must be treated as imperfect to an extreme degree. Proper procedure in geology requires interpolating into a systematically impoverished record the unpreserved events implied by our best theoretical understanding.

Recent Theories

In the last decades of the 20th century a revival of Cuvier's catastrophism, a neo-catastrophic school, gained wide acceptance with regard to certain events (such as the mass extinctions) in the distant past. One stimulus for this change was the work of Walter and Luis Alvarez who in 1980 suggested that an asteroid struck Earth 65 million years ago, at the end of the Cretaceous period, and caused a mass extinction in which 70% of all species, including the dinosaurs, disappeared. In 1990, a 180-kilometer candidate crater marking such an impact was identified at Chicxulub in the Yucatán Peninsula of Mexico. The improbability of such an event is no argument against such a hypothesis, because the improbable, even with odds of once every billion years, must have taken place a few times in geological history. The sedimentological importance of rare events is difficult to assess because the record of such events may be very subtle. This is especially true if a deposit has been thoroughly bioturbated or if the record of an event is simply an erosional surface. Moreover, we know now that catastrophic events occur as natural events, as was illustrated by the observation of the Shoemaker–Levy 9 cometary collision with Jupiter. Since then, most of the mechanisms suggested to explain mass extinction events have been catastrophic in nature.

Thus, new theories such as *actualistic catastrophism* or *episodic sedimentation,* and disciplines like *Event Stratigraphy* and *Cyclostratigraphy,* developed in the geoscience community, represent a synthesis of Lyell's uniformitarianism combined with Cuvier's catastrophism. They are founded on the assumption that the earth as we know it today has been shaped by slow natural processes, but that most of the stratigraphic record was produced during cyclic and episodic astronomically forced events that were disturbed by other occasional natural catastrophic events such as bolide impacts or cataclysmic volcanic activity, which have produced abrupt environmental changes that have greatly affected the evolution of life on Earth. The immensity of geological time is important not only because of the immensity of the cumulative effects, but also because the long duration provides a chance for the improbable to take place.

This conceptual change in evolutionary biology during the last third of the 20th century also produced new theories, such as *punctuated equilibrium* and a revival of *saltationism,* that posit that evolution among the species takes place in rapid bursts separated by long periods in which little change occurs. These ideas contrast with Darwin's gradualism that, influenced by Lyell's uniformitarianism, requires that the fossil record be imperfect to interpolate the intermediate forms that, as Cuvier explicitly noted, have never been found.

Beatriz Azanza

See also Chicxulub Crater; Darwin, Charles; Dinosaurs; Earth, Age of; Erosion; Evolution, Organic; Extinction; Extinction and Evolution; Extinctions, Mass; Fossil Record; Fossils, Interpretations of; Geology; Hutton, James; K-T Boundary; Lyell, Charles; Noah; Paleontology; Stratigraphy; Uniformitarianism

Further Readings

Briggs J. C. (1998). Biotic replacements: Extinction or clade interaction? *BioScience, 48*(5), 389–395.

Dott, R. H. (1983). Episodic sedimentation: How normal is average? How rare is rare? Does it matter? *Journal of Sedimentary Research, 53*(1), 5–23

Gould, S. J. (2002). *The structure of evolutionary theory* (p. 1464). Cambridge, MA: Harvard University Press.

Hsü, K. J. (1989). Catastrophic extinctions and the inevitability of the improbable. *Journal of the Geological Society, 146*(5), 749–754.

Koutsoukos, E. (Ed.). (2005). Applied stratigraphy. *Topics in Geobiology, 23,* 488.

Oldroyd, D. (1996). *Thinking about the earth: A history of ideas in geology* (p. 440). Cambridge, MA: Harvard University Press.

Palmer, T. (2003). *Perilous planet Earth: Catastrophes and catastrophism through the ages.* Cambridge, UK: Cambridge University Press.

Rudwick, M. J. S. (2005). *Bursting the limits of time: The reconstruction of geohistory in the age of revolution.* Chicago: University of Chicago Press.

Virgili, C. (2007). Charles Lyell and scientific thinking in geology. *Comptes Rendus Geoscience, 339*(8), 572–584.

Wicander, R., & Monroe J. S. (2003). Historical geology: Evolution of earth and life through time (4th ed.). London: Brooks/Cole.

York, R., & Brett, C. (2005). Natural history and the nature of history. *Monthly Review, 57*(7), 21–29.

Causality

The belief concerning the causal characteristics of the material world is one of the basic ones. It is possible to adopt a standpoint like the philosopher David Hume (1711–1776), and to assume that causal relationships are only a product of our mind because they cannot be derived from empirical data. Hume believes it is impossible to discover empirically in the world any relation between phenomena that could be called causality. Causality is but a name for a human custom that connects phenomena frequently succeeding each other. According to Hume, cause and effect are considered as mere successions, not as inner causal connections. In this case, science in the modern sense is possible only as a simple description.

The second option is to suppose the objective character of causal relations without being able to present an unambiguous argument; we remain at the level of metaphysical assumption, supported if not by arguments, then by the experience not only of individuals, but also historical experience and the results of science as well as individual practice. The discussion concerning the topic then has meaning only in relation to this; in other cases it will always lead to a situation where there are two opposing claims without the possibility of one decisive argument. We have selected the latter option and we consider it useful to restate the fact here, particularly because there is a rather widespread fallacy in definitions of causality and determinism that quite precludes the understanding of what is going on in contemporary science in this field. This fallacy, briefly expressed, consists in the identification of causality with determinism in a naive assumption that if there is a cause for something, it must be deterministic. The speculation then usually quickly proceeds on the presumption that there is some cause for everything; the whole universe and everything in the world are thus deterministic. To those who turn to etymology and refuse to give up the predetermination of everything that has its cause, we can offer what might seem to be a play on words, but one that is in this case very useful. The point is that we can distinguish between the expressions *determined* and *deterministic.*

Cause and Effect

Let us start step by step, however, from causality. What we understand by *causality* is the relation of material elements or systems, when the change of a state in one of the systems—the *cause*—necessarily elicits the change of a state in the other system—the *effect.* The *elementary causal relation* cause–effect is a certain abstraction that cannot be found in such isolated form in nature. What is closer to reality is the idea of a *concatenation of causes and effects* with which a range of philosophers work—from Aristotle (the hierarchical model of the world from the first cause to the purpose of all purposes) up to the mechanical materialists who aim to trace in the initial causes through their effects all the states the universe gradually acquires. Even this is, however, to a certain extent, a simplified notion counting on the presumption that one and the same cause always elicits an identical effect and that it will never be different. Another approach can thus be a combination of these causal chains in a *causal web* along which the changes from the initial causes gradually spread. In the following step this—so far two-dimensional—web can acquire a third dimension and stretch thus from area into *space,* and when we add a *retrospective effect* to the systems in the form of original causes, we can obtain a more complex picture of causal relations in the structure of material systems.

We can call the perfect knowledge of the initial state of a system in the causal relation *the complete cause;* that is, a cause that always elicits an identical effect. In reality, however, such perfect knowledge often remains an ideal and we have to take into account *conditions* that take part in the effect. The conditions themselves cannot elicit the effect, but they can influence the progress of the process or the very initiation through which the causal relation is fulfilled.

The problems with causality, explicitly expressed in the history of philosophy by Hume, led many natural scientists and philosophers to an effort to replace such a relation in our descriptions with functionality. This particularly concerns those who were close to positivist-oriented philosophy, because the function describes the concurrent interdependence of variables, but not their history. In such a description, some or all of what is called the asymmetries of the causal relation, which in their own way reflect the history of the system, are missing—it is *existential asymmetry* (which expresses the current character of cause and the potentiality of effect—the nonexisting cannot be the cause of the existing), *genetic asymmetry* (which is the expression of the ability to elicit changes, creative activities), and *temporal asymmetry* (which emphasizes the fact that whatever transformation—of matter, energy, and information—is fulfilled at the maximum speed of light, which is final, and that there is thus always a nonzero interval between cause and effect, whose extent depends on the distance in which the causal relation is fulfilled and the speed at which it happens).

Determinacy and Determinism

After a brief review of causality we can define the concepts of determinacy and determinism. *Determinacy* is the dependence of the system on causes; that is, everything that has some cause is determined directly by these causes. *Determinism* is the opinion that we are able to predict all the effects of determined systems if we know all their causes. That is, to emphasize this difference, causality and determinacy are the *objective* characteristics of material structures; determinism is *the view, the belief* that it is possible, with sufficiently exact knowledge of the state of a system, to count and predict all its subsequent states in relation to both the past and the future. The differentiation of determinacy and determinism, however, entails significant difficulties, the basis of which is an onto-epistemological problem. The point is that it implies the idea that we can speculate on the behavior of a system in terms of its "really" happening, independently of the observer (determinacy), and of the behavior of a system in terms of how we can calculate it (determinism). A given problem nonetheless cannot be disposed of by such a claim. It is evident (if only from a brief glimpse at the sky and the movement of celestial bodies) that systems always behave in a certain way, entirely independently of whether we are able to find solutions for their behavior in equations or not. The question of the *full* and *partial* determinacy of a system then arises. A fully determined system would be such that its every state in the arbitrarily distant future would be unambiguously dependent on (regardless of whether we would be able to calculate it or not, if anyone bothered to calculate it at all) the initial conditions or the "first cause" of the given system; that is, the whole chain of causes and effects being in progress in the system would be determined in advance by the initial state. A partially determined system would then once more stabilize after each change of the state and the subsequent state would correct itself according to the changed conditions. The first cause would then "dissolve" in the succeeding generations of causes and effects until it would lose influence on the subsequent states of the system. We can decide between these possibilities either on the basis of our philosophical (or other) belief, by which we at the same time dispose of the obligation to argue, or on the basis of some data, but in that case measurements (physics) must be performed, they must be somehow processed (mathematics), and the result must be interpreted. Through this, however, we step into the field of opinion and our belief; that is, we return to determinism and the additional differentiation of the determined, so that the deterministic loses its sense and what remains is again only causality and determinism. This determinism itself then acquires various forms in history that in fact mimic the route from the full determinacy of the universe (consistent determinism) to indeterministic systems.

A typical example of consistent determinism is *mechanical determinism,* based on the successes of classical physics and the idea of the universe as a mechanism (a big and complex mechanism, but still a mechanism) that is fully, at least fundamentally, quantifiable. This view of the deterministic universe, represented most often by Pierre-Simon Laplace (1749–1827), utterly excludes coincidence from the world, or rather considers it merely a subjective fact or a result of our ignorance of the causes. It is sufficient to discover causes, and coincidences will disappear from this world.

Twentieth-Century Interrogations of Causality

The picture reveals the first lacunae at the turn of the 20th century when Henri Poincaré (1854–1912) distinguished stable and unstable systems; he introduced the term *dynamic non-integrable system* and showed that most dynamic systems are of this kind. In simplified terms, the integrability of a system means that in a dynamic system, which can always be fully characterized by kinetic energy (which is dependent only on the speed of the bodies in the system) and potential energy (the mutual position of bodies, their interaction), transformations can be found such as to allow a perspective within which the potential energy can be eliminated and mutual trajectories thus neglected. It is therefore comparatively easy to find the trajectory of bodies and to define the future states of the system. Poincaré shows that such variables cannot be found and that dynamic systems are non-integrable. This means that in the field of classical physics a difficulty with determinism appears. The problem has been long understood as a mathematical one and it has been expected that the problem of such systems would be solved after the device was refined. This neglect lasted until the second half of the 20th century when chaotic systems, which revived the question, started to be talked about more frequently.

In the meantime, other problems appear. Mechanical determinism, entirely in line with classical physics, does not question the possibility of obtaining information about the state of the system, because it presumes an immediate impact from a distance. This view is, however, disturbed by Albert Einstein's (1879–1955) theory of relativity, which introduces the principle that the speed of light, which is final, is the maximum possible speed attainable in our universe. No signal can travel faster and we therefore find ourselves enclosed in the area of what is called the horizon of particles or—if we intend to place emphasis on mutual interaction—in the area of the causal horizon.

Quantum mechanics means another questioning of determinism, namely in its more moderate form. It shatters the idea of classical physics that it is possible to assume the standpoint of the observer of the system who measures required data without influencing the system itself. Werner Heisenberg's (1901–1976) uncertainty principle in its consequences means that it is not possible to obtain simultaneously with sufficient exactitude all the decisive information (typically the energy and position of the particle) regarding the quantum system. Even though quantum mechanics thwarted deterministic ideas and for many meant a definitive rift with the mathematical predictions of the future and was also understood as the confirmation of freedom from the side of physics, there still remained numerous scientists and philosophers who believed, like Einstein, that "God does not play dice." They were convinced, and some still are, that the impossibility of obtaining at the same time all the required data about the system is just a technical problem or that it is a question of those characteristics of reality that have so far escaped us and that the situation will improve with the development of technology and physics and that determinism will be preserved and the world will not be ruled by accident, out of which the notion of objective fact would emerge in indeterministic conceptions of some quantum physics interpretations. However, all the experiments that so far have been performed with the aim of deciding the situation, including attempts that were inspired by the thought experiments of significant followers of determinism, have proved that most probably it is not a technical problem, but that reality itself is such. So the notions *determined* and *deterministic* blend here again and it seems that the systems really are not the predetermined "first cause" once and for all. The followers of determinism can still argue through the ambiguity of the transition from the world of subatomic particles to our macroworld and rely on the fact that somewhere the rescue of the deterministic world would once again appear. This hope, however, is slowly beginning to fade with regard to the works that do not need to proceed on the basis of quantum mechanics and the uncertainty principle; they do not even require relativist physics, but they are based on the very core of classical physics, namely on dynamics in the form as experienced at the very end of the 19th century (H. Poincaré). It had been presumed for a long time that this was just a problem of technical insufficiency, but since the middle of the 20th century theories have been gradually conceived that prove that even dynamic unstable systems, as defined by Poincaré, show equally indeterministic behavior as, for instance, quantum systems.

The probability description, characteristic of chaotic (and quantum) systems, becomes part of science much earlier, that is, in relation to thermodynamic theory in the second half of the 19th century. It was applicable wherever it was used with systems containing a very large number of elements, so it was not possible (and as a result, as it turned out, not even necessary) to take into consideration the exact characteristics of each of them; but to determine the behavior of a system with a sufficient degree of probability it was enough to know their probable configuration. Yet because it was supposed that it would be enough to have sufficient capacity for finding all the data about each element in order to replace the probability description with an unambiguous (dynamic) one, this *stochastic chaos* did not disrupt the belief in determinism. The incidental behavior of such a system is influenced by external conditions, unlike *dynamic chaos* where the unpredictable behavior is brought about by the impossibility of estimating the initial conditions.

Similar to classical and relativistic physics when the classical model remained a good device for the description of bodies of the macroworld moving at low speeds and became a special case of relativist physics, everything gradually indicates that history will be repeated with new protagonists, and the deterministic description will remain reserved for the relatively narrow circle of simple systems and will become a special case in a more general description, which will be probabilistic.

Josef Krob

See also Aristotle; Determinism; Einstein, Albert; Hume, David; Poincaré, Henri; Quantum Mechanics; Teleology

Further Readings

Coveney, P., & Highfield, R. (1984). *An arrow of time.* New York: Random House.

Gleick, J. (1987). *Chaos: Making a new science.* New York: Penguin.

Horwich, P. (1987): *Asymmetries in time.* Cambridge: MIT Press.

Penrose, R. (1989). *The emperor's new mind: Concerning computers, minds, and laws of physics.* New York: Oxford University Press.

Prigogine, I. (1997). *The end of certainty: Time, chaos, and the new laws of nature.* New York: The Free Press.

Russell, B. (1918). On the notion of cause. In *Mysticism and logic and other essays.* London: Longmans.

Chaco Canyon

Situated within the "House Made of Dawn" (the San Juan Basin) of the Four Corners area (where the boundaries of New Mexico, Arizona, Utah, and Colorado meet), a remarkable culture evolved. The hunter/gatherer nomadic Archaics were the first to populate the area, around 8,000 BCE. This early culture left cosmographic pictographs upon the canyon walls, revealing an ancient knowledge of the seasons and celestial movements. Approximately 700 CE, near the end of the Basket Weaver Period, the Chacoan ancestors, who had inhabited pit houses, began building complex communal architecture, monumental stone edifices now called "Great Houses," that required the engineering of a sophisticated astrological comprehension. One wonders what the temporary means of calculating these alignments might have been, prior to these constructions. These Great Houses were not only planned, but built in stages. Assembled data from tree rings on lumber revealed that construction of some could require decades to complete, while others took centuries. This technology gathered calculations of the equinoxes, solstices, and other cycles of time; these data assisted in planting, harvesting, celebrations, and, possibly, dates for trade fairs. The villages appear to be unsustainable and were low in population on those high desert plateaus; archeologists posit the Chaco Canyon Great Houses, and other cosmological structures, to be evidence of the Chacoan worldview. Chaco Canyon appeared to be a political and cultural center, with Pueblo Bonito the nucleus, as roads of 30 foot (10 m) width, bordered with beams, lead out of Bonito to the remaining major Great Houses in Chaco Canyon. In addition, roads lead out of the canyon to the surrounding 150 communities. The canyon's major distinct architectures were then speculated to be public structures utilized for traditional ceremonial occasions, in addition to trade and commerce. Artifacts divulge evidence of an extensive trade economy. For example, discovered samples of jewelry reveal manufacture from elements originating in Mexico and California.

Scholars such as Anna Sofaer have postulated that the Chacoans demonstrated a "cosmographic expression" with the construction of their habitations, with precisely calculated roads leading out of Pueblo Bonito, in addition to each community's placement. The Solstice Project ascertained that of the 12 major Chacoan villages, 4 have cardinal bearings, one is aligned to the solstice, 5 to the lunar minor, and 2 to the lunar major. In addition, there are Great Houses that illustrate a relationship in bearings; there are North–South and East–West connections, and a three-community relationship with the southern lunar minor standstill. Furthermore, examination of the Great Houses themselves has disclosed more alignments, of which the following is a sample: the sun sets in alignment with a south wall prior to an equinoctial full moon; calculations of terrace umbrae can be observed from East to West for daily reckoning, and seasonal from North to South; there is a kiva window forming a beam of light recording summer solstices on a wall, and an area tracking the 28-day lunar cycle; a doorway frames the rising lunar minor standstill. Other astronomical markers include the stone pillars at Chimney Rock, which frames the rising northern lunar major standstill; and an "observatory" of three sandstone slabs at Fajada Butte, which forms a glissading streak of light that records the solar solstices, lunar equinoxes, and the 18.6 lunar declinations on a petroglyph spiral.

Unequivocally, such precise calculations, constructions, and accompanied celebrations would have a significant influence upon the mindset of the Great House inhabitants and the Chacoan culture as a whole. The estimated zenith of their society peaked near 1020 to 1130 CE. Around 1250 CE, the migration from Chaco Canyon began. The House Made of Dawn stands as a testament to the sophistication of Mesoamerican cosmographic knowledge and the magnificent artistic expression it generated.

Pamela Rae Huteson

See also Anthropology; Archaeology; Calendars, Tribal; Creation, Myths of; Equinoxes; Geology; Navajo; Pueblo; Solstices

Further Readings

Sofaer, A. (1997). The primary architecture of the Chacoan culture: A cosmological expression. In B. H. Morrow & V. B. Price (Eds.), *Anasazi: Architecture and American design* (pp. 88–132). Albuquerque: University of New Mexico Press.

Sofaer, A., Marshal, M. P., & Sinclair, R. M. (1989). The Great North Road: A cosmographical expression of the Chaco Canyon culture of New Mexico. In A. F. Aven (Ed.), *World of archaeoastronomy* (pp. 365–376). Cambridge, UK: Cambridge University Press.

Stuart, D. E. (2000). *Anasazi America: Seventeen centuries on the road from Center Place.* Albuquerque: University of New Mexico Press.

Chambers, Robert (1802–1871)

Robert Chambers, British publisher and amateur geologist, was most noted for his contributions as depicted in the book titled *Vestiges of Natural History* (1844). This controversial work, first published anonymously then later credited to Chambers, directly challenged both theological circles and the scientific community during the Victorian era (1837–1901). Chambers's unique interpretation and synthesis of religion and science promoted several controversial issues. Among these issues, Chambers questioned the barrier between science and the general population—professional versus amateur—and more importantly, the use of science to discredit the literal interpretation of scripture found in the Holy Bible. Although Chambers received a hail of criticism from all directions, his iconoclastic work did provide the possibility for future scientists and "unorthodox" theories to be offered for serious consideration, particularly in the case of Charles Darwin and the publication of his *On the Origin of Species* (1859).

Chambers held that, contrary to scripture, the universe, stars, and planets are beyond humankind's conception of time. Utilizing the nebula hypothesis, Chambers stated that our planet and solar system are but one part within common and innumerable systems contained within the vastness of the cosmos. Each planet, of which there are infinite variations, is subject to the same stages of development and is governed by infinite laws as established by Divine Providence. As for Earth and humankind, science and rational speculation could unravel the divine mystery of our planet's history, its relation to the solar system, and the processes of the divine creator. Geology, not theology, would be essential in uncovering this dynamic concept of time and history.

Chambers speculated, correctly to varying degrees, that geology and fossil remains could expose and explain the history of Earth that had been lost to the sands of time. As the earth proceeded from one stage of development to another, life gradually developed, as depicted by the fossil record within geological strata. Plants, fishes, reptiles, birds, and mammals conformed to the principles of development established by providence; arranged in perfect unity within a hierarchal framework from lowest to highest. This process toward greater complexity set forth by Divine Providence was preordained for the arrival of humankind.

Humankind is regarded by Chambers as the apex of temporal creation. Influenced by the laws of nature, established and governed by God, the mental capabilities of humankind are distinct, by degree, from other animals. Thus, this unity of humankind as depicted by mental capabilities is dependent upon the creation of the human brain. Unlike the rest of life, which is defined and finite, the human animal mind progresses from finite to infinite and gives a sense of consciousness within terms of individuality. Consciousness, intellect, and memory (conception and imagination) are the driving force not only for reproduction but also for creative contemplation of God and eternity. During this act of contemplation, humankind can understand moral laws established by God and that can be found within nature itself. Humankind has autonomy within these natural parameters, for example, design, from which the "good" can be derived and developed. This moral nature of humankind is eternal and fixed. Essentially, our species is depicted as a natural creation, driven by design to discover its natural morality, the divine, and to know God on a personal level.

In assessing Chambers's interpretation of then-known scientific principles, scientists of his era were understandably critical. Today it is Chambers's concept of time that appears most valuable. The age of the universe, as well as of the planets, must be taken beyond the traditional anthropocentric concepts of time. His conceptual framework for the gradual and distinct appearance, in geological terms, of plants and animals, which ultimately culminated in the sudden appearance of our species, denoted the slow and progressive natural state of designed life. Built upon natural geological and atmospheric conditions, the design set forth by the designer or creator resulted in the plethora of life on this planet. Although Chambers believed in the "vestiges of creation" while denying their actual philosophical implications, his synthesis of time directly challenged the traditional interpretation of scripture and some assumptions made by some scientists of his day.

David Alexander Lukaszek

See also Darwin, Charles; Evolution, Organic; Haeckel, Ernst; Huxley, Thomas Henry; Lamarck, Jean-Baptiste de; Saltationism and Gradualism; Spencer, Herbert

Further Readings

Chambers, R. (1967). *Traditions of Edinburgh*. London: W. & R. Chambers.

Chambers, R. (1969). *Vestiges of the natural history of creation*. New York: Humanities Press.

Change

Change takes time and does not happen instantaneously. A rock chip from a mountain, slowly, over centuries of rolling down a river, becomes a smooth, round pebble. A tiny egg and sperm become a breathing, living human in 9 months. A drop of water held at 31 degrees Fahrenheit becomes ice. Whether slow or fast, change is never immediate. Even in the split second between the last swipe of the axe and the tree hitting the ground, turning from a living tree to a dying piece of wood, time elapses. As the seconds tick by, the numbers on the clock and the calendar change, ages grow older. Time is the medium of change, but change occurs only in one direction. Where there is change, there is before and after. The interval between before and after is understood as the passage of time. Time enables change to happen, and at the same time, time is constituted by the observation of change, whether in a cyclic or noncyclic manner.

Although humans have determined ways to measure the distance between the start and end of change, some thinkers have observed that it is not time itself that passes, but rather our senses informing us that change has occurred. Parmenides of Elea and his teacher, Xenophanes, felt change was mere appearance. Paramenides' student, Zeno of Elea, proved that time as change is unreal. Accordingly, time is not seen as a change, but with passage of time, change occurs. Change is also related to time in that the measuring and observing of time changes, yet this same event, despite different numbers measuring it, is still the same span of time, despite man's resistance to changing his method of measure. The definition of time is the same the world over—the passage of life; it is the method used for measuring the time that changes. Whether by using a predetermined method or by how it feels to have passed, time is measured. The shared concept among all measurements of time is the counting of a regularly recurring identical change, sometimes the recurrences and sometimes equal increments between occurrences. Thus, it is this counting of changes that allows time to happen. And it is time that enables us to observe the changes occurring all around us. Yet time appears to change when we observe it without the benefit of counting regular occurrences. An hour can appear to change in length, between the hour waiting for an athletic event to start and the hour an exciting game lasts. An hour can change by how it is measured—a sundial hour can vary from a clock hour. In any case, time cannot be detected without change occurring, whether we observe the change or not. Time is only the measurement at regular intervals of a continuous occurrence. Whether the heartbeat used by Galileo when timing the motions of the pendulum, or the seconds passing as a minute hand goes around a clock face, these are all changes that are occurring and thus are measured to indicate the passage of time. Time cannot be altered; it is the changes in other things that occur as time passes that constitute the change, not the passage of time itself.

In the 19th century, change was often equated with progress. Since then, events have demonstrated that this is not always the case. Change can be progressive, or it can be regressive and destructive. Change can occur in any direction, can end or be open-ended. No matter the direction of change, this alteration is measured, in part, by the time that has passed between start and end, or between one point and another on the continuum of time. In order to measure change over time, one must examine not only the start and end but also intervals along the continuum of the change over time. In some areas of research, such as the social sciences, assessing change over time is often explicitly the focus of the study. In other disciplines of study, such as organizational research, this is often more implicit, but still fundamental to making inferences and deductions from the data gathered. When measuring change over time, the more observations of the occurrences, the more frequent the observations, the more accurate the final outcomes will be. Change occurs over time, and it is because of this that the notions of time-specific and time-related errors need to be considered in any evaluation of change.

It was said by Lothar I, Holy Roman Emperor (840–855), that times change and that we must change with them. It can also be noted, however, that not only do the times change, but so does time itself. We can never return to the time that has passed, nor can we return to the person we were at an earlier time. As time passes, changes occur, whether realized or not. Moreover, as time passes, the ability to observe change alters. Impairments in a person, whether caused by age or improved by age, affect the perceptions of time passage. These differences cause a change to be observed differently, based in part on the perceptions of time's passage. Change, in this instance, can be defined as a variation in a property of a thing. Thus, the change occurs as the time passes and the property thus shifts in the item. Even an event that occurs never occurs in an instant, and thus change occurs throughout the event as the event progresses.

Sara Marcus

See also Darwin, Charles; Evolution, Cultural; Evolution, Organic; Evolution, Social; Hegel, Georg Wilhelm Friedrich; Heraclitus; Lenin, Vladimir Ilich; Marx, Karl; Time, Objective Flux of; Universe, Evolving; Xenophanes; Zeno of Elea

Further Readings

Arundale, R. B. (1980). Studying change over time: Criteria for sampling from continuous variables. *Communication Research,* 7(2), 227–263.

Chacalos, E. H. (1989). *Time and change: Short but differing philosophies.* Rockville, MD: Potomac Press Circle.

MacIver, R. M. (1962). *The challenge of the passing years: My encounter with time.* New York: Simon & Schuster.

Mellor, D. H. (1981). *Real time.* New York: Cambridge University Press.

Van Schendel, W., & Nordholt, H. S. (2001). *Time matters: Global and local time in Asian societies.* Amsterdam: VU University Press.

Charlemagne (742–814)

Charlemagne, or Charles the Great, was king of the Franks and Lombards and first Emperor of the Holy Roman Empire. He is often referred to as the "father of Europe," as his reign witnessed the consolidation of much of Western Europe following centuries of disunity. For this reason, Charlemagne is considered among the most important rulers of all time. His long reign represents a watershed period in human history; during it he expanded the Frankish Kingdom into a vast empire that included much of Western and Central Europe. He oversaw a revival of learning and culture referred to by historians as the Carolingian Renaissance, so named after his family dynasty. During this period, may of the peoples of Northern and Eastern Europe were converted to Christianity. In acknowledgment of these achievements, Charlemagne was crowned *Imperator Augustus,* emperor of the Romans, by Pope Leo III on Christmas Day, 800. This action was deemed provocative by the Byzantine emperor in the east, confirming the schism between the two churches. The famous coronation of Charlemagne gave birth to the Holy Roman Empire, which survived until 1806, when it was dissolved by Napoleon Bonaparte.

Charlemagne was the oldest son of Pepin III and grandson of Charles Martel. At the death of his brother Carloman in 771, with whom he had shared rule, Charlemagne took control of the entire Frankish Kingdom. In 773 he allied with Pope Adrian I, who was in a conflict with the Lombard ruler Desiderius. Charlemagne defeated Desiderius and in 774 became king of the Lombards. He continued the close relationship with the Christian church that had been pursued by his father. Charlemagne greatly expanded his realm in a series of military campaigns in Saxony, in Bavaria, and in Italy, but was checked in Spain in 778. He compelled the Saxons to convert to Christianity. His close friendship with Pope Leo III and coronation as Holy Roman Emperor in 800 incurred the jealousy of Constantinople, which still claimed to rule the Roman Empire. Charlemagne's rule legitimized the old split between East and West and yet also renewed the precedent set by Imperial Rome of uniting the various nations of Europe under one rule. The coronation of Napoleon I in 1804 was done in implicit imitation of Charlemagne's, testament to his influence on history, although with a different role for the Pope.

The Carolingian Renaissance, a resurgence of learning and culture during Charlemagne's reign, was centered at his imperial court at what is now Aachen in modern-day Germany. There he oversaw the creation of the palace school and invited intellectuals from across Europe, including Alcuin and Einhard, to instruct and to promote scholarship. Charlemagne encouraged commerce throughout his empire and dispatched administrators, *missi dominici,* to the most remote quarters of the realm so that he could supervise affairs. His efforts promoted the preservation of classical literature.

Charlemagne has been depicted as a legendary figure in much art and literature since his death in 814, notably in the medieval tale *Chanson de Roland,* and during the 19th century's Romantic period. In modern times he has been referred to as a forerunner for the idea of European unity. Charlemagne is buried in the imposing Byzantine-Romanesque cathedral he commissioned to be built at Aachen.

James P. Bonanno

See also Alexander the Great; Attila the Hun; Caesar, Gaius Julius; Christianity; Genghis Khan; Rameses II; Rome, Ancient

Further Readings

Barbero, A. (2004). *Charlemagne: Father of a continent* (A. Cameron, Trans.). Berkeley: University of California Press.

Chamberlin, R. (1986). *Charlemagne: Emperor of the Western world.* London: Grafton Books.

Chaucer, Geoffrey (c. 1343–1400)

Geoffrey Chaucer was among the foremost poets of late-medieval England. Having been, among other things, a soldier, ambassador, and customs agent, he was also a man of letters who found time to keep abreast of literary developments at home and abroad. Appreciated by 15th-century readers as a moralist, Chaucer appeals to modern audiences largely because of his lively storytelling and judicious insights about human nature.

Chaucer's poetry reveals his acute interest in time, evident even in his choice of poetic genres. Although they focus primarily on love relationships in the manner of the medieval historical romance, Chaucer's *Troilus and Criseyde* and the *Knight's Tale* from the *Canterbury Tales* are clearly indebted to the epic, set as they are in the remote eras of the Trojan War and the siege of Thebes. Time is no mere abstraction in Chaucer; nor is it simply a feature of the background of his narratives. His antique settings in the aforementioned two works complement the aristocratic status and the idealized, heroic behavior of his characters as well. Very different are the *Miller's Tale* and *Reeve's Tale:* as examples of the fabliau, these stories feature coarse characters, scatological humor and frequent deception, and unfold in the narrator's present, a world apart from the epic past. Their peculiar form of entertainment depends on immediacy of action and fast-paced storytelling in the here and now.

Partial or complete sources or analogues can be found for many of Chaucer's works, originality not having been as prized in the Middle Ages as it is in our own day. Despite his frequent debts to earlier and near-contemporary works of literature, however, the poet also saw a good deal of life itself. Born in London in the early 1340s, Geoffrey Chaucer may have attended one of the schools in the district near the River Thames where his father would have plied his trade as a vintner. He also served, possibly as a page, in the court of Elizabeth de Burgh, Countess of Ulster, an opportunity likely brought about by his father's influence as a wealthy wine merchant. Before he was 20 years old he gained firsthand experience, while in the army of King Edward III under Prince Lionel, Elizabeth's husband, of what historians call the Hundred Years' War between France and England (1337–1453). His military years marked the beginning of a varied career as a civil servant. Indeed, it was his service in three royal administrations, not his brilliance as a poet, that led to his being buried in Westminster Abbey in 1400. He was married to Philippa (de) Roet, and one of his children, Thomas, enjoyed an even more brilliant public career than his own.

It is tempting to assume that his political connections and involvement in matters of state must have spurred Chaucer to make overt references to his times. This assumption would be incorrect, however, as the poet seldom mentions significant contemporary events. Whether in his short lyrics or in his longer works, explicit "timeliness" is rare, though his avoidance of topicality also makes it relatively easy for modern readers to enjoy his poetry for its lyrical or narrative qualities.

Although it did not lead him to write social criticism or protest literature in the manner of William Langland, author of *The Vision of Piers Ploughman,* Chaucer's interest in time did find expression in the way he crafted meaning. It appears subtly, for example, in his use of timing in the development of his own fictional personae within his poems. *The Book of the Duchess,* for example, is early work (dating probably to the late 1360s) whose speaker, apparently an unsophisticated, naïve version of the poet himself, recounts a dream of his in which he encountered a grieving knight in a meadow. The farther we read in the account of this dream, the more obvious it becomes to us that the Black Knight is mourning the death of his beloved, the Lady White. Chaucer, however, deliberately portrays his narrator as one who offers consolation and counsel without fully understanding the reason for the grief-stricken knight's suffering until very late in their conversation—until nearly the end of the dream, in fact. After many hundreds of lines, the knight is finally compelled to do away with elaborate, poetic mourning and simply tell the uncomprehending Chaucerian persona that White has died. The bluntness of the revelation leaves the narrator almost speechless, and it is the poet's deliberate strategy to contrast the knight's despair with the narrator's shallowness, prolonging the sense of failed conversation to an extent that makes us aware of the oddly comic quality of the situation.

Although Chaucer wrote short lyrical poems, he is best remembered for longer works like *The Book of the Duchess, The Parliament of Fowls, The House of Fame, Troilus and Criseyde, The Legend of Good Women,* and of course *The Canterbury Tales*. Their length makes it necessary to understand in premodern terms what was said above about Chaucer's sense of timing. Like other writers of his age, Chaucer was fond of long, detailed descriptions and digressions recounted at a leisurely pace. Although modern students occasionally complain that these are distracting features of his work that bog down their progress through it, medieval writers and readers who aspired to literary sophistication (as their culture conceived it) enjoyed them as hallmarks of good verse.

Apart from Chaucer's conscious ideas about narrative time and historical periodization, the poet's place *within* time, specifically literary history, has aroused much scholarly debate over the past decade and a half. Conventionally labeled a "medieval" poet, Chaucer is often placed within surveys of Western European literature before the Italian poet Francesco Petrarca or Petrarch (1303–1374), who lived roughly two generations earlier than the Englishman. This anachronism is related to the modern scholar's sense that Petrarch, having been fascinated with the classical Roman past, was more "modern" than Chaucer: The remnants of that past abounded in 14th-century Italy, and thus a "Renaissance" poet could arise much more naturally there than in contemporary England. Also of relevance is Petrarch's personal distaste for the Scholastic philosophy of his own day, articulated in a Latin that he condemned as barbarous. For his part, Chaucer had a real interest in historical and cultural change, but he had none of Petrarch's despondent yearning to rebuild antiquity on the ashes of his own time or to cleanse the Latin language of its alleged postclassical impurities. Important work in the field of Chaucer studies by David Wallace and others has challenged the knee-jerk temptation to label Chaucer a product of the "Middle Ages" and Petrarch the herald of the "Renaissance."

Joseph Grossi

See also Alighieri, Dante; Coleridge, Samuel Taylor; Eliot, T. S.; Poetry; Shakespeare's Sonnets; Novels, Time in; Woolf, Virginia

Further Readings

Benson, L. D. (Ed.). (1987). *The Riverside Chaucer.* Boston: Houghton Mifflin.

Boitani, P., & Mann, J. (Eds.). (2003). *The Cambridge companion to Chaucer* (2nd ed.). Cambridge, UK: Cambridge University Press.

Brown, P. (Ed.). (2000). *A companion to Chaucer.* Oxford, UK: Blackwell.

Cooper, H. (1996). *Oxford guides to Chaucer: The Canterbury tales* (2nd ed.). Oxford, UK: Oxford University Press.

Lerer, S. (Ed.). (2005). *The Yale companion to Chaucer.* New Haven, CT: Yale University Press.

Minnis, A. J., Scattergood, V. J., & Smith, J. J. (1995). *Oxford guides to Chaucer: The shorter poems.* Oxford, UK: Oxford University Press.

Windeatt, B. (1995). *Oxford guides to Chaucer: Troilus and Criseyde.* Oxford, UK: Oxford University Press.

Chauvet Cave

Both accident and scientific surveys have led to discoveries of caves throughout Europe that contain artifacts and artwork created by Paleolithic populations. Temporally speaking, these caves provide information on early European populations for whom little other evidence exists. Chauvet Cave, a relatively recent discovery, is one of the more noted such caves.

Discovered in 1994 by Jean-Marie Chauvet, Eliette Brunel, and Christian Hillaire, Chauvet Cave is located among the Cirque d' Estre Cliffs in southern France. As evidenced by skeletal remains, the cave was visited by a number of animal species including bears, deer, birds, and wolves. As for human populations, it is the presence of wall paintings and engravings that clearly marks human intrusion into the cave. Spanning hundreds of meters in length, the cave itself is the product of nature's ceaseless attention, particularly in the form of water erosion. Ultimately, after millions of years of alterations due these natural processes working on the cave's walls, ceilings and floors, Chauvet became a multichambered cavern that was augmented by stalactites, stalagmites, collapsed walls, and other geological phenomena. Structurally, the cave's several chambers vary in size from a few meters in width and height to a chamber that is upwards of 30 meters wide. Collectively, the geological phenomena associated with Chauvet Cave provide details about the effects of natural processes on subterranean dwellings while simultaneously providing researchers with an idea of times during which the cave's changes occurred. The remains Chauvet Cave's human occupants left behind give an entirely different picture and temporal understanding.

Remnants of human occupation of Chauvet Cave comprise a variety of artifacts including flint scrapers and blades, the remains of fire pits, and human footprints. Of course, the most evident indications of human occupations are the murals painted and engraved on the walls of the cave. Using charcoal and other miscellaneous matter as a medium, Chauvet's human occupants generated abstract images of animals, humans, and miscellaneous objects upon the walls much in the way other peoples adorned the walls of caves throughout the region during Paleolithic times. Specifically, animal images found were bison, mammoths, bears, rhinoceroses, and horses. As for the detail of the images created, while some images were roughly designed, others were quite detailed in their outline and overall attributes.

Why were the paintings and engravings created? What purpose did they serve? These questions, which have been debated since the first cave paintings surfaced, remain unanswered. What has been determined, however, are the times when Chauvet Cave was visited. With a large sample of carbon-14 dates determined through the analysis of bone and wood charcoal fragments, researchers discovered two main periods of occupation or rather visitation of Chauvet Cave, the first centered around 31,000 years before the present era (BPE) and the second centered around 26,500 BPE.

Chauvet Cave itself has provided researchers with a large sample of carbon-14 dates and breathtaking examples of wall art that clarify the variety of techniques utilized by prehistoric populations to generate their paintings and engravings. With its discovery being so recent, Chauvet Cave will undoubtedly continue to enlighten researchers for quite some time.

Neil Patrick O'Donnell

See also Altamira Cave; Anthropology; Archaeology; Chaco Canyon; Dating Techniques; Lascaux Cave; Olduvai Gorge

Further Readings

Clottes, J. (2003). *Chauvet cave: The art of earliest times*. Salt Lake City: University of Utah Press.

Guthrie, R. D. (2005). *The nature of paleolithic art*. Chicago: University of Chicago Press.

Chemical Reactions

The International Union of Pure and Applied Chemistry's (IUPAC) definition of a chemical reaction is "a process that results in the interconversion of chemical species." A chemical species is "an ensemble of the chemical elements which is identifiable as a separately distinguishable entity."

The transformation of reacting species into a new chemical product can be likened conceptually to events that occur in everyday life—it involves the interaction of objects (molecules, atoms, ions) with each other, and the outcome of the process is governed by their relative sizes, positions, and energies. A key has to be inserted correctly into a lock for it to be opened, and an egg's shell can be broken only by the application of sufficient force. The relation of these ideas will become clearer as the fundamental processes governing a chemical reaction are examined.

A discussion of *chemical reactions* in the context of time is highly appropriate: They have occurred since the dawn of time, they are both controlled by time, and, given the huge range of timescales on which reactions can take place, for example, the rusting of an iron nail compared to dynamite exploding, they exert an influence over the course of time. The history of chemical reactions in time is discussed in a manner complementary to the discovery of the chemical elements, although the two are very closely linked. This entry gives detailed consideration to the timescale on which chemical reactions occur: the very fast; those that are easier for human beings to contemplate; and the very slow. This highlights the technical ingenuity of scientists who have developed many sophisticated techniques to study ultrafast reactions.

History of Chemical Reactions

The world as we know it, indeed the entire universe, is composed of the chemical elements. The 94 known chemical elements (there are more in the periodic table, but they do not occur naturally) were formed shortly after the start of time as we know it—the *big bang*—and have been combining with each other ever since. Shortly after the big bang, extreme temperatures are believed to have favored the fusion of the separate neutrons and protons present, forming helium and deuterium nuclei, in a process termed *big bang nucleosynthesis*. These positively charged nuclei subsequently combined with the negatively charged primordial particles present, electrons, to produce the first atoms, of which most were hydrogen. The extreme conditions generated by the production of the first stars are believed to have created heavier elements through the processes of *stellar and supernova nucleosynthesis,* and *cosmic ray spallation.* The first chemical reactions would have now occurred, with simple chemical entities based on light atoms such as carbon, nitrogen, and oxygen produced in abundance.

The formation of the earth (c. 4.6 billion years ago) was followed by the Hadean eon, where the earth began to take shape. Changes in the chemical composition of the atmosphere, afforded by volcanic eruptions, the cooling of the earth's surface, and asteroid bombardment, have been proposed to have been instrumental in the development of life. The generation of small organic molecules, known to be monomeric constituents of living organisms from the most basic chemical species, is propounded as one of the most widely accepted theories of the origin of life. The combination of α-amino acid molecules to form polypeptide chains; the similar production of nucleotides, phosphates, and sugars could, theoretically, react together in such a way as to give the double-helix of life, DNA. The classic Miller-Urey experiment exposed a mixture of simple gases and water vapor to an electrical discharge (to mimic lightning), and the ensuing chemical reactions were indeed found to produce simple biomolecules that are essential to life. An early earth atmosphere rich in ammonia, methane, water, carbon dioxide, and nitrogen could have been transformed chemically to give a so-called primordial soup.

The suggested transformation of simple biomolecules into the polymeric constituents of life, and their organization to give a living cell, remains a controversial theory. Such an event would mark the cornerstone of evolution and of the history of the earth. The first simple single-celled organisms were all likely to have been heterotrophic, requiring relatively complex organic substrates, for example, simple sugars, to be sustained and to reproduce. It has been proposed that such organisms diverged as a process of evolution to produce autotrophic species, which were able to use an alternative source of energy and were subsequently able to transform the most basic chemical precursors into much more complex ones. The most important example of autotrophic chemical reactions is photosynthesis: the conversion of water and carbon dioxide driven by sunlight into carbohydrates. Photosynthesis is one of the most important natural chemical reactions known to humankind, and the challenge of reproducing it satisfactorily within the laboratory has still not been met.

Profound environmental changes occurred as a result of the production of oxygen. Initially, oxygen dissolved in the oceans and combined with oxophilic elements to produce numerous oxides such as those of the common metals, iron in particular. Over time, its concentration in the atmosphere gradually increased, with far-reaching consequences for the diversity of the living organisms that, until then, existed in anaerobic conditions. Concomitantly, the conversion of oxygen (O_2) to ozone (O_3) in the upper atmosphere by ultraviolet light formed a protective layer around the earth that actually reduced the amount of damaging ultraviolet radiation reaching the earth's surface. A popular notion is that this could have safeguarded the development of simple organisms that were then given the chance to evolve in an increasingly aerobic environment. Moreover, those organisms that did not evolve to be able to assimilate oxygen were largely wiped out by the increasingly toxic environment. Today, the earth is finely balanced by cycles of respiration (effectively the production of energy by oxidation of relatively complex carbon-rich organic molecules producing carbon dioxide and water) and the reverse of this process, photosynthesis. The energy produced by respiration provides the driving force for the conversion of very unreactive nitrogen gas into soluble nitrogen compounds. The combination of photosynthesis, respiration, and the fixation of nitrogen forms the basis of life itself.

The discovery and exploitation of fossil fuels as an energy source by humankind was almost certainly the next most significant way chemical reactions would alter the environment of the planet. Reserves of coal, gas, and oil were formed from decaying organic matter by very slow chemical reactions, but comparatively recently given the estimated age of the planet. Combustion of fossil fuels for heating, driving industrial processes, and travel has been held responsible for the rising levels of carbon dioxide in the atmosphere and is claimed to be a major contributor to global warming.

The commercialization of chemical reactions occurred as an inevitable part of the Industrial Revolution. New raw materials such as sulfuric acid (the production of which is thought to be the first chemical process to be performed on an industrial scale), soda (sodium carbonate), and caustic (sodium hydroxide) were required to support many thriving industries including glassmaking, soap production, and cotton bleaching in the 19th century. It is appropriate to mention that many of these chemicals now being produced on a grand scale had their origins in the alchemical era. The accidental discovery of mauvine (an intensely colored purple dye) during an attempted synthesis of the antimalarial quinine by William Perkin in 1856 was the catalyst for the generation of the modern-day chemical industry. Existing chemical companies such as Imperial Chemical Industries (ICI) and Bayer began to diversify into photography, food, pharmaceuticals, and explosives. The improvements in scientific understanding during this period drove the desire to better understand chemical reactions and the structures of molecules; both academic and industrial chemical research have since flourished. Our current level of understanding means we are able to design and control chemical reactions to provide us with food, health, fashion, and entertainment.

The Timescale and Study of Chemical Reactions

The rate at which a chemical reaction proceeds is studied by *reaction kinetics*. The timescale on which a chemical reaction can occur ranges from the very slow, taking days or years to complete, to the ultrafast, of the order 10^{-15} seconds (one quadrillionth of a second). The majority of chemical reactions require a millisecond (one thousandth of a second) or less. For a chemical reaction to take place, the reacting molecules must collide with one another in a favorable orientation to overcome the energetic barrier to reaction: the activation energy to form the activated complex (or transition state). This represents the highest energy point on the reaction pathway (rather like the top of a mountain); it will then rapidly collapse, with the products of the reaction tumbling downhill, to either the unchanged starting species or the new product(s).

A catalyst lowers the activation energy in forming the activated complex, meaning more of the reacting entities will have the energy required to react on collision. The presence of a catalyst therefore increases the overall rate of reaction. Enzymes are nature's catalysts, and numerous manmade materials are employed in industrial processes in an attempt to compromise between making the speed of a reaction reasonable without making the process economically unfeasible.

In a kinetic study, it is conceptually useful to imagine the whole reaction process being photographed from start to finish. Each "snapshot" represents a different stage in the reaction pathway, and, depending on the rate of reaction, it may be possible to view the discrete stages of the reaction.

The scientific investigation of reaction kinetics has always presented a challenge to chemists. Classical investigations (which predate 1900) of reaction kinetics could be performed only on very slow reactions, as the progress of the reaction had to be followed by some physically variable property that was perceptible to human beings, such as a color change or the evolution of a gas. The change in such a property was monitored over time, producing a relationship between the progression of the reaction and the time elapsed, which could then be used to determine the reaction rate. The shortest observable reactions were of the order of seconds. The development of rapid mixing techniques early in the 20th century allowed so-called stopped flow methods to probe reactions of the order of milliseconds. A significant problem encountered using this technique was that, for very fast reactions, efficient mixing takes an infinitely long time compared to the speed of the reaction itself. Therefore, the reactions would have already taken place before the reacting species had mixed properly, giving inaccurate results. Recent improvements in instrumentation have meant that reactions on the microsecond timescale can now be studied.

Scientists recognized early on that new techniques would have to be developed for the study of faster reactions. Manfred Eigen, Ronald Norrish, and George Porter were co-recipients of the 1967 Nobel Prize in Chemistry for their development of flash photolysis in 1949: a pump-probe technique that could interrogate reactions of the order of microseconds. A chemical sample was irradiated using a very short burst of intense light (from a very powerful flashlight) to produce a reactive (and most often short lived) intermediate, the subsequent decay of which by, for example, chemical decomposition or the reemission of light, was monitored spectroscopically.

With the advent of lasers in the 1960s, the shutter speeds of our notional "camera" could be increased substantially, and the pico- (one millionth of one millionth of a second) followed by the femtosecond regimes were now accessible.

Chemical reactions are also concerned with reaction *dynamics:* changes to the molecular architecture, such as the perturbations in bond lengths and angles that occur as a reaction is taking place. As understanding of chemical reactions improved over the 20th century, scientists became much more ambitious and began to explore the possibility of probing extremely fast reactions, or, more specifically, the direct observation of the shortest lived species known in chemistry: the activated complex. The reorganization of electrons in chemical bonds and the nuclei of the constituent atoms over atomic dimensions (a vibration of a chemical bond) is of the order of femtoseconds (10^{-15} seconds). Thus, to achieve resolution of the activated complex, the shutter speed of our "camera" would have to be around 10 to 100 femtoseconds. Ahmed Zewail pioneered the experimental techniques for the exploration of chemical reactions into the femtosecond regime (with the main technological requirement being sufficiently short exciting laser pulses) for which he was awarded the Nobel Prize for Chemistry in 1999. Femtochemistry has now diversified and been rebranded in many branches of science. Femtobiology has been applied to fundamental biochemical processes such as vision, protein dynamics, photosynthesis, and proton and electron transfer. The understanding of early femtosecond events in a protein environment is important for understanding the function of these systems.

Additional spectroscopic techniques have been developed during the 21st century, not with the aim of studying kinetics of chemical reactions, but to exploit the different timescales of molecular processes that do not necessarily lead to chemical reactions but are more suited to probe reaction dynamics. The Heisenberg uncertainty principle stipulates that, in measuring the position and momentum of an object, the more accurately one property is determined, it follows that the other becomes less accurately determined. Therefore, as a molecule of a particular energy is less well defined, its lifetime will be increased.

Since different molecular architectures have different energies, improvements in spectroscopic techniques that have allowed the changes in energy between molecular states to be very accurately measured can be used to determine how molecular properties such as the distance between two nuclei change over the course of a chemical reaction. A large difference in energy between two different molecules allows them to be distinguished even if they interchange very quickly. High-frequency techniques such as ultraviolet visible (10^{-15} s) and infrared spectroscopy (10^{-14} s) are easily able to distinguish between molecular states that are blurred to electron- (10^{-4}–10^{-8} s) and nuclear-spin resonance (10^{-1}–10^{-9} s) probes.

There is much speculation as to how the earth and even the universe will come to an end, if indeed they will. Humankind's negative influence upon the environment as a result of chemical reactions is only too apparent. The depletion of ozone in the stratosphere caused by the photochemical degradation of CFCs (chlorofluorocarbons); the emission of greenhouse gases; and the poisoning of terrestrial land and water systems promises a bleak future for the earth. It is possible that an increasingly toxic and humid environment will make life on the planet unsustainable.

Looking even farther into the future, in a climax of destruction, all objects created by chemical reactions could disintegrate under the influence of the continually expanding universe into radiation and elementary particles that will move away from each other—an awesome contradiction to the formation of the first elements and their ensuing chemical reactions at the dawn of time.

James V. Morey

See also Aging; Attosecond and Nanosecond; Big Bang Theory; Chemistry; Decay, Organic; DNA; Dying and Death; Evolution, Chemical; Global Warming; Life, Origin of; Oparin, A. I.; Photosynthesis; Thanatochemistry

Further Readings

Ball, P. (2003). *Molecules: A very short introduction.* Oxford, UK: Oxford University Press.

Ball, P. (2004). *The elements: A very short introduction.* Oxford, UK: Oxford University Press.

Hall, N. (Ed.). (2000). *The new chemistry.* Cambridge, UK: Cambridge University Press.

McNaught, A. D., & Wilkinson, A. (Eds.). (1997). *Compendium of chemical terminology* (2nd ed.) (IUPAC [International Union of Pure and Applied Chemistry]). Oxford, UK: Blackwell Science.

Porter, G. (1997). *Chemistry in microtime: Selected writings on flash photolysis, free radicals, and the excited state.* London: Imperial College Press.

Zewail, A. (1999, December). *Ahmed Zewail. The Nobel Prize in Chemistry 1999. Nobel lecture. Femtochemistry: Atomic-scale dynamics of the chemical bond using ultrafast lasers.* Retrieved July 17, 2008, from http://nobelprize.org/nobel_prizes/chemistry/laureates/1999/-zewail-lecture.html

Zewail, A. (2003). *Voyage through time: Walks of life to the Nobel Prize.* London: World Scientific Publishing.

Chemistry

A modern, albeit superficial, definition of chemistry is that it is the science dealing with the composition of substances, their properties and reactivity. All matter in the universe is composed of the *chemical elements;* their systematic study, and that of the *compounds* they form, is chemistry. Chemistry has earned itself the title of the central science, as the study of matter is fundamental to all other sciences, including physics, materials science, biology, and pharmacology to name just a few. Typical applications of chemistry in modern life include the discovery and development of new drugs; the discovery and production of fuels, plastics, fertilizers, pesticides, vaccines, and foods; the use of chemical techniques by forensic scientists to solve crimes; and the production of new materials and pigments for the clothes we wear and the many functional items in our homes. It is certain that chemistry has occurred since time began and will prevail until time ceases, and this makes the discussion of chemistry in time both fascinating and hugely important. The impact that the science of chemistry has had on humanity is huge. The ill-defined and semi-empirical beginnings of what we now know as the highly advanced, organized, and multidisciplinary science of chemistry lends well to a general overview of the subject being discussed within the framework of time.

Initially, the development of chemistry as a widely accepted scientific discipline from its rather chaotic foundation in alchemy and philosophy is discussed from a historical perspective, with particular emphasis on the scientific, technological, global, and economic impact from its initial establishment in the 16th century to the present day. Next, the position and influence of chemistry in the 21st century is introduced by a retrospective exposition of the effect of chemistry on humanity and the environment. The subsequent expansion alludes to the challenges within chemistry itself as both the source of, and solution to, many fundamental problems that currently face humanity, and that will most certainly become more pressing and severe in the near future.

Chemistry in the Past

Around the 7th century BCE, Thales of Miletus is credited as the first of the Greek philosophers who endeavored to explain the natural world around him without invoking any supernatural phenomena. Indeed, he is arguably the first *scientist.* The Greeks explained many natural occurrences, such as lightning and earthquakes, as the direct intervention of anthropomorphic gods and heroes. Such mythological reasoning was sidelined by Thales and he instead proposed, for example, that the earth floats on water, and hence the occurrence of earthquakes can be explained by the striking of the earth by waves of water. Thales held the view that all matter was ultimately derived from water, although this hypothesis was certainly tainted with the supernatural. Thales' Miletian philosophical descendants were more coy: Anaximander ascribed to all substances being made from *apeiron,* a single, unknown substance. Subsequently, air (Anaximines) and fire (Heraclitus) were separately proposed to be the basic constituent of all matter.

The quest by philosophers to produce a simple explanation of the natural world, combined with the observation that one substance could be converted into another, meant the idea that all substances were ultimately composed of the same basic building block was attractive and persisted for some time.

Aristotle (c. 4th century BCE) agreed with the notion that ultimately there was only a single primal substance, but argued that it was incomprehensible to humankind. Somewhat contradictorily, he believed that Empedocles' four elements—earth, air, fire, and water—were the constituents of all matter. He was also sympathetic to Anaximander's view that the phenomena of heat, cold, wetness, and dryness were influential in the interconversion of different substances; a view not alien to our modern-day understanding of the transformations between states of matter with, for example, water converting from a solid to a liquid to a gas by heating; the process being reversed by cooling.

Leucippus is believed to have formulated the idea that all matter is made of many small particles, or *atomos* (a term coined by Democritus, meaning "indivisible"), all of which are made of the same primal substance, but are observed differently depending upon the material. These ideas were made to be compatible with Aristotle's "quartet of elements." There was disagreement between proponents of atomism and those of the older theories. Opponents of Leucippus wanted to know what he claimed might separate these small particles if they were really indivisible?

Empedoclean views of the four elements constituting matter, which was supported by the credible figure of Aristotle, eventually led to the suppression of atomism as a credible explanation for the composition of the natural world. Its perceived blasphemous stance was condemned in the Middle Ages, though it did not disappear completely. It was the experimental input from *alchemy,* rather than conjecture, that progressed our understanding to what we know and accept today.

Although alchemy has long been regarded as pseudoscientific, that is, a practice that claims to be scientific but does not adhere to the scientific method (the proposition of a hypothesis based on a natural phenomenon that is then tested experimentally in an objective and transparent manner), it is the forerunner of chemistry as we know it today.

Closely related to the ancient traditions of Hermeticism, Western alchemy is often viewed as a practice akin to black magic, with practitioners intent on producing gold from a variety of tenuous, mystically based recipes and incantations. This view is somewhat dispelled, however, when it is considered that many of those who practiced alchemy went on to influence much of what is now called modern science, Isaac Newton and Robert Boyle being two examples. In fact, over the course of the early modern period, mainstream alchemy developed into a discipline now recognizable as the precursor to modern chemistry.

A cursory examination of alchemy and its metamorphosis into a rigorous scientific discipline follows. It is significant that it predates the philosophical musings of the ancient Greeks by a considerable margin.

It is believed that "Western alchemy" originated in Egypt (5000–400 BCE) and subsequently became established in Greek and Arabian civilizations, and in Europe from 1300 onwards. Chinese and Indian alchemy were developed independently and remain culturally isolated.

The proliferation of alchemy was motivated by spiritual beliefs that were connected to unexplained and enchanting physical phenomena, such as fire: a mystical force that could transform one substance into another. In the same way compounds are broken down and recombined by the alchemist, it was believed that the immortal spirit was separated from the mortal body upon death, and recombination with matter meant immortality. The search for an *elixir of life* was closely linked to the ongoing challenge of being able to transmute poorer base metals into gold. By the same token, the alchemist sought the perfection of the self, with death not seen as the end.

During the Renaissance, the ideas of René Descartes and Roger Bacon provided the foundations for developing the scientific method. Around this time, Western alchemy began to split into two separate strands. Initially, it was Paracelsus who directed alchemy away from the underlying mystical and spiritual influences and applied a more scientific approach, giving rise to *iatrochemistry.* However, there remained those who held firm to the spiritual foundations of alchemy and continued the search for immortality and metal transmutation.

It has been said that the development of metallurgy (which is inextricably linked with alchemy) was the turning point in history that marked a departure from the Aristotelian elements. The metals, of which a significant number had been discovered by the 17th century, were regarded as "earth," an extrapolation of the notion that the known states of matter corresponded to the physical form of a substance: "air" was gas, "water" was liquid, and "earth" was solid. The cultural importance of gold was increasing, and its obvious difference from the other metals was of great interest, therefore the notion of them being "the same" was unacceptable.

The vague and esoteric language of alchemy, the irreproducibility of experiments, and the exposure of fraudulent practice began to frustrate eminent writers such as Geoffrey Chaucer and Dante Alighieri. Alchemists were accused of deliberately trying to conceal their methods from the uninitiated, and their opponents argued that they were in fact self-deceived; skepticism and distrust toward alchemy became popular opinion.

The publication of *The Sceptical Chymist* by Robert Boyle in 1661 became a cornerstone in the development of chemistry away from its alchemical roots. Boyle refuted the concept of Aristotle's quartet of elements, instead contending that all substances were made of irreducible particles of some shape or form. An important point is that he argued that a proposed theory must be proved by experimentation before it could be accepted as true. Subsequent work in the 18th century by Antoine Lavoisier paved the way for the chemistry we know today. He concluded, rightly so, that water and air were composed of distinct entities, and thus they were not elements at all. Lavoisier also took the significant step of quantitatively measuring his experiments, allowing him to demonstrate mass changes during combustion. Crucially, the identification of oxygen was achieved, though it is certainly debatable whether Lavoisier was the first to discover this element. Joseph Priestley was instrumental in corroborating the work of Lavoisier.

At the turn of the 19th century John Dalton is to be credited with the revival of a modern atomist theory: Elements are made of small particles called atoms; all the atoms of a given element are identical to each other but different from those of another element; atoms from one element can combine with those of another in a fixed proportion; and they cannot be created or divided into simpler particles. He implemented a system for depicting the known chemical elements of that time (though some were erroneous as, in fact, they were chemical compounds) and, most important, gave them a measurable quantity: atomic weight. Jöns Jakob Berzelius proposed the designation of simple symbols for the chemical elements, for example, F for fluorine and Mg for magnesium. This is the modern-day language of chemistry.

Many were now to attempt the tabulation and systematic ordering of the known chemical elements. It was Dmitri Mendeleev who studied the behavior of individual elements, grouped them together by virtue of similar chemical properties, and successfully predicted the existence of elements that were discovered during his lifetime. This culminated in the much-vaunted periodic table of elements, today's chemist's "road map" to all the known chemical elements.

It now remained for the conclusive identification of atoms themselves as being the true "primal matter." In 1909, Ernest Rutherford chose gold with which to perform his experiments to determine to composition of the atom. Being malleable, it could be beaten into very thin sheets, which made it almost transparent. Firing α-particles (positively charged helium nuclei) at thin gold foil afforded some very surprising observations. The refinement of Rutherford's results by Niels Bohr, coupled with Joseph John Thomson's earlier discovery of the electron, and the subsequent discovery of the neutron by James Chadwick in 1932, led to the establishment of the currently accepted view of the atom. It consists of a dense, positively charged nucleus of two distinct subatomic particles, protons and neutrons, surrounded by a cloud of negatively charged electrons, with the two separated only by empty space (an idea intolerable to most early Greek philosophers).

Chemistry in the Present and Looking to the Future

The development of chemistry from the early attempts by philosophers to understand their surroundings to the well-established and undisputedly vital scientific discipline it is today has been key to the development of civilization across the globe. However, the influence of chemistry has been both positive and negative. While people are able to live longer and more comfortably thanks to improvements in agriculture (fertilizers and pesticides), pharmaceuticals, and energy derived from crude oil, the improvement in our quality of life has impacted negatively upon the environment through, for example, global warming, the depletion of the ozone layer, and pollution of terrestrial water systems. Numerous human tragedies have arisen through the irresponsible or malicious use of chemicals: the Bhopal disaster; the deployment of nerve and blister agents during warfare; and the prescription of thalidomide to pregnant women to name but a few. Chemistry and the chemical industry are certainly sometimes viewed with suspicion, and the dogma that "natural" substances are "good" and those produced by man are "bad" persists. Certainly a prominent challenge for the future is to educate the general public; ignorance is perhaps the fault of chemists and other scientific disciplines for allowing themselves to be viewed as impenetrable.

Chemistry today is very much at the forefront of technological development and it is studied intently in academic and industrial institutions. Research efforts are directed toward both blue-sky exploration and the addressing of specific scientific problems. The discovery and development of new chemical reactions and techniques have elements of both, whereas the preparation of new chemical elements by nuclear chemistry and the development of sustainable energy alternatives are restricted to each category, respectively.

Perhaps surprisingly, alchemy, the transmutation of elements, is still an actively pursued area of research. The prospects for the isolation of the heavier nuclei of elements with an atomic number greater than 118 appear to be very challenging.

Humankind's desire to understand and predict the properties of molecules has been unrelenting. The application of quantum mechanical methods to the study of a chemical system has made the most of the improvements in computing power. Chemists are still currently limited to the study of comparatively simple systems under artificial conditions. For example, most density functional calculations on molecules to probe their stability and geometry are performed in the gas phase, with interaction between other molecules unaccounted for. As computers become more powerful, chemists will be able to study the structure of more complex molecules (invariably those that play a key role in biochemistry) and probe their interaction with one another.

Nature has remained far superior in its elegance and efficiency in producing useful chemicals. Humankind has marveled at the complexity of photosynthesis, respiration, and the fixation of atmospheric nitrogen for decades. Attempts to model these systems in the laboratory using a much more basic repertoire of chemicals have met with only limited success. Such attempts have, however, broadened our understanding of these natural processes considerably. The industrial production of bulk chemicals is costly both in terms of energy and its impact on the environment. The development of a process to produce ammonia with the comparable mildness and efficacy of the nitrogenase family of enzymes would make a welcome replacement for the Haber process. Similarly, the cheap and environmentally benign production of hydrogen to be used as an energy source is highly sought after. The increasing levels of carbon dioxide in the atmosphere, generated from the combustion of fossil fuels, are largely responsible for global warming. The sequestration, or ideally, utilization of CO_2 as a feedstock itself is highly desirable.

Similarly, some the most efficacious medicinal compounds are those isolated from natural sources, but they tend to be highly complex structures and very difficult to make in the laboratory. The ingenuity of synthetic chemists means that, given enough time and resources, any molecule can be made in the laboratory. But this process is inefficient and expensive, and largely serves to showcase what chemists can achieve rather than resulting in a useful product. Given the dwindling success of the pharmaceutical industry in generating new medicines, the future will see a renaissance of drugs being developed from natural products. Instrumental in this process will be the crafting of genetic engineering, rendering bacteria, rather than chemists and glassware, the far better choice for producing potential new drugs on the scale likely to be required.

Astrochemistry, the application of chemical techniques to the study of the chemistry in outer space, has afforded interesting insights into the universe itself and its influence on the formation and the development of planet Earth. Many hypotheses have been put forward to suggest that life as we know it, or at least its simple organic precursors, could have developed in space and then subsequently been transferred to Earth by meteorites. Chemistry will continue to be of immense value to space exploration, and it is hoped that it will provide more clues as to our origin, and maybe even our subsequent fate.

James V. Morey

See also Aristotle; Chemical Reactions; Comets; Decay, Organic; DNA; Dying and Death; Ecology; Evolution, Chemical; Life, Origin of; Medicine, History of; Meteors and Meteorites; Oparin, A. I.; Paracelsus; Photosynthesis; Presocratic Age; Space Travel; Thanatochemistry

Further Readings

Ball, P. (2003). *Molecules: A very short introduction.* Oxford, UK: Oxford University Press.

Ball, P. (2004). *The elements: A very short introduction.* Oxford, UK: Oxford University Press.

Donovan, A. (1993). *Antoine Lavoisier: Science, administration, and revolution.* Cambridge, UK: Cambridge University Press.

Greenberg, A. D. (2000). *Chemical history tour, picturing chemistry from alchemy to modern molecular science.* New York: Wiley-Interscience.

Hall, N. (Ed.). (2000). *The new chemistry.* Cambridge, UK: Cambridge University Press.

Lewis, F. A. (1991). *Substance and predication in Aristotle.* Cambridge, UK: Cambridge University Press

Robinson, J. M. (1968). An introduction to early Greek philosophy. Boston: Houghton Mifflin.

Scerri, E. R. (2006). *The periodic table: Its story and its significance.* Oxford, UK: Oxford University Press.

Chicxulub Crater

The Chicxulub crater is an approximately 180-kilometer–diameter structure, which is now buried by a nearly 1-kilometer–thick sequence of carbonate sediments, on the northern edge of the Yucatan Peninsula (southeastern Mexico). The name Chicxulub was selected because a small town, Puerto Chicxulub, is located above the center of the structure. The best-known surface expression of the crater is a concentric pattern of karst sinkholes called the Ring of Cenotes (*cenote* is the local Maya word for sinkhole). The Ring of Cenotes is generated by progressive subsidence of the crater's wall and is visible in satellite images of the region. The formation of the Chicxulub crater represents a significant event in the Phanerozoic's history: it was made about 65 million years ago when an approximately 10-kilometer–diameter extraterrestrial body hit the earth, causing the great mass extinction at the end of the Cretaceous period.

The Chicxulub structure was described initially in the late 1940s as a set of nearly circular geophysical anomalies discovered during oil surveys. In the next decades, three exploratory wells drilled into the structure by Petróleos Mexicanos (PEMEX, the Mexican state-owned oil company) penetrated late Cretaceous rocks (andesite). This andesite was originally interpreted as having a volcanic origin, and the Chicxulub structure was considered a giant end-Cretaceous volcano.

This interpretation changed at the beginning of the 1990s, when certain evidence confirmed an impact origin for the Chicxulub structure: impact melt rock in the crater, an extensive field of tektites around the Gulf of Mexico, and a millimeter-thick layer worldwide that contains material of the meteoritic impact (iridium anomaly, microdiamonds, nickel-rich spinels, microtektites, and shocked quartz grains). This millimetric key-bed represents the dust and fine ejecta that covered the atmosphere after the Chicxulub impact and deposited slowly, probably over months or a few years after the impact.

The environmental perturbations of the Chicxulub impact event included a temporary absence of sunlight caused by dust and aerosols ejected into the atmosphere, impact winter (similar to nuclear winter), acid rain production, worldwide wildfires, and the largest tsunamis and earthquakes of Earth's most recent history. These disruptions caused the second, more severe biological crisis of the Phanerozoic: the Cretaceous–Tertiary mass extinction event. About 75% of all uppermost Cretaceous species were rendered extinct in this event, including the popular nonavian dinosaurs.

Chicxulub crater is the youngest and best-preserved large impact crater on Earth and is relatively untouched by the forces of erosion or tectonic deformation. For these reasons, it is of great interest for the study of impact cratering, including environmental and climatic effects and their biological consequences. The images obtained by the seismic reflection survey will be used to construct models of crater formation that can be applied throughout the solar system.

José Antonio Arz

See also Catastrophism; Cretaceous; Dinosaurs; Extinction and Evolution; Extinctions, Mass; Geology; K-T Boundary; Meteors and Meteorites; Nuclear Winter; Paleontology

Further Readings

Alvarez, W. (1997). *T. rex and the crater of doom.* Princeton, NJ: Princeton University Press.

Hildebrand, A. R., Penfield, G. T., Kring, D. A., Pilkington, M., Camargo, A., Jacobsen, S. B., & Boynton, W. V. (1991). Chicxulub crater: A possible cretaceous/tertiary boundary impact crater on the Yucatan Peninsula, Mexico. *Geology, 19,* 867–871.

Hsü, K. J. (1988). *The great dying (cosmic catastrophe, dinosaurs, and the theory of evolution).* New York: Ballantine.

Chomsky, Noam

See Language

Christianity

A monotheistic religion that originated in the Near East during the first century CE, and whose essence is the belief in Jesus Christ, Christianity is a theocentric faith proclaiming the existence of a personal God, one in the Holy Trinity. The God of Christianity is an autonomous, indivisible, immaterial being, an absolute unity possessed of infinite life and totally distinct from the world. Each of God's persons has only one and the same divine nature and remains in a reciprocal personal relation with the others on the basis of its origin. God the Father is the principle that originates the Son and the Holy Spirit (*Filioque*). As the Almighty Father, God is the creator of the entire universe, which he sustains in existence and upholds in its activities, guiding both the lives of individuals and the history of human communities (divine providence). Having elected humankind from all earthly creatures, both as spiritual creatures (human soul) and material beings (human body), God has granted humans immortality. He created humans in his own image and likeness, and bestowed on humans his grace and friendship (God's children). Human disobedience against God's decrees (original sin) is understood not as having caused God's revenge, but as having brought about the promise of salvation already outlined in the Hebrew Bible, or Old Testament. Thus, Christianity has its source in Judaism and is considered a revealed religion. This entry provides a detailed overview of the history of Christianity from its sources in Judaism and development through the Roman period, through the Middle Ages and into the modern era, an outline of Christian doctrine, and an explanation of Christianity's understanding of, and relationship to, time.

Source of Christianity

The Hebrew Bible shows the eternal covenant between the Israelites and Yahweh (Jehovah). In its oldest confessions of faith, Israel proclaimed God to be the redeemer of the nation, the Lord of the holy history, the one who has chosen the fathers, granted them his promises, and then realized these promises. Such formulas, defined as Historical Creed, for example included in Deuteronomy (Deut. 6:20nn and 26:5b–9), were designed for public recitation in prescribed ritual practices. Through such recitation, Israelites experienced their own selves before God. It was thus acknowledged that the nation responded to God and fulfilled the terms of the covenant not only as a group, but also through individuals. Individuals, however, were not always correct in their responses to God's initiatives and not always righteous toward their neighbors. In monarchic times, the faith and deeds of the kings could either secure the well-being of the nation or cause misfortune. This made the Hebrews reflect on the sinful condition of humanity and on the fact that humanity was constrained by sin, subject to suffering and death. Such a reflection gave rise to thoughts about the need for redemption and led to emergence of the Messianic idea. The life and teaching of Jesus of Nazareth, which were directed against institutionalizing and legalizing faith, confirm his awareness of being the Messiah awaited by the people of Israel. The Gospels show Jesus of Nazareth as the Messiah acting in the name of God and fulfilling the prophecies articulated in the Hebrew Bible (in Christianity, the Old Testament).

History of Christianity

The term *Christians* comes from the word Christ (gr. *Christos*), which refers to the real historical person considered as someone anointed by God and the Son of God, according to Saint Peter's confession of faith: "Thou art the Christ, the Son of the living God" (Matt. 16:16). The life and teaching of Jesus Christ was conveyed from the Pentecost onward in the form of the oral proclamation of God's message of salvation. Later it was written down in books that were considered holy and inspired. These are known as the New Testament and are part of the Holy Scriptures. In terms of chronology, the earliest texts of the New Testament were the Letters of Saint Paul to Thessalonians, written in 50/51 CE. The first gospel was the Gospel of Saint Mark, while the writings of Saint John, comprising three letters, the Gospel, and the Revelation, are the last pieces of the New Testament in the chronological order of composition. The books of the New Testament are the confession of faith of the first Christians. They were not intended as Christ's biography or a history of the first Church, but they nevertheless provide a reliable source for establishing many historical events. The historical existence of the founder of Christianity is also confirmed by a few non-Christian sources. His activity in Galilee and his death on the cross, which was not a major event in political terms, could not have been the center of attention for Jewish or Roman chroniclers. Josephus Flavius, a Romanized Jewish historian, includes in his work *Iudaike archaiologia—Ancient History of Israel,* known also as *Antiquities of the Jews,* reliable information about the person of Jesus Christ ("then there appeared Jesus, a wise man, if he was man at all, because he performed many outstanding things; he was a teacher of the people . . . and many people followed him. On the basis of the accusation formed by our chief men Pilate sentenced him to death on the cross but his former friends did not stop loving him, because on the third day he appeared to them alive, just as God's prophets had foretold" (Matt.–18.3, 3). To the skeptics the text seems too positive, so they consider it to be at least partially interpolated by Christians. But even if this were the case, the interpolation itself is evidence of the historical existence of Christ. Two Roman historians, Tacitus (55–120 CE) and Suetonius (65–135 CE), mention Christ in connection with their accounts of other historical events. Tacitus describes the great fire in Rome (64 CE) and the fact that Emperor Nero blamed it on the Christians.

Suetonius gives an account of the expulsion of the Jews from Rome by Emperor Claudius (50 CE). Both texts prove that the existence of Christ was known in Rome and that his figure was associated with the Christians.

The First Church

A lack of definitive historical documents complicates the study of the origins of Christianity and causes serious controversies. It is generally considered that the first Christian community was formed in Jerusalem around the year 30 CE. It consisted of Jews who had embraced Jesus' teachings during his life on Earth and under the influence of the first catechesis of Saint Peter (the so-called primary catecheses, which include the speech given on the descent of the Holy Spirit, Acts 2:14–36), which proclaimed the resurrection of crucified Jesus. Many other such communities were created by Jews living in the Diaspora and converted from Hellenism. Only some Jews inhabited Jerusalem and Palestine; others were dispersed all over the region. This resulted in cultural as well as political, and even religious diversification of the Jewish nation, although it shared a single cultural background and preserved the faith in one God—Jehovah. In general, Jews in the Diaspora were able to exercise religious and political autonomy. They used the Greek language (*koine*), sometimes even for the liturgy. Because the use of Greek led to the appropriation of other Hellenic influences, people from Jerusalem treated their Hellenizing neighbors from the Diaspora with reserve. Through its connections with Greek culture, the Diaspora was more open to Christian teaching than the Judeans were. In order to facilitate apostolic work with the rapidly growing numbers of Christians, seven deacons were nominated (Stephen, Philip, Prochorus, Nicanor, Timon, Parmenas, and Nicolas of Antioch), probably from the group of Hellenists. They were appointed for the purposes of religious service and works of charity (Acts 6:1–7).

The term Christianity appeared as late as 43 CE in Syrian Antiochia, where the believers in Jesus were called *christianoi* for the first time (Acts 11:26). The term most probably derives from pagan circles and was originally pejorative. The same word can be found in some early Christian writings, for instance in the texts of Ignatius of Antioch, Tertullian, or Eusebius of Caesarea. Before that, the believers in Christ called themselves the commune, the community, or the church (Acts 5, 11), while the Jews treated them as a sect of the Nazarenes, Galileans, or Ebonites (hebr. *Ebionim,* the poor).

Christianity spread thanks to the missionary activities of the apostles and their associates as a result of the first persecution. This started with the bringing of the Apostles Peter and John before the Sanhedrin because the Jewish priests and the Sadducees were aggrieved at the apostles teaching to the people about the resurrection of Jesus. Their first hearing finished with threats and was soon followed by a second arrest and imprisonment from which, according to the Acts, they were delivered by an angel of God (Acts 5:17–19). Both arrests took place on the orders of the high priest and his kin, who rejected the teaching about Christ and feared social unrest in Jerusalem. The following persecution affected not only the apostles, but also the church in Jerusalem and even spread to other Christian communities in Palestine. It started in 32 CE with the charges raised by a group called the Libertines, Cyrenians and Alexandrians against deacon Stephen, whom they accused of blasphemy (Acts 7:54–60). The persecutions that followed his death resulted in a dispersal of Christians over Judaea, Samaria, Galilee, and beyond Palestine, reaching Damascus, Joppa, Philippia, and Antioch in Syria.

When visiting the dispersed Christian communities, Peter and John attracted new believers. Their numbers grew, and new communities were formed. Deacon Philip baptized a courtier of Ethiopian Queen Candace (Acts 8:25–40). Apostle Peter baptized pagan centurion Cornelius together with his household (Acts 10:1n). However, the model in which a Christian was to be strongly linked with the Jewish culture proved incompatible with Christianity as a universal religion.

The dispersal of the apostles was the result of the persecution of the church in Jerusalem instigated by Herod Agrippa I in 43 CE. This was initiated by the king following his appointment by Emperor Claudius as the ruler of all of Palestine. In this way, Herod Agrippa tried to curry the favor of the high priest Ananias after deposing his son Teophilus. The king's sudden death in 44 CE restored peace to the Christian church in Jerusalem.

The next wave of persecution was linked with the destruction of Jerusalem in 70 CE, which followed the Jewish uprising against Roman rule. Started 4 years earlier, the Jewish uprising turned into a bloody war; the Roman response left the nation in ruins. The war also caused serious damage to the church in Jerusalem, although its members left the city before the siege, seeking refuge on the east bank of the river Jordan. Most of them settled in the small town of Pella and created a local church led by Bishop Simon, a relative of Jesus.

Faced with an influx of numerous converts from paganism, some communities began to abandon various Judaic religious traditions, such as circumcision and other Mosaic rituals. The resulting schisms, which caused problems for the new converts, were officially conciliated by the so-called Jerusalem Council (Acts 15:1–35).

The Missionary Journeys

The growth of Christian communities gained particular impetus thanks to the missionary journeys of Saint Paul. In the years 46–48 CE, he visited together with Barnabas and his cousin John Mark such locations as Cyprus, Pisidian Antioch, Iconium, Lystra, and Derbe. The second journey, dated 50–52 CE, took Paul to Troas, Philippi, Thessaloniki, Beroea, Athens, and Corinth. On this journey Paul was accompanied by Silvanus, and they were joined at a later point by Timothy and Luke. With the exception of Ephesus, this missionary journey was intended as a visitation to the local churches as some of them were adversely influenced by groups of Judeo-Christians or the followers of Apollos, a Jew who taught the philosophy of Plato. Through the efforts of Paul and Barnabas, a Christian community was also founded in the capital of the empire, Rome. The activities of the other apostles after leaving Jerusalem went unrecorded until the turn of the 2nd century, and those accounts are doubtful, modeled as they often were on ancient tales of fictitious heroes. Also, it is possible that they were written by Gnostics, who tended to attribute their writings to the apostles. Nevertheless, it is possible to find out from them about the geographic reach of Christianity at the end of the apostolic period. According to these sources, Andrew (brother of Peter) continued his missionary activity in Scythia, Thrace, Epirus, Greece, and the Crimea. James the Elder did not work outside of Jerusalem; he was killed in the city and became the first martyr among the apostles. Apostle Philip (frequently confused with Philip the Deacon) was reported as working in Asia Minor and among the Parthians. Bartholomew went in all likelihood to South Arabia, erroneously identified in the sources as "India." Thomas is mentioned as a missionary to the peoples inhabiting the regions between Syria, Persia, and India (Malabar Christians consider him as the founder of their religion). Matthew the Evangelist, son of Alphaeus, conducted a mission to Palestine and allegedly also to the Aramaic-speaking peoples; Aramaic was his mother tongue and the language in which he originally wrote his Gospel. James the Younger, son of Alphaeus, probably never left Jerusalem, where he was head of the local church. Jude Thaddeus, brother of James, preached the gospel first in Palestine and then in Arabia, Mesopotamia, and Syria. Simon, known as the Canaanite, was a missionary in the regions around the Black Sea, perhaps also in Africa and Persia. Finally, Matthias, who was elected a member of the Apostolic College after the death of Judas (Acts 1:23–26), was reported to have conducted missionary work in Ethiopia and Colchis.

Structure of Local Churches

In order to make the ministry to new communities more efficient, the apostles appointed superiors for local churches known as *episkopoi* (literally, "overseers"), while smaller individual congregations were headed by the elders or presbyters (*presbiteroi*). James was appointed head of the community in Jerusalem, Titus in Corinth, and Timothy in Ephesus, giving rise to the church hierarchy. This fact was obliterated, however, by the still unsettled terminology, because in Paul's descriptions of church structures we find more emphasis on posts rather than on offices. It is certain that the posts of bishops and presbyters, like those of deacons, have always been connected with one local church. *The Pastor* (Ποιμή́υ) *of Hermas*—dated the last decade before the year 150—uses these terms interchangeably; *Didache,* known also as *De doctrina apostolorium,* has only one term, *episkopoi;* Polycarp in his *Letter to Philippians* mentions only *presbiteroi* and *diakonos;* while Ignatius of Antioch makes a clear distinction of three groups in a local church: *episkopoi* (bishops), *presbiteroi* (priests), and *diakonos* (deacons). According to him, the college of presbyters and deacons is subject to the bishop. Such a structure, called monarchic episcopacy, is widely mentioned after 140 CE. Apart from institutional structures, there also existed some charismatic faculties of the members of the communities. These faculties were temporary and served the completion of certain tasks, for instance the gift of prophecy or glossolalia, that is, the gift of tongues (1 Cor. 12:8–11).

The apostolic letters indicate that there occurred tensions and divisions among Christian communities (1 Cor 1:10–12). In theology, it is considered that the inviolable principle of unity is founded in the deposit of faith called the symbol of faith (the doctrine that all converts belong to the Mystic Body of Christ—1 Cor 12:12–13). The institutional element is considered the other fundamental principle (the fact that the church is subject to the College of Twelve, with Peter as its head—1 Cor 12:28). The first Councils already showed the spiritual and honorary primacy of the Roman community and its bishop. At first, however, the bishops of Rome themselves did not claim the right to the title of pope, that is, head of the whole church. It was only in 451 that Leon I, Bishop of Rome, formulated his thesis, which stated that all Christian communities derive their authority from the Roman Church and that local bishops are the delegates of the bishop of Rome. These opinions influenced the future growth of Christianity as both a doctrinal and institutional monolith.

Persecutions of Christianity

In the first century, Christianity existed in Asia Minor, Syria, Greece, Egypt, and Italy. In the 2nd century, it spread to Gaul and North Africa. The hostility of the Roman authorities resulted in the fact that Christianity was persecuted by many emperors: Nero (54–68), Domitian (81–96), Trajan (98–117), Marcus Aurelius (161–180), Decius (249–251), and Diocletian (284–306). The first official pronouncement of the imperial authorities directed against Christianity was connected with the burning of Rome on July 16, 64. Rumors were spread that the city was burned at the emperor's order, because he wanted to see it in flames and compose poems about it, the way Homer described the destruction of Troy. Anxious about the consequences, the emperor, following Tigellinus' advice, accused the Christians of arson. Tacitus had no doubts that this was a false accusation, although he shared the opinion that the Christians deserved severe punishment for their "hatred of humankind." The persecution instigated on private motives could not have been designed to exterminate Christians in the whole empire, although some later apologists described Nero as a tyrant who aimed at the total extermination of Christians. Lactantius in the 4th century argued that the emperor's decree (*Institutum Nerinianum*) did not introduce any legal act against Christians but was meant to spread the conviction among all the officials that being a Christian was a crime if the emperor persecuted it in Rome. A series of further persecutions started in the times of Emperor Domitian. Like Nero before him, he instigated terror because of private motives. This weak and suspicious man lived in constant fear of being deposed, therefore he ordered the killing of Jude Thaddeus, who was a simple man but descended from the family of King David. Having learned about the prophesy about David's offspring who would rule the world, the emperor interpreted it as a direct threat to his rule. Roman historian Dio Cassio mentions "many others" who fell victim to Domitian's orders, although Tertullian estimates this was but a small fraction of what happened as a result of Nero's cruelty. In the time of Domitian, the majority of losses suffered by the church occurred in the East, where the emperor's cult was most widespread, and since Domitian assumed the title *Dominus ac Deus* (Lord and God), all those who refused to use this title were severely punished. The persecutions ordered by Nero and Domitian confirmed the conviction of the pagans that Christians were untrustworthy and wicked people. They were often charged with the same crimes as the Jews, since, in the beginning, the former were identified with the latter, but even when the difference was finally acknowledged, not only were the old charges not withdrawn, but at the turn of the first century new accusations were added. Asia Minor became the first arena of local persecutions under the next emperor, Trajan. This is confirmed by a letter from the governor of Bithynia, Plinius the Younger, to the emperor. The governor writes that the Christians are abundant in the cities and villages. Pagan citizens bring them before the judges who question them and often sentence them to death. Plinius asks the emperor how to treat the Christians because he noticed that the investigations revealed no real offenses against the law, and some denunciations were clearly motivated by a craving for revenge. The letter proves that until then there were no special regulations against the church except for a general rule from the time of Nero that it was forbidden to be a Christian. Marcus Aurelius, an adherent of Stoicism, claimed that the ruler should seek happiness in service of his subjects, but did not prevent many dangerous outbursts of pagan hatred of Christians. The persecutors wanted to make the Christians guilty of the wrath of gods, which they believed was the reason behind the misfortunes brought about by the invasion of the Parthians in the eastern and southern provinces of the empire, the disastrous floods caused by overrunning rivers, as well as the attack of the barbaric peoples on the western borders of the empire, which had been safe until then. The Christians were not always sentenced to death. Some were banished or forced to work in the mines and quarries. Decius, the first emperor of Illyrian origin, wanted to strengthen imperial authority after the period of military anarchy. This desire caused him to imprison many Christians in the first weeks of his rule. The edict proclaimed after 250 CE ordered all inhabitants of the empire to take part in public propitiatory sacrifice to placate the gods and avert misfortune to the empire. Whoever refused to obey this order was cast in prison, where torture was used to break their resistance. Although the Christians were not explicitly mentioned in the edict, it was directed mainly against them. Many did not withstand the trial, becoming apostates who were called *lapsis* (the fallen). Some tried to escape or buy official documents confirming that they had participated in the sacrifice. Who was imprisoned and managed to survive was called a confessor, and those who died were given the honorable name of a witness—*martyr.* The death of Decius in 251 on the marshes in Abrittos for a short time put an end to the persecution, though it was instigated again by Diocletian. The reason for this new outburst of hatred after nearly 20 years of peace and tolerance is not known. Undoubtedly, some Neoplatonists, like Hirecles and Galerius, could have had some share in it; it also might have been connected with the emperor's drive for strong and divine-like power, which gradually transformed *Imperium Romanum* into a totalitarian state. After Diocletian had secured the borders, strengthened his rule, and removed economic difficulties, he finally undertook the task of reviving the old Roman religion: the Christians were the main obstacle. He started his struggle against Christianity by cleansing the army, issuing in 299 an edict in which he demanded that all soldiers and officials should make sacrifice to the gods. In the next edict, in 303, he ordered the destruction of all Christian temples and the burning of the holy books.

Hostility against the Christians was apparent not only in persecutions but was also articulated in virulent writings and satires. Marcus Cornelius Fronton (c. 100–175), a Roman orator, teacher, and friend of Emperor Marcus Aurelius, delivered a public speech against the new religion, although he confused the Christians with the Gnostics and repeated commonplace accusations formed by the pagans; his speech was later disseminated in written form. Celus, a learned representative of Platonic philosophy in the 2nd century, criticized the new religion on philosophical grounds and became a serious intellectual adversary. In his anti-Christian treatise *The True Word* (Ἀληζής λόγος) from the year 178, which he wrote after studying the scriptures and debating with the Christians, he rejected the existence of a personal god and the doctrine about the creation of the world. His work confirmed the learned pagans in their appreciation of Greek literature and contempt for Christianity.

Development of Christianity

Despite adverse historical circumstances until the 4th century, Christianity spread to nearly half of the provinces of *Imperium Romanum.* From the 3rd century onward it reached the neighboring countries: Armenia, Georgia, and Persia. In 313, Constantine the Great issued the Edict of Milan, which officially recognized the existence of Christianity and included it among the religions tolerated by the state. After 324 he increased the privileges of Christianity, granted it almost unlimited missionary possibilities and freedom of building temples, making it also possible to replace apology, which was no longer necessary, with theology. The next ruler, Theodosius I the Great, issued in 380 an edict, *On the Catholic Faith,* in which he proclaimed that he wished all the peoples of the empire to accept the religion conveyed by Apostle Peter. In this manner, Christianity was recognized as a state religion. On the basis of this law, heresy became an offense punished by the state, and heretics had drastically limited civic rights. The next regulations forbade public debates on doctrinal issues. Historians consider Theodosius the real founder of the "state Church," which does not entail approval of every decision made by the authorities, but rather points to the public acknowledgment of strict cooperation between the church and the state. Theodosius zealously supported the position of the orthodox church through his legislative initiatives, but he did not openly interfere in its policy.

Although Origen and Hippolytus describe the practices of baptizing children, in the first centuries the converts were mainly adults whose consciousness and knowledge was shaped either by the Mosaic religion and the Jewish culture, or polytheism and the Hellenic culture. The introduction of a long period of preparation before baptism, which included the explication of the symbol of faith, did not, however, remove the risk of individual interpretation of the Christian dogmas. The earliest occurrences of doctrinal difficulty are recorded among the converts from Judaism, for whom the main problem was the relationship of Mosaic law with the Gospels and the relationship of Jesus to Jehovah. Different interpretations of the principles of faith led to the errors called heresies, while differences in the sphere of law, religious practices, and life of the church resulted in divisions into factions, or schisms. The first schism took place in the Jerusalem Church after the death of James the Younger when a group of Christian Jews observing rigorously all the precepts of Mosaic law refused to obey Simeon, the legitimate bishop, and elected their own superior, Tebutis. It is worth stressing that while schisms destroyed the original unity of the church, heresies rather stimulated the shaping of the Christian doctrine. As early as ancient times, Western theology was manifestly different from what was believed in Eastern theology. The West was mainly concerned with the problems of soteriology, especially with regard to the objective sanctity of the church (on this ground arose Donatism, which was concerned with the legitimacy of the sacrament dispensed by a presbyter-traitor, and Priscillianism, which preached dualism and extremely radical asceticism), the original state of humanity, and the results of original sin (the Pelagian heresy held that the sin of Adam was not the original sin of all people because everyone had free will and could therefore avoid sin since they could distinguish between good and evil; Pelagianism maintained that baptism removes only sins of individual people, and that children, who have no sins, do not need it for their salvation), and finally the relation of the effects of God's grace to human freewill (the semi-Pelagian heresy, originated by John Cassian and Bishop Faustus from Riez, according to whom God's grace helps only those who have begun to desire salvation, but does not influence the desire itself). The multicultural East was more concerned with Trinitarianism and Christology. On their basis arose such heresies as Arianism (which held that the Son of God, *Logos,* is not coexistent with God the father, only the first and most perfect creature, but is as far removed from the being of the Father as finitude is removed from eternity), heresy against the Holy Spirit (i.e., the opinion that the Holy Spirit is a creature and differs from the angels only through a higher degree of perfection), Nestorianism (i.e., a dissenting conception of the Incarnation, according to which *Logos* was not born together with the body of Jesus of the Virgin Mary: the "Word" dwelt in Jesus only as another person but was connected with him), Monophysitism (a heresy that held that Jesus had only one nature, which was primarily divine with human attributes), and Monothelitism (a heresy recognizing the existence of one will in Jesus). Due to lack of cultural unity, the crystallization of the dogmas of faiths resulted in the East in the creation of many national churches, such as the Nestorian Church in Persia; the Coptic Church, which accepted monophysitism, in Egypt; the Ethiopian Church; the Armenian Church; and the Jacobite Church as well as the Maronite Church, which upheld monotheletism in Syria.

The Middle Ages

In the early Middle Ages, Christianity spread mainly in the Mediterranean and in Western Europe. The areas of Africa and Asia Minor were then under Arabic rule, which in 711 took hold also of the Iberian Peninsula. Consequent to the Turkish expansion between the 11th and 15th centuries, Islam spread all over Asia Minor, and in Europe held sway in the Balkans. At the same time, Christianity was introduced in Spain, France, England, Germany, and Lombardy. The Gaelic and Germanic tribes, with the exception of Romania, were under the influence of Western Christianity. The conversion of the Slavonic tribes started in the 7th century and continued until the 11th century. It occurred successively in Croatia, Slovenia, Bohemia, Slovakia, Poland, and among the Polabian Slavs (i.e., the Slavs who lived along the Elbe). The areas inhabited by the Hungarians, Finns, or the peoples of the Baltic region were Christianized even later, at the turn of the 9th century. In the 8th through the 10th centuries the missions in the East reached Bulgaria, Serbia, Russia, and finally Romania. The missionary obligation imposed on the apostles by Jesus resulted in the Christanization of such remote areas as the East Indies (5th century) and parts of China (7th–10th centuries). It was only the persecutions, which became particularly severe in the 12th through the 15th centuries, that forced the church to reduce and then abandon altogether the Christianization of the Chinese people.

With regard to institutional dependence, Western Christianity was closely connected with the Apostolic See, especially after the missions of Saint Willibrod and Saint Boniface (org. Wynfrith). All the attempts at creating autonomous local churches in the Merovingian period failed not so much because of the unity of government that was connected with the reestablishment of the western empire by Charlemagne the Great in 800, but rather thanks to the supremacy of the empire that was made possible by the Georgian Reform. This reform consolidated the centralization of church government, with the pope as its head. Other important unifying factors included the common Latin language, canonical law, and scholastic teaching. Attempts at creating patriarchates in Arles, Aquilea, and Hamburg were unsuccessful. Eastern Christianity was completely different; despite one common Byzantine culture, church law, and liturgy, the ancient patriarchates were the agents of decentralization and finally led to factual division. An important step in this process was taken at the Second Trulan Council in 692, when the equality of Constantinople and Rome was officially recognized. From among all the general councils, only the first seven (including the Council of Nicea in 787) were officially approved by Byzantine Christianity, although the bishops from the East were still present at the three following councils: the Eighth Council of Constantinople in 869, the Second Council of Lyon in 1274, as well as the Council of Basel and Rome in 1439. The following councils were attended only by bishops of the Western church. The distance between Western and Byzantine Christianity (including the church in Georgia) was becoming more and more apparent. A combination of political, cultural, ethnographic, social, and religious events (e.g., the problem of iconoclasm in the 8th century and the Focius affair in the 9th century) led to the ultimate separation, which took place in the year 1054 and is known in history as the Great Schism. Efforts to restore unity yielded no positive results. A formula of unification was worked out at the Florentine Council (1439), but some political factors prevented it from being effective (in Russia the problem was the Tartar bondage, while Byzantium and the Balkans were troubled by the Turkish invasion, which ended with the total destruction of the Byzantine Empire). The only exception was the union with the Maronite Church, which was achieved in the 17th century and exists until present times. The Middle Ages were also marked by violent reactions against the accumulation of material goods by the church. In France and Italy the movement of apostolic poverty called Catharism appeared; in Bohemia the Hussites criticized the abuses of the church.

Modern History

The geographic discoveries in the 15th and 16th centuries provided a stimulus for missionary activity first in Central, then South and North America. The missions were, however, associated with Portuguese, Spanish, and French colonialism, due to which they often failed to bring the desired evangelical results. Having recovered from the turmoil of the Great Schism and after the period of concilliarism, which postulated the transfer of power from the pope to the general councils, Western Christianity retained its hierarchical structure. The turning point in the history of the Western church occurred in the year 1517, which marks the beginning of the Reformation and Protestantism. It eventually resulted in the formation of the Augsburg Evangelical Church in Germany, the Reformed Evangelical Church in Switzerland and France, and the Anglican Church in England. Later on, other reformed groups separated from these larger communities; the Baptists and Congregationalists separated from the Anglican Church in the 17th century; the same time saw the birth of the Quakers; the Methodists appeared in the 18th century, and the Salvation Army was founded in the 19th century. All the European churches had their missions in Africa, Asia, and Australia, and they became particularly intense in the 19th and the beginning of the 20th century. The Eastern church, struggling for survival under the rule of Islam, did not undertake any major missionary activities. Only the Orthodox Church in Russia organized missions from the 16th up to the beginning of the 20th century in territory that was the former Tartaric khanates of Kazan, Astrakhan, and Crimea; among the native inhabitants of the areas beyond the Urals; in Siberia, Alaska, and in the Far East. Thanks to the missions, in the 19th century Christianity reached the farthest ends of the world. The 20th century brought other evangelical works that were mainly addressed to the followers of non-Christian religions.

The centralization of the Catholic Church was strengthened by the Council of Trent (1545–1563), which emphasized the principal role of the Apostolic See, and was consolidated by Catholic reform; in effect, the history of papacy came to be identified with the history of the church. Papal control was challenged by such claims for local independence as state control in Spain (etatism), Jansenism and Gallicanism in France, episcopalism in Germany, and Josephinism in Austria. Further development of these tendencies was curbed by the First Vatican Council in 1870, which declared the dogma about the primacy of the pope and the infallibility of the teaching authority of the Roman Catholic Church. Those in disagreement with both dogmas formed the Old Catholic Church. The effect of centralization was that many former local prerogatives, for instance those that belonged to the Primate or the Metropoly, were lost. Such close unity was unknown in the Protestant churches and communities, which mostly relied on the authority of the state. The lack of juridical unity resulted, however, in the lack of agreement in doctrinal matters.

In the East, meanwhile, the Turkish conquest contributed to the growing authority of the ecumenical patriarch in Constantinople, the centralization of church government, and the assumption of the Greek form of liturgy and church offices. The national patriarchates in Bulgaria and Serbia, which had been established in the Middle Ages, ceased to exist while the Melkite patriarchates in the Middle East were being gradually subjected to Constantinople. The only exception was the Orthodox Church in Russia, which had received autonomy in 1448 and began to play a significant role in Orthodox Christianity. In 1589, a patriarchate was established in Moscow, but its significance decreased in the 17th century under Patriarch Nicon, and it was finally abolished in 1720 by Czar Peter I. The revival of the national consciousness of the Balkan peoples and the political division of the Turkish Empire in the 19th century led to the decentralization of the church and the growing autonomy of the national autocefalic churches in Greece, Serbia, Bulgaria, and Romania. The continuous efforts at reestablishing unity among the Christians in the East resulted in partial unions of these churches with Rome. In effect, the particular churches were divided into Catholic Unites, on the one hand, and the pre-Chalcedonian or Oriental Christians, on the other. (In Poland, the Union of Brest established the Unite Church called, since the 18th century, the Greek Catholic Church.)

The infiltration of Byzantine Christianity by Protestantism led to internal crisis. The liturgical reform undertaken in Russia at the turn of the 17th century resulted in a schism and the establishment of the sect of Raskolnikovs. The pre-Chalcedonian Church, threatened by extermination or Islamization, struggled for existence. In the Protestant churches and communities, which in the Enlightenment, dominated by rationalism, went through a deep crisis up to the point of doctrinal negation of Christianity and suffered the loss of many believers who accepted deism or atheism, followed a period of revival of orthodoxy. Widespread movement of pietism was conducive to the deepening of spiritual life and stimulated social engagement.

The split of Christianity resulted in violent religious wars that seriously eroded doctrinal authority and made for the development of deistic and atheistic trends. The Christianity of the 18th century was frequently perceived as residual, an anachronistic legacy of the Dark Ages, and was blamed for the regress of religious life. The 19th century brought the restoration of religiosity as well as the reawakening of Christian philosophy and theology, which to some extent could be linked with the influence of Romantic thought. The same period witnessed also the process of growing independence of the church from the state, thanks to individuals engaged in social activity. Christian trade unions, which were established in France and quickly spread to other European countries, began to defend the working class in agreement with the Christian social doctrine. From the pontificate of Leon XIII, who formulated a program of social activities of Christianity in his encyclical *Rerum novarum,* published in 1891, started a process of re-Christianization of society, which affirmed the employment of scientific discoveries, technological progress, and the development of modern culture in the service of humanity.

The Christian Concept of Time

In all religious systems worldwide, including Christianity, time is conceived of as the dimension where hierophany, the manifestation of the sacred, takes place. Sacred time is contrasted with secular time. The former entails the works and the manifestation of the sacred, whereas the latter denotes the time of human actions, which are identified with history. Many tensions between sacred and secular time can be listed, the most important of which concerns the passing of time. Sacred time can be personified as a deity (e.g., Cronus or Aion) or may be referred to as the eternal.

The Christian notion of time is rooted in a linear conception, with a marked beginning and the end toward which everything is destined. The initial moment is placed in real history rather than in the mythical *illud tempus.* The linear conception determines the logic of history, which precludes the possibility of repetition. Its nature is theocentric; on its terms, time and space become antagonized also as modes of human existence. This conception can be juxtaposed with the cyclic (cosmo-centric) notion of time, according to which human actions take place only in space, not in time. In the linear notion of time, typical for monotheistic religions, God is not limited by a definite space, but instead is a lord of time, which is the sum of his acts.

The Christian notion of time no doubt refers to the Hebrew religion, in which God is shown by the prophets as the one who intervenes in human history, which has become his epiphany. On the basis of the linear notion of the sacred time, Judaism developed a linear understanding of secular time; the 7 days of creation became prototypes of the 7 days of the week. Both times find their culmination in the moment of the Apocalypse. Through theophany, which takes place in sacred time, God reveals his acting in history. Thus historical events have become a continuum of interconnected episodes, without the possibility of their cyclic repetition. On the basis of the Hebrew concepts, Christianity has worked out the system of universalism. Christ is perceived as *Kairos,* that is, time of salvation. *Illud tempus* is treated as always accessible for humans desirous of mending their ways. It is possible, thanks to the figure of the Messiah (Christ), who separates the present moment from the past, identified with the result of the First Parent's sin. The second coming of the Messiah denotes merely the closure of the present, while eternity lies beyond this point. Thus Christianity stresses the fact that we live in last times, although the second coming will take place in the unpredictable and divine *kairos,* not *chronos,* which can be derived from experience and knowledge about the cyclicity of some events.

In the first centuries Christianity was marked by millenarianism, probably derived from Persian tradition (the best-known proponent of this idea was Papias, the bishop of Hierapolis in Phrygia). The millenarianists prophesized a 6,000–year history (through an analogy to cosmogony) followed by a 1,000-year–reign of the just after the imprisonment of Satan. The end of time was to come at the turn of the 8th millennium, when the world would become the arena for the battle against released Satan.

The linear concept of time was strongly confirmed by the patristic tradition (e.g., Ireneus of Lyon and Augustine of Hippo), although some cyclical trends were not totally absent from Christian thought. This is why Gnosis, Arianism, and Docetism were opposed by the church, because by challenging the linear conception of time they also contested the temporal and historical nature of the Incarnation. On their terms, it ceased to be a historical fact, a temporal point of reference, and the moment when the sacred entered historical time. On the other hand, up until the present day Christianity has kept the notion of the liturgical year, which is a cyclical remembrance of Christ's biography, from his incarnation to ascension. The Holy Mass is a peculiar form of periodicity, since it reenacts the sacrifice of Christ.

According to the Christian conception of time, human life is once given and unique. Hence the fear of wasting the indivertible. The uniqueness of earthly life endows Christian eschatology with special significance. The medieval memento mori—"Remember that Thou Shalt Die" rings until the present day the note of anxiety and urges everyone to do good in order to save one's soul, for even the slightest delay in this matter may have fatal consequences.

Doctrine

Viewed against other religions, Christianity, being focused on resurrection, has an eschatological and integral character, by which is meant that it is held to be the supreme and ultimate religion and not a stage in the development of civilization, and also that it embraces the whole of earthly reality, including all people and all aspects of human existence.

The conditions for becoming a Christian (belonging to the church) are faith in the word of God and baptism. By observing the norms of behavior prescribed in the Ten Commandments (the Decalogue), interpreted in the spirit of the New Testament formula of the love of God and one's neighbor, humans realize their salvation in the moral sense. Because of the universality of God's saving will, also toward people who are non-Christians, believers can achieve salvation also in non-Christian communities, even those whose activity is restricted to earthly existence, because salvation comes only through Christ, in Christ, and with Christ (*anakefalaiosis*). Doctrinal truths, which belong to the deposit of faith, are preached and infallibly interpreted by the magisterial authority of the church. In Roman Catholic Christianity, infallibility in the matters of faith and morality belongs to the pope and the bishops who are united with him; it concerns both the official teaching (*ex cathedra*) and regular teaching. In Orthodox Christianity, which has adopted the principle of concilliarism, this infallibility belongs to the bishops and all believers; in the Anglican Church it is the prerogative of the entire ecclesiastical community and it is called the ultimate criterion of the infallibility of truths defined at the council by human authority. The particular doctrinal issues have often received a new form of expression due to theological reflection, influenced by different philosophical and cultural conditions. Although there exists a considerable agreement among different Christian groups in the matters of trinitology and anthropology, much wider dissent can be observed in the interpretation of the origin of humankind, the concepts of grace (charitology), and the teaching about last things (eschatology). The most significant differences occur in the sphere of Christology (knowledge of Christ), soteriology (knowledge of Christ the Savior), knowledge of Saint Mary, eclesiology (teaching about the church), as well as sacramentology (teaching about the sacraments).

Because of its ability to develop outside its native cultural environment, Christianity belongs to the family of universal religions, along with Buddhism and Islam. In this group it retains the leading position, with 37% of the believers of all religions; the most numerous groups in this number are Catholics (c. 1.1 billion), Protestants (570 million), Orthodox Christians and members of Oriental churches (178 million), as well as Anglicans (70 million).

Jacek Stanislaw Tomczyk

See also Angels; Apocalypse; Aquinas, Saint Thomas; Augustine of Hippo, Saint; Bible and Time; Charlemagne; Devils (Demons); Ecclesiastes, Book of; Genesis, Book of; God and Time; God as Creator; Judaism; Last Judgment; Mysticism; Nero, Emperor of Rome; Parousia; Religions and Time; Revelation, Book of; Satan and Time; Sin, Original; Teilhard de Chardin, Pierre; Time, Sacred

Further Readings

Baker, R. A., & Landers, J. M. (2005). *A summary of Christian history.* New York: B & H Publishing Group.

Barnett, P. (2002). *Jesus & the rise of early Christianity: A history of New Testament times.* Madison, WI: InterVersity Press.

Bormans, M. (1990). *Guidelines for dialogue between Christians and Muslims.* New York: Paulist Press.
Chidester, D. (2001). *Christianity: A global history.* San Francisco: HarperCollins.
Coogan, M. D. (2005). *The Old Testament: A historical and literary introduction to the Hebrew scriptures.* Oxford, UK: Oxford University Press.
Dupuis, J., & Berryman, P. (2002). *Christianity and the religions: From confrontation to dialogue.* New York: Orbis.
Feuerbach, L. (1898). *The essence of Christianity* (Great Books in Philosophy). New York: Prometheus.
Frend, W. H. C. (1986). *Rise of Christianity.* New York: Augsburg Fortress.
Johnson, P. (2005). *History of Christianity.* New York: Touchstone.
Whiston, W. (1908). *The works of Josephus: Complete and unabridged.* Peabody, MA: Henderickson Publishers.
Woodhead, L. (2005). *Christianity: A very short introduction.* Oxford, UK: Oxford University Press.

Chronology

The term *chronology* is derived from Greek *XpovoXoyia,* or computation of time. In contemporary science, chronology is understood simultaneously as a consequence of historical events in time and as a discipline dealing with regularities of these events as arrangements in time, as well as with general principles and scientific methods of time measurement. In this context, chronology could be viewed in at least three main dimensions: astronomic, historical, and general chronology.

Astronomic Chronology

Astronomic chronology is a branch of chronology that studies regularities of repeated celestial phenomena, establishes precise astronomic time, and often is understood as one of the basic methods of historical chronology. In this dimension it is very close to timekeeping, or chronometry.

Small-scale observations of astronomic chronology are based on the earth's spinning motion (the so-called sidereal day) and the earth's revolution around the sun (true solar day), while longer periods usually involve observations of the visual localization of the moon and sun among stars of the celestial sphere (sidereal and synodic month, sidereal and tropic year). On this basis, different systems of solar, lunar, and lunisolar calendars were developed, and their earliest forms can be traced back to late prehistoric times. The history of the invention and implementation of different calendar forms of timekeeping are the subject of the other branch of chronology—historical or technical chronology.

Historical (or Technical) Chronology

This type of chronology traditionally is regarded as a special subdiscipline of history, occupied with the study of calendars and calendar systems as these existed in the historical past in different regions of the world. Among the important tasks of this branch of chronology are the assignment of precise dates to events and phenomena, defining the time of historical narratives (chronicles), and specification on this basis of the true dates of particular facts. In such a context, historical chronology is deeply connected with other historical subdisciplines—historiography and the study of historical sources.

Studies of Calendars and Calendar Systems

The alteration of day to night was already obvious to early prehistoric hunter–gatherers and probably was reflected in the peculiar Magdalenian notched bones that are often regarded as the earliest archaeological records of primitive notational systems. The origin of land cultivation and agriculture required more complicated chronometry where warm/cold and dry/wet seasons' alternation and repeated climatic events such as inundations were taken into consideration. Such observations could be recorded in the ornamentation of special forms of ceramic vessels and clay figurines used in celebration of fertility rites and traditional ceremonies supposed to exert an influence over the weather. Most such systems were correlated with the vernal and autumnal equinoxes, which were marked by special ceremonies involving thousands of people. Probably the original megalithic constructions, such as Stonehenge in Britain, were specially built to make these events easy to observe for shamans and pagan priests and illustrative for local populations.

According to oral tradition, Druid priests were highly skilled in the organization of such calendar ceremonies.

The first complex calendar systems based on observation of lunar and solar phases appeared during the period of the formation of early civilizations in the Near East and were connected with the necessity of rational organization of the early state economy as well as appropriate celebration of basic cults of the community. Traditionally, it is thought that the earliest forms of the solar calendar were invented in ancient Egypt, and, with slight modifications caused by the need to correlate the solar calendar with the true astronomic year, reflected in the introduction of the leap year, it remains widely used in contemporary Western civilization. Early forms of the lunar calendar were developed by the Arabs, and today this calendar remains the basic form of timekeeping in the Muslim world. The ancient Hebrews are regarded as inventors of the lunisolar calendar, which continues to be applied in traditional Jewish chronometry up to the present day. Other ancient civilizations created their own particular systems of timekeeping, among which are included the Babylonian, Persian, Chinese, Indian, and Vietnamese calendars.

Rapid development of mathematics and astronomy in ancient Greece contributed greatly to the comprehension of discrepancies between the rough division of time into years and the real recurrence of celestial events. In order to correlate the solar calendar with astronomic reality, an 8-year system based on the addition of a supplementary month every 3rd, 5th, and 8th year of the cycle and the so-called Methon cycle was introduced.

The Roman calendar in its early stage was less than precise, consisting of only 10 solar months. Its principal revision, undertaken in 46 BCE under the initiative of Julius Caesar on the basis of advice from Sozigen (an astronomer from Egyptian Alexandria), resulted in the expanded Julian calendar, the basic cycle of which consists of 3 years of 365 days each and 1 leap year of 366 days. This calendar, introduced on January 1, 45 BCE, and in regular use since the 8th year of the common era, was the basic frame of timekeeping in Europe and its colonies until the end of the 16th century.

The reason for a new revision of the calendar was a discrepancy between the astronomic and the calendar vernal equinox, which was noticed for the first time at the end of the 13th century and became more and more apparent during subsequent ages. Pope Gregory XIII, by his decree of February 24, 1582, introduced amendments to the Julian calendar. His new version was called the Gregorian calendar. It was immediately applied in the Catholic countries, while most of the Protestant nations adopted it only in the 18th century. The transition of the civil states of Russia, Bulgaria, Serbia, Romania, and Greece (countries with predominantly Orthodox Christian populations) to the Gregorian calendar at the beginning of the 20th century made it the most widespread form of timekeeping in the world. Nevertheless, the Orthodox Church officially rejects the Gregorian calendar and still maintains its own system of timekeeping, based on the Julian calendar, to the present day.

Apart from these widely disseminated and well-studied calendar systems in the historical past, many other forms of systematic timekeeping based on solar, lunar, and combined lunisolar time observations were used. Some of them still remain in use, mostly in vast areas of Eastern Asia (in the traditional Chinese and Japanese calendars) and in Muslim communities all over the world that observe the traditional Islamic calendar; others are used only in the context of traditional rituals and ceremonies of native cultures (e.g., calendars of the ancient Maya) or have become an integral part of Western civilization's spiritual life (e.g., the zodiacal calendar). Calendars have also been introduced in the wake of epoch-making events in modern times (e.g., the calendar of the French Republic, and the Soviet revolutionary calendar); these soon became obsolete. In the contemporary world community, the Gregorian system of timekeeping is recognized internationally by official bodies; the other calendars can be applied locally, ethnically, or occasionally.

Historical Events and Phenomena Dating

Specification of the true dates of historical events is another important task of historical chronology. This procedure is based on two kinds of primary data: one originated from historical sources (chronicles, narratives, etc.) and the other obtained with the help of natural sciences.

In the case of historical sources, determining their true dates, authenticity, and reliability is a cornerstone of the dating process. In most cases, the problem of historical source verification is solved through multilevel comparisons of different sources and their correlation with data from the natural sciences, if available.

Usually a distinction is made between absolute and relative dating. Relative dating is aimed at defining the strict order of certain events or delineating the period of time when they could have happened. Relative dating is most widely applied in archaeology, based on typological and stratigraphic methods. Relative dating is important in many social sciences when determining the actual date of an event or phenomenon is not possible. In these cases, cross-dating based on matching known dates for events and phenomena can be used. Glottochronology, which attempts to determine when certain languages separated based on the percentage of words remaining from their primary basic vocabularies, is another example of relative dating methods.

The goal of absolute dating is to identify actual dates of specific events. In history this is usually expressed as a day, month, year, or century; in archaeology it might be in thousands or even millions of years. Absolute dates are established with the help of the scientific methods of the natural sciences or by correlation with established actual dates of other events.

Physical methods of absolute dating have been considered to be most reliable since radiocarbon dating was invented in 1946 and rapidly introduced into scientific methodology all over the world. This method is currently widely used for the dating of organic artifacts (objects made mostly of bone and wood). Later, thermoluminescence and uranium–thorium balance dating methods were added to absolute dating methods and helped to cover intervals of up to several million years. Chemical methods of absolute dating, such as the obsidian hydration technique, are also used to determine ages of relatively "old" objects as precisely as possible. Biological dating, such as dendrochronology, which dates objects based on the annual growth rings of trees, is used to examine artifacts like buildings. It is useful for relatively "young" artifacts that are no older than several centuries.

When it became possible to derive absolute dates by comparing a variety of sources, the problem of correlating, for example, references referring to "years ago" versus "years before Christ" became especially critical. During the past decade this problem was often considered more serious than deriving the correct date.

General (or Scientific) Chronology

The main task of general chronology is the reconstruction of the exact order of historical events and phenomena as well as establishing the duration of historical processes. General chronology (as well as dating) can be precise only when an event or phenomenon can be dated with absolute numbers, or relative if ascertaining the order of events or by determining a time period in which they could have taken place. Ancient chronologies, often referred to in most of the important events and phenomena in the histories of specific populations (nation, country, etc.), were regarded by their creators as the best way to satisfy the needs of both versions of general chronology.

In Ancient Egypt, events usually were dated consecutively based on the year of a specific pharaoh's rule. Every new pharaoh established his own "era" of timekeeping. A crucial task in Egyptian chronology is determining the details and specifics of each pharaoh's rule.

Ancient Greek history offers a more complicated version of event correlation with the comparison of information about specific facts and events obtained from various historical narratives that were created in different periods. Even so, ancient Greece has no unified general chronology, and historians have to date an event simultaneously in several year-keeping systems, the most widespread of which are correlated with the reigns of Persian rulers and the governments of Ephorus of Sparta and Archonts of Athens. In the 4th century BCE, historian Timaeus proposed introducing a general chronology based on lists of Olympiad winners, which had been kept since 776 BCE. This system was widely used by historians but not by official administrations. The first general scientific chronology of ancient Greece was created by Eratosthenes in the 3rd century BCE; he established the absolute date of several basic events (e.g., Xerxes' invasion, the beginning of the Peloponnesian War, etc.) and on this basis calculated the dates of other events.

A general chronology of Roman history was based primarily on lists of Roman consuls, which are easily integrated with ancient Greek chronological systems. Also, a dating system originating from the foundation of Rome (753 BCE) was introduced by Varro in the 1st century CE.

In the late Roman period, the Diocletian influence became most widespread in 284 CE because of its connection with calculating the dates for Easter, but soon it was replaced by the "Christian era" introduced in 532 by Dionysius Minor as the *ab incriptione* era. During the Renaissance, historical event dating based on the Christian era developed into the modern chronology system, the basics of which were formulated by Joseph Scaliger (1540–1609). He managed to transfer all existing dates into a unique system of dating originating with the Julian period (started in 4713 BCE) and reintroduced the process of historical date verification by reference to astronomic events mentioned in historical sources. Later, Petavius proposed a system of back-keeping years before the Christian era; this scheme has been widely recognized since the 18th century.

Critique of General Chronology

The problem of the reliability and authenticity of dates is regarded as critical in both genres of general chronology, and it inevitably implies a process of exhaustive critique of various dates and their sources. So, for example, the Diocletian era was recognized as reliable when the starting date of Diocletian's reign was established independently by three scientists using three different methods. This and a series of other coincidences established a background that allows scientists to believe that Roman general chronology is rather reliable. Greek chronology could easily be synchronized with Roman since there many dates known in both traditions. Synchronization of Egyptian, Persian, and some other chronologies widespread in the ancient Middle East is based on lists of rulers made by the Egyptian historian Manetho. Chinese general chronology also is regarded as rather reliable since even today it is based on the same 60-year cycles; in ancient times, moreover, it is reinforced by a highly developed historiographic tradition with a detailed chronology. The decree by India's king Ashoka, in which names of Hellenistic rulers are mentioned, is regarded as the cornerstone for verification of ancient Indian general chronology.

Another branch of general chronology critique—the so-called New Chronology invented by the Russian academician Nikolay Fomenko in the late 1990s—makes the radical claim that all dates established in ancient times and studied today should be regarded as invalid. This concept is based on the assumption that all historical narratives in fact were created recently in attempts to prove the great antiquity of human history and culture, whereas the true duration of human history does not exceed a thousand years.

Fomenko's hypothesis has provoked a new phase of discussion about the reliability and authenticity of general chronology that, it is hoped, will enable obtaining new details to enhance our knowledge of the human past.

Olena V. Smyntyna

See also Archaeology; Clocks, Biological; Dating Techniques; Egypt, Ancient; Geologic Timescale; Longevity; Rome, Ancient; Stonehenge; Time, Cosmic; Time, Historic; Time, Measurements of; Time, Perspectives of; Time, Prehistoric

Further Readings

Edwards, O. (1999). *When was anno Domini?* Edinburgh, UK: Floris Books.

Harvey, O. L. (1983). *Calendar conversions by way of Julian day number.* Philadelphia: American Philosophical Society.

Higuera, T. P. (1998). *Medieval calendars*. London: Wiedenfeld & Nicolson.

van der Meer, P. (1947). *The ancient chronology of Western Asia and Egypt*. Leiden, The Netherlands: Brill.

Mellersh, H. E. L., & Williams, N. (1999). *The Hutchinson chronology of world history.* Oxford, UK: Helicon.

Poole, R. L. (1934). *Studies in chronology and history.* Oxford, UK: Clarendon Press.

Teeple, J. B. (2002). *Timelines of world history.* London: Dorling Kindersley.

Thomas, H. L. (1967). *Near Eastern, Mediterranean and European chronology: The historical, archaeological, radiocarbon, pollenalytical and geochronological evidence*. Lund, Sweden: Astron.

Chronometry

According to Saint Augustine, we measure time by mind. The sense of a length of time is indeed a basic human experience, but it depends on the person and his or her momentary state; consequently it cannot serve as an objective and reproducible indicator of duration of time. Therefore, periodical processes have been used for time measurement from time immemorial. It was on these processes that *clocks* were based. The oldest clocks were based on astronomical phenomena—the movement of sun, Earth, and stars in the heavens. Mechanical clocks were already in use in antiquity—water or sand, later on spinning balance wheels and vibrating springs. Galileo counted the beats of his heart in order to verify the regularity of swings of the pendulum.

Although originally time periods were only counted, the idea of their in principle unlimited divisibility was developed in antiquity. According to Aristotle (*Physics*), past and future time is separated by the moment "now," which in itself has no length. Nevertheless, time is in some sense compounded from moments. Later on, this idea was made precise by mathematics, which represented time's moments as elements of the set of real numbers. The lengths of time sections between pairs of events—the beginnings and ends of occurrences—is then ideally determined by a real number, although measurement allows us to determine this rate with only limited precision.

Of course, thinkers in antiquity were already aware of the problem that whereas motion is measured by time, and time is measured by motion, why are there not as many times as motions? It appeared essential for the measurement of time that various clocks exhibit a more or less common rhythm. The concept of *ideal clock,* measuring the time *solidary,* follows from it. The data t^* and t of solidary clocks can differ only by the choice of unit of measurement and the choice of beginning of reading of time, and thus they are connected by the relation

$$t^* = K\,t + C$$

where $K > 0$, C are constants. After deciding on a common unit of time, we *calibrate* all the clocks in the same way and then we are able to measure time intervals between events in the same units. The theoretical background for the existence of ideal clocks is based on the validity of universal physical laws, which are, expressed in ideal time, nonvariable; therefore a given periodical process subjected to these laws lasts—in the case where equal inner and outer conditions are the same length of time. We call this the *homogeneity of time.*

For 2 centuries, the role of ideal time was played by the *absolute time* of Newtonian physics. This time is not only the time of a specific clock or of a definite object but also determines the time difference among the simultaneous states of all the world. It makes it possible not only to determine the lengths of time intervals for the given object (or clock connected with it) as its *proper time,* but it also integrates all events into the time course of the world as a *coordinate time.*

The theory of relativity cancels this connection between proper time and coordinate time. According to the *special theory of relativity* (STR), clocks in different places can still be synchronized (best by the exchange of light signals) in the *inertial systems of reference* (mutually uniformly and rectilinearly moving systems, where the law of inertia is valid), but this synchronization gives different results in different reference systems. An even more radical change is connected with the *general theory of relativity* (GR), according to which it is impossible to introduce global inertial systems in curved spacetime. Consequently, coordinate time loses its immediate metrical meaning and only proper time τ, defined as a length (integrated interval) of the section of world line $x^i(s)$ in four-dimensional spacetime, remains absolute. Thus

$$\tau = \int_P^Q \frac{ds}{c} = \frac{1}{c}\int_0^\sigma \sqrt{g_{ik}(x^j)dx^i dx^k}$$

where g_{ik} are the components of metrics, and c is speed of light serving as a coefficient of conversion between the spacetime interval and the proper time.

Thus it is possible to say that the clock (even a wristwatch) is an instrument capable of measuring the lengths of sections of world lines. [A world line is the path in spacetime traveled by an elementary particle for the time and distance that it retains its identity.] Then the solidarity of clocks follows from the fact that they determine the fundamental geometric properties of spacetime. The data of ideal clocks directly depend only on the length of world line and are not influenced by the curvature of spacetime (tidal forces) or by the curvature of the world line in spacetime (acceleration). A practical question arises: Which clock is closer to the ideal?

Throughout most of human history, time as defined by the motions of astronomical bodies has played a crucial role. Observation alone taught people to experience and explain the variances from the ideal. The contemporary unit of time—*second*—was originally derived from the threefold partition of the solar day (the interval between middays) into *hours* (based on the partition of the circle described by the sun on the sky), *minutes* (the "diminution" of the hour) and *seconds* (the "second" diminution). But the length of a solar day changes seasonally by minutes as a consequence of the inclination of Earth's axis and the variability of the velocity of the passage of Earth around the sun.

A more precise standard of time is provided by the rotation of Earth with respect to the fixed stars. But this period is also influenced by the season, accidental and systematic changes of the shape of Earth, and of the distribution of its mass. Moreover, as it was shown by the philosopher Immanuel Kant in the 18th century, a permanent deceleration of Earth's rotation is taking place due to the action of tidal forces. Although it slows by only 1.5 milliseconds in a century, its influence accumulates with time and leads, for example, to shifts in location for eclipses observed in antiquity. Consequently, the best standard of time in astronomy is *ephemeris time,* based on complex observations and calculations of motions in the solar system. Since 1956 the definition of a second has been based not on the day (1/86,400 of the solar day), but on the year (1/31,556,925,9747 of the tropical year from the beginning of the 20th century). Currently, three times are used for the purposes of astronomy—terrestrial, barycentrical, and geocentrical—in order to account for the effects of relativity.

A new type of astronomical clock with small, precise, and stable periods over the long term is based on *pulsars,* discovered in the 1960s and explained as rotating neutron stars whose directionally concentrated radiation strikes the earth with reliable regularity.

Timekeeping based on astronomical observations found its way into the manufacture of clocks produced in factories and laboratories. The turning point was the introduction of pendulum clocks in the 17th century, owing chiefly to the work of Christiaan Huygens. Further improvements were made to the clock with piezoelectric crystals, and in 1946 with the atomic clock based on the regular vibrations of atoms.

The basic advantage of atomic clocks follows from the principle of identicalness of objects of the microworld. It is impossible to produce perfect copies of macroscopic objects, and their aging leads to irreversible changes, but the states of atoms are ideally reproducible and unchanged by the flow of time. Since 1967 the second has been defined as a time with the duration of 1,922,631,770 periods of oscillation between two precise levels of a hyperfine structure of certain basic states of the atom of cesium-133. The best cesium clocks are correct to within hundredths of a microsecond per day (compare with 100 milliseconds per day for the best mechanical clocks in the 18th century). *International atomic time* (TAI; the acronym is based on the French: Temps Atomique International) is based on readings of the most precise atomic clocks over the world. The times used in present-day astronomy are derived from atomic time. The next essential improvement in measuring time will no doubt involve the methods of quantum optics and laser spectroscopy, which were honored with the Nobel Prize in physics in 2005 (R. Glauber, J. Hall, and T. Hänsch). According to Hall's Nobel lecture, "time is the most powerful metrological variable." The effort to increase the precision of the measurement of time is by no means purposeless. It will result not only in many-sided development of techniques, but it will also lead to new discoveries. Observations of the periods of pulsars measured by atomic clocks give support to the existence of gravitational radiation; the measuring of frequencies of radiation of objects at cosmological distances can inspire new cosmological and microphysical theories; and so on.

From a theoretical point of view, it is important that the ideal clock can be defined on the basis of the simplest physical phenomena: motions of free particles and light signals, and thus, geometric properties of spacetime, as stated by R. Martzke and John. A. Wheeler in 1964. The ticks of the *light clock* arise from the permanent exchange of light signals between mirrors with a constant distance; it is possible to check and keep this constancy with the help of the motion of other free particles and light signals, even allowing for curved spacetime.

Hence, the continuous timeline of physics can be determined with a conceptual and technical precision that far transcends the possibilities of its perception and experience by humans, because its physical foundation remains a psychological and philosophical mystery to us. It is supposed that the natural limit of the continuous concept of time is *Planck time:*

$$t_P = \sqrt{\hbar G/c^5} \approx 5 \times 10^{-44}\text{seconds}$$

This limit for continuous time is built up from fundamental physical constants ($\hbar$ is the Planck constant, G the Newtonian gravitational constant, c is the speed of light). However, the theory of discontinuous time could manifest its necessity in efforts to unify physics with an understanding of the earliest stages of cosmological evolution.

Jan Novotný

See also Aristotle; Augustine of Hippo, Saint; Clocks, Atomic; Clocks, Mechanical; Earth, Rotation of; Galilei, Galileo; Hourglass; Newton, Isaac; Planck Time; Spacetime, Curvature of; Sundials; Time, Relativity of; Time, Cosmic; Time, Measurements of; Timepieces; Watches; Worlds, Possible

Further Readings

Bruton, E. (1993). *The history of clocks and watches.* London: Black Cat.

Glauber, R. J., Hall, J. L., & Hänsch, T. W. (2006). Nobelian lectures. In K. Grandin (Ed.), *Les Prix Nobel, the Nobel Prize 2005.* Stockholm: Nobel Foundation.

Higgins, K., Miner, D., Smith, C. N., & Sullivan, D. B. (2004). *A walk through time.* Gaithersburg, MD: National Institute of Standards and Technology. (Available online: http://physics.nist.gov/GenInt/Time/verhist.shtml)

Lämmerzahl, C., Everitt, C. W. F., & Hehl, F. W. (Eds.) (2001). *Gyros, clocks, interferometers . . . : Testing relativistic gravity in space.* Berlin: Springer.

Mackey, S. L. (1980). *Clocks and the cosmos: Time in Western life and thought.* Hamden, CT: Archon Books.

Misner, C. W., Thorne, K. S., & Wheeler, J. A. (1973). *Gravitation* (esp. pp. 23–29; 393–399). San Francisco: W. H. Freeman.

Chronostratigraphy

Chronostratigraphy is a discipline of stratigraphy that studies the relative time relations and ages of stratified rocks. The aim of Chronostratigraphy is to organize stratified rocks into units on the basis of their age or time of origin. A chronostratigraphic unit is a stratified body that includes all rocks formed during a specific interval of geologic time, and only those rocks formed during that time span. There is a hierarchy of formal chronostratigraphic unit terms that correspond with equivalent geochronologic unit terms. The first are stratigraphic units, whereas the second are time units. The chronostratigraphic units, according to their ranking, are the following: chronozone, stage, series, system, erathem, and eonothem; they correspond in rank to the following geochronologic units: chron, age, epoch, period, era, and eon. The position within a chronostratigraphic unit is expressed by adjectives such as *basal, lower, middle, upper,* and so forth. The position within a geochronologic unit is expressed by temporal adjectives such as *earliest, early, middle,* and *late.*

The boundaries of chronostratigraphic units are synchronous horizons by definition. There are several geologic methods of time correlation and dating, although their resolving power usually is greater than 20,000 years in most cases. The methodology used for the chronocorrelation is derived from Steno's law of superposition, which states that in an undisturbed sequence of sedimentary strata the uppermost strata are younger than those on which they rest. The determination of the order of superposition provides unequivocal evidence for relative age relations. The bedding plane is the best indicator of synchroneity, but such a method usually has only local validity. The identification of lithostratigraphic units always has some chronostratigraphic connotation, since their boundaries eventually cut across synchronous surfaces, but this lithostratigraphic method also has local validity.

The paleontological methods have greater utility because they are based on the orderly and progressive course of biological evolution.

The fossil record is an important source of chronostratigraphic information. Several calibrated biochronological scales have been established from biostratigraphic data and integrated correlation. In order to attain a better biochronocorrelation, the identification of index taxa is necessary. Index taxa are fossils useful to define and identify geologic periods. The best index taxa belong to the following paleontological groups: foraminifera, calcareous nanofossils, dinoflagellate cysts, acritarchs, ostracods, ammonites, trilobites, bracheopods, graptolites, and conodonts in Phanerozoic marine environments, and pollen and spores, vertebrate microfossils, charophytes, and ostracods in Phanerozoic terrestrial environments. However, the paleontological methods do not provide unequivocal data, since the strata and the fossils they contain are not necessarily synchronous.

Periodic reversals of the polarity of the earth's magnetic field are utilized in chronostratigraphy, particularly in upper Mesozoic and Cenozoic rocks, where a magnetochronological scale has been developed. Polarity reversals are binary, however, and specific ones cannot be identified without assistance from some other method of dating, mainly paleontological (biostratigraphic) methods. Biomagnetostratigraphic correlation, calibration, and dating is the best method known to date.

Radioisotopic dating methods are unique in providing numeric age values, expressed in years. They are based on the radioactive decay of certain parent nuclides at a rate that is constant and suitable for measuring geologic time data with high precision with analytical errors in the range of 0.1% to 2%. Radioisotopic dating provides the best hope for working out the ages and age relationships of Precambrian rocks. However, not all rock types and minerals are amenable to radioisotopic age determination, so it can be used only on sporadic occasions.

Today, two new methods have been added for chronocorrelation and dating: cyclostratigraphy/astrochronology and eventstratigraphy. The cyclostratigraphic methods try to identify evidence of the earth's orbital fluctuations in the stratigraphic record. These fluctuations have caused climate cycles in the past, such as the quaternary glaciations, that may be recognized in the stratigraphic record from lithological, paleomagnetic, isotopic, and paleontological data. The best-known orbital periodicities are the precession (cycles of 21,000 years), obliquity (cycles of 41,000 years), and eccentricity (cycles of 100,000 and 410,000 years). Their recognition provides an impressive chronocorrelation and dating method (astrochronologic scale), although it needs assistance from other methods of correlation.

Chronostratigraphic units, mainly the stages, must be defined by boundary stratotypes. The boundaries of a chronostratigraphic unit of any rank are defined by two designated reference points in the rock sequence. The selected point must be a marker horizon favorable for long-distance chronocorrelation; thus it must represent a global event. The identification of global events in the stratigraphic record is the aim of a new discipline called *eventstratigraphy.* In geological history, the most frequent globally occurring events are: paleoclimatic changes (e.g., glacial deposits, evaporites, red beds, coal deposits, faunal changes), tectonic and eustatic changes in sea level, volcanic events, meteoritic impacts, and mass extinctions. The identification of these events and their calibration with paleontological, isotopic, paleomagnetic, and astrochronologic methods are the best tools for establishing the chronostratigraphic and geochronologic scales.

Three eonothems are recognized, from older to younger: Archean (3,900–2,500 million years ago [mya]), Proterozoic (2,500–542 mya), and Phanerozoic (540–0 mya), although a fourth eon is generally considered, the Hadean (4,550–3,900 mya). The informal Precambrian terms include Hadean, Archean, and Proterozoic (i.e., all time before the Cambrian). Subdivisions of the global geologic record are formally defined by their lower boundaries from a basal Global Standard Section and Point (GSSP), except for Precambrian units, which are formally subdivided by absolute age (Global Standard Stratigraphic Age, or GSSA). GSSP and GSSA are approved by the International Commission on Stratigraphy (ICS) and ratified by the International Union of Geological Sciences (IUGS).

The Hadean spans the time period between the earth's formation and the age of earliest-known rocks. It has no geological record known to date, except for some zircon crystals of Hadean age. The Archean, also called Archeozoic, is defined geochronometrically (GSSA) and not stratigraphically. It is subdivided formally in four erathems or eras: Eoarchaean (3,900–3,600 mya), Paleoarchean (3,600–3,200 mya), Mesoarchean (3,200–2,800 mya), and Neoarchean (2,500–2,800 mya). The Proterozoic represents an eon before the first abundant complex life on Earth; that is, before the first period of the Phanerozoic, the Cambrian. Its geologic record is much better than that from the preceding eonothem. The Proterozoic includes three erathems or eras: Paleoproterozoic (2,500–1,600 mya), Mesoproterozoic (1,600–1,000 mya), and Neoproterozoic (1,000–542 mya). Finally, the Phanerozoic spans the period of geologic time during which an abundant fossil record has existed. It subdivides into three erathems: Paleozoic (542–251 mya), Mesozoic (251–65 mya), and Cenozoic (65–0 mya) whose boundaries coincide with major mass extinction events: the Permian/Triassic boundary mass extinction event occurred between the Paleozoic and Mesozoic eras, and the Cretaceous/Paleogene or K-T boundary mass extinction event between the Mesozoic and Cenozoic eras. The Phanerozoic erathems are subdivided into systems or periods that are widely known popularly: Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian for the Paleozoic; Triassic, Jurassic, and Cretaceous for the Mesozoic; and Paleogene and Neogene for the Cenozoic. Moreover, the Paleogene is subdivided into three well-known series or epochs called Paleocene, Eocene, and Oligocene; whereas the Neogene is subdivided into Miocene, Pliocene, Pleistocene, and Holocene. Historically, the Cenozoic has been divided into Tertiary (Paleocene to Pliocene) and Quaternary (Pleistocene and Holocene), although most geologists no longer recognize these.

Ignacio Arenillas

See also Chronology; Dating Techniques; Earth, Age of; Fossil Record; Geologic Timescale; Geology; K-T Boundary; Paleontology; Permian Extinction; Stratigraphy; Synchronicity, Geological; Time, Measurements of

Further Readings

De Graciansky, P. C., Hardenbol, J., & Jacquin, T., & Vail, P. R. (Eds.). (1998). *Mesozoic and Cenozoic sequence stratigraphy of European basins.* Tulsa, OK: SEPM Special Publication.

Gradstein, F. M., Ogg, J. G., & Smith, A. G. (Eds.). (2004). *A geologic time scale 2004.* Cambridge, UK: Cambridge University Press.

CHRONOTOPES

Chronotope is a term of literary theory that designates the spatiotemporal matrix of narrative texts. It was used for the first time by the Russian philologist and literary theoretician Mikhail Mikhailovich Bakhtin (1895–1975). The definition as well as the application of the concept of chronotope is Bakhtin's primary aim in his essay *Forms of Time and of the Chronotope in the Novel* (written 1937–1938). It is part of *The Dialogic Imagination,* a work that was not translated into English until 1981.

Bakhtin defines chronotope as the inseparable connection of spatial and temporal relations in literary texts. The word *chronotope* can literally be translated as "time-space" (from the Greek nouns *chronos,* time, and *topos,* place). "Time" is the first component of this neologism: this shall indicate that it is the dominating category in the chronotope.

Literary–artistic chronotopes share three basic features. First, they have generic significance, which means that a particular conception of spatiotemporal relations determines a literary genre. For Bakhtin, the history of literary–artistic chronotopes parallels the history of literary genres. Second, literary–artistic chronotopes determine to a large degree the image of individuals. The conception of characters in narrative texts is marked considerably by the spatiotemporal conditions surrounding them. The third basic feature of literary–artistic chronotopes is their representational significance. By locating narrative events and characters in a certain place at a certain time, the flow of time becomes visible. Thus, the novelist's design of a literary–artistic chronotope makes time and space concrete.

Bakhtin points out the existence of six types of literary–artistic chronotopes that emerged during the course of literary history from the Greek romance to the Rabelaisian novel. The first type of these chronotopes is the "adventure novel or ordeal." It is typical for the Greek romance (e.g., Heliodorus's *Aethiopica,* Chariton's *Chareas and Callirhoë,* and Xenophon's *Ephesiaca*) and dominated by "adventure-time," an immobile, reversible, mythological kind of time that is structured by extra-temporal gaps between moments in time. Adventure-time also determines the image of literary characters: as a nonbiographical time it turns them into unchanging, passive individuals, the irresolute objects of fate. The Greek romance is thus devoid of character development. On account of its mythological immobility, adventure-time leaves no trace in the characters.

The second type of literary–artistic chronotope is, according to Bakhtin, the "adventure novel of everyday life." It is characterized by a mixture of adventure-time and "everyday-time." To illustrate the significant features of this type of chronotope, Bakhtin refers to Petronius's *Satyricon* and Apuleius's *The Golden Ass,* two Roman novels that were written in the 1st and 2nd centuries CE. The chronotope of these narratives resembles to some extent the chronotope of the Greek romance: in accordance with adventure-time, the works of both authors describe exceptional moments in a person's life. They present no temporal progression in a strict sense. Yet, time in the adventure novel of everyday life differs to a significant degree from time as it is presented in the Greek romance. In contrast to the latter, it is not a reversible but an irreversible kind of time that leaves profound traces in the characters. The different conception of chronotope in the adventure novel of everyday life leads therefore to a different conception of character. In Apuleian and Petronian narratives the characters are no longer unchangeable objects of fate. Instead, their description is structured by the idea of metamorphosis. Metamorphosis is a method for portraying the whole of an individual's life in its most important moments of crisis. It shows how persons become other than they were before (e.g., the protagonist of *The Golden Ass,* Lucius, is presented before his transformation into an ass, he is presented as an ass, and he is presented as a mysteriously rehumanized character). According to Bakhtin, the metamorphosis of characters—that is, their development in time—is possible only because they are immediately confronted with everyday life. It is Lucius's punishment to participate as an ass in everyday life for a certain period of time. Yet, being vis-à-vis everyday life is exactly what distinguishes the Apuleian and Petronian chronotope from the chronotope of the Greek romance.

The remaining types of the literary-artistic chronotope are explained exclusively with respect to their temporal structure. The "life course of one seeking true knowledge" is the third type of literary-artistic chronotope discussed by Bakhtin. It is typical for ancient biography and autobiography. Time in these literary genres has a biographical character; that is, it presents an individual's temporal development. The fourth type of literary-artistic chronotope is the "miraculous world in adventure-time." It occurs predominantly in the chivalric romances of the Middle Ages (e.g., in Wolfram's *Parzival* and Hartmann's *Erec*). The chronotope of the miraculous world is characterized by a subjective playing with time: hours are compressed into moments, moments are stretched into days. The "Rabelaisian chronotope" is the fifth type of literary-artistic chronotope. It is marked significantly by an expansion of time and space, which means that the spatial and temporal dimensions are exaggerated as much as possible, creating an impression of grotesque unreality. The "idyllic chronotope" is the last type of literary-artistic chronotope described in Bakhtin's essay. It is characterized primarily by a cyclic rhythm of time in which the life of a character is just a repetition of the life of the generations before.

The description of the different chronotopes makes clear that Bakhtin regards spatiotemporal relations in narrative texts as the fundamental coordinates that determine to a large degree the literary parameters of a narrative piece of writing.

Verena Kammandel

See also Bakhtin, Mikhail Mikhailovich; Novels, Time in; Perception

Further Readings

Bakhtin, M. M. (1981). *The dialogic imagination: Four essays.* Austin: University of Texas Press.

Gardiner, M. (Ed.). (2002). *Mikhail Bakhtin* (Sage Masters of Modern Social Thought). London: Sage.

Morris, P. (Ed.). (1994). *The Bakhtin reader. Selected writings of Bakhtin, Medvedev and Voloshinov.* London: Edward Arnold.

Clarke, Arthur C. (1917–2008)

Sir Arthur Charles Clarke is considered one of the preeminent futurists, science popularizers, and space visionaries, as well as being one of the most recognizable names in science fiction today. He was able to predict many aspects of space travel accurately, and may have even actually influenced those aspects. His writings deal with time, particularly his best-known novel, *2001: A Space Odyssey* (which spans human evolution from apelike protohumans, through our own species, to a conjectured future "star child").

Clarke was born on December 16, 1917, in Somerset, England. He grew up quickly, working on the family farm and helping the family, especially after his father died when Arthur was 13 years old. At this early age, Clarke was already showing interest in both science fiction and astronomy, which included the construction of his own rockets and telescopes. He also joined the British Interplanetary Society in 1934, and was later its chairperson.

After a brief career as an auditor, Clarke joined the Royal Air Force and eventually became a radar specialist. During the final days of his war duties, he published an article titled "Extra-Terrestrial Relays" in the October 1945 edition of *Wireless World*. This article showed the importance of, and laid the groundwork for, geostationary satellite communications. His idea to synchronize satellites (so they appeared to be stationary from the earth) made possible all forms of global communication throughout the world, including television, radio, and (now) cellular phone technology.

Due to the cost involved, Clarke was not able to attend college until after his stint in the RAF. He earned degrees in mathematics and physics from King's College after World War II and worked briefly as an assistant editor for *Physics Abstracts* before turning to writing full-time. Many of his early, nonfiction published works were on space travel, such as *Interplanetary Flight* (1950), *The Exploration of Space* (1951), and *The Exploration of the Moon* (1954). However, Clarke also continued to write fiction. During his college years, he wrote *The Sentinel,* a story that some readers have identified as the core of the idea for his most famous work, *2001: A Space Odyssey.* He was also contributing to the major science fiction magazines of the time, including *Fantasy, Astounding Stories,* and *New Worlds*.

During the 1960s, Clarke began his collaboration with director Stanley Kubrick on *2001: A Space Odyssey.* The screenplay for the movie was actually being written while the novel was being written, so there are differences between the two. The success of this masterpiece of science fiction led to several other works, most notably *2010: Odyssey Two,* which was adapted for the film *2010: The Year We Made Contact.* Again, Clarke showed his prowess for predicting space travel and future events.

Clarke became increasingly well known for his knowledge of space through his television appearances with reporter Walter Cronkite for the coverage of the *Apollo 11* moon landing, as well as some of the other Apollo missions. His expert analysis regarding the future of space travel during these events was astonishing in its accuracy. Clarke moved to Ceylon (now Sri Lanka) in 1956 and maintained dual citizenship in the United Kingdom and Sri Lanka. Toward the end of his life he became almost completely wheelchair-bound due to post-polio syndrome.

Clarke's published works include numerous science-fiction short stories and novels, as well as nonfiction books (including works about the ocean: scuba diving was another passion). His fiction mirrors his nonfiction in that he wrote from a strong background in the sciences; in addition, it demonstrates his uncanny ability to predict the course of scientific advancement and space travel.

Timothy Binga

See also Bradbury, Ray; Novels, Time in; Space Travel; Verne, Jules; Wells, H. G.

Further Readings

Bizony, P. (1994). *2001: Filming the future*. London: Aurum Press.

McAleer, N. (1993). *Arthur C. Clarke: The authorized biography.* Chicago: Contemporary Books.

Scorsese, M. (2000). *The making of* 2001: A space odyssey. New York: Modern Library.

Clock, Doomsday

The doomsday clock, which now reflects international security status, is one of the best-known symbols of nuclear danger. Originally referred to as the *Bulletin* Clock or the Clock of Doom, it debuted in the June 1947 issue of *Bulletin of the Atomic Scientists,* a publication founded in 1945 by Chicago-area scientists who were part of the Manhattan Project, which developed the first atomic bomb. The *Bulletin* was designed as a forum to explore the implications of the new power these scientists and their colleagues had unleashed.

Originally in a newsletter format, the publication developed into a magazine. At the request of cofounder Dr. Hyman H. Goldsmith, artist Martyl Langsdorf, the wife of physicist Alexander Langsdorf, created the design. Better known for her landscapes, the artist hit upon "the idea of using a clock to symbolize urgency." Langsdorf had planned on repeating the image of the upper-left quadrant of a clock face, with the minute hand approaching midnight, every month with a different background color. She drew her first sketch on the back of a bound volume of Beethoven sonatas. She credited "good design" as the deciding factor to start the clock at 7 minutes to midnight. The idea of moving the minute hand came later, in 1949, as a way to dramatize the *Bulletin's* response to world events. The clock dominated most *Bulletin* covers until 1964. Langsdorf updated the clock's design once more in 1989 by placing its hands on the globe.

Between 1947 and 2007, the minute hand has been moved back and forth 18 times. The first movement was to 3 minutes to midnight to acknowledge the Soviet Union's explosion of its first atomic bomb. In 1953, the doomsday clock read 2 minutes to midnight to emphasize the Soviet Union's and the United States' testing of thermonuclear devices within 9 months of each other. The most peaceful movement occurred in 1991 when the doomsday clock was set back to 17 minutes to midnight. The United States and the Soviet Union had signed the long-stalled Strategic Arms Reduction Treaty (START) and announced further unilateral reductions in tactical and strategic nuclear weapons. In 2007, the minute hand moved for the 18th time. Five minutes to midnight was based on the United States' and Soviet Union's continued ability to stage a nuclear attack within minutes. North Korea had conducted a nuclear test, and many were worried that Iran had plans to acquire the bomb. The challenge of climate change and its toll on ecosystems was also factored in.

Suzanne Colligan

See also End-Time, Beliefs in; Extinction; Nuclear Winter; Time, End of; Time, Measurements of

Further Readings

Boyer, P. (1985). *By the bomb's early light: American thought and culture at the dawn of the atomic age.* New York: Pantheon.

Moore, M. (1995). Midnight never came. *The Bulletin of the Atomic Scientists, 51*(6), 16–27.

Clocks, Atomic

With advances in science and technology, traditional mechanical clocks have been supplemented with atomic clocks, which give far more accurate time measurements. Further progress in atomic clocks will enhance practical uses ranging from medical research applications to outer space travel.

Origin

In 1945, Isidor Rabi, professor of physics at Columbia University, proposed the idea that an exceptionally accurate form of timekeeping could be procured from a process known as Atomic Beam Magnetic Resonance (ABMR), a process developed by Rabi during the mid to late 1930s. In essence, ABMR is composed of a harmonized magnetic field with an oscillating magnetic field being applied to it at right angles. This forces a transition between the nuclei of atoms with varying states of magnetic quantum numbers. The transition occurs only each time the frequency of the oscillating magnetic field possesses parallel and precise qualities. Given the closed environment in which this process occurs, the interval between one nucleus and the next obtaining the specific characteristic values is nearly flawlessly precise, thus making ABMR an excellent platform from which to launch a method of logging time. Mechanical clocks also use oscillating motion, with tuning forks, pendulums, and balance wheels. But the rate of movement for an ammonia atom in this type of motion is much higher—23,870 vibrations per second, as opposed to the average of 5 to 10 vibrations per second on a mechanical watch—with the elevated oscillations correlating to a greater degree of accuracy.

Prototype

Given the allure of a method of time recording and reporting more true than astronomical time (itself accurate to within only 3 minutes, 55.9095 seconds per 24-hour cycle), the United States National Bureau of Standards (NBS, now referred to as the National Institute of Standards and Technology, NIST) unveiled the world's first atomic clock in 1949, with nuclei of ammonia molecules providing the movement, or vibrations, as a result of the interaction between constant and oscillating magnetic fields. The mean accuracy of ammonia-based atomic clocks, as dispersed throughout the globe, is approximately 1 second every 3,000 years (with even the best mechanical watches being off a handful of seconds each day). By necessity, the device—and all future atomic catalysts used for the gauging of time—is connected to a time recording device; without the registering device being affixed, the near-perfect oscillation cycle would have no way of presenting itself to the outside world, thus rendering it useless as a measurement of time.

Progression

In 1955, the National Physical Laboratory (NPL) based in Teddington, United Kingdom, constructed the first cesium beam clock, utilizing atoms of cesium rather than ammonia. The clock's very precise frequency of 9,192,631,770 vibrations per second has been correlated to a margin of error equaling plus or minus 2 seconds every 3 million years. Throughout the following years, cesium-based clocks began to undergo various modifications and advancements, and during the 13th General Conference on Weights and Measures it was determined the SI second—or cesium-based 9,192,631,770 vibrations per second—would define 1/60 of 1 minute. Because of the acute accuracy of such a measurement, there is little reason to question the motives of this conference when, in 1967, it was determined world time would forever be based on an atomic and not an astronomical basis.

Despite the nearly flawless regularity of cesium vibrations and the subsequent recording of said vibrations, slight discrepancies still exist from one clock—most of which are housed in various research institutions throughout the world—to the next. As such, all "official" clocks (commercially produced cesium-based clocks are available, but their accuracy is at best dismal when compared to that of the laboratory-based models) are recorded and then averaged to produce the global standard, International Atomic Time (TAI, an acronym for the French: Temps Atomique International).

Points of Interest

Usage for so accurate an instrument is vast; time signals broadcast via shortwave radio stations and artificial satellite make it possible for "true time" to be had anywhere upon the globe. This highly accurate and standardized time format is then used in a variety of applications, from synchronization of the Internet to space shuttle launches, to the opening and closing of stock markets, and everything in between.

Contrary to the belief held by many, atomic clocks are in no way radioactive. The clocks are not a result of, related to, or bound in any way by atomic decay, the precursor to radioactivity. Without a working relationship with the catalyst to radioactivity, the chance of accidental radiation is nil. Instead of using the potentially hazardous energy or decay of an atom, the clocks rely on an oscillating part and "springs," not dissimilar to commonplace mechanical clocks. In lieu of the conventional metal coil spring and balance wheel used in mechanical movements, an atomic clock uses gravity, the mass of the nucleus, and an "electrostatic spring" caused by the positive charge of the nucleus and negative charge of its surrounding electron assemblage.

Of distinct interest is the direction that the advancement of atomic clocks has taken during the past decade. As of 1999, NIST began using the world's most precise and stable cesium clock, it being accurate to within 1 second over 20 million years. This instrument is composed of a 3-feet–long vertical tube that is encased within a larger unit. Lasers are incorporated to cool the cesium atoms so that ideal conditions are maintained, helping to ensure greater accuracy in the replication of vibrations per second, thus accuracy. Simultaneously, other lasers are incorporated to "toss" the cooled ball of atoms, thus creating a fountain effect within the 3-foot tube, allowing greater opportunity for the observation of oscillating atoms, much more so than previously allowed within enclosed housing units.

Outlook

The future of atomic clocks seems full of promise when considering ever-diminishing margins of error for replicability of motion, that is, identical units of time. First with ammonia and now cesium, researchers have begun construction of clocks based on hydrogen, beryllium, and mercury atoms, with good indications that these prototypes, once refined into fully operable units, could be up to 1,000 times more accurate than the atomic clocks of today.

Daniel J. Michalek

See also Attosecond and Nanosecond; Clocks, Mechanical; Dating Techniques; Decay, Radioactive; Time, Measurements of

Further Readings

Audoin, C., & Guinot, B. (2001). *The measurement of time: Time, frequency and the atomic clock.* Cambridge, UK: Cambridge University Press.

Jones, T. (2000). *Atomic timekeeping* (Vol. 1). Oxford, UK: Taylor & Francis.

Clocks, Biological

Biological clocks are internal mechanisms that help humans, animals, and other living organisms measure time and regulate the rhythms of their bodies and activities. Most commonly, these clocks tell us when to eat, sleep, rest, become active, and mate. Biological clocks allow organisms to determine internally, at any given moment, the actual time of day, month, or year. The internal mechanisms are triggered by fluctuations in environmental variables like changes in daylight or temperature. These internal timekeeping devices have evolved to interrelate with the daily, lunar, and seasonal changes. Environmental rhythms are predictable and set their course on planetary cycles. For example, as the earth spins on its axis, we experience day and night patterns. When the moon orbits the earth, we experience lunar phases and daily tidal changes. The predictable seasonal changes occur during the yearlong travels of the earth around the sun. Even absent human-made calendars and clocks, living organisms detect these environmental variables and naturally modify their behavior consistent to these variables.

Body time is controlled by the suprachiasmatic nucleus, or SCN. This cluster of cells resides within the hypothalamus, which is a tiny portion of the brain that forms on the bottom of the left ventricle and regulates many basic bodily functions, such as body temperature. The ability to synchronize biorhythms to the day and night cycles of the earth's 24-hour–long rotation around its axis provides evidence that this internal mechanism exists and responds to environmental change. The most common examples of biological rhythms for humans include sleeping, waking, eating, urination, and physical and mental performance and alertness. These patterns of behavior show that organisms behave as if they are independently capable of determining time.

The scientists who study biological clocks are called chronobiologists; they believe the biological clock begins functioning even before humans are born and that it develops as they grow. At 7 months of age, human babies have developed sleep patterns that are free-running, meaning that their sleep cycles are not regulated by external cues such as the rising or setting of the sun. Chronobiologists have also discovered that biological rhythms send messages to the brain, telling people what activities to perform. Because the urinary biological rhythms take longer to develop in babies, they wear diapers until they have mastered the rhythm, sometimes until they are 3 or 4 years old. As children grow, the biological clock matures and begins to slow urinary frequency during sleep hours, freeing older children from the urge to urinate and allowing them nights of uninterrupted sleep. The circadian or daily rhythms of 10-year-olds are disrupted by their high energy levels. Concomitantly, adolescents hit growth spurts and require more sleep than they did when they were younger. When they reach their 20s, they generally settle into a routine 24-hour day cycle. As energy levels fall for the elderly, their sleep cycles and circadian patterns are again disrupted.

Biological rhythmicity has also been seen in research studies involving groups of plants, animals, and microorganisms. In the late 19th century, plant physiologists researching circadian rhythm found that if a plant was removed from its natural habitat and was confined to a laboratory and subjected to disturbances in its daily cycles of day and night, the plant would maintain its primary biorhythms. Many plants that exhibit daily rhythms in which they raise and lower their leaves to correlate to the time of day or night will continue to exhibit similar patterns even after the source of light is disrupted. For example, if a plant normally lifts is leaves upward during daylight hours, it will continue to do so even if placed in a laboratory and removed from its light source. These plants slowly adapt to the new environment provided in the controlled study and can eventually reverse their normal daytime/nighttime routines. They can later even revert successfully to their natural habitat and primary biorhythms when returned to their native habitat. Laboratory experiments have consistently shown this extraordinary stability of biological rhythms. Daily rhythms for a wide variety of single-cell organisms, mammals, and plants also remain unchanged when they confront constant light or dark.

A strong sense of time enables organisms to most fully explore and participate in the portions of the day in which their activities will be most productive (eating, mating, sleeping, hunting, migrating, etc.). When an animal is relocated to a geographic area where the environmental cycle is greatly different, the animal's clock maintains synchronicity with its original environment. Similarly, if humans are rapidly translocated a great distance and experience significant time zone disruptions, they will also maintain synchronicity. Most humans and animals will slowly readjust after this period of initial disruption. This reaction to loss of time is a phenomenon commonly called jet lag, and many people describe physical effects of fatigue, lowered productivity, and decreased alertness until their internal mechanisms readjust.

Fluctuations occur at every level, from cellular to complete physiological activities, in which chemical, behavioral, and physiological responses are evidently correlated to the environment. Many biological rhythms correlate to periodic planetary changes, also referred to as geophysical correlates (ocean tides, amount of sunlight in a day, the changing months and years, and the seasonal differences). Some fluctuations or biorhythms do not have geophysical or external correlates, such as the biological rhythm of a heartbeat or a respiratory rate.

Debra M. Lucas

See also Cryonics; DNA; Hibernation; Life Cycle; Longevity; Metamorphosis, Insect

Further Readings

Dunlap, J., Loros, J., & DeCoursey, P. (Eds.). (2004). *Chronobiology: Biological timekeeping.* Sunderland, MA: Sinauer Associates.

Koukkari, W., & Sothern, R. (2006). *Introducing biological rhythms: A primer on the temporal organization of life, with implications for health, society, reproduction and the natural environment.* New York: Springer.

Clocks, Mechanical

The first mechanical clocks appeared about 1250 CE and employed weight-driven gears to keep time. Their invention represented an important step in the quest to discover a way to keep time accurately. The inventor of the first mechanical clock is unknown, but records indicate the timepiece originated in Europe. In all likelihood, the devices were invented in monasteries, where they were used to call the monks to prayer.

Mechanical clocks represented a vast improvement over previous timekeeping mechanisms of the day, including hourglasses and water clocks, which proved to be unreliable for accurate timekeeping.

The mechanical clock is composed of a few necessary parts, including a suspended weight that provides a driving force; a train of gear wheels that transmit power and turn a dial to indicate time; a time-controlling device that regulates the falling weight; and a mechanism known as an escapement. The escapement is a key component of the clock and is that which distinguishes it from its predecessors. This device takes energy from the power source, transmits it through gears, and releases it in beats, generally one per second. Early escapements were quite primitive and were unable to keep a regular beat. Later escapements were designed to fit on the top of the gears and were stimulated by the pendulum's motion. Rocking back and forth on the wheel, the escapement allowed the gear to advance one notch but blocked advancement to the next notch. When the pendulum returned, the escapement released another notch. In this way the escapement controlled the rate at which the clock beat.

Clocks relied on the pull of gravity as a power source. A weight was attached to a cord that was tightly wound around a toothed spool known as a capstan. As the cord unwound, the capstan turned a set of gears that then caused the hands on the clock's face to move. Although the early "modern" clocks represented a great leap forward, the devices were inaccurate at best, losing or gaining 15 minutes per day, and often much more than that. Such clocks often had to be reset daily at solar noon. Furthermore, their mechanical parts required a great deal of upkeep.

The next major advancement was the application of the pendulum to the clock in 1657, which provided a more reliable power source and hence represented a much more precise way to keep time. Clockmakers immediately began to employ the pendulum as a new type of "regulator," and timekeeping errors were reduced even further. The pendulum allowed clockmakers to add a minute hand to the clock, which previously had sported only an hour hand. Furthermore, continued refinements to the shapes of clocks added to the increased accuracy of the devices because they could house and protect long pendulums. Thus were longcase clocks born, later known as grandfather clocks. Mechanical clocks continued in use for more than 400 years before the advent of the electric and, ultimately, the atomic clock in modern times.

Patricia J. West

The Orloj is a famous astronomical clock in Prague, Czech Republic. It was one of a number of complex astronomical clocks designed and constructed during the 14th and 15th centuries, soon after the invention of the mechanical clock.

Source: Justin Horrocks/iStockphoto.

See also Clocks, Atomic; Hourglass; Pendulums; Sundials; Time, Measurements of; Timepieces

Further Readings

Barnett, J. E. (1998). *Time's pendulum: The quest to capture time from sundials to atomic cocks.* Boulder, CO: Perseus.

Guye, S., & Michel, H. (1971). *Time and space: Measuring instruments from the 15th to the 19th century.* New York: Praeger.

Landes, D. S. (2000). *Revolution in time: Clocks and the making of the modern world.* Cambridge, MA: Harvard University Press.

Swedberg, R. W. (1989). *American clocks and clockmakers.* Radnor, PA: Wallace-Homestead.

Coelacanths

The term *coelacanth* refers to fish that are members of the order Coelacanthiformes, renowned for their multiple limb-like lobed fins and extensive fossil history. Prior to the 20th century, they were thought to have been extinct for approximately 70 million years, but the fish catapulted to worldwide fame when several living populations were discovered.

The ancient lineage of coelacanths is part of the order of lobefin fishes and currently represented by two living species, *Latimeria chalumnae* and *Latimeria menadoensi*. They display a remarkable combination of morphological features that are unique or rare among all living fish, among which the most obvious are their seven fleshy fins. These include several pairs of muscular lobed pectoral and pelvic fins that are quite dexterous, being able to rotate and serve as multidirectional paddles for greater control in currents.

The shape and placement of the bones in these lobed fins show a clear similarity to amphibians' forelimbs, and at times it was thought that the colloquially named "four-legged fish" might be the direct ancient relative of all land-dwelling vertebrates. However, the molecular and paleontological evidence suggests that Coelacanthiformes are at most a side branch of an earlier ancestor that would later give rise to limbed animals capable of terrestrial domination.

Adult coelacanths can weigh up to 90 kilograms and grow as long as 2 meters, although they are often smaller. Specimens of *L. chalumnae* have thick scales of a pale mauve to blue color, while *L. menadoensi* is brown; both have flecks of iridescent white or silver. These markings provide excellent camouflage within their preferred habitat of encrusted rocky marine caverns, where they shelter at depths between 100 and 700 meters during the day, before foraging in shallower zones at night for fish, eels, skate, octopus, squid, and crustaceans. They are relatively sluggish, seen feeding by drifting head down in currents, aligning their gape with crevices in which to find food and swallow it whole.

The fossil record shows coelacanths emerged during the Devonian period, approximately 400 million years ago (mya). The group diversified into both marine and fresh water, becoming most abundant in the Triassic before suffering a slow decline terminating during the Cretaceous period 70 mya, after which no more fossils are known. Thus, the world was shocked when in 1938 a live specimen, dubbed *Latimeria chalumnae,* was caught off the coast of South Africa. Sixty years later, a new population of coelacanths (*Latimeria menadoensis*) was discovered north of Sulawesi in the Indonesian archipelago. Genetic analysis indicates that the two populations diverged about 5 mya.

The coelacanths have been an icon of evolution to both scientists and the public, thanks to their renown as a "living fossil," seemingly surviving extinction and appearing entirely unchanged over time. Both terms are somewhat misapplied. Coelacanths have always been present in the world's oceans. Humans were just unaware or ignorant of their presence—as we surely remain for much marine life. And far from remaining unchanged over time, there are periods of rapid morphological evolution in their history. One of the oldest specimens from this group, for example, has an eel-like morphology (*Holopterygius,* from 385 mya, found near Cologne, Germany). Other relatives from the same epoch had round, disk-like bodies or a range of disparate morphologies. This indicates the group went through an early period of anatomical experimentation before settling on the distinctive features of present-day coelacanths.

Coelacanths play an important role in our understanding of vertebrate evolution, and serve as a significant symbol of life's diversity and adaptive nature. Although humans do not eat coelacanths for food, some have been harvested for nonsensical medicinal purposes. In addition, they suffer byproduct mortality from other fishing activities. Their rarity indicates their future survival is in doubt, to the point that one species is listed as critically endangered and the other is unclassified until further evidence of their population can be found.

Mark James Thompson

See also *Archaeopteryx;* Dinosaurs; Fossil Record; Fossils, Interpretations of; Fossils, Living; Ginkgo Trees; Stromatolites; Trilobites

Further Readings

Forey, P. (1998). *The history of the coelacanth fishes.* New York: Chapman and Hall.

Weinberg, S. (2001). *A fish caught in time: The search for the coelacanth.* New York: HarperPerennial.

Cognition

Cognition has multiple meanings and is often used as a general term for all mental thought processes. More specifically, it often refers to the use and acquisition of both language and knowledge (including self-knowledge). Other mental processes frequently associated with cognition are judgment, perception, reasoning, awareness, intuition, and memory. Time is a fluid idea in relation to cognition, interweaving with it; the idea of time is shaped by cognitive processes, yet also shapes those same processes. Metacognition, mental representation, attention, and perception seem to be the primary areas where time and cognition most overlap.

Present mental states are formed and grounded in past interactions and ideas; these past interactions are then imposed on future possibilities. Nonetheless, thought about thought, often called metacognition, can invert this process and view it in an opposite manner from what is normally considered. Although time usually is thought of as flowing from the past to the present and then into the future, metacognition will often begin by forming a plan (projecting a course of action into the future), carrying out what is planned in the present, and then considering what has been accomplished (by looking at actions that are now past).

This process of reflecting on one's own mental state can be regarded as a form of mental time travel. It is also possible to contemplate times not personally experienced, such as the remote past or the distant future. A related idea is the mental representation of self as both a past memory and also as imagined in the future. Indeed, the Bischof–Kohler hypothesis, which claims that nonhuman animals are unable to consider future needs, holds that it is this ability that distinguishes humans from other animals. Others believe humans are not the only species to manifest this ability; research on the matter continues. Thus far, however, a conclusive case has not been made either way.

This flexibility in relation to views of time may be further demonstrated by the preference of English speakers (who consider time sequences as before/after) in contrast to Mandarin Chinese speakers (who often prefer to regard time sequences as up/down). Neither of these spatial metaphors is misplaced; time is often viewed as an object, more as a physical entity than a mental construct. Nonetheless, whether time is actually a physically existent entity or not can be debated. What is certain is that people often talk about time in terms of space but rarely about space in terms of time. It has also been determined that when the hippocampus (a part of the brain) is damaged, not only spatial memory but also episodic memory (the memory of particular events) is impaired. This suggests the two are intertwined in thought.

Humans have developed multiple gradations with which to consider time: minutes, hours, days, weeks, months, years. It has been suggested that both verbal and image-based processes are used. Perhaps this is why one often might recall exactly where and what time of day something happened . . . but not exactly the month or year.

Time can also seem to expand and contract depending on how intently one is paying attention to it. "Attention" is generally regarded as a cognitive function that allows a person to notice some aspects of a situation or object but not others. Exactly which aspects are noticed may to some extent be culturally dependent. What matters for this discussion is the fact that while one is noticing them, the nature of one's concentration is impacted. When a person is concentrating intensely, the passage of time may not be noticed at all; consequently it may seem as if time passes very quickly. When waiting for something to happen, however, it may seem as though time passes ever so slowly. Indeed, in such a situation it may be there is nothing else to pay attention to except the passage of time.

Carolyn Evans

See also Amnesia; Consciousness; Critical Reflection and Time; Intuition; Language, Evolution of; Memory; Psychology and Time; Time, Subjective Flow of; Time, Teaching; Time, Units of

Further Readings

Casasanto, D., & Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors [Electronic version]. *Cognition, 75,* 1–28. Retrieved December 18, 2007, from http://www-psych.stanford.edu/~lera/papers

Evans, V. (2003). *The structure of time: Language, meaning, and temporal cognition.* Philadelphia: John Benjamins.

Suddendorf, T., & Corballis, M. (2007). The evolution of foresight: What is mental time travel and is it unique to humans? [Electronic version]. *Behavioral and Brain Sciences, 39(3)* 299–313.

Coins, Ancient

Our knowledge of earlier civilizations has been greatly improved by direct examination of those artifacts that have survived the ravages of time. Unlike most animal and plant tissues, which undergo rapid or gradual decay, metal objects, particularly of the less reactive or precious metals, can remain preserved intact underground or underwater for centuries, even millennia. Included among such objects are the earliest examples of ancient coins. Coins themselves are actually a relatively recent historical development; the first specimens date back to the 7th century BCE. Most such coins were metal tokens, usually in the shape of a disc, that represented a specific value based upon metal composition, weight, or assigned value. On at least one side, coins had an image—and later an inscription—representing the authority that issued the coin.

History of Development

Trading based upon a bartering system using objects, such as shells, skins, salt, grain, cattle, and precious metals such as silver and gold, predates the first coins by millennia. When people began using metal for bartering, value was based upon the weight and purity of the metal, not the form or shape of the metal. An early standard of value was based on the price of cattle, such as an ox. Over time, people came to prefer to exchange metal because it did not wear out as easily as other materials and generally remained stable in value.

The first coins were struck in the 7th century BCE in the kingdom of Lydia, a region corresponding to modern western Turkey. These coins were made of electrum, a naturally occurring alloy of gold and silver; however, electrum quickly ceased to be used in preference to gold and silver. These coins were of an oval shape and had a lion figure stamped on one side and one or more punch marks on the other (what historians call punch-mark coinage). Due to close ties with and influence from Greece, coin usage speedily spread throughout the Greek colonies and into the larger Mediterranean world by the mid-6th century BCE.

Greece quickly developed a preference for silver coins and issued few gold coins. Although Athens and Corinth had the first mints, silver coins became so popular that they began to be minted in areas all around the Mediterranean Sea. By 500 BCE, these mints were using dies—striking a blank disc between two die—to stamp out coins rather than using single punches. The obverse die was seated in the anvil and the reverse die was on the base of the punch. The craftsman placed a blank piece of metal and struck the punch several times, thus making a coin.

Because of the existence of many mints, a custom developed that a particular mint would stamp its own design on a coin to identify the location where the coin was made; hence, the first mint marks. In the 200s CE, Roman mints began using standardized mint marks for their coins; these were located at the bottom of the reverse side.

The Romans began producing coins early in the 3rd century BCE, being highly influenced by Greek coins. About this same time (289 BCE), coins began being used for the first time as money, that is, having an exchange value not based on metal or weight. Initially, the Romans minted only coins of silver but by the late 3rd century BCE had begun issuing large quantities of bronze coins. After the unprecedented financial demands of the wars with Carthage (264–241, 218–201 BCE), Rome standardized its coin values based upon the *denarius* for silver coins and the *as* for bronze. Because Rome took booty and tribute from the people it conquered, silver and gold became scarce in the provinces, and coins made of those metals petered out by the middle of the first century BCE except in Rome. Throughout the first centuries CE, coin usage vastly expanded throughout the empire,

These Roman, silver-coated coins date to 240–244 CE. Obverse: The inscription says IMP GORDIANUS PIUS AUG, meaning "Emperor Gordian III, Augustus." The radiant crown indicates that the denomination of the coin is an Antoninianus. Reverse: the inscription says SECURIT PERP, meaning "eternal security."

Source: Photo courtesy of Terry W. Eddinger.

mainly via the army. This trend continued to the end of the empire. Roman coins had become so common in usage for purchasing goods or paying laborers that their impact continued to influence the coins of European groups well into the Middle Ages.

Just as the Greeks spread coin usage in the Mediterranean basin, the Persians spread its usage in the East (as far east as modern Afghanistan and Pakistan). Cyrus the Great (550–530 BCE) introduced coins to the Persian Empire after he conquered Lydia in 546 BCE. His grandson Darius I (521–486 BCE) introduced a thick gold coin he named after himself, the *daric,* which weighed 8.4 grams. He is pictured on the *daric* holding a bow and arrow. Because of Persian influence in the Far East, coins began to be used in northern India by 400 BCE. These early coins, made of silver, seem to have been an adaptation of Greek prototypes, with an image on one side and up to five punch marks on the other.

China developed coins independently of Greek and Persian influence. The first coins date to the Zhou kings (late 7th or early 6th century BCE) and were in the shape of a knife or spade. These bronze coins contained an inscription of the clan name, place name, or weight. In the late 3rd century BCE, Qin Shi Huangdi unified the Chinese states and issued round coins with a square hole in the center. These coins contained a two-character inscription indicating their weight. This coin continued until the Tang Empire, when the emperor Gaozu redesigned the coin, adding a four-character inscription that gave the weight and the period of issue and designated the coin as money. Coins of the Tang Empire spread throughout the Far East, with similar designs being adopted in other nations. The Japanese introduced coins in 708 CE, the Vietnamese in 970 CE, and the Koreans in 996 CE. Eastern Asian coins followed the Chinese design until influenced by European nations in the 18th century.

Values

Early bartering in Mesopotamia placed a value on precious metals based upon their weight in shekels (11.5 grams). The first coins in Lydia had value based upon their weight—the *stater* (a word meaning "standard") weighing about 14.1 grams. The smallest Lydian coins were as tiny as 1/96 of a stater (0.147 grams). The largest weight was one *mina,* equaling 50 staters.

Within a century of their introduction, coins became standardized by one of three standards: Athenian, Persian, or Phoenician. Greece (the Athenian standard) used the stater early and then the *tetradrachma,* which weighed 17.5 grams, as its standard. These were divided into the smaller *drachma* coins of 4.2 grams. The Persians used the 8.4 gram gold daric and 5.6 gram silver *siglos* (Persian variant of the shekel) as their standard for coins. One daric equaled 20 *sigloi.* The Phoenicians used a silver stater coin of 13.9 grams as their standard, which they subdivided into 24 parts. However, the main coin they used was the half-stater of 6.5 grams. By the 5th century BCE, coins began to have a designated value assigned by the issuing authority, apart from the net worth of the material of which they were made.

The Romans' standardized silver coin was the *denarius,* which was the equivalent of one Greek drachma. The standard for bronze coins was the *as,* which equaled a fraction of a denarius (one denarius equaled 10 *asses* before 140 BCE and 16 asses after 140 BCE). In the first century BCE, the Romans introduced the gold *aureus,* equal to 25 *denarii.* This coin became fairly common, an indication of the wealth of the early Roman Empire. In the 3rd century CE, corruption and inflation plagued the empire. The value of gold coins reverted to being based solely upon their weight in order to correct the problem; however, this did not work. As inflation grew, silver coins were made containing a lower percentage of pure silver until they contained almost no silver (less than 1%).

Before the invention of coins, some merchants used dishonest scales to cheat people out of their valuables. Evidently, the invention of coins did not solve the problem. Some ancient coins have chisel cuts in them where someone sliced the coin to check its purity. Furthermore, Rome had problems with coin forgery at times when there were shortages of official coins (the 40s, 270s, and 340–350s CE).

Designs

From the first coins, designs varied by mints and included images of animals, plants, persons, mythic beings, deities, city symbols, and so on. Later scenes depicted rulers, significant events, patron deities, and the like. Each mint designed its own coins. However, in the 3rd and 4th centuries CE, the Romans made all of their coins uniform so that all their mints made coins of the same designs, metallic quality, and size—a first in history. The only variant was the mint mark, which remained unique for each mint.

Terry W. Eddinger

See also Economics; Egypt, Ancient; Rome, Ancient; Values and Time

Further Readings

Howgego, C. (1995). *Ancient history from coins* (Approaching the Ancient World series). London: Routledge.

Klawans, Z. (2003). *Handbook of ancient Greek and Roman coins* (K. E. Bressett, Ed.). Atlanta, GA: Whitman Publishing.

Williams, J. (Ed.). (1997). *Money: A history.* New York: St. Martin's.

Coleridge, Samuel Taylor (1772–1834)

Samuel Taylor Coleridge was one of the most influential poets and critics of the 19th century. Considered one of the founders of the Romantic movement in England, he is best known for his poems *The Rime of the Ancient Mariner* and *Kubla Khan.* He also wrote a voluminous amount of literary criticism and philosophy that still resonates in contemporary discussions of the imagination. Most of Coleridge's major poems and prose writings wrestle with the poetic imagination and with the poet's ability to create independent states of reality. The nature of poetic genius—and more specifically the way in which this faculty transcends both literary convention and the laws of time and space—becomes the central theme of *The Rime of the Ancient Mariner* and *Kubla Khan.* It is also the dominant concern of Coleridge's important critical work, the *Biographia Literaria.*

Coleridge was born in Devon in 1772 into a large family. His early life was marked by loss; his father died in 1781, and Coleridge was sent away to study at Christ's Hospital School in London. Here he developed a lifelong appetite for reading and for philosophy in particular. He entered Cambridge but never took a degree. Coleridge came of age in the turbulent years surrounding the French Revolution, and the volatile sociopolitical climate of the late 18th century is reflected in his life: He dropped out of Cambridge, enlisted in the dragoons, made an early and unhappy marriage, and eventually aborted a fantastic dream for a utopian community in the United States. Coleridge struggled with illness, poverty, and instability through most of his adult life.

It was not until 1798 and the publication of *Lyrical Ballads* that Coleridge really came into his voice as a poet. This joint collection of poems by him and his close friend William Wordsworth was a seminal text for the Romantic movement. Although it was not especially well received, in retrospect we can see in it the seeds of a new poetic vision that views the human imagination and its intersection with nature as the fertile nexus for a poetry that can release humanity from the restraints of rational thinking, including the conventional boundaries of time. Coleridge's output steadily diminished over the years as he struggled with poor health and opium addiction. His final years in Highgate, outside London, were relatively peaceful; he enjoyed there the status of a wise seer as he received visits from the leading poets and thinkers of his day.

Major Poems

Two poems invite special consideration of Coleridge's poetic concern with the nature of time. In *Kubla Khan,* published in 1816, the poet conjures a remarkably sensual and otherworldly landscape situated in a remote but not strictly historical past. Kubla Khan has ordered the construction of a "pleasure dome" by the sacred river Alf, and the poem then paints a remarkably detailed and mysterious vision of gardens, river, and sea that suggests the poet's penetration of an alternate reality, one that suspends time. Coleridge stated that he composed the poem while he slept through an opium-induced dream. Upon waking he simply wrote down what he remembered of it before being interrupted by a visitor. Whether true, embellished, or completely invented, both the poem and its purported composition express Coleridge's abiding belief that the poet's imagination had extraordinary creative power to stretch our understanding and experience of time.

In *The Rime of the Ancient Mariner* we see Coleridge using a ballad style to explore the nature of guilt, redemption, and spiritual love, but this long poem also challenges our conception of time. A sailor, or mariner, embarks on a long voyage that takes him with his fellow mariners to the South Pole. The mariner inexplicably shoots an albatross whose earlier appearance had freed the ship from dangerous ice. Wearing the albatross as sign of his guilt, the mariner endures a series of symbolic experiences that culminate in his release from abject desolation and his embrace of a restored sense of the sacred beauty of creation. Coleridge subtly contrasts the experience of time-based reality with the supernatural reality of the mariner's voyage. The result is one of the most symbolically complex poems in English literature, one that continues to compel critical questions about human perception of experience and time.

Eric Stenclik

See also Alighieri, Dante; Chaucer, Geoffrey; Eliot, T. S.; Novels, Time in; Poetry; Shakespeare's Sonnets; Woolf, Virginia

Further Readings

Grant, A. (1972). *A preface to Coleridge.* New York: Scribner.

Hill, J. S. (1984). *A Coleridge companion: An introduction to the major poems and the* Biographia Literaria. New York: Macmillan.

Columbus, Christopher (c. 1451–1506)

A navigator and cartographer, Christopher Columbus is presumed to have been born in Genoa, Italy, in 1451, son of Giovanni Colombo and Susana Fontanarossa. During his adolescence, he worked in his father's weaving shop. In the busy port of Genoa, Columbus learned the rudiments of navigation and cartography. During his youth, he traveled as a sailor to various countries such as Iceland, Flanders, and Portugal, where he was shipwrecked in 1476. In Lisbon he married Felipa Moñiz de Perestrello, a lady of the Portuguese court, whose connections permitted him not only to further his readings about navigation but also to present King João II with his project to travel to India by sailing westward. His project would later be approved, but more important, he received the title of Captain, which would grant him greater prestige and credibility when presenting his project to the Catholic Monarchs of Spain, Ferdinand and Isabella, in 1486. Undoubtedly a very important figure of modern history, Columbus helped to transform the knowledge and the history of his time.

Columbus set sail from the port of Palos in Frontera, Huelva, Spain, on August 3, 1492, and arrived on the island of Guananí on October 12 of that same year. In all, Columbus embarked on four voyages that circumscribed the Caribbean Sea and the Panamanian Isthmus. Although the Capitulations of Santa Fe stipulated that Columbus would receive the titles of Admiral of the Seas, Viceroy, and Governor, his failed experience in Hispaniola demonstrated that, although an excellent navigator, he was a terrible military officer, a disastrous politician, and a failure as an entrepreneur. Of his *Onboard Diary,* only the abstract compiled by Fray Bartolomé de las Casas has survived; in this fragment Columbus details the exploits of his four expeditions and makes an inventory of the newly discovered lands in rhetorical flourishes designed to convince the Catholic monarchs of the viability of his enterprise.

Myths and legends have sprung up around Christopher Columbus's name. Elevated to the stature of a Romantic genius by leaders who have wanted to see the mythical origins of their nations in his heroic deeds, Columbus has been represented in multiple novels and movies, exalted to the point of paroxysm in poetry, and lauded in extensive biographies and studies. That which is known for sure is that Columbus's arrival on the American continent heralded the genocide of millions of Indigenous people and the annihilation of important civilizations such as the Aztec and the Incan, as well as opened one of the most shameful chapters of human history: African slavery. Christopher Columbus died in Valladolid, Spain, in 1506. There is a controversy regarding his remains. While some scholars assure that his remains rest in the Cathedral of Seville, others claim that his remains are buried in the Columbus Lighthouse, in Santo Domingo, Dominican Republic.

Fernando Valerio-Holguín

See also Christianity; Polo, Marco

Further Readings

Chase, A. (2003). Christopher Columbus. *The Columbia companion to American history on film* (P. C. Rollins, Ed.) (pp. 148–152). New York: Columbia University Press.

Fernández-Armesto, F. (2000). *Columbus and the conquest of the impossible.* London: Phoenix Press.

Forbes, J. D. (1992). *Columbus and the other cannibals.* Brooklyn, NY: Autonomedia.

Stam, R. (1993). Rewriting 1492: Cinema and the Columbus debate. *Cineaste 19*(4), 66–71.

Comets

Many comets have regular orbits and appear at predictable time intervals. In 1705, Edmund Halley hypothesized that four comets previously assumed to be individual entities were actually one comet with a regular orbit, based on his awareness that all items in space were affected by Newton's law of gravity. Halley successfully predicted that the comet would appear again in 1758.

Comets are normally equally distributed between those that have direct orbits and revolve around the sun in the same manner as planets, and those that have retrograde orbits and revolve in a manner opposite to the planets. Orbits are measured in Earth years.

Comets are categorized by their orbits and fall into three categories. More than 1,000 comets have fairly well defined orbits. The most widely studied comets are short-period, or periodic, comets that orbit around the sun every 200 years or less. Popular short-period comets include Encke: 3.3 years; Halley: 76.1 years; Kopf: 6.5 years; Temple: 5.3 years; and Wolf: 8.4 years. Long-period comets are those whose orbits are longer than 200 years but are still influenced by the gravitational forces of the sun. The Hale–Bopp comet has an orbital period of 2,400 years, and the orbital period of Hyakutake is 31,000 years. Some comets appear once and do not find an orbit but pass around the sun and get lost in space. These are referred to as single-apparition comets.

Although generally regular, orbits of comets are not always consistent. While there are more than 100 short-period comets whose orbits are mapped, astronomers occasionally lose track of one of them. Likewise, although infrequently, a comet that is thought to be "new" turns out to be a formerly "lost" comet. An example of this is Comet 11P/Tempel–Swift–LINEAR, which was discovered in 1869, lost after 1908 due to disturbances caused by Jupiter, and rediscovered in 2001.

Comets do not last forever. Each time they pass around the sun, comets lose some of their matter. Eventually, the comet will be reduced to a meteor. Comets can also collide with the sun or a planet and be destroyed. Some comets also develop parabolic or hyperbolic orbits that shoot them out of the solar system.

Comets are sometimes referred to as "dirty snowballs" due to their makeup of 50% gas and dust and 50% ice that is primarily frozen gas. They are believed to be ejected from either the Kuiper belt or the Oort cloud. Most originate from the Oort cloud, an outlying area of the solar system hypothesized by the Dutch astronomer Jan Hendrik Oort. Some of the short-period comets develop from the Kuiper belt, also known as the transneptunian region, a theoretical collection area of celestial debris beyond the orbit of Neptune described by

Comet Hale–Bopp was photographed in the constellation Andromeda by George Shelton, photographer for The Bionetics Corp., at 8:14 p.m. on March 31, 1997, from Merritt Island, Florida, close to the Kennedy Space Center. During this 24-hour period, Comet Hale–Bopp was making its closest approach to the Sun.

Source: NASA Kennedy Space Center.

K. E. Gerard Kuiper in 1951. Following ejection, the comet becomes caught in the sun's gravitation field and develops an orbit around the sun.

As comets get closer to the sun, the ice begins to melt, forming a gaseous cloud tail called a coma. There is also a second tail of dust and gas, though the two are generally perceived as one tail. Sometimes the tail of the comet will be seen in front of the comet since the dust and gas tails are lighter than rest of comet, and the solar winds can push the tail out in front of the comet when the comet is close to the sun. When the earth passes through the orbit of a comet, meteor showers are created. For example, in May and October every year, the earth encounters the meteor stream from Halley's comet.

Beth Thomsett-Scott

See also Extinction and Evolution; Life, Origin of; Meteors and Meteorites; Nuclear Winter; Omens; Star of Bethlehem; Time, Galactic; Time, Sidereal

Further Readings

Levy, D. H. (1998). *Comets: Creators and destroyers.* New York: Touchstone.

Schechner Genuth, S. (1997). *Comets, popular culture, and the birth of modern cosmology.* Princeton, NJ: Princeton University Press.

Whipple, F. L. (1985). *The mystery of comets.* Washington DC: Smithsonian Institution Press.

Comte, Auguste (1798–1857)

Auguste Comte is known as the founder of sociology and the father of the paradigm of positivism. He was born Isidore Marie Auguste Francois Xavier Comte on January 17, 1798, at Montpellier, in southwestern France, at the culmination of the French Enlightenment. As a scholar, Comte wrote about the historical development of the special sciences in general, and the historical development of the interpreting human mind in particular. He saw each science and each explanation of it unfolding through time, passing from a religious stage (theology), through a metaphysical stage (philosophy), to an ever more empirical stage (science).

As a young man, Comte excelled in his studies. In August 1814 he entered competition for the entrance exams and was admitted to the École Polytechnique in Paris, an elite school that espoused the French Enlightenment ideals of republicanism and progress. Although he found Napoleonic tyranny distasteful, he preferred it to the restoration of the monarchy, and thus supported Napoleon during his years at the school. However, in April 1816 his studies were halted when the school closed owing to conflict between students and administration over the school's outmoded methods of examination. Comte did not reapply for admission when the school reopened and instead supported himself by tutoring in Paris.

In the summer of 1817, Comte made a social connection invaluable to his career as a scholar. He met Henri Saint-Simon, the 60-year-old director of the periodical *L'Industrie,* whom he then began to work for, in his own mind as a collaborator but apparently in the mind of Saint-Simon as a protégé and disciple. By 1824 this difference of perspectives erupted into a disagreement about whether or not one of Comte's essays ought to be published in his own name or under the name of Saint-Simon. They also disagreed about the importance of activism and theory, Saint-Simon favoring the former and Comte favoring the latter, and Comte disagreed with the tinge of religiosity that Saint-Simon gave his thought and writing. The differences were irreconcilable, and the two parted ways.

After some tumultuous years following the split with Saint-Simon, Comte became ever more ambitious in his thought. This is the point at which he began to develop his conceptions of positivism, the "law of three stages," and social science as the dominant unifier of all other sciences, all of which he discussed in his masterpiece, *Cours de philosophie positive,* written from 1830 to 1842.

Comte's positivism can be seen as a paradigm commensurate with the values and ideals developed during the Age of Enlightenment. One premise of the paradigm is that knowledge comes from the positive affirmation of theories through scientific methods such as observation. However, it is important to note that he felt it was necessary for theory to precede any type of observation so as to inform the observer what to look for.

For Comte, scientific positivism was the capstone of human social evolution. It is the third stage in his law of three stages, being preceded by the metaphysical stage, which is preceded by the theological stage. The theological stage itself was divided into three phases those being fetishism (object worshipping), polytheism, and monotheism. The theological stage, Comte argued, embodied man's earliest social existence. It is during this stage that humankind uses God or supernatural forces as an explanation for things and as an apex from which societal order descended. Thus, nature was mythically conceived and humans made no accurate causal connections between phenomena in nature. Comte thought that humanity had been in this stage until the French Enlightenment, and thus that this stage comprised the bulk of human history up to 1750 CE.

The second stage Comte discussed is the metaphysical stage, in which God, or supernatural beings, as an explanation for phenomena is replaced by rational explanations, and during which society is ordered according to rational principles rather than assumptions of divine intention. Philosophers began to theorize about the way the world works and to formulate postulations about the relationships of phenomena to each other. It was during this stage that humans began to have a conception of universal human rights existing on a higher plane than the whims of a monarchical ruler, and during which philosophers began to design forms of society in which the state would serve the people rather than vice versa.

Comte's third stage was positivism, which was characterized by the proliferation of science, especially morally charged science meant to restructure and perfect society as a whole. Thus positivism marked a development beyond the metaphysical stage because rational explanations themselves were no longer sufficient unless supported by empirical observations. Essentially, positivism meant the development of science, and then science leading humankind into a better future. He also believed that this stage would be characterized by the abandonment of the human rights developed during the metaphysical stage in order to serve society in the best way possible. He coined the word *altruism* to describe the responsibility of the individual to put the interest of the many above the one. He believed society at the positivist stage would function more as a single unified body than a collection of individuals.

Mirroring Comte's hierarchical view of stages in human social evolution was the hierarchy he ascribed to the sciences, which he termed the "encyclopedic law." According to this law, the sciences developed in a linear order and were necessarily built upon one another. Comte viewed inorganic physics such as astronomy, earth science, and chemistry as the crudest of the sciences, and thus the base of what one might envision as a scientific pyramid. Built upon these sciences was organic physics or biology, which marked the second stage in the development of scientific thinking. Finally, Comte felt that social science, which he first named social physics and then sociology, would be the apex of this scientific pyramid, encompassing all previous sciences to make for the superior science of society that would guide human action toward perfecting society.

By the end of his life, Comte had attached more than just a tinge of religiosity to his thought and to his vision of human history and future. By 1846 he had begun believing himself to be a sort of prophet of the religion of humanity that he believed positivism to be. By the end of his life he began declaring himself the Pope of Positivism. While in retrospect this may seem like folly, it is important to note that his contributions to human thought were invaluable. His focus on the interconnectedness of social elements was a precursor to functionalist theory, and his bold ambition laid the groundwork for the discipline of sociology within academia today.

Mark Koval

See also Cognition; Diderot, Denis; Enlightenment, Age of; Evolution, Cultural; Evolution, Social; Humanism; Materialism; Metaphysics; Progress; Values and Time

Further Readings

Comte, A. (2003). *Positive philosophy of Auguste Comte* (Vols. 1–2). (H. Martineau, Trans.). Kila, MT: Kessinger.

Comte, A. (2000). *The catechism of positive religion.* Boston: Adamant Media.

Comte, A. (1988). *Introduction to positive philosophy.* Cambridge, MA: Hackett.

Hubbard, E. (2005). *Auguste Comte.* Kila, MT: Kessinger.

Condorcet, Marquis de

See Enlightenment, Age of

Confucianism

Confucianism is a system of belief based on the ideologies of the 6th-century BCE Chinese scholar Confucius (Kong Fuzi). Living in a time of great social turmoil, Confucius devoted his life to the goal of restoring social harmony, which, he argued, was to be achieved by following the social order established by the sage kings and cultural heroes of antiquity. By creating citizens and rulers who were as virtuous as the sage kings, a perfect society would result.

Fully understanding Confucian doctrine requires that time be examined along several dimensions. First, the time period during which Confucius lived, known as the Eastern Zhou Dynasty (771–256 BCE), provides the context for his goal of social restoration. Second, the means for obtaining this goal are derived from elements of ancient Chinese culture extending to a legendary golden age of the past. Third, setting Confucianism along a historical timeline demonstrates its profound influence on Asian culture in the centuries following Confucius's death, an influence that continues now more than 2 millennia since its inception.

Confucius

The English name Confucius is derived from the Latinized name Kong Fuzi, meaning Master Kong. His birth name was Qiu of the family Kong. While he is credited as the founder of Confucianism, it really was not until several centuries after his death, through the work of scholars such as Mencius (c. 371–289 BCE) and Xunzi (c. 298–238 BCE), that Confucian principles were developed into a unified, established system. Confucius was born in 551 BCE in the state of Lu in northeastern China in what is today Shantung province. His father was a distinguished soldier who died when Confucius was a young child. His mother had little money, but worked hard to raise Confucius as an educated gentleman. Growing up he worked at menial tasks and lived a life of poverty, but also enjoyed opportunities such as hunting, archery, art, and a good education.

As an adult, Confucius desired a government post that would allow him the opportunity to persuade rulers to adopt his strategies for restoring order to society. However, he was unable to pass the qualifying examinations required for such a post. For a while he served as a clerk in the Memorial Temple of the Duke Zhou performing sacred, ancient ceremonies. He then turned his focus to teaching. Unlike other teachers of his time, Confucius accepted students based solely upon their intelligence and willingness to learn rather than on their social class. In his early 50s, Confucius finally passed the civil service examinations and obtained a government position as a magistrate, but soon resigned in frustration over his failure to influence the corrupt rulers. For the next 15 years he journeyed to various states in an unsuccessful quest to locate rulers who would implement his social policies. At the age of 68 he returned home to Lu where he spent his final years teaching and editing the ancient writings known today as the Five Classics.

Confucius died at the age of 72 in 479 BCE, thinking that his ideas would never be taken seriously by those in power. However, scholars of later centuries transformed Confucius's ideologies into a well-defined philosophical system that would shape and be shaped by Chinese culture and society, and eventually other Asian cultures as well, for more than 2 millennia.

Goals of Confucianism

Confucius lived during the second half of the Zhou Dynasty, known as the Eastern Zhou period (771–256 BCE). China was not yet a unified empire but rather consisted of numerous small, semi-independent kingdoms ruled by relatives of the hereditary king. These, in turn, were divided into districts ruled by governors. In the 8th century BCE, an invasion by non-Chinese tribes from the west forced the Zhou king to move his capital to the east. The weakened power of the Zhou rulers resulted in a historical time period characterized by civil war and social turmoil.

Numerous schools of thought arose in response to these changes, with each proposing a distinct solution to the crisis. Many blamed traditional values and sought contemporary solutions. Confucius looked instead to the traditions of an ancient past. His main goal was to restore the social harmony that existed during the golden age of the virtuous sage kings of antiquity who ruled by the Mandate of Heaven. This was a two-part goal. First, ordinary people would be transformed into *junzi,* which is often translated as "noble person" or "superior person." For Confucius, however, this term did not refer to nobility ascribed at birth. Rather, anyone could become junzi by cultivating the moral virtues of the sage kings. The junzi is a person who puts the needs of others before his or her own. Such a person sincerely refrains from self-interest in order to act in the best interest of society. Second, Confucius desired to create a perfect society. These two goals reinforce one another as superior people will naturally create a perfect, harmonious society and a perfect society will produce virtuous people.

The Golden Age of the Sage Kings

The foundation of Confucian doctrine is based on the virtues of the mythical culture heroes and sage kings of an ancient time. This is a time that predates the first historical dynasty. Confucian culture heroes are credited with the perfection of human social order. Therefore, many, such as Fu Xi and Shen Nong, later became canonized as deities. Fu Xi, the serpent-bodied emperor, is attributed, among other things, with teaching humans how to domesticate animals. Shen Nong is credited with the invention of agricultural tools and discovering the medicinal properties of plants. All of the culture heroes offered equally momentous gifts to humanity.

After the period of the culture heroes followed the golden age of antiquity of the sage kings who ruled during the legendary Xia Dynasty (ca. 2200–1750 BCE). Bestowed with the Mandate of Heaven, they ruled by virtuous example rather than by force. Exhibiting great altruism, their only concern was the welfare of their subjects. For this reason, they were junzi. The result of such ethical ruling was a perfect social order and harmony between heaven and humanity. However, the last Xia emperor lost the Mandate of Heaven due to his corruption and so was overthrown by the ruler of the first historical dynasty: the Shang Dynasty (c. 1750–1100 BCE).

Ancient Chinese Culture

The roots of many of the principal tenets of Confucianism can be located in ancient Chinese culture and religion. A few of the more central concepts that have shaped Confucianism include heaven, filial loyalty, and the emphasis on social relations.

During the Shang Dynasty (c. 1750–1100 BCE) there was a belief in the high god Shang Di (the Lord on High) who was conceived as a personal god. By the time of the Zhou Dynasty (1100–256 BCE) the Shang belief had been replaced with the notion of Tian (heaven). Tian was viewed as an impersonal sacred force that regulates human affairs and establishes moral order. Rulers were considered to be the Sons of Heaven, bestowed with the Mandate of Heaven. However, if a ruler became corrupt, Tian would remove the mandate and punish the ruler by sending disasters such as floods and wars. Confucius claimed that heaven had given him the mandate to reform the world.

Filial loyalty and respect for elders in Chinese culture is evident in numerous ways. The family has long been the basic unit of Chinese society and, according to Chinese legend, is what separates humans from animals. In fact, the family name (surname) precedes the individual name in China. Elders, far from being considered unproductive or outdated, are venerated for their wisdom. Children are to honor their parents as instructed in the Five Great Relations. Ancestor worship, dating back to at least the Shang Dynasty (c. 1750–1100 BCE), demonstrates that people not only are to be obedient and respectful to the living elders, but also to those who have died. Ancestor worship is particularly important insofar as deceased ancestors continue to exist in the realm of heaven and can even be elevated to the status of deity in the celestial hierarchy. If deceased ancestors are not appropriately honored, the living family may suffer negative consequences.

Finally, Chinese culture historically has emphasized group interdependence over rugged individualism. Rather than being viewed as autonomous, independent agents, the Chinese notion of personhood stresses the interconnectedness of individuals forming social networks. As our actions will influence others who share a single web of social relationships, we must think and behave unselfishly.

Obtaining the Goal: The Five Great Relationships

There are numerous virtues people must acquire in order to achieve social harmony. According to Confucius, humans are inherently good, but require training in virtue. The primary way in which to provide this training is through education that fosters the values of the golden age of the sage kings.

The Confucian emphasis on proper social relationships as a basis of a harmonious society is evident in the Five Great Relationships. Asian cultures have traditionally stressed the role of a person's social ties to others. The only way a perfect society may be achieved is if all people behave appropriately in their interactions with others. The ancients enjoyed social harmony because people knew their social roles and behaved appropriately. To know what is expected of any given individual in a particular social interaction, that person need only consider his or her social role and title. This has been referred to as the Rectification of Names. The required behaviors for each social role are outlined in the Five Great Relationships.

The first relationship, which forms the very foundation of society, is the Father–Son relationship (sometimes referred to as the Parent–Child relationship). The father is responsible for the education and moral values of his children and they, in return, are to be respectful, loyal, and obedient. The father is to have unquestioned authority in making decisions for his children. Eventually the children will take care of the father in his old age. This relationship does not cease upon the father's death. Rather, sons are expected to have their own children who will continue to worship their ancestors long after the death of those ancestors.

The second great relationship is that between Elder Brother–Younger Brother (or, Older Sibling–Younger Sibling). Many Asian languages have distinct words for siblings based on their age-position relative to other siblings. Older siblings are meant to help guide and protect younger siblings, and younger siblings are expected to comply obediently.

The Husband–Wife relationship, like the previous two relationships, is based on one person, here the husband, having authority and responsibility over the other person, in this case the wife. The husband is expected to be the breadwinner and to meet his wife's material needs in addition to serving as her protector. The wife, in turn, is to serve as a devoted housewife, acting in a motherly way, attentive to her husband's needs.

The fourth relationship is that of Senior Friend–Junior Friend. The friend with senior status helps shape the moral character of the junior friend. This may entail the senior friend acting as a mentor or offering advice to the junior friend. The junior friend is expected to be respectful and amenable to the advice of the senior friend. Examples of this relationship may be found between teachers and students, bosses and their employees, or even between coworkers of the same age but who differ in rank.

The final relationship is the Ruler–Subject relationship. Subjects should loyally and obediently follow their rulers, but rulers must place the interests of their subjects above their own. While it may seem that the Ruler–Subject relationship should be the first of the Five Great Relationships, scholars often place it last insofar as Confucius viewed the Father–Son relationship as a model for rulers' behavior. Confucius claimed that social order must originate at home.

Obtaining the Goal: The Five Virtues

When social interactions are guided by the precepts outlined in the Five Great Relationships, harmonious relations result. Similarly, on an individual level, for a person to work toward the goal of becoming junzi, it is necessary to adopt the Five Virtues. The Five Great Relationships and the Five Virtues are clearly interrelated.

Ren is the most fundamental of the Five Virtues. The Chinese character for this word blends the characters for person and for the number 2, stressing the importance of considering others. This word can be translated as "benevolence," "consideration," or "sympathy." It is respecting the interest of others in all that we do. When we truly care about the well-being of others, then social strife and petty competition are eliminated. Confucius explained how rulers, especially, must place the welfare of their subjects above that of themselves. The second virtue, *li,* which is often translated as "propriety," requires that we speak and behave properly in social life. As dictated in the Five Great Relationships, what is considered appropriate will vary according to a person's specific age, gender, social status, and the given social situation. A third virtue is *shu*. Some have translated this as "reciprocity" in that it instructs us to think of the impact of our actions on others. This has often been termed the Silver Rule, which states that we should not force upon other people that which we do not want done to ourselves. *Xiao* refers to family devotion. Not only does this entail that children respect their parents and that parents care for their young, but that everyone also honor the dead ancestors through appropriate sacrificial rituals. Finally, Confucius stressed the value of *wen,* or of cultural arts. Confucius maintained that education was required to instill proper virtues and so must include an appreciation for, and even some ability to participate in, such fine arts as poetry, literature, painting, music, and calligraphy.

Obtaining the Goal: The Confucian Classics

The most fundamental of the Confucian literature extant today consists of The Five Classics, which predate or were contemporaneous with Confucius, and the Four Books, which postdate him but are based largely on his teachings. Confucius did not write the majority of this literature, but is credited with editing and transmitting earlier works and adding his insight in the form of commentary.

For Confucius these texts were an important means of conveying the ancient traditions necessary for the restoration of social harmony that had existed during the time of the ancient sage kings. In fact, the earliest of the texts are thought to be the teachings of the sage kings themselves. The Confucian texts discuss the virtues of the ancient sages, providing examples in the forms of maxims and anecdotes of how we are to achieve virtuous government and citizens. For example, the Doctrine of the Mean contends that people must avoid excess and seek moderation. Whenever people exhibit too much pride or indulgence, for example, social strife and competition result.

The influence of Confucian literature on the worldview of the Chinese cannot be overstated as it served as the core curriculum of the state educational system for more than 600 years and formed the basis for the civil service exams required of all government workers.

Historical Influence of Confucianism on Asian Culture

In addition to considering the time period of the ancient sage kings and the role of social upheaval of the Eastern Zhou Dynasty, it is also necessary to outline the historical time periods following Confucius' death in order to demonstrate the profound effect of Confucianism on Chinese culture—an influence that has persisted for more than 2,000 years.

Even though the rulers of the Eastern Zhou Dynasty (771–256 BCE) failed to recognize the value of Confucius's ideas during his lifetime, the established doctrine of Confucianism was developed later in this dynasty by scholars such as Mencius (c. 371–289 BCE) and Xunzi (c. 298–238 BCE) who desired social reform based on a Confucian model. Rulers of the following dynasty

(Qin Dynasty, 221–206 BCE) forcibly suppressed Confucianism, but this dynasty was short lived. The longer period of the Han Dynasty (206 BCE–220 CE) was favorable for the advancement of Confucian ideals. It was during this dynasty that Confucianism was made official state policy, and elaborate temples were erected in Confucius's honor. Confucian influence was particularly strong by 126 BCE when the state adopted the writings of Confucius and Confucian scholars as the foundation for the state system of education.

The Han Dynasty fell in 220 CE, ushering in a period of political instability known as the Six Dynasties Period (220–589 CE). During this time Buddhism was introduced to China from India and Daoism was growing in importance. Confucianism was now relegated to a more peripheral role in Chinese culture than had been the case during the Han Dynasty. By the time of the Tang Dynasty (619–907 CE), Confucianism regained some of its former importance with a state mandate that every province in China erect a Confucian temple and conduct regular ceremonies and sacrifices.

By the beginning of the Song Dynasty (960–1279 CE), rulers were desperate to restore the social order lost in the turmoil of the preceding five dynasties. This coincided with the rise of neo-Confucianism developed by scholars such as Zhu Xi (1130–1200 CE), who aimed to bring about social order using Confucian models.

By 1313, in the Yuan Dynasty, Confucian literature formed the core curriculum of the civil service examinations that were required of anyone who wanted to enter a government post. During the Ming Dynasty (1368–1644 CE) neo-Confucianism continued to gain strength with the work of scholars such as Wang Yangming (1472–1529 CE). Even in 1644, when the foreign Manchus overtook the capital and ruled during the final imperial dynasty (Qing Dynasty, 1644–1911 CE), Confucianism continued to thrive.

Confucianism in the 20th and 21st Centuries

In 1911, as a result of Sun Yat-sen's revolution, China witnessed the collapse of the last imperial dynasty and the subsequent establishment of the Republic of China. Since that time, Confucianism has not held the state support or central role in education imparted by former dynasties. By 1916 the New Culture Movement had destroyed vestiges of the past deemed traditional and, therefore, as impediments to progress.

The Communist takeover in 1949 and the formation of the People's Republic of China only increased the aversion to Confucianism. During the Cultural Revolution (1966–1976), Mao Zedong (1893–1976) ordered his Red Guards to destroy all of those things considered traditional and backward, such as temples, sacred images, and sacred texts. All outward forms of religious expression, including Confucianism, were forbidden.

After the death of Mao, many ancient traditions began to resurface, and since the 1980s China has eased many of the restrictions against religion. It has been many years since Confucianism has enjoyed the vast state support of the dynastic periods. It nonetheless continues to form a central core of Chinese culture while increasingly spreading in influence to the island of Taiwan, as well as to other Asian countries such as South Korea, Japan, and Singapore.

Catherine M. Mitchell Fuentes

See also Calendars, Asian; Morality; Religions and Time; Values and Time

Further Readings

Bilhartz, T. D. (2006). *Sacred words: A source book of the great religions of the world.* New York: McGraw-Hill.

Confucius. (2000). *Confucius: The analects* (D. C. Lau, Trans.). (2nd ed.). Hong Kong: Chinese University Press.

Hall, D. L., & Ames, R. T. (1987). *Thinking through Confucius* (SUNY Series in Systematic Philosophy). New York: State University of New York Press.

Ivanhoe, P. J., (2000). *Confucian moral self cultivation* (2nd ed.). Indianapolis, IN: Hackett.

Molloy, M. (2004). *Experience the world's religions: Tradition, challenge, and change* (3rd ed.). New York: McGraw-Hill.

CONSCIOUSNESS

Ideas and theories of consciousness have changed over time, from the early ideas presented by the ancient Greeks to modern 20th- and 21st-century philosophy. These ideas and theories have been profoundly influenced over the years by philosophy, metaphysics, naturalism, and more recently by psychoanalytic psychology, neuroscience, and quantum mechanics. Presently there is no uniformly accepted definition of consciousness; rather it has become more of an integrated theory consisting of several schools of thought. As science and technology evolve and humankind begins to develop a better understanding of the primate brain and how it works and the apparently subjective reality surrounding it, more is beginning to be understood about consciousness.

Ancient Greeks

The ancient Greeks provided early speculations on the human mind. Plato was one of the first thinkers to attempt to formulate the definition of what would become known as consciousness. Of course at that time there was no word equivalent that had the wide range in meaning that the word *consciousness* has in 20th- and 21st-century thought. Therefore the ancient Greeks speculated on what was known as mind.

Plato was one of the first to develop the idea of the mind. He proposed that the mind is something in the head and that objects existed as impressions in the material world. However, he maintained that these impressions were visible forms that are conveyed through what he called "the mind's eye" by a third nature: light. Plato further elaborated that these visible forms were observed by the mind's eye as mental content arranged as geometrical forms. Plato proposed that these geometrical forms were provided by the soul.

Another ancient Greek philosopher who expanded on the early ideas of consciousness was Aristotle, who was a physicalist, meaning that he believed that all things, including human beings, are intrinsically incorporated in a material universe. This is why he thought that the study of the soul (or psyche and to an extent consciousness) would fall within the confines of the science of nature. Aristotle made note of the concept of signals (sight and sound), the transmission of information (those signals reaching the human mind), and in many ways the notion of perception (the mind's realization of those signals).

Aristotle's idea of the mind, in general, supported Plato's idea that mind was something in the head (the brain), and that an object in the material world existed as an extension of time. However, Aristotle proposed that an impression of these objects was received by the sense organs (eyes and ears), and that the impressions received were relayed in a changed state to the mind and were extended throughout time and space.

Early Theories of Consciousness

René Descartes (1596–1650) was another influential thinker on the topic of consciousness. He was also responsible for coining the very famous Latin phrase *cogito ergo sum,* which in English means, "I think, therefore I am." While Plato and Aristotle maintained that faculties of the mind and soul could not be outlined or represented by mere terms of physiology, Descartes expanded their ideas into what is know as dualism (or Cartesian dualism). Descartes proposed that the physical world occurs in an extended form in the brain (which is material), but through a particular process it is then condensed into a nonextended form in the mind where thought occurs (which is nonmaterial). He also believed (much like Plato) that thoughts were produced by the soul, which is also nonmaterial. Therefore, according to Descartes' theory of dualism, the actual process of consciousness involves a material and a nonmaterial component.

In theory, Descartes' philosophical idea of consciousness was similar to that of Plato's idea of mind. In addition, the concept of consciousness being partly a product of an immaterial soul was maintained and undoubtedly a by-product of popular Christian thinking at that time. Also due to the indoctrinating influence of Christianity, which upheld that only our species has a soul, Cartesian dualism would imply that consciousness is exclusive to humans. The idea that only humans possess consciousness is also known as the *anthropistic theory.*

The Neurological and Evolutionary Perspectives of Consciousness

The *neurological* theory or *Darwinian* theory insists that consciousness is a direct result of the centralization of the nervous system, which was brought forth by progressive evolution. This theory implies that only humans and higher mammals with this anatomic tendency can possess consciousness. In addition, because the centralization of the nervous system has evolved over time, consciousness itself would implicitly have had to evolve over time. This would mean that the type of consciousness that *Homo sapiens sapiens* experiences now would have to be different to some degree compared to the consciousness that was experienced by our early hominid ancestors.

The idea that our current form of consciousness is not immutable, that it has changed over time and may be subject to change in the future, would seem to refute the dogmatic notion that consciousness is exclusive to our species, and that in fact animals (this is known as the "animal theory") or at the least higher mammals (such as chimpanzees) may experience different forms of consciousness similar to our own.

It is worth noticing that toward the end of the 19th century the influence of naturalism, due primarily to the writings of Charles Darwin, was influencing philosophical opinions about consciousness and causing them to change. The theme of consciousness was beginning to be viewed as a natural and biological process rather than a spiritual phenomenon. This would later motivate neuroscientists to explore and propose neurological bases of consciousness.

Psychoanalytical Ideas of Consciousness

Sigmund Freud (1856–1939), the founder of psychoanalysis, was influenced by Charles Darwin's concept that our species is part of the animal kingdom (not separate from it as previously believed) and his mentor Ernst Brucke's concept of "dynamic physiology," which applied the laws of thermodynamics (in particular the law of conservation) to living systems, in particular humans. These concepts compelled Freud to form his psychoanalytical theory, which he applied to the understanding of human consciousness.

Freud proposed that in human consciousness there is a conflict in place between pleasure-seeking behavior (known as the pleasure principle) and the rules or laws of the environment and society (known as the reality principle). He illustrated that this conflict is internalized by three properties. First is the *Id,* which operates in co-ordinance with the pleasure principle (known as the primary process). Second is the *Ego,* which attempts to enforce the reality principle (known as the secondary process); Freud considers the ego to be a human's consciousness. Third is the *Superego,* which according to Freud represents society and cultural restraints.

Freud's psychoanalytic contribution to the study of consciousness is that it allowed investigators to investigate further the consciousness of humans scientifically and opened up the doors to explore it psychologically. Freud's approach was novel because it superseded the conflict of the material versus nonmaterial basis of consciousness. His approach also focused on the individual experience and how it is internalized, interpreted, and expressed psychologically by the mind.

Freud also paved the way for consciousness to be viewed later in terms of introspectionism and individual psychotherapy. *Introspectionism* is a school of thought that maintains that consciousness is best understood in first-person accounts. Therefore it upholds that the conscious experience can be explained only in terms of data acquired from introspection. *Individual psychotherapy* is a school of thought that maintains that consciousness is a result of an organism's (or person's) adaptive capacity. Psychotherapy typically involves scheduled discussions between a patient and a mental health professional.

The psychoanalytical approach to explaining consciousness was different from previous philosophical approaches to consciousness in that it did not merely propose ideas, but rather attempted to make definitions based on psychological observations. It is important to note that during the early 20th century, consciousness was beginning to develop several different subdefinitions and new schools of thought. These opinions involved solely an individual's account of the conscious experience in order to define what consciousness was.

Twentieth-Century Philosophies of Consciousness

During the 20th century, metaphysics began to play a more critical role in engaging the problems of understanding consciousness. Implicitly, metaphysical thinkers were beginning to question the underlying theoretical principles of the already established theories of consciousness.

An important figure in the early 20th century was Alfred North Whitehead, who was a mathematician and a philosopher. He pointed out that there were limitations to our understanding of consciousness because the descriptions of our conscious experience were based in 19th-century ideas of space and time. According to Whitehead, 19th-century materialist views of time and space were not grounded in observation and scientific reality. He also believed that mind and nature are part of the same process, and in order to understand them scientifically one must understand relations within nature and the simultaneity of events.

Another important 20th-century thinker was Gilbert Ryle, a professor of metaphysical philosophy. He was most notable for his deliberately abusive declaration that the "official doctrine," which hails from Descartes, is absurd. The Cartesian doctrine was that human bodies are in space and are therefore subject to the mechanical laws that govern all bodies in space, yet human minds are not in space and are therefore not subject to those same mechanical laws. Ryle proposes that the human body is a complex unit and therefore the human mind is another complex unit; however, the mind is a complex unit composed of a different form (or forms) of material than the human body.

During Ryle's time psychological schools of thought known as "cognitism" were addressing the issue of consciousness. Cognitivists maintained that in understanding the mind, one must understand the "internal" rule-bound manipulation of symbols. Ryle opposed this school of thought vehemently with his famous "Ryle's Regress," which is essentially an argument discrediting the cognitivist theories of consciousness, claiming that they do not explain what they propose to explain.

More recently Daniel C. Dennett, a former student of Gilbert Ryle, has become well known for his multiple drafts model of consciousness, which is the theory that consciousness is based upon the premise that the brain acts as an information processor. According to Dennett, there exist a variety of sensory inputs from a given event; therefore there are a variety of possible interpretations of these inputs that arrive in the brain. Once these sensory inputs arrive in the brain they are interpreted at different times, which gives rise to a succession of discriminations. These discriminations then become available for eliciting behavior to that event.

It can be clearly seen that views of consciousness have changed over time, especially in the 20th century. Theories of consciousness have obviously become more complex, as seen in Dennett's multiple drafts model compared with the generalizations constituting the ancient Greeks' idea of the mind. This is mostly due to advances in understanding biology and humankind's place in nature (naturalism); the maturation of metaphysics; and the ensuing rigorous reevaluation of previous philosophical thought. Another common theme in 20th-century philosophy regarding consciousness is the rejection of previous dogmas, as illustrated by thinkers such as Whitehead and Ryle.

Twenty-First Century Explanations of Consciousness

As has been illustrated, the ancient ideas and early philosophies of consciousness have not only changed over time, but in some cases, as shown, were discredited and replaced in the 20th century. New thoughts in the 21st century may do the same to the views established in the 20th century.

Sir Roger Penrose originally proposed (actually in the late 20th century) the theory of the quantum mind, which asserts that consciousness is a quantum mechanical phenomenon. Quantum mechanics are scientific laws that are not seen on the macroscopic level; rather they become apparent at the atomic and subatomic levels. According to quantum mind theory, classical physics is inadequate to fully explain consciousness; the quantum model, which is associated with a number of intractable paradoxes, must be invoked. A major difficulty surrounding quantum mind theory is that many of its hypotheses require investigation for which no adequate technology capable of providing scientific proof yet exists. For now it remains only a theoretical explanation.

The Future of Consciousness

Eventually theories and models of consciousness will reach a limit in their attempt to explain consciousness. In the future, a more comprehensive study of neurophysiology, neurochemistry, and quantum mechanics (to rule in or rule out its validity) should begin to stabilize scientific thinking on what consciousness actually is as a process, and how it is able to occur in the brain or elsewhere. In addition, advances in technology may give rise to penetrating insights that in turn could give credibility to the idea that human consciousness perhaps is composed of different type(s) of matter, which is why we currently are having difficulty understanding it entirely.

As we continue to struggle to understand our own consciousness, an intriguing concept has emerged: that perhaps different forms of consciousness may exist among animals, cells, molecules (in particular DNA), and even atoms. These different forms of consciousness would be unobservable to humans, who do not completely understand their own consciousness. There is also the possibility that with the advent of artificial intelligence, forms of artificial consciousness or silicon-based consciousness may be created. No less intriguing is the question of what types of exobiological (alien) life forms may exist elsewhere in the universe and what types of conscious experience they may possess.

John K. Grandy

See also Amnesia; Aristotle; Bergson, Henri; Cognition; Creativity; Critical Reflection and Time; Darwin, Charles; Déjà Vu; Descartes, René; Memory; Plato; Whitehead, Alfred North

Further Readings

Dennett, D. (1991). *Consciousness explained* (The Phillips Collection). Boston: Little, Brown.

Edelmann, G. M., & Tononi, G. (2001). *A universe of consciousness: How matter becomes imagination.* New York: Basic Books.

Grandy, J. (2005). Consciousness. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (Vol. 2, pp. 563–566). Thousand Oaks, CA: Sage.

Grandy, J. (2005). Freud, Sigmund. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (Vol. 3, pp. 1005–1007). Thousand Oaks, CA: Sage.

Penrose, R., & Gardner, M. (1989). *The emperor's new mind: Concerning computers, minds, and the laws of physics.* Oxford, UK: Oxford University Press.

Pinker, S. (1999). *How the mind works.* New York: Penguin.

Copernicus, Nicolaus (1473–1543)

Nicolaus Copernicus (in Polish, Mikotaj Kopernik) was a Polish mathematician and astronomer, best known for his heliocentric theory of the solar system. The heliocentric theory, also known as the Copernican system, holds that the sun is at the center of the universe, and that the earth rotates on an axis and revolves around the sun. Copernicus published his theory in *De Revolutionibus Orbium Coelestium,* often considered to be the starting point of the scientific revolution.

In Copernicus's lifetime, the Ptolemaic theory of the solar system was accepted as accurate. Ptolemy had reasoned that the earth was motionless and was situated at the center of the universe. Copernicus challenged Ptolemy's theory by formulating his own system, the heliocentric, or "sun-centered," theory. The heliocentric theory transferred to the sun functions previously given to the earth. The major principles of Copernicus's theory are that the earth revolves around the sun yearly while rotating daily on its own axis. The movement of the earth is not apparent because we travel with it. Copernicus based his system on careful mathematical calculations, as well as by drawing on the ideas of ancient Greek and Arabic astronomers. His major work, *De Revolutionibus Orbium Coelestium,* or *Concerning the Revolutions of the Celestial Spheres* (1543), changed the existing notions of time and the universe. Copernicus did not publish his major work until the year of his death because he feared opposition from the religious establishment.

Background and Education

Nicolaus Copernicus was born into a successful family of merchants in Torun, Poland, on February 19, 1473. Debate over his nationality arises from the fact that West Prussia, including Torun, was ceded to the Kingdom of Poland following a conflict with the Teutonic Knights that ended in 1466. Though Copernicus was from a German family, he was born a Polish subject. He was taken into the care of his uncle, Bishop Lucas Watzenrode, after the early deaths of his parents. In 1491, Copernicus enrolled at the Jagiellonian University of Krakow where he studied astronomy and the liberal arts. Through the influence of his uncle, Copernicus was appointed a church canon in Frombork, Poland. This administrative position guaranteed his financial security as he pursued his work in astronomy. Copernicus obtained a leave of absence in 1496 in order to continue his studies. He spent several years in Italy studying law and medicine at the universities of Bologna and Padua, and received a doctorate in canon law at Ferrara in 1503. Copernicus returned to Poland in 1503 and assisted his uncle in the administration of the diocese, and in the defenses against the invading Teutonic Knights. Sometime around 1510 he wrote an essay known as the *Commentariolus,* in which he first articulated the principles of his heliocentric theory.

Copernicus was a skilled administrator, physician, scholar, diplomat, and mathematician in addition to his work in astronomy. He was invited to take part in the Fifth Lateran Council's commission on calendar reform in 1515. In 1517 he published his theory on monetary reform. During this time he also observed the heavenly bodies and began his major work, *De Revolutionibus,* publication of which was delayed by the author for many years due to its implications. Copernicus has been compared to Charles Darwin in this regard. In 1539, Copernicus began to study with a young mathematician named Georg Joachim Rheticus. Rheticus published a short introduction to the Copernican system, *Narratio Primo,* and then finally convinced Copernicus to publish his theory in detail. It is said that Copernicus held a copy of *De Revolutionibus* in his deathbed on May 24, 1543.

The Copernican Revolution

Copernicus's theory is often seen as a decisive moment in time. In replacing the earth with the sun as the center of the universe, he revolutionized humankind's understanding of science and religion. The heliocentric theory was a fundamental part of the transition of Western thought from the medieval to the modern period, as it transformed humankind's position in the universe and relationship to God. Like Darwin's theory centuries later, the Copernican system ignited controversies in religion, philosophy, and the social sciences. Its implications extend far beyond astronomy. Critics of Copernicus argued that his theory diminished humanity's place in the universal order and removed humankind as the center of God's creation. Copernicus anticipated a negative reaction to his work because of its disagreements with the Bible. He included a dedication to Pope Paul III (1534–1549), most likely as an attempt to circumvent criticism. Management of the printing of *De Revolutionibus* was given to a Lutheran minister named Andrew Osiander. Osiander added his own anonymous preface in which he claimed that Copernicus was merely suggesting a hypothesis rather than a factual description of the heavenly bodies. *De Revolutionibus* circulated widely throughout Europe, and a second edition was released in 1566. Though Copernicus can be seen as the heir of Ptolemy, the elapse of nearly 2 millennia makes his contribution all the more significant. Copernicus's work, therefore, has been deemed a revolution.

Influence

During the 16th century, most people still found it difficult to believe that the earth was in motion. Even other astronomers could not accept Copernicus's theory in whole. In 1588, the Danish astronomer Tycho Brahe developed a compromise position in which the earth remained motionless. Others, such as Johannes Kepler and Galileo, accepted the basis of the heliocentric theory and supported parts of it with their own work. Galileo was forced by church authorities to renounce the Copernican system. The English scientist Sir Isaac Newton used the Copernican system as the basis for his laws of gravity. Newton sought to confirm the Copernican system with his own complex calculations on the motion of objects. In time, many people came to accept as accurate the heliocentric model of the universe proposed by Copernicus.

James P. Bonanno

See also Bruno, Giordano; Cosmogony; Darwin, Charles; Einstein, Albert; Galilei, Galileo; Hawking, Stephen; Newton, Isaac; Nicholas of Cusa (Cusanus)

Further Readings

Blumenberg, H. (1987). *The genesis of the Copernican world* (R. M. Wallace, Trans.). Cambridge: MIT Press.

Kuhn, T. S. (1985). *The Copernican revolution: Planetary astronomy in the development of Western thought.* Cambridge, MA: Harvard University Press.

Westman, R. S. (1975). *The Copernican achievement.* Berkeley: University of California Press.

Cosmogony

Cosmogony is the scientific discipline that explores the formation of the universe and the celestial bodies. There is agreement within cosmology that the universe came into being about 13–14 billion years ago with the so-called big bang. The nature of this event is beyond any physical interpretation due to the presumably immense temperatures close to the big bang, canceling any contemporary physical theory.

In the course of a symmetry break immediately after the big bang (BB) a very short-time explosive cosmic expansion occurred. One assumes this epoch of *inflation* to last for about 10^{-35} to 10^{-33} seconds after the BB. During this short phase the universe was undergoing expansion by a factor of 10^{30} to 10^{50}; the amount posited depends on the mathematical description.

Inflation is of fundamental meaning for the formation of cosmological structure. Prior to inflation, the universe as a whole was subject to the laws of quantum mechanics. In particular these say that some uncertainty underlies the position and momentum of a particle; this must not be understood as a limitation of our perception and information, but rather as a natural, inherent property of matter and energy. As a consequence, the quantum fields during pre-inflation *cannot* be distributed over space in a perfectly homogenous manner. The very early universe is, rather, infused with *quantum fluctuations*. While the universe expands exponentially during inflation, these quantum fluctuations are as well "inflated" to macroscopic size. The density variations arising in this way constitute the sprouts for any formations of large cosmological structures.

After the end of inflation the "normal" cosmic expansion begins, described by the general theory of relativity. For the first 10,000 years in the life of the universe, radiation energy density dominates over matter. This prevents any early increase in perturbations in the density of matter. The situation changes when matter gets the upper hand in the cosmic energy budget after some 10,000 years; the universe changes from being radiation dominated to being matter dominated. The reason is that radiation loses its energy more rapidly than matter due to the additional effect of redshift in an expanding space. From this moment of *matter–radiation–equality* on, matter density fluctuations are able to self-gravitationally amplify.

This effect of self-amplification concerns only so-called dark matter at first. This is some form of matter, the nature of which remains unknown at the time of this writing, that interacts only via the gravitational (and maybe the weak) force—this is also the reason for dark matter being hard to detect. Numerous observations show, however, that dark matter provides more than 80% of the substantial content of the universe. Only 15%–20% consists of "normal," so-called *baryonic* matter that makes up all interstellar gas and dust, the stars and planets and ourselves. Whereas dark matter can now obey the process of self-gravitation to develop local density peaks unhindered, baryonic matter is still prevented from doing so by the influence of the ubiquitous high-energy background radiation; the temperature in the universe is still high enough to keep all baryonic matter in the state of a *plasma,* a hot gaseous mixture of negatively charged electrons and positive atomic nuclei. The high-energy background photons thus permanently interplay with the charge carriers. Any attempt of the baryons to accumulate within some region would be scotched by the effect of radiation pressure.

Approximately 380,000 years after the BB, the global temperature falls enough to allow for stable combinations of electrons and atomic nuclei: Neutral atoms can form. Because electromagnetic radiation is not coupling to neutral particles, the large-scale streaming of baryonic matter is no longer influenced by the background radiation. The baryons are now able to stream freely into regions of high-density dark matter established soon after the BB. In the course of time these initially moderate high-density regions gain mass via matter accretion until they start to decouple from the general flow of cosmic expansion due to their self-gravity and finally constitute independent, isolated objects, so-called *dark matter halos*. Baryonic matter also becomes denser and denser within the dark halos until, again, its self-gravity is powerful enough to overwhelm its intrinsic thermal pressure and thus causes the gas cloud to collapse. This, just like the dark matter decoupling from the cosmic flow, as mentioned above, is called a *nonlinear* phase of structure growth. During the collapse, shock waves arise and heat the gas to millions of degrees Kelvin. Unlike dark matter, gas can cool via several atomic processes. Thus it can further contract around the dark halo center until it becomes a rotation-stabilized flat disk. Local condensations occur within this gas disk, forming molecular clouds in which stars can finally emerge.

It is known from observations as well as numerical simulations that there are fragmentation processes occurring inside molecular clouds, producing even higher-density peaks of small local extension. These *globules* are the cradles of the stars. Stars form in groups rather than singly. The progressively rising power of self-gravitation leads to a further compression of the globules, while the temperature increases due to the growing pressure. The collapse ends as soon as the thermal pressure becomes as strong as the gravitational force. When the inner temperature reaches some 15 million degrees Kelvin, the fusion of hydrogen can start to produce helium nuclei. This will provide for the energy production of the star over the largest part of its lifetime. Prestellar objects with less than 8% of the solar mass ($M_{®} = 1.99 \times 10^{30}$ kg) are not able to generate temperatures high enough to enable the hydrogen fusion process. These objects, much smaller than normal stars, are called *brown dwarfs*. On the other hand, stellar objects with more than 60 $M_{®}$ presumably cannot form because of strong winds being generated before the onset of the nuclear burning and blowing away a considerable fraction of the prestellar material.

During the star formation process, angular momentum conservation causes a gas disk, within which planets can form, to form around the prestellar object. Different from stars, planets form in a growth process, starting from microscopically small dust particles that stick together after encountering each other and thus form continuously growing clumps. The *planetesimals* that build up in this way collect material by gravitation along their orbit and thus accelerate their further growth. In this manner, planets half the size of the earth can form within only some 100,000 years. Such objects, thousands of kilometers in size, can successively build up huge planets with up to 10 Earth masses. Giants like these are additionally able to accrete gas from the surrounding disk, which can finally lead to gas giants like Jupiter and Saturn.

Helmut Hetznecker

See also Aquinas, Saint Thomas; Aristotle; Augustine of Hippo, Saint; Black Holes; Bruno, Giordano; Copernicus, Nicolaus; Cosmology, Inflationary; Demiurge; Einstein, Albert; Galilei, Galileo; Hawking, Stephen; Lucretius; Newton, Isaac; Nicholas of Cusa (Cusanus); Plato; Presocratic Age; Singularities; Stars, Evolution of; Time, Emergence of; Time, Galactic; Time, Sidereal; Universes, Baby

Further Readings

Carroll, B. W., & Ostlie, D. A. (2006). *An introduction to modern astrophysics.* San Francisco: Pearson, Addison-Wesley.

Coles, P. (2001). *Cosmology: A very short introduction.* Oxford, UK: Oxford University Press

Longair, M. S. (1998). *Galaxy formation.* Berlin, Heidelberg, New York: Springer.

Cosmological Arguments

Cosmological arguments try to establish the existence of an uncreated creator of the cosmos. They argue for the conclusion expressed in the first verse of the Judeo-Christian Bible: "In the beginning God created the heaven and the earth." Although most cogently formulated by philosophers such as Saint Thomas Aquinas (1225–1274), al Ghazali (1058–1111), and Gottfried Leibniz (1646–1716), cosmological arguments have a powerful appeal also to those nonphilosophers who feel that the "ultimate" explanation for the existence of the *natural* universe is that it was created by some sort of *supernatural* entity: God.

Such arguments belong to religion, not science; to metaphysics, not physics. Along with various versions of the ontological argument and the teleological argument (argument from design), they constitute one of the standard "proofs" of the existence of God.

Yet a broad consensus of philosophers, including many who agree with the conclusion, hold that none of these arguments, however persuasive they may seem, really establishes the desired conclusion. This is why Immanuel Kant (1724–1804) concluded that the existence of God is not for reason to demonstrate but for faith to proclaim.

The *Kalam* Cosmological Argument

Of the countless versions of the cosmological argument devised by metaphysicians and theologians in the Greek, Roman, Judaic, Christian, and Islamic traditions, that devised by Arab scholars during the Islamic Golden Age (750–1258) is particularly noteworthy for its intuitive appeal, the sophisticated way in which it can engage the intellect of scientists and mathematicians as well as philosophers, and for its overall persuasive power. As reconstructed by the contemporary Christian philosopher–apologist William L. Craig, it is designated as "the *kalam* cosmological argument" (*kalam* means "talk" in Arabic, alluding to the seeking of religious principles through dialectic). Many of the lessons learned by examining its credentials can be applied to the evaluation of other versions.

Craig's Formulation of the Kalam Argument

Craig presents the first stage of his version as a simple syllogism:

Premise 1: Whatever begins to exist has a cause.

Premise 2: The universe began to exist.

Conclusion: Therefore the universe has a cause.

This first stage of the argument is valid. But are its premises true? And a second question: How does God get into the act, as it were? How does one get from the conclusion that there is a first cause to the further conclusion that this is God?

Aquinas thought it sufficed to say: "this all men call God." Craig, however, supplies a second stage of argument, claiming that the most plausible account of the first cause is that it is a personal God who, while creating space and time, is (or was) himself not in either.

Premise 1: *"Whatever begins to exist has a cause."* As with all other versions of the cosmological argument, the kalam has at least one empirical claim among its premises—a claim, that is, for whose truth we have to rely on our experience of the world around us. So the question arises whether, *in our experience,* everything that has a beginning does in fact have a cause.

To most people Premise 1 seems so obviously true as not to need defending. Objects don't just "pop into existence." Likewise with events (changes in things or states of affairs). They begin and end in a temporal series of causes and effects. Things, we say, don't "just happen." Rather, every event is caused by, and hence determined by, some event or events that precede it in time.

Yet this commonsense belief is not beyond dispute.

First, the standard interpretation of quantum physics maintains that the commonsense belief in universal causality must be abandoned. The occurrence of events at the microphysical level is unpredictable, uncaused, and indeterministic in character. Or so many claim. Yet if this interpretation of quantum phenomena is sound, then Premise 1 is just plain false, notwithstanding its endorsement by ordinary experience.

Second, the truth of Premise 1 is inconsistent with the account of free will that is embraced by many theists, Craig included. The problem is that, if it were true, and the chain of causes did indeed go back to God as the ultimate cause and creator of the universe, then God would thereby be made the ultimate cause of all the evils that universe contains. We would have to take him at his word when he claims, "I make peace, and create evil: I the LORD do all these things" (Is 45:7).

One way of avoiding this unpalatable conclusion is to say that genuine free will involves a break in the causal chain, that our free acts are uncaused by anything other than ourselves, and hence that it is we (and perhaps other free agents like Satan and his cohorts) who bring about all the evils in God's universe. But on this so-called contra-causal account of free will, Premise 1 is false. It makes our free choices *uncaused* causes of our free acts. Hence the theists' dilemma: Either accept Premise 1 and make God causally responsible for evil, or reject Premise 1 and abandon the cosmological argument for God's existence.

Premise 2: *"The universe began to exist."* Craig has two subsidiary arguments for the truth of the second premise. One involves an appeal to *empirical* evidence from current scientific cosmology. The other involves an a priori argument (an argument that requires no appeal whatever to experience) from the supposed impossibility of an actually infinite number of things or events.

Subsidiary Argument From Scientific Cosmology

Three main cosmologies have engaged the attention of physicists over the past half century or so: the steady state model; the oscillating model; and the big bang model. The first two hold that the universe never had a beginning but always existed, either in the same steady state or in successive states of recurrent expansion and contraction. Only the third postulates a temporal beginning of the universe.

Which of these models is correct? An overwhelming scientific consensus supports the big bang model according to which both the physical universe and time itself began about 12–14 billion years ago. Yet if empirical evidence tells us anything it is that, in the fullness of time, this model may give way to one of the others or to some other model yet to be conceived or empirically confirmed. Craig claims that models allowing for a beginningless universe are "physically impossible." But this is too strong. It presupposes that the big bang theory has been established beyond all possibility of revision and that any further tests of its truth would be fruitless. Yet such tests proceed.

But suppose that the big bang model is in fact true (not just currently accepted as true). Since it asserts that time and space began with the expansion of a so-called singularity, its truth would indeed lend support to Premise 2. But at the same time, its truth would undermine Premise 1. For if time itself began with the big bang, then no temporally preceding event can have caused it to begin. In short, current physical cosmology can be invoked to support Premise 2 only at the expense of having it controvert Premise 1.

Either the spatiotemporal universe had a beginning or it didn't. If it did begin—as the big bang model postulates—then, so far as science can tell us, Premise 2 is true but Premise 1 is false. On the other hand, if it didn't have a beginning—the scenario painted by both the steady state and oscillating models—then, so far as science can tell us, Premise 1 is true and Premise 2 false. On either scientific account, the kalam argument is unsound.

Subsidiary Argument From the Impossibility of an Actual Infinite

A common feature of all versions of the cosmological argument is the claim that the regress of causes postulated in Premise 1 "cannot go on forever." What distinguishes the kalam version from these others is that it offers an a priori argument for the impossibility of the regress of causes being infinite.

Craig presents this subsidiary argument thus:

> An actually infinite number of things cannot exist.
>
> A beginningless series of events in time entails an actually infinite number of things.
>
> Therefore, a beginningless series of events in time cannot exist.

Clearly this argument is valid. Equally clearly, the conclusion, if true, would rule out the kind of endless chain of events envisaged in both the steady state and oscillating models of the physical universe. It would provide a priori endorsement for the sort of beginning of spacetime that is postulated in the big bang theory.

But what, we need to know, is meant by an "actual infinite"? And what is impossible about the notion that an actually infinite number of things should exist?

A collection of things (objects, events, or moments of time) is said to comprise an actual infinite if it satisfies the conditions for being an infinite set as defined by the mathematician Georg Cantor (1845–1918), namely, that the members of that set can be put into a 1-to-1 correspondence with the members of one of its proper subsets. Consider the claim, "For every natural number there exists a successor that is itself a natural number." Clearly this claim entails the existence of an infinite set of natural numbers. This set satisfies Cantor's conditions for being an infinite set since the proper subset comprising just the odd numbers can be thought of as standing in 1-to-1 correspondence with all the natural numbers, even as well as odd.

The idea of a set all of whose members are equinumerous with one of its proper subsets is certainly counterintuitive. But this, it has been argued, arises from the fact that most of our thinking about sets focuses on the properties of *finite* sets, not infinite ones. So we have no good reason to suppose the latter to have the same properties as the former. In any case, despite its "paradoxical" consequences, Cantor's theory of transfinite numbers is logically self-consistent and cannot be shown to be logically impossible.

Now just as the statement, "For every natural number there is a successor that is a natural number" generates an infinite set of natural numbers, so the statement, "For every event that begins to exist there is a preceding event that is its cause" generates an infinite series of events. Likewise with the claim, "For every moment of time that begins to exist there is a moment of time that precedes it." Yet both these latter claims are entailed by Premise 1 of Craig's kalam argument. Hence if there is nothing logically impossible about the existence of an infinite set of natural numbers, there would seem to be nothing logically impossible about the existence of an infinite series of events or an infinite series of moments of time.

Craig is prepared to allow the logical possibility of infinite sets in mathematics, despite their paradoxical consequences. So on one interpretation of "things," namely, that in which the things concerned are abstract entities like numbers, he is prepared to allow (contrary to the first premise of his subsidiary argument) that an actual infinity of things can exist after all. What he cannot accept is that interpretation of "things" in which the things concerned are constituents of the spatiotemporal universe, such as physical objects, events, or moments of time. But infinite sets of the latter sorts of entity are no more paradoxical than are infinite sets of abstract entities.

The upshot of his second subsidiary argument then is this. If the paradoxical nature of infinite sets did indeed demonstrate that an actually infinite number of events in time cannot exist, then Premise 1 is false since it entails just such an actually infinite set. But if, on the other hand, the paradoxical nature of infinite sets does *not* demonstrate the impossibility of an actually infinite number of events in time, then it provides no grounds for holding Premise 2 to be true.

Interim Conclusion: "Therefore the universe has a cause."

Set aside the previously noted objections to Premise 1: that its truth is threatened by both quantum theory and the contra-causal account of free will, and that the infinite series of beginnings it entails is rendered impossible by the argument against actual infinites. There are still more problems.

Consider, once more, the experiential warrant that is claimed on behalf of Premise 1. It is that within our ordinary experience of things that happen *within the spatiotemporal universe,* the beginnings of all events are brought about, or caused, by preceding events that themselves had beginnings. That is the scope and limit of our empirical grounds for holding Premise 1 true. There is, therefore, no experiential warrant whatever for our extending its scope to the case of the beginning of the universe itself. It is not as if we have experienced cases of many universes beginning and have found from our experience of these universe-beginnings that all of them are caused.

If we were to be more guarded in generalizing about how things happen (at least at the macrophysical level) in the spatiotemporal universe we experience, we would formulate Premise 1 so as to read, "Whatever begins to exist *within the spatiotemporal universe* has a cause." It would then become clear that we have no warrant whatever for extending the limited universality of this more defensible premise to the beginning of the spatiotemporal universe itself. As Bertrand Russell (1872–1970) pointed out, to suppose that we do have such a warrant would be like supposing that from the statement that every human has a mother we can infer that humanity has a mother.

Final Conclusion: "The cause of the universe is God."

Set aside all previously noted objections and, for the sake of argument, suppose that the spatiotemporal universe did have a cause. What then entitles us to conclude that this cause is anything like the personal God of theism?

Many questions call for answers. Why should not the cause of our universe be, or have been, some entity in another physical universe, a being or group of beings, perhaps, endowed with God-like magical power to conjure other universes out of nothing? What sense does it make to invoke the existence of a supernatural being with the powers of a Grand Wizard who, by some incomprehensible means, conjures the natural world into existence? Why suppose there is just one such being? Why suppose that such a being, if there were one, is a person with personal attributes akin to our own? And wouldn't both the existence and the acts of any such being call for explanation in terms of what caused it to exist or to act?

Craig addresses only the last two questions. The creator, he argues, cannot be *in* time for then there would be an infinite series of events in his life; and that, according to his argument against actual infinities, is impossible. Hence, he concludes, God must be conceived as a changeless being in whom, prior to creation, no events whatever—not even sequences of thoughts—occurred. He is to be conceived as having been, so to speak, an ultra-catatonic being—a being who suddenly, but inexplicably, springs into action, creates a temporal universe, and only then begins his own temporal career.

But then still other questions arise. What *caused* this beginning of the series of events in God's temporal career since time began? Premise 1 demands that there be such a cause. Yet if there was one, it must in turn have had a cause, and that another, and so on ad infinitum. Any puzzles there might be about the beginning of the universe seem to be paralleled by puzzles about the beginning of God's involvement with that universe.

There seems no way of escaping the dilemma: Either something can exist without having been caused to exist by something else (in which case there is no reason why the natural world should not be that thing), or there must be a cause for God's existence, and for the being that caused him, and so on ad infinitum.

Is the timeless God postulated by Craig's kalam argument the kind of God in whom most theists believe—one who has existed "from everlasting to everlasting" (Ps 106.48)? That, as Kant would insist, is a question for the psychology of faith. But one thing is certain. As a logical proof of the existence of such a God, the kalam argument—arguably the best yet ventured—is a failure.

Raymond Dynevor Bradley

See also Aquinas, Saint Thomas; Bruno, Giordano; Causality; Determinism; Cosmogony; Einstein, Albert; Experiments, Thought; God and Time; God as Creator; Hawking, Stephen; Islam; Metaphysics; Newton, Isaac; Regress, Infinite; Time, Emergence of; Time, End of

Further Readings

Craig, W. L. (1984). *Apologetics: An introduction,* Chicago: Moody Press.

Craig, W. L. (1980). *Cosmological argument from Plato to Leibniz.* London: Macmillan.

Craig, W. L. (1979). *The kalam cosmological argument.* London: Macmillan.

Mackie, J. L. (1982). *The miracle of theism: Arguments for and against the existence of God* (chap. 5). Oxford, UK: Clarendon.

Cosmology, Cyclic

Cyclic cosmology refers to the concept that the cosmos undergoes continuous cycles of evolution. Time itself has generally been defined by the beliefs regarding the specific nature of the cycles.

Cycles of destruction and renewal have been a recurrent theme in mythologies and religions, inspired by such natural changes as day and night, the seasons, and birth and death. In the ancient world, the concepts of linear and cyclical time were already being debated, but nearly every culture recognized the existence of cycles and had its own beliefs about when they would occur. The concept of time was generally defined by the cycles of nature. For example, the duration of cycles in Hindu cosmology were related to periods of the life of Brahma, the god of creation.

The Greek philosopher Heraclitus was the first known person to address the inevitability of change and the need to understand its nature. Western thought generally favored cyclical cosmology up until the time that Christian interpretations of the Book of Genesis became influential, though examples of cyclical theories continued to appear. In the 18th century, James Hutton, considered the founder of modern geology, referred to the recurrent destruction and renewal of the "great geological cycle." In the late 19th century, German philosopher Friedrich Nietzsche developed the theory that, given the limitless nature of time, events must inevitably recur. Various cyclic models that failed to withstand the test of time were proposed in the 1920s and 1930s by cosmologist Richard C. Tolman and others.

Most recently, cosmologists Paul J. Steinhardt and Neil Turok have introduced the cyclic model of the universe as an alternative to the big bang theory, which they have described as having been generally dominant during the past 40 years.

The original big bang theory involves a singularity that occurred about 14 billion years ago, creating the universe from an infinitesimally tiny area of space with a density and temperature that were nearly infinite. Since then, the universe has continued expanding and cooling. A more recent version of the theory includes the concept of inflation, or the brief, accelerated expansion that occurred immediately after the big bang.

Steinhardt and Turok's cyclic model had its beginnings in the model of the ekpyrotic universe, which the two had developed earlier with other cosmologists. The word *ekpyrosis* is a Greek word for conflagration, referring to an ancient cosmological model wherein the universe was created in a burst of fire.

The cyclic model also includes a big bang, as well as a "big crunch" at the end of a cycle. But since the model indicates that the universe has no beginning or end, it should now be viewed as a bridge to a past of endlessly repeating cycles. When a big bang occurs, it creates heat and radiation at a finite temperature and then cools to form galaxies and stars. The bang represents a transition from a contracting phase to an expanding phase where matter spreads out to become a nearly perfect vacuum. The interval between big bangs is believed to be about a trillion years, far longer than the 14 billion years predicted by the inflationary model.

Steinhardt and Turok describe the concept of an endless universe as still in its infancy, but they believe the model might be able to explain some points not included in the big bang theory. Those points involve extra dimensions, branes, and dark energy.

The *string theory* in physics refers to particles as waves on strings and was conceived as a way to reconcile quantum mechanics with general relativity. *M-theory,* which unites all five existing string theories, allows for the existence of additional dimensions. The three dimensions that expanded and contracted in the older theory now should be seen as expanding and stretching from one big bang to the next. As the stretching rate slows, an additional dimension is squeezed to nearly zero size before it begins expanding again.

Branes (short for mathematical membrane) in string theory consist of surfaces of varying dimensions that can move through space. In the cyclic model, our universe is referred to as a *braneworld.* It is separated by only a small gap from, and collides at regular intervals with, a second braneworld that we cannot observe. Matter and radiation are confined to branes, which can always be stretched. The space between the two eventually shrinks to zero when the big crunch occurs, but energy doesn't become concentrated as described in the original big bang theory.

Though no specific role for dark energy had been established in the inflationary model, it plays three essential roles in the cyclic model. First, it speeds up the rate of expansion of the universe, allowing its components to spread out. Branes eventually stretch to a near-vacuum condition, resulting in an equal distribution of energy and smoothing out wrinkles so that each cycle begins with the same basic physical conditions. Second, dark energy serves as a stabilizing force by regulating the speed of branes and acting as a shock absorber to ensure that brane collisions don't become completely random. Finally, dark energy has the ability to shut itself off. As the energy draws branes together, it gradually changes from positive to negative. This allows the branes to speed up and for the additional dimension to contract so that the next cycle can take place.

Steinhardt and Turok point out that the before and after of the cycles can be described in a way that follows the laws of physics and is justified by current astronomical observations.

The cyclic model has been described as more optimistic than earlier models. The universe remains essentially the same. Every part evolves through a series of regular cycles, starting with a bang and ending with a crunch. The existence of dark energy is important in helping to keep the cycles on track.

Steinhardt and Turok emphasize that the cyclic model is still only a theory that should be discussed and tested by the scientific community along with alternatives. They express optimism that recent advances in astronomical observation, along with laboratory experiments, will lead to the identification of the best model to explain our universe within the next two decades.

Betty A. Gard

See also Big Bang Theory; Big Crunch Theory; Cosmogony; Eternal Recurrence; Heraclitus; Nietzsche, Friedrich; Plotinus; Time, Cyclical; Universe, Closed or Open; Universe, Contracting or Expanding

Further Readings

Kragh, H. S. (2007). *Conceptions of cosmos: From myths to the accelerating universe: A history of cosmology.* Oxford, UK: Oxford University Press.

Kragh, H. S. (1996). *Cosmology and controversy.* Princeton, NJ: Princeton University Press.

Steinhardt, P. J., & Turok, N. (2007). *Endless universe: Beyond the big bang.* New York: Doubleday.

Cosmology, Inflationary

The inflationary scenario constitutes an extension of the cosmological standard big bang model. According to the inflationary model the universe undergoes a phase of extremely rapid expansion starting around 10^{-35} second and ending 10^{-33} second after the big bang. Within this short time interval, the universe is believed to have expanded by a factor of about 10^{30}–10^{50}. Although not confirmable, the inflationary theory is considered as integral to the basic cosmological theories.

The epoch of inflation was presumably initiated by a phase transition (comparable with the transition from water to ice below the freezing point), causing the strong interaction to separate from the *grand unified force*. The basic ideas of an inflationary phase were proposed in 1979 by the Russian physicist Alexei Starobinsky and developed to a first consistent theory 2 years later by the American physicist and cosmologist Alan Guth. In 1982, inflation was brought to its modern shape independently by Andrei Linde, Andreas Albrecht, and Paul Steinhardt. The occasion to postulate an inflationary event in the very early universe was a number of unsolvable problems associated with the standard picture.

The Flatness Problem

Numerous observational hints independently suggest that the density parameter of the universe is $\Omega = 1$ with tight tolerance. That is to say, the mean density of the universe is close to a value known as *critical density,* which separates a universe of eternal expansion ($\Omega < 1$) from one that is to turn its expansion to a collapse in a remote future ($\Omega > 1$) due to the gravitational deceleration effect of its high mass content. In terms of Einstein's general theory of relativity, the cosmological classification according to the mean density is identical to 1, according to the intrinsic geometry of space: While a density parameter $\Omega > 1$ comes along with a "closed" geometry (the three-dimensional equivalent of a spherical surface), the under-critical "open" $\Omega < 1$ universe is affected by the intrinsic geometry of a saddle. The limiting special case $\Omega = 1$ finally accords to a flat ("Euclidean") geometry of a plane surface. The cosmological standard model predicts that any small deviation from $\Omega = 1$ in the early universe will be amplified massively in the course of time. Thus the universe should have a density parameter that is orders of magnitude larger or smaller than 1. Or, on the other hand, Ω has to be extremely close to 1 right after the big bang. This is a classical problem of fine-tuning.

Solution Within Cosmic Inflation

After rapid expansion comes to an end, the size of space by far exceeds the diameter of the region that makes up our observable universe today. However strong the cosmic curvature may be today, the curvature of "our" space region, the "universe" by definition is tiny, just as the earth's surface appears to be flat due to our limited perception.

The Horizon Problem

In theories of time and space one frequently uses the term *past light cone* of an event. An *event* is a point that determines a "here and now" in spacetime. The past light cone of an event E contains all events (points of spacetime) E_i in the past of E from which light or information could have reached the event E. An event E' is able to influence a (future) event E only if E' lies within the past light cone of E.

In 1965, physicists discovered a constant extragalactic microwave radiation that is now known to have been generated less than 400,000 years after the big bang. That so-called cosmological microwave background radiation is reaching us with identical physical properties from all directions of space. A close to perfect isotropy like this clearly seems to contradict the finite propagation velocity of light and information: The birth locations of the background radiation photons measured today have distances of 13 billion light-years from the earth. However, the cosmic background radiation, coming from opposed directions, is measured to have identical temperature and spectral distribution, while the past light cones of the according regions could not have overlapped 400,000 years after the big bang. There is no way to understand the isotropy of the cosmic microwave background in a universe without inflation.

Solution Within Cosmic Inflation

Prior to the onset of inflation the entire space of the universe may well have been in thermodynamic equilibrium. This means there was a common, well-defined temperature throughout the universe and all energy was smoothly distributed. In the course of inflation, all regions of space were torn apart at many times the speed of light and thus lost their causal contact—in other words, their past light cones would no longer overlap after the explosive separation.

Nevertheless, all physical properties have either remained constant or changed in identical ways (density, temperature) within any volume element while inflation happens.

The Monopole Problem

James Clerk Maxwell's (1831–1879) empirical formulation of the electromagnetic laws contains an asymmetry, running counter to the ambition of highest simplicity in modern physical theories: Classical electrodynamics does not allow for magnetic monopoles; that is, isolated magnetic south or north poles. In fact, a magnetic monopole has so far never been observed in nature. Electric monopoles (charges), on the other hand, are well known. In any case, grand unification theories predict that massive magnetic monopoles formed in the very early universe. Why are these undiscoverable today?

Solution Within Cosmic Inflation

According to grand unification theories, magnetic monopoles should have been created with extremely low numbers within much less than a second after the big bang. The monopole frequency should have diminished during the inflationary expansion in such a manner that there is a close to zero chance of discovering one today.

In terms of quantum theory, the universe was brought from a pure quantum mechanical being into a macroscopic classical one by inflation. Thus the inflationary scenario yields a possible explanation for the onset of structure formation in the universe: Due to Heisenberg's uncertainty principle, there must have existed tiny quantum fluctuations within matter and radiation (the "primordial soup") right after the big bang. While the rapid expansion of inflation was acting, these quantum fluctuations were being transformed to a macroscopic density contrast. Starting from this, large structures like galaxies and clusters of galaxies were able to form by gravitational instabilities in the course of time.

There is little agreement on the physical details of how inflation occurred. This is due partly to the uncertain state of knowledge of the corresponding high-energy physics. Second, cosmologists are far from being able to perform experimental tests of the inflationary model. In any event, inflation is in principle falsifiable in terms of Karl Popper's philosophy of science. This means one can think of feasible experiments that would allow (depending on their results) the inflationary scenario to be disproved. Such an experiment was performed by the NASA space probe *WMAP* launched in 2001. Its very detailed measurements of the cosmological microwave background radiation are compatible with the inflationary picture. Note, however, that this is by no means a proof of inflation.

Because the big bang itself cannot be considered as encompassed by the time evolution of the universe, inflation marks the first significant change in state of the universe and the beginning of its macroscopic being.

Helmut Hetznecker

See also Big Bang Theory; Black Holes; Popper, Karl R.; Quantum Mechanics; Universe, Contracting or Expanding; Universe, Evolving; Universes, Baby

Further Readings

Guth, A. H. (1998). *The inflationary universe.* Reading, MA: Perseus.

Linde, A. (1990). *Inflation and quantum cosmology.* Boston: Academic Press.
Linde, A. (1990). *Particle physics and inflationary cosmology.* Chur, Switzerland: Harwood Academic.

Cosmos, Evolving

See Universe, Evolving

Creation, Myths of

"In the Beginning . . ." and "Long, long ago..." began the theogonies of creation myths that were composed by the primordial peoples who, in observing the celestial patterns in correspondence with the seasonal changes in their habitat, concluded from these extrinsic evidences theories of creation of the cosmos, flora and fauna, and especially of humankind. These myths became the foundations that shaped the distinct cultural worldviews, mannerisms, and rituals that their belief systems would dictate. There were gods that were personal and dwelt among humankind, gods that dwelt in the heavens, and a pantheistic god that is believed to reside *in* everything. Globally, the creation myths have a myriad of origins and important characters, yet similar motifs are evident. This entry examines analogous themes and will initiate each creation section with a passage from Genesis, as a bellwether creation motif, being one of the most recognized of creation legends.

Darkness, Divine Chaos, and the Primordial Gods

> In the beginning . . . the earth was without form, and void: and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters. And God said, Let there be light . . . and God divided the light from the darkness. And God called the light Day, and the darkness he called Night. And the evening and the morning were the first day. (Bible, King James Version, or KJV)

The Romans tell of Chaos, the shapeless form of the four elements—water, fire, air, and earth—before the beginning of time; when these elements finally separated, the result was the formation of Janus, the "god of gods." From China, the gods Yin and Yang were the first to form from the *hun dun* or shapeless vapors; with the remainder of these vapors Yin and Yang created the universe and humans. The Hopi legends recount how the entirety of existence was endless space and the sun spirit; the sun spirit formed the earth from himself and endless space. The Mayans' "Book of Counsel" tells that there was silence in the beginning prior to creation. The Taoist Chuang-Tzu describes the subtle stages of "Being"; there was: "Not-Yet-Beginning-to-Be-Non-Being," and "Not-Yet-Beginning-to-Be-a-Not-Yet-Beginning-to-Be-Non-Being," and how "suddenly" the vitality of Being and Non-Being came to pass. A New Zealand Maori chant tells how everything emerged from a void origin. The Taoist Lao Tzu wrote of an unknown thing, "confusedly formed," with the potential of being the mother of worlds. In the Slavonic legends the dual forces of positive and negative created Byelobog the Black God, and Chernobog the White God. To the Haidas of the Pacific Northwest (of the U.S.), the Supreme Being is called "The-Light-of-the-Shining-Heavens," while the Incas call it the "Hidden-Face-of-God"; and the Iroquois call it the "Old-One-in-the-Sky." To the Hebrews, the name of God is so revered that it is unspeakable; in writing, the consonants JHVH were arranged to denote God. An Inuit legend describes Raven as being the creator, yet it is the Sparrow that not only accompanied Raven throughout the creation processes, but was there from the inception; while the Inupiaq of Alaska tell of the Primevous Shaman that created Raven the god-man, Raven who became a creator in his own right and transformed into a bird. In Siberia the Chukchi call the Reindeer Being their Creator. The Evenks have two names: Amaka the guardian for humans, and Ekseri who oversees the animals. The Korean Supreme Being is Hanullim, the "ruler of heaven." In Australia the Aboriginals recognize the "All Father," which goes by several names depending on location, and/or the "The Great Mother" or "All Mother."

The *Zohar,* a Judaic text, describes how the creator was without shape or form, and so created a divine man that he descended upon and utilized for further creations. The Memphis Egyptian legend recounts Ptah as the creator and "Father and Mother of all the gods." Within the Greek legends the "deep-breasted" Gaea, Mother Earth, was created from the chaos of the void. The Celts' "Good God," the Dagda, is known to them as the "Great Father." In Northern Europe, creation transpired within the merging point of the icy north and the inferno from the south; the melting ice from this fusion formed the giant Ymir. The dark nothingness and divine chaos that is prevalent in creation lore and that antedated creation and the primordial slime, is a similitude of the darkness, then the chaotic nebulae from the aftermath of the early stages of the evolution of the universe.

The Deep Waters and Children of the Gods

> And the Spirit of God moved upon the face of the waters . . . And God said, Let there be a firmament in the midst of the waters, and let it divide the waters from the waters . . . God called the firmament Heaven. And the evening and the morning were the second day. (KJV)

Some cultures believe that Father Sky and Mother Earth were in continuous lovemaking, in an inseparable embrace. These parents have numerous appellations: Apsu and Tiamat (Babylonian), Ouranos and Gaea (by Hesiod), Rangi and Papa (Polynesian), and An and Ki (aka Nammu) (Sumerian); in Egypt the parents are reversed and the mother is the sky and father the earth. Given that their children are imprisoned between them and more "offspring" are being created, the siblings launched a campaign against their parents to improve their living conditions.

In Japan the creative substance of primordial slime resembled oil or a gelatinous mass from which five gods took form and lived on the High Plains of Heaven; from these five gods, seven following generations of gods and goddesses were created. Then, Izanagi and Izanami, the youngest god and goddess, took a sacred spear, swirled it in the waters of the deep from the Floating Bridge of Heaven, and the drops that fell when retrieving the spear created the beginnings of land, their new home; their children would become the remainder of the creation process of Earth. These global motifs of gods forming from the mists, the waters separating, and the promontories arising from the endless body of water represent the nebula condensing into planets in the star systems.

Earth and the Cosmos

> And God said, Let the waters under the heaven be gathered together unto one place and let the dry land appear . . . Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit . . . And God saw that it was good. And the evening and the morning were the third day. And God said, Let there be lights in the firmament of the heaven to divide the day from the night, and let them be for signs, and for seasons, for the days, and years . . . And God made two great lights: the greater light to rule the day, and the lesser light to rule the night: he made the stars also . . . And God saw that it was good. And the evening and the morning were the fourth day. (KJV)

In a Persian legend, a 9,000-year battle between light and darkness ensued prior to the world's formation. Globally, the theme of the separating of Father Sky and Mother Earth played an important role: for example, the children of Rangi and Papa are bent over and sideways; their miserable state prompts them to conjure conspiracies to destroy their parents, but the child "Father of the Forest" pushed the parents apart; in Egypt, it is Shu the child of the Air. In an early Chinese creation legend, the sky god Zhuan Xu orders the two grandsons Chong and Li to separate the sky and the earth; and in another version the sky had to be propped up from the earth, in another tied down to the earth. In Korean legends it was Miruk who separated heaven and earth and placed pillars to keep them in their place, then filled the sky with the stars, the moon, and the sun.

In the Eastern cultures, the cosmic egg arose from the primordial waters of the deep. From Hermopolis, Egypt, the creation legend tells of a mound that emerged from the waters of Nun, and upon the mound an egg from which the sun god appeared. In Orphic legend the egg is silver, and is cracked by Time and Need. Love, named Eros, "father of the night," emerges from the egg "wearing both sexes"; Eros fathered Zeus, who in turn swallows his father; Eros returns as the cosmos.

The Chandogya Upanishad of India recounts how the egg was half silver and half gold; the silver became the earth, the gold the heavens; the Brahman legends tell how a golden egg floated upon the waters a year prior to becoming the heavens and the earth. The Vedic hymns tell how each of Vishnu's seeds became golden eggs, and from each seed a universe was created; the god Brahma was born from Vishnu's navel; Brahma then created the stars and demigods to assist in the creation and control the earth and universe. With the Chinese, 18,000 years of incubation occurred prior to the egg separating into Yin and Yang: the Yang, being lighter, arose to create the heavens, while the Yin was heavier and lowered to mold into the world. In Africa, Mebege created the cosmic egg by combining a portion of his hair, brain, a pebble, and his breath; a spider brought the egg between the sea and the sky until the egg obtained the optimum temperature, at which Mebege fertilized the egg. Following the birth of his three children, Mebege created termites and worms to leave droppings, which thereby created land.

At times a god's or demigod's being was utilized as a cosmological body for the creation to be complete. In Babylonia it is the third-generation god Marduk, the sun god (Assyrians call him Assur), who slays the mother of the gods, Tiamat, and thereby creates the earth and heavens with her body. In Northern Europe the three brother gods Odin, Vili, and Ve slay the giant god Ymir and use his carcass to create the earth. From the southwest area of China, the being of the semi-divine human, giant Pan Gu, was formed while the Yang separated from the Yin; after an unspecified time the dying remains of Pan Gu were used in the finishing touches of the creation process of the earth: for example, his eyes were placed in the sky for the sun and moon, and his body lice become human beings. The Inupiaq tell of Raven killing a whale in order to create the world from its carcass.

Life on Earth was a paradise, explains the New Guinea legend, filled with flora, fauna, and demigods called *Demas;* but then, the world of paradise was burned to the ground by the demigods playing with fire. So Darvi, the great *Dema,* created rain, which not only brought a cessation to the flames, but formed rivers in the process. Enraged over the holocaust, the great *Dema* threw a charred piece of land into the ocean; this is the beginning of New Guinea, and brought a metamorphosis of the flora and fauna to be changed into humans. Also from New Guinea, a story of three brothers at the beginning of the world who became the ancestors of the people on Earth: people of the grassland and people of the bush, but the third brother left and was never seen again; the arrival of Europeans brought speculation that these were the descendents of the third brother. Another Oceanian legend recounts how the god Tiki made his wife from sand. Their children and children's children fill the island, giving Tiki the impetus to create more islands, the solution to the unprecedented population problem. Another island, Turtle Island, is the term from the Cheyenne of North America, whose legends inform that the Earth resides on the shell of Grandmother Turtle. In the Caribbean the sons of the supreme spirit Yaya were secretly consuming fish from a gourd that belonged to their father; upon hearing their father's arrival they accidentally overturned the gourd filled with fish and water, thereby creating the ocean. The Unambal tribe of Australia tells of two creators: the Ungud who is shaped like a python and finds its habitation within the earth, and the Wallanganda or one that "belongs to the sky" and dwells in the Milky Way; their creation process transpired during Dreamtime. In the North American Iroquois legend, "The-Old-One-in-the-Sky" impregnated Ongwe and then thrust her through a hole in the sky, resulting in the birth of the world.

A Mongolian story tells of seven unmoving and unbearably hot suns that grieved the residents of Earth. The hero, in human form, the intrepid marmot, shoots six arrows into the sky, to which six of the suns fell; this sent the seventh sun into a continuous cycle around the world. In the early Chinese calendar a week was 10 days, in which the sun goddess Xi He or Breath Blend conceived 10 children or suns that would alternate journeying across the sky, to each occasive conclusion; when all 10 decided to come out one day, which threatened Earth's habitat, the hunter god shot and pulled them down with cords attached to his arrows. Maui, a Hawaiian demigod, pulled the land out of the water, much like the sons of Bor raising the dead body of Ymir from the waters to create the earth. Maui also trapped and convinced the sun to slow its passage across the sky; prior to this the sun moved swiftly, making the days too short.

Within the diverse creation versions, the entry of humans occurs at various stages; some prior to the creation of the cosmos and others afterwards. In a Tlingit legend, all the world was dark and the people complained of the gloomy existence. It was the legerdemain of Raven that brought the sun, moon, and stars to the people; the trickster secreted into the drinking water of the daughter of the Great Chief, thereby impregnating her. Raven, now the grandson, cried until the Great Chief opened his bentwood boxes filled with his most valued clan items: the stars, the moon, and especially the sun. First, he let Raven play with the least of these, the stars, and Raven let loose the stars through the longhouse smoke-hole; next Raven released the treasured moon, when the slaves weren't looking; at the opportune moment he transformed into a raven and with the sun in his beak, he attempted his escape; the Great Chief commanded the smoke hole to be shut, it trapped Raven midway, the sun's fire and smoke blackened Raven's white feathers; he wriggled free and liberated the sun for the earth's inhabitants.

The ancient Chinese calendar recognized 12 moons; the moon goddess Chang Xi or Ever Breath's 12 children or moons rotated their pilgrimage across the sky. Another account has Chang E, or Ever Sublime, consuming a stolen potion of immortality, thereby creating her as the goddess of the moon as she rose up into the sky. Arctic dwellers describe the sun and moon originating from a man chasing his amour, his sister; they ran so quickly that their bodies lifted into the skies, his sister became the sun and he the moon, so that to this day the moon chases the sun; their brief embrace creates an eclipse. The Mayan legend reveals that the sun god's only journey through the sky was on the initial day; a disk with his reflection is now in the sky. The stars, according to Slavonic legends, are the children of the sun and the moon.

Thus, the earth and the universe were very personal to the early peoples of the world, to the point of being considered family or part of the clan. Many tribes, like the Pueblos, attempted to live in harmony with the movements of the planets, and so it is understandable why the earth and star systems were created in our image.

The galaxy, its movements, their movements, and accompanying legends powerfully influenced civilizations. Here is a representation of a Haida story concerning Raven and the Moon.

Source: Illustration by Steven Yates.

Humans, Animals, and Plants

> And God said, Let the waters bring forth abundantly the moving creature that hath life, and fowl that may fly above the earth . . . And God created great whales . . . And God saw that it was good. And the evening and the morning were the fifth day. So God created man in his own image, in the image of God created he him: male and female created he them . . . And God saw every thing that he had made, and behold, it was very good. And the evening and the morning were the sixth day. (KJV)

From Egypt, the Heliopolis explains how the god Atum, the "ancestor of humankind," created from himself the first human couple. In Northern Europe, the gods Odin and his brothers Vili and Ve, upon discovering two dead tree trunks, proceeded to create the human male—Ask, and female—Embla. In the Haida legends Raven finds humans emerging from a clamshell washed up on the shore. The African Togo legends inform that the creator brought the humans down from the sky via a chain, to live on Earth. Insects fell from heaven in the Korean legend, as Miruk prayed to be able to create humans while holding a golden tray and a silver tray; those that fell upon the golden tray transformed into men and those on the silver into women. From Uganda comes the legend of the creator Gulu and his daughter and son; the daughter married the primordial man and gave birth to children, and when they refused to allow her brother to marry their children, he created death. The *Brihadaranyaka Upanishad* of India tells of the creation of man; he was lonely, and so separated himself into male and female. A Greek legend told by Plato explains how the early peoples were male/female, female/female, and male/male. The gods split them in two; so that to this day, each person is still trying to find his or her "other half."

Some creations took several processes or numerous attempts to perfect. The primordial Hopis at one time lived in caves and resembled insects; Grandmother Spider escorted them through a long cavern, and the journey transmogrified them into animals. After another pilgrimage with Spider Grandmother they completed the evolutionary process into human beings. Then in order to separate from the evil people, a ladder of bamboo grown tall through the power of songs was employed to reach the sky world; then two young warrior gods transformed that world of mud into hills, valleys, and plant life. Afterward, Spider Grandmother instructed the people to make disks, and then to hurl them into the sky, and so created the sun and the moon. When the world was complete, the people emerged from the *sipapu* and were instructed to go separate ways and migrate. Among the Aztecs, legends recount how the world had undergone five creations and four destructions, each resulting from battles between positive and negative forces; and that humankind's final origins are a mythical island called Aztlan. With the Mayan creators Gugumatz and Huracan, four attempts were made before creating the kind of people they desired; during the process they even called upon *their own* ancestral diviners for assistance. The Inca god first created giants from rocks, then destroyed them; then fashioned people from clay and painted them distinctly to create various cultures.

In Greek mythology, humans were created twice; the first time Prometheus fashioned humans from earth and water; later when Zeus was upset with the humans' sacrificial offering, he withheld fire from them. Prometheus then stole it for the humans. At the behest of Zeus, Hephaestus formed the first female, Pandora, from clay and water, and she was sent with a gift, a vase filled with miseries that fell upon the earth. Zeus destroyed the first humans in a flood; after which it was Deucalion and his wife Pyrrha, with guidance from Titan Themis, who walked along tossing rocks over their shoulder to recreate humans; men sprouted from the rocks thrown by the husband, while women sprang from those of the wife.

Sumerian legends recount generations of gods, each with a specific duty on Earth. Some of the gods' tasks involved hard labor, which grieved them. Humans were created to spare the gods these menial tasks. In Babylonian legends, humans were created to "bear the yoke"; the blood of a slain god combined with clay created seven human beings. Clay was also employed in an Egyptian origin legend, when the god Khnum created people on a potter's wheel. In China the goddess Woman Gua sculpted humans from yellow clay, and then mass-produced more humans from mud falling in a furrow, thereby creating the upper and lower caste system.

Lesser gods were also nominated to "finish" the creation project, as with the brothers Enmesh (Summer) and Enten (Winter); or the two daughters of Spiderwoman, who were given baskets filled with objects to create flora and fauna. During the final stages of creation, humans and animals could converse with one another, as with the snake in the Garden of Eden; and in the Tlingit and Haida legends where humans and animals could transform into each other, marriages sometimes occurred among the species. Magic was evident as the mythical creations ensued; for example the legend of the man Naatslanei, who created killer whales by carving them from yellow cedar in order to institute revenge upon his brothers-in-law who deserted him for dead upon an island rock.

Amythia

The introduction of the theory of evolution, over 100 years ago, liberated the scientific mind while it shook the Christian world to its foundation. Christians were then subjected to the condition that Indigenous tribes worldwide faced during colonization: to be informed that their belief system was benighted, a myth, a fictional myopic story. Friedrich Nietzsche's *Thus Spake Zarathustra* not only makes the controversial declaration "God is dead," but adds that this resulted from our own "knives." In *The Birth of Tragedy,* Nietzsche further posits that "myth-less" humanity's displacement formulated the circuitous exploration for knowledge following the ruination of their mythical touchstone; later, philosopher William Barrett claimed that "neuroticism" was the consequence. The composer Richard Wagner's opera cycle *Der Ring des Nibelungen* theatrically encapsulated this moment in history, this witnessing of the theomachy and the death of the gods in power. It is Loyal Rue who coined the term *amythia* for the emptiness felt by these modern Christian peoples. Rue speculated that unless our cultures rebalance by discovering an approach to cosmology and morality that is framed in workable symbols once again, thereby creating a revised belief system, our survival may not be ensured through the end of the 21st century.

The Myth Returns

Richard Wagner's operatic poem *Der Ring des Nibelungen* contains a tetralogy of a unique perspective on the cycle of mythological archetypes. "Das Rheingold" reveals the deep primordial waters of the Rhine, from which the universe was created; we are introduced to the maidens of the Rhine who, much like Dagon of the Philistines, have a fishlike tail; the dwarfs come next, who in earlier versions were also partly creatures of the water, which would then represent the monsters that first formed from the primordial slime; then the gods and goddesses and giants appeared, which is similar to the Mayan stages. Then within "Die Walküre" the mortal children of the god Wotan incite his wrath, to the point of his ordering their annihilation, in similitude with Zeus' wrath toward the humans. The independent choices of the heroine Brünnhilde and her estrangement from her father parallel the autonomous actions of the children of Father Sky and Mother Earth, not to maintain the status quo, which forced a separation; as well as Prometheus' interception for the clans of humans. In "Siegfried," the hero wields the sword Notung, kills the dragon, receives the golden ring, and rescues Brünnhilde, reflecting the newly discovered power of the offspring of Father Sky and Mother Earth. The opera "Götterdämmerung" reflects the lingering magic, as when Brünnhilde reveals the protection she has bestowed on her husband. In the end the gods are destroyed, but the world continues. Interestingly, the Rhinemaidens are still as beautiful and youthful as ever, and Erda, Mother Earth it is assumed, still sleeps within the earth, perhaps using the Dreamtime to envision the next order of gods.

The culturally distinct transmundane myths of creation have been at the nucleus of humankind's belief system for thousands of years. It appears that mythological history has repeated itself in this modern age: since the end of the 19th century the world has witnessed the gods subjected to scrutiny by human children who were suffocating beneath the weight of religion. Meanwhile, the accumulated knowledge of the cosmos, of philosophy, of medicinal plants and agriculture (all ascertained during their ancestors' immersion in "myth") is being used to create a new world. Comparable to the chaos initiated by the beginning stages of the universe, the new scientific thought brought a chaos of its own and created a space and time for a world of new thought. Faith in the legends and myths of ancestors and the secular empirical science at first appeared at an impasse, and although traditionalists continue to hold fast to a 7–human-day creation (Genesis), growing numbers in today's diverse theology embrace both evolution and the divine. In turn, scientists are researching myths and legends for their symbolic patterns of the creation of the universe relating to scientific theories. In 1992 the COBE (Cosmic Background Explorer) satellite sent information about radiation from the big bang, proving a sudden creation; it was described as "the discovery of the century"—Stephen Hawking, and "like looking at God"—astrophysicist George Smoot. The scientific community rejoiced in the confirmation of a respected scientific theory, while the theological community celebrated the sudden birth of the universe, albeit some 13 billion years ago as opposed to the creation in 7 days, and viewed the discovery as verification of a Supreme Creator. The interpenetration of science and religion appears to be in progress, as scientific facts are integrated with the symbols of honored spiritual belief systems.

Pamela Rae Huteson

See also Adam, Creation of; Becoming and Being; Christianity; Creationism; Bible and Time; Genesis, Book of; Jainism; Mythology; Nietzsche, Friedrich; Pueblo; Totem Poles; Wagner, Richard

Further Readings

Campbell, J., & Moyers, B. (1988.) *The power of myth.* New York: Doubleday.

Cotterell, A. (1999). *Encyclopedia of world mythology.* Bath, UK: Dempsey Parr of Parragon.

Courlander, H. (1979). *The fourth world of the Hopi.* Albuquerque: University of New Mexico Press.

Freund, P. (2003). *Myths of creation.* London: Peter Owen.

Graves, R. (1968). Introduction. *New Larousse encyclopedia of mythology.* New York: Hamlyn.

Huteson, P. R. (2002). *Legends in wood, stories of the totems.* Tigard, OR: Greatland Classic.

Maclagan, D. (1977). *Creation myths: Man's introduction to the world.* London: Thames & Hudson.

Malville, J. McK. (1981). *The fermenting universe.* New York: Seabury.

Rue, L. (2004). *Amythia: Crisis in the natural history of Western culture.* Tuscaloosa: University of Alabama Press.

Sproul, B. C. (1979). *Primal myths: creating the world.* San Francisco, CA: Harper & Row.

Creationism

In its broader sense, creationism is the belief that the universe was created by a personal God, at a specific time, and for a specific purpose. In its narrower sense, creationism is the belief that the account of creation as related in the Judeo-Christian Bible is completely reliable. This is held to be the case because of the unique authority of the Bible, and because contemporary science has confirmed its account as related in the Book of Genesis. More specifically still, creationism has come to amount to the following set of assertions: that the earth was a special creation by a creator; that the law of entropy reveals deterioration in the earth as opposed to the supposed evolutionary ideas of progress; that life is also a special creation by a creator; that, once created, each species remains fixed according to its initial model; that *Homo sapiens* has an ancestry distinct from the animals; that the flood as reported by Noah is a historical event, and that, as reported in the Book of Genesis, the earth is relatively young.

The core feature of these assertions, for creationists, is that they are true because they are found in the Bible. It is only an incidental corollary that science is believed to have confirmed them. The strong emphasis on the Bible explains the largely Protestant nature of contemporary creationism. In contrast, Catholic and Orthodox varieties of Christianity have had fewer qualms about accommodating evolutionary teaching within a Christian perspective. No less a Protestant than Martin Luther spoke in terms of a 6-day creation and a worldwide flood. In the United States the Adventist prophet Ellen White (1827–1915) was one of the first to insist specifically on the main features of what is now called creationism.

Historical Background

Origins

Without doubt, the core tenets of creationism owe a large debt to the five fundamentals laid down by the Presbyterian General Assembly of 1910 in the United States as being fundamental to Christianity. The first four fundamentals all relate to the dogma of Christ: his miracles, the Virgin Birth, his bodily resurrection, and his atoning sacrifice. But the fifth fundamental laid down is that the Bible is directly inspired by God and therefore literally true. It was from this document, and the ones that followed it until 1915, that the notion of being a "fundamentalist" derived. The word *fundamentalism* was not coined until 1920. The five fundamentals were important in the growth of creationism in America.

Creationism, like the Protestant fundamentalism of which it is an offshoot, is best understood as a by-product of secularization. Since the 17th century, the Christian scriptures have receded in importance as the sole source of authoritative accounts of how the universe works and of the place of humanity in that universe. This has provoked a range of responses among Christians, with most accepting the scientific account and understanding that an amendment to the role of the Bible is required. For a significant minority of Christians, however, this response seems inadequate. To people used to seeing the Bible as the sole repository of authoritative information about the world, the new authority of science could not go unchallenged.

What has come as a surprise to many people is the strength and resilience of this backlash. As the pace of scientific, technological, and social change has quickened, so has anxiety about them developed among fundamentalists, leading, in turn, to a determination to halt what they see as a collapse of the only world that makes sense to them.

Creationist thinking had been simmering away unnoticed in some lesser theological colleges in the United States early in the 20th century. Of particular importance was the Adventist George McCready Price (1870–1962), whose books, in particular *The New Geology* (1923), presented an essentially creationist account. Price had no formal training in any area of science, but had grown up familiar with the writings of fellow-Adventist Ellen White. Mainstream opinion seemed to be moving against them at the time, and the creationist account was seen as little more than a peripheral relic.

The Scopes Trial and Its Aftermath

All this changed in 1925 as a result of the trial of a young biology teacher, John T. Scopes (1900–1970), in Tennessee. The trial attracted widespread attention, not least because of the stature of the lawyers brought in to conduct each side's argument. The creationist case was conducted by William Jennings Bryan (1860–1925) and the evolutionist champion was Clarence Darrow (1857–1938), a very well-known progressive lawyer. The creationists can be said to have won the battle but lost the war. Scopes was found guilty, since Tennessee law specifically forbade the teaching of evolution. But the negative publicity, largely at the hands of the influential journalist H. L. Mencken (1880–1956), did much to discredit the creationists' cause.

The Scopes trial stimulated a flurry of protocreationist literature around the English-speaking world, as conservative Christians woke up to the threat they perceived evolution posed to their beliefs. A quick survey of titles published outside the United States will be instructive and help dispel a long-standing fallacy that creationism is a phenomenon peculiar to that country. An early example of British antievolutionary writing in the interest of evangelical Christianity was *The Bankruptcy of Evolution* (1924) by Harold C. Morton, who made specific use of the word *creationism*. Morton was familiar with some of the works of George McCready Price, but most of his sources were British or European. In the wake of the Scopes trial an evolution protest movement (EPM) conducted a series of debates and a pamphlet campaign critical of evolutionism and its necessary links with unbelief. Their chief spokesman was Douglas Dewar, a barrister and amateur ornithologist. The EPM was also active in Australia and New Zealand and achieved its greatest victory in New Zealand in 1947 when the government of the day responded to complaints from its leading spokesperson, Dr. D. S. Milne, about the content of a radio series called *How Things Began*. Milne complained that the series was "unbalanced" in its presentation of a naturalistic account of human origins. The minister of education agreed and pulled the series, to the dismay of the Royal Society of New Zealand and much of the public.

Another prominent British antievolutionist was R. E. D. Clark, whose *Darwin: Before and After* (1948) and *The Universe: Plan or Accident?* (1949) explored many themes used later by the American creationists, such as the appeal to entropy as a disproof of the supposedly "upward" trajectory of evolution. Clark's books were part of a series published by Paternoster, a religious publishing house, and designed as refutations of a popular series of publications by the Rationalist Press Association called the Thinker's Library. Paternoster's series was called The Second Thoughts Library.

Despite all their activity, it was clear that by the end of the 1950s the antievolution movement in Britain and the English-speaking commonwealth was petering out. Contemporary British fundamentalism has not developed exclusively along creationist lines. At about this time new impetus to the movement came once more from the United States. As a result of the Scopes trial, evolution was left out of American school science teaching. The

Tennessee decision remained in force until 1967. The need for change became apparent after 1957 when the United States was embarrassed to find its science program lagging behind that of the Soviet Union, which had recently put an unmanned spacecraft, *Sputnik*, into orbit in space. Realizing it needed to catch up, the U.S. government oversaw a comprehensive overhaul of science education, which included the teaching of evolution. But this decision, coming as it did shortly before the massive social and political upheavals of the 1960s, motivated religious fundamentalists once more to bestir themselves.

After Sputnik

The first evidence of this new assertion of creationism came in 1961 when Henry M. Morris (1918–2006), an engineer, and John C. Whitcombe (1924–), an Old Testament theologian, coauthored *The Genesis Flood,* which owed a significant debt to McCready Price's earlier work. Two years later Morris helped establish the Creation Research Society (CRS), which became a leading voice of creationism in the United States.

In 1972 Morris set up a new vehicle for his cause, the Institute for Creation Research (ICR). Coincident with the establishment of the ICR was Morris's next book, *The Remarkable Birth of Planet Earth* (1972), which reiterated the central role of the Bible as a record of the creation of the earth. Morris's handling of the issue of the age of the earth can stand as representative of his overall approach: "The only way we can determine the true age of the earth," Morris wrote, "is for God to tell us what it is. And since He *has* told us, very plainly, in the Holy Scriptures that it is several thousand years in age, and no more, that ought to settle all basic questions of terrestrial chronology." This, and many other similar works, including those by Duane T. Gish (1921-), became the staple of creationist literature, being short and designed for nonspecialist readers.

At first the creationists tried to have the teaching of evolution banned and replaced by creationism. But the tide of opinion was moving against them. In 1967, the Tennessee decision from the Scopes trial of 1925 was overturned by a second challenge by a high school teacher in that state, Gary Scott. The next year Arkansas followed suit. A case going to the Supreme Court ratified the states' decisions, confirming that the bans on the teaching of evolution were unconstitutional.

As a result of these defeats, the creationists turned to a new tactic. They rebranded creationism as "creation science." Overt Christian references were expunged and a more "scientific" flavor was added. As part of their campaign to gain acceptance as a credible scientific movement, the Creation Research Society (CRS) prepared a textbook for use in schools. *Biology: A Search for Order in Complexity* (1974), by J. N. Moore and H. S. Slusher, purported to be a credible scientific work. Alongside this came a shift in their campaign goals. No longer were the creationists campaigning for a simple replacement of evolution with creationism. Now the tactic was to argue for "equal time" for the two accounts.

This was a very shrewd move, as it tapped into a deeply held preference among Americans for open disputation and for all sides to get an equal hearing. The scientific community was at something of a disadvantage as they now had the difficult job of demonstrating why "creation science" did not merit equal time. The creationists' case was helped by the intervention of some prominent antiscience philosophers such as Paul Feyerabend. At the beginning of 1977 a large number of scientists and science educators signed an open letter condemning creationism. The sponsoring committee for the letter included Isaac Asimov, Linus Pauling, and George Gaylord Simpson. The preamble began by denying that creationism is a science at all, but rather a "purely religious view held by some religious sects and persons and strongly opposed by other religious sects and persons." As evolution had the confidence of the scientific community and most of the religious community as the best available explanation of the existence of diversity of living organisms, they saw no need for poorly supported and religiously inspired alternatives to be given equal time in schools.

Scopes II

The equal-time argument was a clever move and was beginning to win support for the creationist movement. A new tactic of turning their attention away from state legislatures to local school boards, which were easier to influence, was also beginning to pay dividends. For example, in Arkansas and Louisiana, pressure from these sources persuaded their state legislatures to pass legislation in 1981 requiring equal time for creationism with evolution.

The Arkansas decision, known as Act 590, could not go unchallenged and soon developed into a test case. And a lot was at stake; the case was widely seen as a rerun of the Scopes trial 56 years previously and became known as Scopes II. The American Civil Liberties Union (ACLU) filed a case against the Arkansas Board of Education. In the case that followed, a wide range of leading theologians, scientists, and philosophers testified. But it was not a simple science-versus-religion divide. Indeed, the case presented by the evolutionists included a large number of theologians and church historians whose testimony was probably the most decisive in the case.

On January 5, 1982, Judge William Ray Overton of the District Court overturned Act 590, ruling that creationism was not a genuine scientific theory and did not justify equal time in schools alongside evolution. Overton had clearly paid attention to scientists who had testified, because he outlined a simple 5-point criterion for something to be labeled scientific, including being guided by natural law; being explanatory by reference to natural law; being empirically testable; presenting tentative conclusions; and being falsifiable. Overton then described at length how creationism failed to meet any of these criteria. A court later that year in Louisiana made the same decision, adding that creationism's main goal was to discredit scientific evolution with a religious belief masquerading as a scientific theory.

Creationism never recovered any serious momentum as a major public force after these landmark defeats. The scientific credentials for creationism had failed to achieve traction, and now the "equal time" argument had been dismissed as spurious. This is not to say, however, that creationism withdrew from the scene altogether. It has continued its program within the American evangelical community and, increasingly, in other English-speaking Protestant countries as well. Its continuing success in holding this market is reiterated each time a new opinion poll emerges that shows a high percentage of Americans reject the evolutionary account of human origins. And in Kentucky a large and generously funded creationist theme park is being developed to cater to this market.

Recent Developments

More recently, the creationist community has regrouped and rebranded itself once again, this time calling itself "intelligent design." For a short while it looked as if it had finally acquired a degree of scientific legitimacy in the form of Michael Behe's work, *Darwin's Black Box* (1996), in which the design argument was applied at the biological and molecular levels of organization. But within 2 years the grave weaknesses of Behe's argument had been given a thorough airing. Behe, as with most other supporters of intelligent design, was anxious to distance himself from the discredited creationism, but few people saw a great deal of difference. Indeed, the essential similarities were part of an important decision in Dover, Pennsylvania, where, in December 2005, Judge John E. Jones III overthrew a move by creationist parents to impose antievolutionary teaching in the classrooms there.

From the beginning, the creationist movement was beset by contradictions, no more so than in its shifting positions on science and religion. On the one hand, it demanded it be seen as a valid arm of science, but on the other, it argued that science is no less a religion than Christianity. This then tied in with the other contradiction: Creationists insisted that "secular humanism," its bête noir, was a religion and should therefore be treated as other religions (which presumably included creationism) and be banned from the classroom.

One of the ironies of American creationism is that its closest allies are conservative Muslims, whose views are very similar regarding evolution, the fixity of species, and the paramountcy of scripture as a reliable creation record. There is little active creationism in the Muslim world to date, because there is very little in the way of a scientific critique of Quranic claims about creation. Active, organized creationism is strongest in Turkey, the most secular country of the Muslim world. There the Bilim Arastirma Vakfi, or Science Research Foundation, works in ways very similar to its American colleagues.

Bill Cooke

See also Bible and Time; Creation, Myths of; Design, Intelligent; Genesis, Book of; God as Creator; Gosse, Philip Henry; Mythology; Religions and Time; Scopes "Monkey Trial" of 1925

Further Readings

Behe, M. (1996). *Darwin's black box*. New York: The Free Press.

Brockman, J. (Ed.). (2006). *Intelligent thought: Science versus the intelligent design movement*. New York: Vintage.

Eldredge, N. (2000). *The triumph of evolution and the failure of creation*. New York: Freeman.

Godfrey, L. R. (Ed.). (1984). *Scientists confront creationism*. New York: Norton.

Morris, H. M. (1972). *The remarkable birth of planet Earth*. Minneapolis, MN: Dimension Books.

Morton, H. C. (1932). *The bankruptcy of evolution*. London: Marshall Brothers.

Plimer, I. (1995). *Telling lies for God*. Milsons Point, NSW: Random House Australia.

Creativity

Over time, the definition of the term *creativity* has evolved; there are more than 60 definitions in the literature of psychology alone. The Merriam Webster dictionary defines creativity as the ability or power to create something new, or improve upon an existing product or idea through imaginative skills. Creativity is considered boundless if nurtured but does not occur unless one devotes time to cultivating the imagination. To lose oneself in creative activity is to express what is at the root of the subconscious. Thus, creation occurs as a physical manifestation of mental images that emerge from the unconscious to consciousness.

Charalampos Mainemelis, a scholar noted for his work on the relation between time and creativity, explains that the creative process takes place within a state of timelessness or intense concentration. When one is in a state of timelessness, thoughts are directed away from the self and toward that which is outside the self. Timelessness has a major impact upon creativity because for some, a sense of timelessness is sometimes perceived as counterproductive. Even though creativity and time go hand in hand, more often than not some individuals express that it is a struggle to set aside a block of time to be creative. Nonetheless, the association between creativity and time cannot be ignored, because one's creation is a reflection of one's identity that only time on task can reveal. In addition, as some observers have pointed out, time to be creative should occupy a position of greater value in our culture because humanity benefits greatly from creative producers. Indeed, creativity is central to human activity and well-being.

The spirit of creativity is life sustaining. It provides energy and inspiration. Moreover, it provides joy and satisfaction. Creativity is the impetus for productivity; yet despite all of this, the challenge of connecting the importance of creativity with time still persists. Therefore time has a way of sabotaging creativity, especially when the creative process is misunderstood.

Daydreaming is an important aspect of creativity. However, in considering the cultural context of "work," that is, laborious efforts, it is understandable that daydreaming is not encouraged. Furthermore, daydreaming is considered by some to be an example of "killing" time. In this sense, time and creativity are at odds. If, for instance, educators continue to view daydreaming as a sheer waste of time, especially for primary and secondary school-aged children, inventiveness and imaginative creativity stand to be compromised.

In our struggle to be productive and meet the standards of what society perceives as useful, the very nature of a dream-like state is underrated. Then again, how often do we as individuals declare that before making a decision, we choose to "sleep on it"? True to creativity, dreams are known to tap into the creative spirit. Here, creativity and time reconcile because time to sleep is acceptable if it is not excessive. Yet it is during this natural periodic suspension of consciousness that a series of thoughts, images, or emotions occurs, as in dreaming. It is believed that the unconscious mind is far more open to insight than the conscious mind. While daydreaming cannot sustain itself without some unfocused time to allow for sparks of innovation to ignite, dreams work in concert with time. To dream is to permit the imagination to roam freely without judgment to suppress it due to time constraints. Time to dream and time to daydream are equally important for creativity. As Edgar Allen Poe said, "Those who dream by day are cognizant of many things that escape those who dream only by night."

This entry examines (1) creativity within the context of time, (2) what is deemed creative, (3) how creativity is utilized, and (4) some of those who have shaped our culture through their creativity.

Demystifying Creativity

The definition of creativity is often contingent upon the discipline, such as Art, Science, Business, but results in a product or an outcome that emerges from the creative process. For instance, through the process of generating questions and ideas that center on specific problems, many medical discoveries have emerged to prevent or cure diseases.

Besides referencing creativity as innovative ideas that emerge through the creative process across disciplines, creativity or creative expression encompasses a state of being or frame of mind. When the focus is upon a mission or an unsolved puzzle, a positive attitude and positive thinking motivate the individual to be productive, and within an organizational context it promotes a sense of belonging. That sense of belonging or ownership, as well an enthusiastic interest in common goals, boosts creativity. Simply put, creativity involves emotion.

With regard to creativity and emotion, Lee Humphries's work illustrates the relevance of passion and optimism. Originally trained as a musician, Humphries extended his expertise to systems theory, mathematics, linguistics, and cognitive science. Although he focused on problem solving in a traditional sense, more importantly, he expressed that the impetus for the flow of ideas is emotionally driven. According to Humphries, some of the most excellent creations emerge when the design, meant to improve the quality of life for one person, is more far-reaching and benefits the masses. However, if the initial goal of the creation is to benefit society, it is important to note here that this quest by no means negates the importance of a creation that is individualistically driven. Again, every aspect of creativity is important, whether the creation is intended to address a personal or a societal need. Emotional landmarks such as an illness, death of a loved one, divorce, or the birth of a child can serve as a catalyst for creativity. Indeed, personal pain is known to deliver some of our finest work. In the final analysis, emotions drive creativity and personal needs provide pathways to meeting needs for the greater good. In short, as Humphries asserts, the excellence of a creation is not measured by what the creation is, or for whom it is intended, but rather by the extent to which its benefits serve the "we" as opposed to the "I." Equally important, the creator receives a sense of accomplishment and camaraderie when, out of pain and suffering, the creation that was meant to entertain somehow serves humankind beyond expectation. In conclusion, emotions trigger creativity and the creator experiences a deeper sense of accomplishment when the creation does more than what was initially intended.

The Magnitude of Creativity: Artistic and Scientific Creativity

Generally speaking, one may not be able to anticipate the importance of a creation, especially when it transpires in the form of art. As an illustration, the depth of importance of a song may not be realized until it is tied to a message of hope, triumph, and survival after experiencing a personal loss. That is to say, music has the potential to have a positive impact upon an individual's emotional health similar to the ways in which a medical breakthrough offers hope of surviving a seemingly terminal illness. In general, creative activity has the power to nurture resiliency for both the creator and the recipient. Potentially, both artistic and scientific creativity play an important role in attitude adjustments. In this regard, music has the capacity to encourage optimism and one's ability to look beyond a difficult situation to see the beauty of the experience. For example, creative thinkers who use art and laughter as therapy focus less on pain and more on gain. As a designer, the creative thinker is challenged by obstacles and welcomes the subsequent lessons learned. Whether the emotional boost occurs from art or science, in this sense, one cannot determine the magnitude of either artistic creativity or scientific creativity when the question of importance becomes apparent.

The psychologist Dean Keith Simonton asserts that, rather than privileging one type of creativity over another, the process that involves scientific creativity is different from artistic creativity. The creative process for the scientist is more regimented. In this manner, creativity is detached from everyday experiences or from the emotions that fuel artistic creativity. On the other hand, the artist operates under fewer constraints and the creative process is fueled by lived realities, thus expressing the feelings of a broader audience. Simply stated, the artist experiences more freedom. It is essential for the artist to have freedom to tap into the natural flow of emotions and ideas in order to fuel the imagination.

If the creative process for the artist is all-encompassing, it has been argued that the creative process for the scientist is compartmentalized. In any event, the magnitude of creativity is immeasurable, as is the magnitude of the types of creativity (basket weaving, computer technology, theology, etc.) that may be generated. Perhaps what is important is that there are different creative outcomes and, conceivably, one must turn from the creator to the recipient to determine the value.

When a creation is shared, whether artistic or scientific in nature, it takes on energy of its own. Accordingly, the potential to meet the needs of others besides the creator is exponential. In the final analysis, it is important to value and trust the ideas that unfold from the human mind and to appreciate scientific discoveries, technological advances, and cultural contributions.

The most highly creative people, as noted by Pamela Braverman Schmidt, are said to have heightened reactions to their surroundings. In other words, they possess a keen sensibility that allows them freedom to draw from nature and to transform elements of light, darkness, and beauty into representational works of art. This keen sensibility to one's environment crystallizes one's sense of identity and promotes a sense of accomplishment. Hence, creativity feeds the human spirit. It provides an avenue to having an impact on social conditions when it is viewed as a vehicle to improve upon the quality of life. Creativity is at the heart of those novel experiences that are inherently unorthodox, and unique individuals are at the heart of capturing creative flashes from the imagination. At some point or another, all human beings are creators. Therefore, all human beings possess creativity, the magnitude of which is immeasurable.

Creative Genius: Theoretical Frameworks of Creativity and Intelligence

Consider the concept of "genius." Simonton views creative genius in terms of reputation; that is, how well known creators are for their work. If creativity is truly "something" that all human beings possess, it is important to examine it from a theoretical framework. Darwin's theory on evolution has proven useful in examining creativity or what comprises creative genius. His theory provides a framework of how cultures survive, namely, the coexistence of mental and material phenomena. How humans manage the social world is contingent upon human thought, as in creativity.

In reference to creativity, the primary focus of Darwinian theory is the degree of transferable variations. Therefore, when creativity is defined as the ability to generate variations of an idea or a creation, the pool of creative genius expands. Although some individuals are considered to be a "one-hit wonder," sometimes that one "hit" or creation earns fame for the creator due to the extent of creative versatility that the creation carries. Moreover, creativity is linked to every form of human endeavor. That is to say, creativity is the ability to transform nothing into something and something into something more. To this end, every human being is engaged in the creative process at some point or another.

Psychologist Howard Gardner views creativity as phenomenological. He explains creativity as divergent thinking (e.g., brainstorming and elaboration) and intelligence as convergent thinking (i.e., more analytic and evaluative). When creativity is viewed from multiple levels such as spiritually, socially, economically, or intellectually, Gardner's working theory on multiple intelligences (MI) provides yet another theoretical framework with which to view creativity. Although the word *intelligence* is used to explain a process of how individuals learn or process information, Gardner's eighth MI, naturalistic intelligence, provides understanding of an individual who is aware of how nature impacts human existence as we know it. In other words, the naturalist understands how to interpret the patterns in nature (e.g., planting, harvesting, and conserving), as well as being able to extract cures for human ailments from nature.

Gardner's most recent intelligence concerns existentialism. Existentialism entertains fundamental questions that center on human existence, the meaning of life, spirituality, universal truths, and cosmology. Although questions concerning life, death, and the existence of other life forms elsewhere in outer space are now common, existentialism as intelligence could be controversial because it hinges on nontraditional ways to view the world. At this time, existentialism is yet to be included in Gardner's list of multiple intelligences. Nevertheless, the existentialist offers unconventional ways of examining creativity. In other words, creativity unlocks the door to questions that focus on how human nature interacts with Mother Nature, Father Time, and the unknown.

In addition, creativity does not always refer to original creations or authenticity. Creativity is the ability to come up with multiple associations or uses for an existing creation and make use of it beyond what was originally intended (e.g., a paperclip becomes a key). Whereas art and creativity have been closely linked, intelligence and creativity have been thought to be one and the same. Similar to defining creativity, how to define intelligence is just as expansive in its interpretations. Philosophically speaking, one might agree that intelligence and creativity are interdependent processes because it is essential that the individual possess a level of intelligence in order to be creative. Yet ways in which one may view creativity could possibly place a different spin on intelligence. The most creative people may not be thought of as the most intelligent people. For instance, a political figure may be perceived as being "highly" intelligent as opposed to being regarded as creative or vice versa. Due to the spirit of the concept of creativity, the word *genius* partners most often with intelligence. If one examines the genius of Charles Darwin or Albert Einstein, one might develop a deeper respect for creativity and how intelligence impacts humanity.

Although societal views reflect that "highly" intelligent people are creative, Roger L. Firestien argues that all human beings possess creativity and that creativity exists in every aspect of human thought. Case in point: Intelligence is not an indication of creativity as in "highly" intelligent. For example, Charles Darwin's self-assessment informs us that he considered himself a slow learner as compared to his younger sister. Further, his teachers viewed him as ordinary. Yet according to Dean Keith Simonton, Darwin's genius has become an eponym or household word that represents discovery.

Darwin's eponymic status emanates from his theory of evolution, thus Darwinism and Darwinian theory are still referred to and discussed as a basis for understanding not only biological evolution, but cultural evolution. Although creativity and intelligence are linked, one cannot measure one's intelligence based upon one's level of creativity. Gardner, for example, looks at how individuals are intelligent or "smart." To further this point, creativity or how individuals demonstrate or exhibit their creative nature may serve to determine how they are intelligent or gifted. However, creativity and intelligence are not the same. According to psychologist Joy P. Guilford's research, an individual may be far more creative than intelligent or vice versa. In brief, individuals express creativity in various ways. For example, the Dalai Lama demonstrates creativity in how he expresses his views on peace and peaceful coexistence between humankind and nature, whereas Luther Vandross demonstrates his creativity in more traditional ways through music and lyric. Nonetheless, both ways are essential in that creativity enhances the thinking process and promotes balance in one's thinking and behaviors. Creativity spawns neutral spaces where differing perspectives can meet. All things considered, in order to differentiate between creativity and intelligence and for the purpose of this work, I view intelligence as the process of acquiring knowledge, and creativity as the process of transforming that knowledge into something that is functional.

Creativity and Social Acceptance

As previously established, the relationship between creativity and time is not always reciprocal. Beyond that, other friendly and unfriendly relationships occur; for instance, creativity and social acceptance. Without a doubt, creativity has been suppressed or supported based on social acceptance or public opinion. In some cases, new ideas are sometimes regarded with suspicion, particularly when these creative expressions challenge the status quo or the ideas appear to be too futuristic. Accordingly, creative thinkers have themselves suffered ostracism and even banishment. Thus, creativity can be very political. Furthermore, the freedom to engage in creative expression can be regarded as a privilege, especially when the creator is subject to social constructions of, but not limited to, race, class, and gender. Hence, the fate of the creator depends heavily upon public acceptance.

To illustrate how politics impact creativity, the musical career of Igor Stravinsky is a prime example. Historically, musicians and composers have struggled to gain respect for their craft. In the early 20th century, when scientific pursuits and technological innovations were accorded greater prestige than the arts, Stravinsky invigorated music by reinventing the image of the musician as a skilled professional requiring the dexterity of a carpenter and the expertise of a jeweler. Such expertise resulted in a proficient manipulation of pitch and rhythms to produce variations of sound referred to as music. Stravinsky himself became recognized as a master of his craft.

With respect to creativity and social acceptance, gender imposes tension upon women creators. Hildegard Von Bingen (1098–1179), also known as the "Sybil of the Rhine," is an extraordinary study. She exemplifies creativity and spiritualism. Hildegard achieved remarkable status as an intellectual, an artist, a healer, and a theologian during a time when women were seldom valued for their opinions, let alone for their creativity. To be more precise, Hildegard achieved respect for her musical compositions, poetry, and spiritual interpretations. She made extraordinary achievements in a time when creative expression was afforded mostly to men. Some of her artistic expressions are: *Scivias* (Know the Ways of the Lord), *Liber vitae meritorum* (Book of Life's Merits) and *Liber divinorum operum* (Book of Divine Works), and *Physica* and *Causae et Curae*. Although she was not a physician, she had natural abilities to obtain healing properties from nature. Perhaps her religious path and her spiritual credentials allowed her to leave a legacy of important work that, in addition, greatly influences naturopathic professions.

As was the case with Veronica Franco (1546–1591), whose gender and class were primary in her struggle to become a respected literary figure. Although she was educated, advancing as a creative thinker was not easy in a time when women's voices were silenced by a patriarchal system. As well, her profession as a courtesan interfered with her progress in gaining social acceptance. However, Franco's creativity redefined women, not only those in the writing profession, but to a certain extent, women in general. Rather than drawing from antithetical representations of women, Franco advanced an ideology that positioned women as moral agents. As a courtesan, she took advantage of the relative freedom afforded her by virtue of her profession to participate in intellectual milieus and civic projects. To her literary credit, Veronica Franco published poetry and selected letters (*Terze rime* and *Lettere familiari a diversi*).

Concerning gender and class, Veronica Franco's life illustrates unfriendly relationships between creativity and social acceptance. Frances Ellen Watkins Harper's life, however, makes clear how creativity and social acceptance were shaped by race, class, and gender. Watkins Harper, though not a slave or born of slave parentage, was subjected to laws that governed slaves. Here, the effects of a divisive institution that advanced the enslavement of the personhood of men and women of African descent helps us to see how creativity and social acceptance were at odds. As previously stated, creativity is an important aspect of human activities. Watkins Harper used creativity to address social problems. She lectured and focused her literary work on antislavery and temperance issues (Christian principles for black women). Much like spiritual credentials for Hildegard, temperance work within the context of Christian liberation provided a space where creativity and social acceptance could become friendly acquaintances for Watkins Harper. During her era, social acceptance and creativity in the face of race, class, and gender oppression were not easy accomplishments. To her credit, Frances Ellen Watkins Harper published her poetry in 1854. *Forest Leaves, Eliza Harris Crossing the River on the Ice, To the Union Savers of Cleveland* (a piece about a young slave girl), and a host of papers and letters are examples of her work.

Zora Neale Hurston did not gain recognition for her creativity. However, her creativity was encouraged by her mother, Lucy Hurston. Although

Zora did not live during the period of American slavery, acceptance for her artistic abilities was disadvantaged by race, gender, and class bias. As well, her career was suppressed by literary themes that depicted people of African descent as victims. Public opinion also had a negative impact upon the finances of many artists. Although financial dependency weighed heavily upon Zora, her creative spirit rose to document black life with characters that fed imaginations across cultural boundaries. Zora Neale Hurston did not receive full recognition for her creativity during her lifetime. She left a humanizing genre of folklore, poetry, novels, plays, and her autobiography in spite of her intellectual lynching. Some of her most popular pieces are: *Dust Tracks; Their Eyes Were watching God; Mules and Me; Tell My Horse; How It Feels to Be Colored Me; Moses, Man of the Mountain;* and *Jonah's Gourd Vine*. Through the work of Zora Neale Hurston and a host of other artists, creative expressions grace our lives in spite of barriers such as social acceptance and time constraints.

The Potential Within Time: The Creators

Over time, humankind has made great strides in the awareness of the potential to be creators. Although creativity and time are inextricably linked, these terms do not overlap in meaning. Also, it is the prevailing ideas at the time along with culture that determines what is deemed creative. Again, Simonton speaks of scientific creativity as being different in structure compared to artistic creativity. In addition, the nature of creativity varies based on the motivation for the creative process, as in creative problem solving or the ways in which an individual disseminates knowledge. Creative thinkers are multifaceted, and creativity therefore manifests itself in many ways.

With each creative thinker comes an evolution of how humans view themselves and experience the world around them. Creativity has launched the unthinkable, as well as unleashed ideas from imaginative spaces that have improved the quality of life over time. A glimpse into the minds of creative thinkers provides a common thread: how humankind has come to be. Charles Darwin provided questions and answers concerning the meaning of life such that other philosophers, scientists, and social scientists continue to use his work to distinguish between science and spirituality.

Pierre Teilhard de Chardin, philosopher and scientist, presented what some might feel were conflicting ideas with respect to God and the universe (i.e., Catholic doctrine and evolutionary theory). Hence, some believe that God is misplaced or displaced when science is used to explain the "always was and always will be." In terms of creativity, Teilhard de Chardin's perspectives placed him in opposition to the church, and he was excommunicated. However, Teilhard de Chardin's work exemplifies the synthesis of theological, philosophical, and scientific thought that provides yet another way of understanding human creativity.

The philosopher Henri Bergson was also fascinated with the intellectual form of human thought. He explained human reality through biology, astronomy, and environmental adaptation. He viewed the life process as a plan of renewed creativity. As Arthur Mitchell put it, species survival is based upon changing the imposed conditions of existence. Alfred North Whitehead, a 20th-century British philosopher, viewed science as a way to explain modes of human perception of what is (e.g., sounds and shapes) and how lived realities are shaped. He spoke of two modes of perception: presentational immediacy and causal efficacy. Presentational immediacy is represented by symbols that are cultural in that they provide a deeper understanding of shared realities. On the other hand, causal efficacy refers to human emotions. Here, humans become aware of what has an effect on the human psyche. In this way we come to understand that creativity is dependent on the time that one is willing to invest to become creative. The physicist Albert Einstein devoted his entire life to creative thought; his revolutionary ideas on gravity, space, and time continue to influence our views of intelligence and creativity, and his theories still stand as a challenge to future thinkers and creators.

Virginia A. Batchelor

See also Bergson, Henri; Critical Reflection and Time; Dali, Salvador; Darwin, Charles; Einstein, Albert; Experiments, Thought; Teilhard de Chardin, Pierre; Wagner, Richard; Whitehead, Alfred North

Further Readings

Baltazar, E. R. (1996). *Teilhard and the supernatural.* Baltimore, MD: Helicon Press.

Bright, L. O. P., (1958). *Whitehead's philosophy of physics.* New York: Sheed and Ward.

Calder, N. (1979). *Einstein's universe: Relativity made plain—The amazing achievement of Albert Einstein and what it means today.* New York: Greenwich House.

Darwin, F. (Ed.). (1958). *The autobiography of Charles Darwin and selected letters.* New York: Dover Publications. (Original work published 1892)

Firestien, R. L. (1988). *From basics to breakthroughs: A guide to better thinking and decision making.* East Aurora, NY: United Educational Services.

Gardner, H. (1993). *Creating minds.* New York: Basic Books.

Guilford, J. P. (1950). Creativity. *American Psychologists, 5*(1950), 444–454.

Mainemelis, C. (2002). Time and timelessness: Creativity in (and out of) the temporal dimension. *Creativity Research Journal, 14*(2), 227–238.

Mitchell, A. (1944). *Creative evolution.* New York: Random House. (Original work published 1911)

Simonton, D. K. (1999). *Origins of genius: Darwinian perspectives on creativity.* New York: Oxford University Press.

Cretaceous

In geological time, the Cretaceous (from Latin *creta* meaning "chalk") is the third and last period of the Mesozoic era; it follows the Jurassic period and precedes the Paleogene. The Cretaceous extended from 145 to 65 million years ago, and it presents 12 globally recognized subdivisions (ages): Berriasian, Valanginian, Hauterivian, Barremian, Aptian, and Albian (Lower Cretaceous); and Cenomanian, Turonian, Coniacian, Santonian, Campanian, and Maastrichtian (Upper Cretaceous). The beginning of the Cretaceous is not marked by a significant mass extinction event and, by international consensus, is located coinciding with the lowest occurrence of the ammonite *Berriasella jacobi* in the fossil record. The end of the Cretaceous (also called the K-T boundary) is marked by the mineralogical and geochemical anomalies related to the impact of the Chicxulub bolide, and with the Cretaceous–Paleogene catastrophic mass extinction event.

The Cretaceous period differed from our present world in several major respects: It was a much warmer world with high oceanic volcanic activity and sea levels higher than those of today. Moreover, there were complex biological continental and marine communities dominated by large reptiles such as the dinosaurs.

Continental Breakup

By the beginning of the Cretaceous, the old supercontinent Pangea divided into two large continents: the northern Laurasia (including present-day North America, Europe, and Asia), and the southern Gondwana (including present-day South America, Africa, Antarctica, Australia, and India-Madagascar). They were separated by an east–west equatorial seaway known as the Tethys Ocean. During the Cretaceous, there was a second phase of continental breakup. In Laurasia, the drifting of the continents caused the separation between North America and Europe and the birth of the North Atlantic Ocean. Moreover, Gondwana began to break into four large pieces: South America, Antarctica-Australia, Africa, and India-Madagascar. The progressive drifting of these continents opened the South Atlantic and Indian oceans. These plate tectonic movements during the Cretaceous were concurrent with a period of unusual seafloor spreading. For example, the volume of mid-oceanic crust produced in the Aptian-Campanian interval was almost three times greater than in the Jurassic or Paleocene periods. The high oceanic volcanic activity caused flooding of the continents, especially around the Cenomanian–Turonian when the sea level was about 200 meters higher than at present, and one third of present-day Earth's land area was submerged. During that time, Europe was an archipelago.

Climate Change

The abundant emission of volcanic greenhouse gases (mainly carbon dioxide) into the atmosphere-ocean system caused a global warming during the middle part of the Cretaceous, about 120 to 80 million years ago. This interval is considered an example of ice-free greenhouse climate conditions. Fossil records suggest a gentler latitudinal temperature gradient becoming the high-latitude climate that was one of the warmest in the earth's history. For example, Upper Cretaceous dinosaurs and palm trees were present in the Arctic Polar Circle, in Antarctica, and in southern Australia; Cenomanian breadfruits flourished in Greenland; and crocodiles and turtles inhabited the Turonian–Coniacian Canadian Arctic. Although there is evidence of some cooler episodes in the Lower Cretaceous, geological and geochemical data support that the global annual mean temperature during the Cretaceous was 6°C to 14°C higher than at present.

The absence of high-latitude ice caps during most of the Cretaceous contributed to the maintenance of considerably higher sea levels, forming numerous Tethyan shallow seaways in southern Laurasia platforms. Warm waters coming from the Tethys were transported northward, warming the polar regions. In contrast to what occurs at present, oceanic circulation during the Cretaceous was driven mostly by warm, saline deep water derived from low-latitude areas with high evaporation. The locus of deepwater formation was not the cold polar waters, which occupy the deep ocean at present, but the warm Tethyan waters. These conditions were favorable for the development of the well-known oceanic anoxic events (OAEs) that occur only during short intervals of very warm climate that is characterized by high levels of carbon dioxide. OAEs stratigraphic records consist of widespread, episodic deposits of organic-rich shales in the ocean basins. The characteristic anomalous accumulation of organic matter in these rocks corresponds to conditions of low levels of dissolved oxygen (anoxia), high biological productivity (atmospheric carbon dioxide led to increased weathering of the continents and greater delivery and availability of nutrients in the marine realm), and poorly oxygenated deep water. It is thought that mid-Cretaceous OAEs were the result of an excess of carbon dioxide in the atmosphere-hydrosphere system from volcanic eruptions, and of the alteration of deepwater circulation patterns.

Effects on the Biosphere

Tectonic forcing of climate and ocean fertility had a profound impact on terrestrial and marine ecosystems and on the evolution of life during the Cretaceous. The breakup of the Laurasia and Gondwana supercontinents led to increased regional differences in flora and fauna between the resultant continents. The mild climatic conditions favored the development of ectothermic animals like reptiles, amphibians, or fish, whose internal body temperature is the same as the temperature of their surroundings. Dinosaurs are generally reckoned to have been the dominant terrestrial vertebrates from the Upper Triassic through the K-T boundary. Some Cretaceous dinosaurs are popularly known, including *Tyrannosaurus, Triceratops,* and *Velociraptor.* The large sauropods (quadrupedal herbivorous dinosaurs) that had dominated in the Jurassic period declined during the Cretaceous, being replaced in importance by the iguanodontids, such as *Iguanodon.* Pterosaurs were common for most of the Cretaceous, though not in the last millions of years due to ecological competition with new types of birds. During the Cretaceous, giant crocodile and new insect and mammal groups appear, as well as the first flowering plants (angiosperms).

Mild climatic conditions and the existence of extended shallow tropical seas strongly affected the evolution of marine communities. Plesiosaurs, mosasaurs, and other marine reptiles coexisted with rays, sharks, groups of modern fishes, and with ammonites and belemnite cephalopods. Rudist and inoceramid bivalves, echinoderms, and benthic foraminifera were abundant in the bottoms of the Cretaceous seas. Floating at the sea surface, microorganisms with calcareous test, such as coccolithophores or planktic foraminifera, were ubiquitous. The gradual accumulation of the minute calcite plates and test on the sea bottom formed a large quantity of chalk, a soft, white, porous sedimentary rock that is very abundant in the Cretaceous.

Growing interest in the Cretaceous climate is largely a product of the current concern over modern human-induced global warming. Studying the complex Cretaceous world offers a good opportunity to understand and appreciate how the biosphere responds to climate change in terms of migration, extinction, adaptation, diversification, and organic evolution.

José Antonio Arz

See also Chicxulub Crater; Dinosaurs; Evolution, Organic; Extinction; Extinction and Evolution; Extinctions,

Mass; Fossil Record; Geologic Timescale; Geology; Global Warming; K-T Boundary; Paleontology; Pangea; Permian Extinction; Plate Tectonics

Further Readings

Barrera, E., & Johnson, C. C. (Eds.). (1999). Evolution of the Cretaceous ocean-climate system [Special paper]. *Geological Society of America, 332.*

Gradstein, F. M., Ogg, J. G., & Smith, A. G. (Eds.). (2004). *A geologic time scale 2004.* Cambridge, UK: Cambridge University Press.

Skelton, P. (Ed.). (2003). *The Cretaceous world.* Cambridge, UK: Cambridge University Press.

Critical Period Hypothesis

The critical period hypothesis states that there is a specific and limited time for language acquisition. More specifically, this hypothesis states that the first few years of a child's life is the critical time in which an individual can acquire language if presented with adequate stimuli. Proponents of the hypothesis argue that if a child does not receive the appropriate stimuli during this "critical period," then the individual will never achieve full command of language. In other words, once a child passes a certain age without language acquisition, it is not possible to learn language at a later age.

The scientific focus on a critical time for language acquisition began in the late 1950s when neurologist Wilder Penfield discussed language acquisition from a physiological perspective. Penfield pointed to the superiority for learning language demonstrated by young children. He argued that children learn language easily before the age of 9; however, after the age of 9, learning language becomes difficult. Penfield claimed that the reason for this change in the ability to learn language was due to the plasticity of the human brain. The brain of the child is plastic, whereas the adult brain is rigid.

In 1967, linguist Eric Lenneberg further advanced the idea of a critical period for learning language in his classic work, *Biological Foundations of Language.* Like Penfield, Lenneberg asserted that the acquisition of language, like other biological functions, was successful only when it was stimulated at the right time and in a linguistically stimulating environment. Drawing on evidence from studies of brain growth and from clinical studies of deafness, mental retardation, and brain damage, Lenneberg claimed that there are age constraints on language acquisition caused by brain maturation. He maintained that the critical period for language learning occurs between the ages of 2 and puberty, with the crucial period occurring between 4 and 5 years of age. Lenneberg argued that before the age of 2 the brain has not developed the capacities it needs for learning language. He maintained that after puberty the brain's lateralization shuts down the brain's ability to acquire language. Therefore, if an individual did not learn language within the critical period, the individual would never be able to acquire language in any normal sense.

More recently, in 1994, psychologist and cognitive scientist Steven Pinker similarly claimed a critical time period for language acquisition by stating that language is instinctual. Language, Pinker asserted, is a biological adaptation rather than a cultural creation. He asserted that the brain contains innate means of creating an endless number of grammatical sentences from a limited vocabulary. Pinker held that the acquisition of normal language would occur for children up to 6 years of age when properly stimulated. He asserted that, after 6 years of age, the possibility of normal language acquisition declines and is rarely successful after puberty.

What evidence exists to support the critical period hypothesis? A basic limitation of the critical period hypothesis is that testing this theory, using traditional scientific methodology, is unethical. Scientists cannot intentionally isolate a child from the rest of the world for several years and then assess the effects of such isolation on language acquisition. Therefore, scientists have documented evidence of the critical period hypothesis mainly from abused and feral children who grow up deprived of exposure to language in childhood and who, consequently, do not acquire language normally. The most famous example used to demonstrate evidence of this hypothesis is the case of Genie, a pseudonym for a girl discovered in 1974, at the age of 13, strapped to a potty chair and wearing diapers. Genie had little linguistic ability and, over several years of rehabilitation, was unable to acquire language completely, although researchers involved in Genie's rehabilitation disagreed on the degree to which she acquired the normal use of language.

Critics of the critical period hypothesis point to the use of examples of abused children and feral children as the central limitation of empirical evidence for this hypothesis. They argue that the lack of language in later life may be due to deprived and extreme social and physical environments that cause neurological changes in the brain, rather than specifically to the lack of exposure to language. In addition, behavioral approaches challenge the biological view of language acquisition and maintain that individuals learn language like any other behavior, through positive reinforcement. Therefore, they argue, it is possible to gain new skills, including learning language, at any age.

Researchers have extended the study of the critical period hypothesis to deaf children learning American Sign Language (ASL) and older learners of a second language. For deaf children learning ASL, there is evidence that language learning ability declines with age, but there is no sudden drop off at puberty. Children exposed to ASL at birth become the best at learning the language. Research examining older learners of a second language consistently indicates that most individuals are able to learn a second language when they are well into adulthood. However, there is a continuous decline in the ease of learning a second language with age. Researchers have found that learning a second language from mere exposure to the language declines after puberty. Therefore, in the adult years, the individual wanting to learn a second language has to spend much time and focused effort studying the language. Moreover, research indicates that adult second language learners nearly always retain an identifiable foreign accent that children as second-language learners do not display.

Patricia E. Erickson

See also Consciousness; Creativity; Language; Memory; Psychology and Time

Further Readings

Bialystok, E., & Hakuta, K. (1994). *In other words: The science and psychology of second language acquisition.* New York: HarperCollins.

Lenneberg, E. (1967). *Biological foundations of language.* New York: Wiley.

Penfield, W., & Roberts, L. (1959). *Speech and brain mechanisms.* Princeton, NJ: Princeton University Press.

Pinker, S. (1994). *The language instinct.* New York: Morrow.

Critical Reflection and Time

Anthropology, biology, geology, and physics evolved a compilation of theories and related methodologies born from the critical reflection and creative deliberation of some of history's most brilliant minds. Yet, theories from evolution to relativity did not emerge spontaneously. Their named progenitors needed a key ingredient to assist in their ideas' long germination. That key ingredient is time.

Giordano Bruno (1548–1600)

Infinite space and eternal time were Bruno's great visions; as departures from the orthodoxy of his time, these visions ultimately cost him his life. Trained in theology as a monk, Bruno held vast knowledge, which he vigorously added to, likely until the day of his execution for heresy. Between years of nomadic existence and offering public and academic lectures, Bruno reflected on and perceived fallacies in the universal understandings of his day. Staying a step ahead of the authorities who sought his arrest for heretical beliefs, Bruno found reflection inspiring and vehemently defended his philosophical discoveries, even under severe duress. While his collected knowledge, through self-education, armed the philosopher with insight, it was undoubtedly his time in solitary reflection that brought about his comprehension of and belief in a universe of eternal time without end.

Baruch de Spinoza (1632–1677)

Spinoza reasoned that every occurrence, physical or mental, was integral to a larger, sustaining entity that he equated interchangeably with God and Nature. Such a profound perspective, however, was not attained overnight. Spinoza spent much of his adolescence and adulthood investigating new technological advances while simultaneously weighing and considering the philosophical theses of his contemporaries and of earlier philosophers. Ultimately, Spinoza arrived at the aforementioned ideas, as well as a critical geometrical methodology, well in advance of the prevailing thought of his time. Yet, it was not the role of a teacher or wealth through inheritance that provided Spinoza the opportunity to reflect on others' discoveries and discourses. For most of his adult life in the city of Amsterdam, Spinoza pursued the trade of crafting and cleaning glass lenses, a career that provided the philosopher not only with the means to survive, but also the time to reflect on all that he had encountered.

Charles Darwin (1809–1882) and Alfred Russel Wallace (1823–1913)

Evolutionary theory, as proposed by Darwin and Wallace, revolutionized science in general and the understanding of biological development throughout time in particular. Darwin certainly received more recognition than Wallace did for the theory of natural selection and held different perspectives on issues, including the placement of Indigenous peoples within the framework of evolution. Yet, both naturalists spent considerable time reflecting on their observations of biological specimens before proposing their ideas about organic evolution. Darwin's legendary voyage on HMS *Beagle,* particularly its visit to the Galapagos Islands (1835), and Wallace's excursions into South America and Indonesia, provided each with a wide array of species to observe and study over extended periods of time. With both of them guided by the research of contemporary geologists and paleontologists, they separately developed ideas about evolution, taking years to reflect on their experiences before publishing their findings and conclusions. For Darwin and Wallace, time for critically reflecting on the diverse environments and multiple species they encountered provided the impetus for the eventual generation of the idea of natural selection. One has to wonder where our understanding of evolution would be had each quickly published his notes, as opposed to taking time to reflect on them.

Alfred North Whitehead (1861–1947)

Whitehead's life represents the epitome of critical and creative reflection. With a broad array of interests, especially process philosophy and relativity physics, he embraced life through the study of thought, time, and change. Ultimately, his experiences led him to perceive life as reflecting what individuals encounter and how they react to events. As with the great thinkers previously mentioned, Whitehead did not reach his cosmological conclusions as a youth. Rather, it was over a span of nearly 70 years and through multiple careers that he acquired his impressive understanding of time, change, and creativity.

Albert Einstein (1879–1955)

Einstein is arguably the most famous physicist of the 20th century. Through his own observations and collaborations with others, he ultimately influenced the world as few other scientists have. As a young man who often struggled to find employment or worked in less than optimal jobs, such as his work at the Bern patent office, Einstein used his time away from work to delve into physics and philosophy, consequently venturing off on his own intellectual path. Einstein's own view on the failure of his early conclusions substantiated his continued search for a universal physics as a result of rigorous reflection on scientific experiments and philosophical speculations. Today, Einstein's highly original theories of relativity are justifiably considered a major triumph of scientific thought and the very model of a solid contribution to theoretical physics. It is the time that Einstein reserved for critical reflection that ultimately enabled him to generate his greatest ideas.

Pierre Teilhard de Chardin (1881–1955)

Teilhard, a Jesuit priest who was also an avid scholar, is widely acknowledged for his contributions to geology and his advocacy for the theory of evolution. Unfortunately, Teilhard did not live to see the publication of his great works concerning evolution and his own thoughts on God. Yet, from even a cursory evaluation of Teilhard's efforts and writings, it is clear that his interests in the evolutionary sciences, his excursions to study the geologic formations of China (including the Zhoukoudian site), and his exposure to the tragic events of World War I, as well as his personal struggles to support the teaching of evolution, helped to shape his own thoughts over his lifetime. Teilhard's ultimate views on God and the place of humanity in a spiritual universe, evidenced in works including *The Phenomenon of Man* (1940) and *Man's Place in Nature: The Human Zoological Group* (1950), highlight his belief in an evolving universe. According to Teilhard, evolution will lead all humankind to an incomprehensible, mystical future existence, which he referred to as the Omega Point. Through careful observation of geological and biological processes, the comparison of remains of past and present human species, and after decades of reflection on what he had witnessed as a scientist and priest, Teilhard arrived at an unorthodox vision of the meaning and purpose of humankind within the process of evolution.

Neil Patrick O'Donnell

See also Bruno, Giordano; Darwin, Charles; Einstein, Albert; Spinoza, Baruch de; Teilhard de Chardin, Pierre; Whitehead, Alfred North

Further Readings

Cahn, S. M. (1990). *Classics of Western philosophy.* Indianapolis, IN: Hackett.

Murrell, J. N., & Grobert, N. (2002, January). The centenary of Einstein's first scientific paper. *Notes and Records of the Royal Society of London, 56*(1), pp. 89–94.

Tattersal, I., & Mowbray, K. (2006). Wallace, Alfred Russel. In H. J. Birx (Ed.), *The encyclopedia of anthropology* (pp. 2295–2296). Thousand Oaks, CA: Sage.

Cronus (Kronos)

In ancient Greek myth, Cronus (Κρόνος = Kronos) is the youngest brother of the titans and son of Uranus, the god of the sky, and Gaia, the goddess of the earth. In connection with Chronos, the personification of time, he plays an important role in time perception in ancient Greek myth. Later he was associated by the Romans with Saturn, god of the planets and of agriculture.

Cronus' father Uranus so hated his children that he banished them to Tartarus, below the earth. Consequently his wife Gaia gave birth to her children secretly. Eventually she put her son up to fight against his father. Cronus took a sickle, castrated Uranus, and threw the genitals into the sea. Aphrodite, the goddess of love, grew out of the sea's arising foam and was therefore called Aphrodite (the foam-born). Furies, giants, and nymphs emerged from Uranus's blood that dripped on the ground. Cronus liberated his brothers and sisters, and they proclaimed him their ruler. A prophecy told him that a fate similar to his father's would strike him. To prevent this prediction from coming true, he swallowed all children to which his wife Rhea gave birth, but she planned to deceive him to protect her son Zeus. She delivered Zeus in the secret place Lyktos and instead of the child, Rhea gave her husband a stone to eat, which was wrapped up in clothes. Zeus, successfully hidden by his mother, grew up, and when he was a young man, cunningly castrated his father, bound him, and forced him to spit out the swallowed children.

The further destiny of Cronus is unclear. According to Homer's opinion, Cronus once again sits in Tartarus; Hesiod, on the other hand, describes him as a friendly king of the dead heroes on the isle of the blessed at the edge of the universe. Under the supremacy of Cronus, the people were believed to have lived in happiness, without worries and fears. They did not have to work, ate wild fruits and honey, and did not age. As a result, this period is described as the Golden Age.

Cronus is usually represented as an old, weakly, grumpy, melancholic man with a sickle, which became a scythe in the Middle Ages, the attribute of death. However, this imagination of the god gained meaning only with the modern age. In connection with time, the sickle often gained other meanings, too. It could be an allusion to the castration of Uranus. It is also a symbol of time because the sickle is able to cut out and into something. But it could also refer to Cronus as the god of harvest. Although he was not worshipped like the other gods, once a year a kind of harvest celebration took place in his honor; it was called *Kronien.* Plutarch describes the celebration as cheerful and merry, and one in which social differences were abolished and servants also could feast.

Nevertheless, in ancient Greek representations, Cronus had no special characteristics. In the second part of the 5th century BCE he was described as a man of mature age with hair, a beard, and a coat that covered the back of the head. The Orphics saw Cronus as a dragon with the heads of bulls and lions on its hips.

Since antiquity, the titan and ruler Cronus was identified with the personification of time, chronos. According to some theories the similar spelling and pronunciation in Greek is the reason for the misidentification, because only the initial letters of the two words differ. For example in Cicero's writings you can find the equation of Cronus (Κρόνος) and Chronos (χρόνος). Associating Cronus and the word *time* continues to have consequences. Plutarch refers to this extension of meaning with reference to Cronus as the father of truth.

Chronos (χρόνος = Kronos) is the personification of time. In the Orphic theogony, Chronos/Cronus plays an important role. In some interpretations it is seen as a continuation of Hesiod's theogony, sometimes it is regarded as a parallel idea that reminds of the sovereignty of gods and grants him some special honors. In the old Orphic tradition, Chronos is missing, but he appears in Hellenistic time. There he emerges as the third original paradigm from water and mud and appears as a never-aging snake or dragon with heads of different animals. Only the rhapsodic theogony regards Chronos as a personification of time, which was not divine, as the beginning of the world. In this view he is a snake that has heads and wings on its shoulders. Chronos produced both the calm Aither and Chaos, which was seen as a high, dark room without any solid ground. He created a silver egg, from which hatched Phanes, who had four eyes, four horns, golden wings, bellowed like a bull and a lion, and was a hermaphrodite. As original god of the universe, Chronos was a symbol of development and change. In addition, Chronos was called father of truth, an allusion that might play with the idea that time brings everything to light.

In Roman religion, Cronus is equated with the god of planets, Saturn, who is also the god of agriculture.

Chronos as well as Cronus did not have a fixed place in the Greek mystery cults, so there are hardly any known rites, ritual acts, or mythological stories, and the meager information we do have is often contradictory or incoherent.

Nevertheless, this figure associated with time was absorbed by various forms of art. Paintings with illustrations of Chronos, Cronus, and Saturn were created by, for example, Vasari, Veronese, Blanchard, Rubens, Van Dyck, and Goya. They mostly focus on themes such as the castration and the swallowing of the children. In literature, the Cronus motif was used by Johann Wolfgang Friedrich Goethe in the poems *An Schwager Kronos* or *Kronos als Kunstrichter;* by Friedrich Hölderlin in the poem *Saturn und Jupiter;* and by Günter Grass in the poem *Saturn.* In fairytales like *Little Red Riding Hood* and *The Wolf and the Seven Little Goats,* the motif of swallowing and bringing somebody back is reflected, too. In music, works like Gioachino Rossini's *I Titani* and a libretto by Pietro Metastasios can be mentioned.

Sophie Annerose Naumann

See also Change; Duration; Mythology; Rome, Ancient

Further Readings

Hard, R. (2004). *Routledge handbook of Greek mythology.* London: Routledge.

Lücke, S., & Lücke H.-K. (2005). *Antike Mythologie. Ein Handbuch* [Ancient mythology: A handbook]. Wiesbaden: Marix Verlag GmbH.

Nilsson, M. (1967). *Geschichte der Griechischen Religion.* [History of Greek religion.] München: Verlag C. H. Beck.

Panofsky, E. (1964). Father Time. In R. Klibansky, E. Panofsky, & F. Saxl, *Saturn and melancholy: Studies in the history of natural philosophy, religion and art.* London: Thomas Nelson.

Cryonics

Cryonics comes from the Greek word *kryos,* meaning icy cold. Today, cryonics is the practice of lowering the body temperature of a person who is recently deceased or terminally ill to prevent the death and deterioration of living tissue. Even when a person is considered "clinically dead," a majority of the cells in the body are still alive. The hope is that by freezing either the head or the whole body, the cells that are still alive can be preserved for an extended period of time. Advocates believe that in the future, when the technology becomes available to cure diseases, the body can be restored to health. For some, cryonic suspension is considered a realistic and feasible way of overcoming death.

It was the book *The Prospect of Immortality* by Robert C. W. Ettinger that spread the idea of cryonic suspension of a human being in the United States. Published originally in 1964 and revised in 1966, the book described Ettinger's theories about life and death. In it, he states that "most of us now breathing have a good chance of physical life after death—a sober, scientific probability of revival and rejuvenation of our frozen bodies." He believed that even if the techniques of today for freezing are rudimentary and flawed, given enough time, "sooner or later our friends of the future should be equal to the task of reviving and curing us." In 1976, Ettinger helped establish and was subsequently elected president of Cryonics Institute in Clinton Township, Michigan. Known as the "father of cryonics," he remained president until 2003.

The process for preserving a body is begun as shortly after death as possible. This is to reduce further tissue deterioration. The water within the body is replaced by a cryoprotectant that, when cooled to very low temperatures, hardens like glass. This is necessary because if a cryoprotectant were not used, the cells would burst: When water freezes, it expands and forms ice crystals that would damage or kill all of the cells. This process of converting cells to a crystalline-free solid is called vitrification and is the backbone of the cryonic suspension procedure. Vitrification can also be seen in nature. Some animals, like the wood frog, can survive days or weeks with up to half of their body water frozen. The liver in these frogs produces glycerol, which lowers the freezing point and reduces ice crystal formation, causing the water to harden like glass. Patients are generally frozen using liquid nitrogen at a temperature of –196° C. Liquid nitrogen is used because it lowers the temperature in a very short time. One important effect is that when water is frozen very quickly, it does not have time to form ice crystals. This, in addition to the use of cryoprotectants, preserves as many cells as possible.

The reason why freezing a body, or any living tissue for that matter, preserves it is that lowering the temperature decreases metabolism. Metabolism is the conversion of nutrients into energy. Within normal physiological temperatures, the body breaks down nutrients to acquire energy and sustain life. As temperatures lower, metabolism slows because the chemical and enzymatic reactions that use up energy occur less rapidly. Many animals, such as the frogs mentioned earlier, can survive long periods without food as a result of decreased energy consumption. The practice of lowering metabolism is not limited to lower forms of life. The ability of the bear to survive throughout an entire winter without food is due to its low metabolism while hibernating.

The first person to be cryonically frozen with the intent of future resuscitation was Dr. James Bedford, on January 12, 1967. The 73-year-old psychology professor was frozen by scientists from the Cryonics Society of California. Using dimethyl sulfoxide (DMSO), a primitive cryoprotectant, his body was frozen first with dry ice and then transferred to liquid nitrogen. Of the 17 people preserved between 1967 and 1973, Dr. Bedford is the only one still being cryopreserved. In 1982, he was moved to the Alcor Life Extension Foundation in Scottsdale, Arizona, where he remains today. Alcor currently has 77 cryonically preserved patients. The Cryonics Institute in Michigan cares for 84 patients and an additional 50 pets.

The cryonics movement progressed slowly and was generally rejected and dismissed by the general public. Since cryonic suspension had little scientific credibility, most in the scientific community did not support it either. For some, however, the idea that a body could be preserved for thousands of years was very alluring. Through the 1980s and 1990s, scientific developments in the fields of molecular nanotechnology, computer science, and mathematics made great strides toward overcoming the biological obstacles of cryonic suspension. For example, advancements in cryoprotectants made them more effective and less toxic. A more precise understanding of organ preservation also changed the way in which the body is cooled after death. In addition to lowering the body temperature before transport to a cryonics facility, where it will then be frozen, the body's blood is first replaced with an organ-preserving solution. This solution is not a cryoprotectant. Its only purpose is to protect the organs from further cell death during transport. Prior to vitrification, it is replaced by a cryoprotectant at the cryonic facility. But for all the publicity and money spent on research, the successful freezing and thawing of a human being is not yet possible; it is the complicated thawing process that will take more time to perfect. Because the body is deceased when frozen, even if every living cell were to be resuscitated successfully, the body would still be "clinically dead."

Although the successful cryonic suspension and resuscitation of a human being is still very far off, it is not irrational to maintain that someday the technology will exist to repair any cellular damage in the body. If all obstacles are overcome with time, then the possibilities for human beings could be endless. Not only could humans live an indeterminate life span on Earth, but a cryonically suspended body could travel to places in the universe millions of light years away, and the trip would be seemingly instantaneous to the traveler.

Michael F. Gengo

See also DNA; Dying and Death; Hibernation; Longevity; Medicine, History of

Further Readings

Ettinger, R. (1966). *The prospect of immortality.* New York: Macfadden-Bartell.

Kastenbaum, R. (1989). *Encyclopedia of death* (R. Kastenbaum & B. Kastenbaum, Ed.). Phoenix, AZ: Oryx.

Kurtzman, J., & Gordon, P. (1976). *No more dying: The conquest of aging and the extension of human life.* Los Angeles: J. P. Tarcher.

Web Sites

About cryonics. (n.d.). Cryonics Institute. Retrieved October 20, 2007, from http://www.cryonics.org/reprise.html

Vitrification. (n.d.). Suspended Animation Inc. Retrieved October 24, 2007, from http://www.suspendedinc.com/vitrification.html

Cryptozoology

Cryptozoology is the study of animals that are hypothesized to exist, but concrete physical evidence to prove their existence has not yet been found. These "unknown animals" could be either undiscovered species or living specimens of species thought to be extinct. The term is derived from the Greek, and means literally "the study of hidden animals." Individuals who study and search for these animals are referred to as cryptozoologists, and the elusive animals investigated are called cryptids.

The origin of the term cryptozoology is widely credited to Bernard Heuvelmans, a Belgian zoologist. However, in Heuvelmans's own book, *On the Track of Unknown Animals,* written in 1955, he credits Ivan Sanderson, a Scottish explorer, with coining the term in 1947 or 1948.

Cryptozoology is a combination of biology and anthropology. It relies heavily on eyewitness accounts and circumstantial evidence. Stories, legends, and local folklore attract cryptozoologists, who then expend most of their energy trying to establish the existence of a creature. Then a live specimen has to be found. Throughout history Western explorers have dismissed these tales as fantasy, only to be proven wrong years later. When first reported by natives, the giant squid, mountain gorilla, platypus, and panda, to name a few, were considered hoaxes by European explorers.

Most people have heard of the more extreme examples of cryptids. Bigfoot, the Loch Ness Monster, and the Yeti are familiar, but there are literally hundreds of species rumored to exist. Cryptozoology generally does not refer to newly discovered small organisms. New species of insects and frogs, for example, are not uncommon. They are not especially difficult to find, there is simply the time factor involved in cataloging them. Cryptozoology also does not refer to ghosts, UFOs, psychics, or anything paranormal. It is also not intended to describe out-of-place animals, such as exotic pets released into the wild by disenchanted owners.

Cryptozoology has acquired a bad reputation as a pseudoscience. Critical thinking and solid research are necessary when investigating claims of a new species. An individual who hunts for a sasquatch one month and a sea serpent the next may have little background in either. A primatologist or physical anthropologist studying evidence of a sasquatch would be more likely to synthesize and apply known data properly to new evidence. Likewise, scientists with a degree in marine biology would be better able to evaluate claims of sea serpents or lake monsters. Until detailed, methodical research becomes standard practice among cryptozoologists, the field will remain disrespected by more traditional biologists and zoologists.

Jill M. Church

See also Anthropology; Extinction and Evolution; Fossil Record; Fossils, Interpretations of; Paleontology

Further Readings

Arment, C. (2004). *Cryptozoology: Science and speculation.* Landisville, PA: Coachwhip.

Coleman, L. (2007). *Mysterious America: The revised edition.* New York: Simon & Schuster.

Coleman, L., & Clark, J. (1999). *Cryptozoology A to Z: The encyclopedia of loch monsters, sasquatch, chupacabras, and other authentic mysteries of nature.* New York: Simon & Schuster.

Newton, M. (2005). *Encyclopedia of cryptozoology: A global guide to hidden animals and their pursuers.* Jefferson, NC: McFarland.

Shuker, K. (1995). *In search of prehistoric survivors: Do giant "extinct" creatures still exist?* London: Blandford.

CUSANUS

See NICHOLAS OF CUSA (CUSANUS)

CYBERTAXONOMY

Cyber-enabled taxonomy, or cybertaxonomy, represents a fusion of cyberinfrastructure and the goals of descriptive biological taxonomy. Taxonomy is the science of biological classification; its goal is to compare organisms in order to place them into groups based on defining characteristics. Cyberinfrastructure is a technological solution to obstacles that have slowed progress in descriptive taxonomy and is comprised of a foundation that provides speed and capacity for data analysis, storage, and communication, plus domain-specific hardware and software that meet the specific needs of taxonomy. Examples of domain-specific cyberinfrastructure include robotics, imaging technologies, instrumentation, and data acquisition, searching, and interpretation systems. Cybertaxonomy represents the future practice of taxonomy and promises to accelerate the processes of descriptive taxonomy without sacrifice of theoretical and procedural excellence. Virtually every aspect of descriptive taxonomy from collection, preparation, and curation of specimens to electronic publication of revisions and monographs can be improved or transformed through cybertaxonomy.

Most of the impediments to rapid advances in taxonomy have to do with issues of access: access to specimens, historic literature, existing data, and colleagues around the world. Cybertaxonomy has the potential to open access to research resources required by practicing taxonomists as well as opening their research findings to a wide range of user communities. The traditionally high standards of taxonomic research are evident in taxonomic revisions or monographs, comprehensive comparative studies of all previously described species with the addition of all newly discovered species. Due to such comprehensive studies of thousands of specimens, at most only a few monographs are completed per century for any given taxon. Consequently, a perception exists that descriptive taxonomy is inherently slow and inefficient. This is not so. Such comparative studies are in fact highly efficient means for testing large numbers of hypotheses about species simultaneously. The vision of cybertaxonomy is to compress this time of hypothesis testing by making monographs living, dynamic electronic entities that are continually updated as new specimens and characters are found. Another aspect of cybertaxonomy involves teamwork, using cyberinfrastructure to enable colleagues in several countries to collaborate by examining specimens together and consulting in real time, thereby accelerating the discovery and testing of species. Thus cyber-enabled knowledge communities would arise that are focused on particular taxa and that collaboratively manage and update all information associated with species of a given taxon.

Rudimentary examples of cybertaxonomy exist, including virtual libraries and herbaria, online monographs, remotely controlled microscopes, and access to specimen and collection databases. Cybertaxonomy, in time, will reduce the need to loan or handle specimens as well as the time and effort required to access historic literature and data from other institutions. Online monographs reduce the cost of collaborative projects and increase the visibility of taxonomic revisions or discoveries. The demands of cybertaxonomy are underpinned by innovations in digital imaging, visualization software, databases, the development of data models since the mid 1990s, and, more recently, robotics. Cybertaxonomy is dependent on emerging technologies and online communication tools rather more than on physical access to museum collections, libraries, and collecting sites. The future merger of cyberinfrastructure with goals of traditional taxonomy will increase the visibility of museum collections and vastly accelerate the work of descriptive taxonomists, making taxonomic information both openly accessible and understandable to the many users who need it.

Why Cybertaxonomy?

The current biodiversity crisis has resulted in a demand for stable classifications and reliable specimen identification. Traditional taxonomy, underfunded during the 1990s and 2000s in part due to an overemphasis on technological "solutions" to the practical problems of identifying species and assessing their cladistic (phylogenetic) relationships, has not produced the number of descriptions and revised classifications needed in order to satisfy the demand of end users, such as ecologists, policymakers, conservationists, agriculturists, foresters, and fisheries managers. The demands of end users as well as taxonomists themselves have led to the creation of hundreds of databases that reflect information content associated with specimens, many accessible through the Global Biodiversity Information Facility (GBIF) portal, growing support for a registry of animal names, scanning legacy literature, and creating a Web page for every known species. A typical specimen database minimally includes the species name, reference to higher taxa, collection locality and geographic coordinates, date of collection, name of collector, method of collection, and the name of the institution and a unique identification number. The pace at which taxonomic classifications are revised and published has slowed due to the amount of effort invested in databases and technology outweighing the number of adequate taxonomists. This imbalance has led to new initiatives in data storage, such as combined databases, library catalogs, digitized bibliographies, and image databases. Even so, a large majority of these projects do not provide taxonomists with ways to access specimens or efficiently "truth" and improve the data. Alternative technologies aimed at end users of taxonomic information are intended to provide ways with which to identify and classify species quickly without the need for traditional taxonomic methods. These technologies have put a greater burden on taxonomy, contributing to poor funding and employment opportunities. Ironically, such databases are accelerating access to information that is less frequently updated and verified than in the past.

Previous efforts to revitalize taxonomy have focused on user communities in the hope that they would step up to the challenge and do their particular part to revive species discovery, description, and testing. The high cost of emerging technologies and the lack of access to collections have prevented many user groups from revitalizing taxonomy in a way that preserves the integrity of its best theories and practices. Cheaper technologies such as online descriptive keys and DNA bar coding are being adopted by user communities as ways to mimic reliable identifications and classifications. Data associated with specimens are accessed efficiently at the same time that the testing and enhancement of the information content of those collections are ignored. User-driven initiatives tend to focus on species identification and access to existing publications and data rather than acknowledging the significant work required to create, update, and verify the status of species and the reliability of associated data. As technologies rather than theory-dependent methodologies, such approaches ultimately fail to describe, classify, and identify taxa reliably. Their use in taxonomy is highly questionable and detracts from the important scientific questions associated with taxonomy as an independent science. DNA bar coding, for example, appears to be limited as an identification tool and is potentially misleading as a species discovery tool. Its appropriate application requires the prior discovery and delimitation of species and the creation of a complete reference "library" in order to approach the reliability of traditional species identification methods. The debate surrounding end user needs versus the needs of taxonomists has generated controversy in the scientific media. Many have called for an end to the "taxonomic impediment" through quick identifications, while others have highlighted the demise of taxonomic training and funding. The taxonomic impediment entails a lack of awareness of the importance of reliable descriptions, robust classifications, and effective identifications and the continuing need to train taxonomists as well as provide opportunities for funding and employment of taxonomists, and the improvement of taxonomy's research infrastructure.

Ironically, calls to resolve the taxonomic impediment include adopting inferior alternatives rather than increased taxonomic funding, further fueling the debate between technology-driven expediencies and rigorous taxonomy. The development of cybertaxonomy is not intended only to meet end user demand, but primarily to serve taxonomy and increase the opportunities for taxonomists. Through enabling taxonomic research at the highest levels of quality and efficiency, end users will gain access to the most reliable information possible, which is presumably what all end users would choose. And taxonomists will be positioned to pursue the "big questions" of their field that remain unanswered and that are fundamental to understanding Earth's biological diversity.

Taxonomy in Practice

Taxonomy, as noted earlier, is the science of biological classification; the goal of taxonomy is to compare organisms in order to place them into groups based on defining characteristics. These groups may be artificial, for example based on one arbitrary character system; or natural, based on shared or common relationships. Artificial groups are often based on few characteristics, such as the sexual organs of plants as devised by the 18th-century naturalist Carl Linnaeus (1707–1778), although they may be based on large numbers of characteristics as in phenetics, popular in the 1970s. Although artificial systems can help in identifying organisms through the generation of identification keys, they do not necessarily reflect the relationships that unite natural or real groups. A major breakthrough in taxonomy occurred in the early 19th century when taxonomists Augustine Pyramus de Candolle (1778–1841), Antoine Laurent Jussieu (1748–1836), and Jean-Baptiste Lamarck (1744–1829) attempted to order groups based on relationships, or homologies, that are shared among members of a natural group. Many taxonomic groups described in the 19th century remain in use today. Nevertheless, classifications must be repeatedly revised and taxa added or deleted if they are to remain reflections of our full knowledge and evidence of such natural groupings.

Willi Hennig (1913–1976) refined the concept of natural classifications even further. His vision was for classifications to be the general reference system for biology, reasoning that the only common thread running through all life was phylogeny, their shared history. Hennig understood that classifications provided a conceptual framework within which to consider any biological fact or phenomenon in the context of evolutionary history; that such natural classifications were the best all-around way to store and retrieve information; and that natural classifications allowed for predictions about the distribution of attributes not yet known. The ultimate goal of taxonomy is such a natural classification. Contributing to this goal are cladistic or phylogenetic analyses that reveal natural relationships that subsequently can be reflected in formal classifications and names.

Nomenclature

The formal naming of species and groups of species plays a role in biology whose importance cannot be overstated. Names refer to species or groups and allow for the storage, retrieval, and communication of information about them. They are also notations for taxonomists' hypotheses about taxa and their characteristics, providing an efficient way to refer to the accumulated knowledge associated with such names. International codes of nomenclature exist that guide the proper naming of species of plants, animals, and microbes.

These include provisions for dealing with situations where a type specimen is lost or destroyed. In such cases, replacements or neotypes may be designated, usually based on specimens from the original type locality, and not infrequently elevated from material available to the original describer, paratypes.

Names for species and certain other categories in the Linnaean system are typified. Types are specimens that are the name bearers for species. Types serve like international standards against which changing ideas about the identity of species or higher taxa may be referenced. There is no expectation that a type specimen is in any sense typical of its species or that it reveals all or even any particular characteristics of the species or groups to which it belongs. Species, higher taxa, and their characteristics are all hypotheses and like other hypotheses are subject to improvement through time as more specimens or evidence becomes available. If a species is later found to be comprised of several previously unrecognized species, the name applies to that division in which the type specimen is deemed to belong. Types are most often specimens that have been named, described, diagnosed, and photographed or illustrated, published, recorded, and cataloged within a museum collection. Taxonomists frequently must reexamine type specimens in order to resolve species boundary disputes and ensure stability in the application of names. Because type specimens are unique and usually fragile, many museums and herbaria are appropriately reluctant to lend them for study and taxonomists are forced to travel to many institutions in order to resolve such problems. Cybertaxonomy offers two avenues of assistance in this regard. First, as archives of images of type specimens accumulate, many questions about the specimens can be resolved by simply examining these images online, some of which may be three-dimensional (3-D) or detailed images of diagnostic characters. Second, as remotely operable microscopes become more commonplace a taxonomist can potentially examine, manipulate, and photograph a specimen from any computer in the world linked via the Internet.

A recent trend to analyze phylogenetic relationships and publish "trees" rather than revised formal classifications has resulted in a widening gap between what we think we know about natural groups and the names that refer to them. Such studies underestimate the inherent strength of precision of scientific names. Trees alone may suffice to meet the needs of a few scientists attempting to interpret their observations in the light of phylogeny, but they are not a substitute for formal classifications and names or Hennig's general reference system. Significant confusion may ensue in verbal and written communication, published findings, and use of public databases when such a gap remains unclosed.

Collections

Any specimen material that is collected in the field is deposited in a collection of some kind. Ideally, museum collections are publicly accessible repositories where types and other specimens are stored, registered, and maintained. New specimens are always being added, and some museums act as official state or national repositories for all types. Museum collections ensure that specimens are available in order to be compared to new species. Without collections it would be difficult to create new species or to validate species names. Many museums and universities allow interinstitutional loans of specimens, although this is not practical for large, fragile, or rare specimens. A large proportion of such loans rely on individual honesty and a reliable postal system, and many specimens have been lost or damaged while on loan.

Collections will remain the primary infrastructure for cybertaxonomy, just as they have been for taxonomy for centuries. Many collections have been developed largely for taxonomic research and as such may appear curious to other biologists. Collections typically do not reflect relative abundance of species in a habitat or frequency of particular "morphs" within populations. There are often as many or more specimens of species that are rare in the field as there are of species common in the field. Taxonomists place a premium on access to the full range of variation within and among species and access to as many species as possible for comparative studies. The ultimate goal of such collections is to provide a comprehensive representation of species for study and comparison. The scientific value of collections resides in their information content. Unless we know where and when specimens were collected or their identities and relationships, their value to science is enormously diminished. Thus, curators of collections and the institutions that possess collections have two fundamental obligations. First is to provide for the physical care of the specimens to maximize the period of time they remain available to science. This involves temperature and humidity control and protection from pest species. Second is to provide for the care of the information content of the collections. This primarily involves support for taxonomic research that ensures that species are accurately identified and reflect the state of our knowledge. Unless existing specimens are reassessed and newly accessioned specimens included in taxonomic works, collections retain or add very little scientific value.

Collections are at the heart of cybertaxonomy, and many of the priorities of cybertaxonomy involve access to or enhancement of the information content of collections. Ways to maximize the growth and development of collections and the expansion and improvement of taxonomic knowledge will remain the core of cybertaxonomy. Above all else, the deposition of specimens in collections makes taxonomic assertions and descriptions testable by virtue of reexamining the actual material upon which such works were based. If dire predictions of species extinctions in the 21st century are realized, collections will take on even more importance. The estimated 3 billion specimens in museums and herbaria around the world already reflect most of what we know of biodiversity. As biodiversity is diminished, collections will become literally irreplaceable evidence of biodiversity.

Literature

Taxonomic revisions, new species, or nomenclatural notes are published in scientific journals, monographs, books, and online. The majority of taxonomic literature is published in scientific journals and kept in museum or university libraries. Any revision or addition of a new species needs to be compared not only to a vouchered type specimen, but also to its diagnosis and description. The practice of recording new species or revised species, genera, and families was introduced by Linneaus in the 18th century. Publication of new species names, synonymies, or revisions is essential in keeping track of the number of described species and valid names. Access to relevant publications is limited due what each individual library holds and what material is kept elsewhere. Taxonomists who need a particular publication rely on electronic library catalogs in order to track publications in other libraries. Many museum or university libraries receive interlibrary loan requests from taxonomists. Taxonomists may also rely on societies or other scholarly networks in order to access literature that is not found in online library catalogues. Taxonomists often need to travel to libraries that do not loan rare or fragile texts.

Monographs and Revisions

The process of revision is based on periodic comprehensive reviews of all species previously described in a taxon plus the incorporation of specimens accumulated since the most recent revision, adding any newly discovered characteristics, and critically reassessing previously documented characteristics. Conclusions are expressed in revised and corrected diagnoses, and descriptions and verification of appropriate and stable name usage also typically require reexamination of type specimens. Species described in the context of revisions and monographs are almost always preferable to isolated species descriptions. In the past, the amount of unsorted material that had accumulated since the most recent revision and the number of isolated species contributed to the literature were usual indicators of the time when a new revision was called for. In the context of cybertaxonomy and taxon knowledge communities, it is possible to envision a process whereby the "knowledge base" for a taxon (the sum total data from which a current monograph could be assembled) is continuously updated as new specimens and characteristics arise. This would make monographs dynamic and always up-to-date "documents" rather than infrequently completed studies that are out of date for most of their existence. Monographs are so important in taxonomy because their focus is on a single group; they provide a comprehensive treatment of all known species in that group and all available relevant information about them. Taxonomists typically focus on monophyletic groups, meaning that they transcend geographic and ecological boundaries that often shape other biological studies. In the case of revisions, they may or may not include all species, some revisions being restricted to one or more but not all biogeographic regions. In botany there is a strong history of such geographically focused species treatments—floras—although these not infrequently follow monographs.

Any artificial constraint, such as setting arbitrary geographic bounds, obviously detracts from the comprehensive comparativeness that gives monographs their greatest strength, yet such regional works have very great value to users of taxonomic literature who need to identify species in the field. Cybertaxonomy promises to meet both needs by creating a community "knowledge base" from which monographs, floras (or faunas), or region specific species treatments could be extracted at the touch of a button. Academic societies, museums, and publishers tend to print monographs in small print runs. While demand at any one moment may not be great, the longevity of monographs is impressive. A well-done monograph may remain a standard reference for a century or more, and may change with electronic or e-monographs that are potentially renewed with every addition or correction and that can be produced on demand.

An e-monograph is an online electronic document, such as a word processing file, that contains an embedded database. The document can be reviewed by several authors, who could edit the text simultaneously. The e-monograph can be published when the initial edition is completed, either as an electronic file or as hard copy with an assigned DoI (digital object identifier). Any changes made to the e-monograph will be recorded for the next edition and updated on linked online databases such as EoL (Encyclopedia of Life) and GBIF.

End Users of Taxonomy

Taxonomists make species identifiable, provide names that enable us to communicate about species as well as retrieve data about them, and classify species in a cladistic context that enables us to interpret their attributes in an evolutionary (historical) context as well as make predictions about the distribution of properties among poorly studied species. Ecologists, conservation biologists, agriculturists, aquaculturists, government agents, policymakers, breeders, farmers, fishmongers, greengrocers, gardeners, and eco-tourists are just some of the many end users of taxonomy. The importance of a correctly identified species that is linked to a scientific name (and in some cases to standardized common names) is vital in all areas of industry, government, conservation, and biological research. Correct species descriptions ensure accurate identification of pests. Correctly assigned names help policymakers target the right groups for conservation. A misapplied name or poor species identification, for instance, could lead to mass poisoning, species extinction, or crop failure and famine. Providing high-quality taxonomy is essential in maintaining scientific integrity and rigor within society. A complete inventory of species allows biologists and land managers to detect increases or decreases in biodiversity, ecologists to detect introductions of nonnative species, and border agents to recognize trade in endangered species and to intercept introductions of pest species or potential agents of bioterrorism.

End User Impediments

The number of taxonomists and taxonomic monographs has dwindled since the 1980s. The biodiversity crisis has led to much funding being diverted away from taxonomy and toward environmental assessments, conservation projects, or molecular genetics. A lack in funding has also reduced career prospects in taxonomy and dampened the productivity of existing taxonomists. Many large, diverse, and economically, ecologically, or evolutionarily important taxa have few living experts. Because no young taxonomists are apprenticing, much existing knowledge stands to be lost and will be recreated only through inordinate expense and effort. Recent advances in molecular systematics have also had an impact on attracting younger people to phylogenetics, population dynamics, and evolutionary biology. Taxonomy as a science of classification has received criticism for being nonmolecular or "stamp collecting." Given that environmental assessments, conservation biology, and molecular systematics are dependent on taxonomy, the lack in funding since the 1980s has led to an *impediment* for end users; that is, a lack of reliable taxonomic information for those who need it. Molecular systematics and ecology are using taxonomic groups that have not been described, which leads to poorer phylogenies and environmental assessments. Because such undescribed, unnamed species are rarely vouchered with museum or herbarium specimens, many such studies cannot be repeated and are thereby marginally scientific. The call for more reliable taxonomic information sparked a debate in the late 1990s as to how to store and update taxonomic information in a reliable and user-friendly way. Cybertaxonomists will increasingly use these and other systems to more efficiently make what is known of species readily accessible to users.

Biodiversity Informatics

Electronic databases for generating keys, providing geospatial species information, and editing names and synonymies has existed since the mid-1990s as *biodiversity informatics*. The rationale behind biodiversity informatics has been to provide end users of taxonomy with data via an easily accessible technology such as electronic databases, keys, and georeferencing tools. End users can modify those data, which are then updated instantly, avoiding the need for printed publications. The innovations provided by biodiversity informatics has lead to a number of electronic resources and tools that can help taxonomists, such as online databases or names and descriptions that are edited by taxonomists, and virtual libraries.

Electronic Databases

An electronic file that contains structured data (i.e., records) is an *electronic database*. Computer software may utilize the database either by extracting the data in order to make a key or by editing the data in order to keep records up to date. The database is simply an efficient way to store data based on some types of categories. In taxonomy, a database can contain names, synonymies, descriptions, distributions, numbers of specimens, where they are kept, and the name of the person who collected them. New data can be added at any time based on data extracted elsewhere, such as another database. The Encyclopedia of Life (EoL) uses a database to organize its information on any given species. Information that is missing can be extracted elsewhere, added, and edited. Databases may be accessible to all, as in the case of Wikipedia, or only to registered users (e.g., FishBase). In some cases any edited or newly added data need to be reviewed for rigor before they are accepted and published online. Databases are used for all information systems in biodiversity informatics.

Digital Libraries

The benefit of a digital library is that it eliminates the need to borrow taxonomic texts or travel to libraries to consult rare or fragile books in order to do taxonomy. Rules of nomenclature dictate that all available names, names proposed in accordance with the codes, be taken into consideration. As an example, in zoology taxonomists must generally be aware of every species described since January 1, 1758. Thus taxonomists have a special and unusually demanding dependency on access to such rare publications. A digital library contains a database and images of texts. The database contains *metadata,* that is, a structured template that provides information such as author's name, year of publication, title, publisher, number of pages, and plates and figures. Catalog software extracts the relevant information from the database, informing the taxonomists where a particular author, title, and/or subject can be found. A digital library differs from most online catalogs in that it can also find particular words within a text, such as species names or descriptions. This information is extracted from scanned or photographed images of whole texts using optical character recognition (OCR) software. A fully accessible text in any given virtual library can provide all the information given by the metadata. The innovation of digital libraries is that texts, normally unavailable, can now be searched page by page.

Cybertaxonomy in Practice

Cybertaxonomy is emerging in a series of initiatives that each seek to resolve some aspect of the *taxonomic impediment*. Any hindrance to taxonomy, the employment or training of taxonomists, and taxonomic funding is a taxonomic impediment. The National Science Foundation (NSF) has several relevant initiatives, including Partnerships to Enhance Expertise in Taxonomy (PEET), Revisionary Syntheses in Systematics (RevSys), and Planetary Biodiversity Inventories (PBI). Other grants exist to build, maintain, and house museum collections as well as provide funding for taxonomists; for example, the Australian Biological Resources Study (ABRS). The future of cybertaxonomy lies in furthering these initiatives by incorporating technology from biodiversity informatics, medical sciences, and space exploration in order to expedite species descriptions and identifications; provide remote access to collections and virtual libraries; assist in collecting specimens in the field; and attract a new generation of taxonomists, training possibilities, and funding.

Collecting

Sampling and collecting populations in the field is time consuming and costly. The procedure for any fieldtrip involves obtaining permissions to enter reserves as well as to collect, which is followed by organizing a team of taxonomists and resources. No online technology is tailored to organize fieldtrips, obtain permissions electronically, and contact the taxonomic community. Currently, several software programs exist that are used by the travel and hospitality industries to achieve similar aims (i.e., visas, package tours, accommodation, travel, etc.). In the future, cybertaxonomy will be able to reduce the time involved organizing fieldtrips through incorporating the existing cyberinfrastructure from industry. Similarly, hardware used in remote sensing, such as satellites and geospatial technology, can be used to assess whether areas are physically accessible. Robotics used in space exploration (e.g., Mars rovers) can also be used to collect in areas not easily accessible (e.g., hydrothermal hot springs, deep sea vents, caves, boreholes). Similar advances are on the horizon for the preparation of specimens and making those specimens more accessible to experts around the globe.

Specimen Curation

The practical difficulties of specimen curation can be resolved through creating online databases that can track specimen loans, register specimens, and produce specimen labels and tags. Several software programs exist that use such databases and provide the necessary services. In the future, specimens might also be housed in collections operated by automated archival systems powered by robotics. Similar systems are in use for a large array of services from car parking to document archives. Prepared and labeled specimens could be archived in an automated system with minimal risk of damage or loss.

Remote Access to Specimens

Currently, taxonomists are impeded by collections or specimens that are housed at distant institutions. In order to complete a revision, a taxonomists would need to visit institutions that either contain rare or fragile specimens (such as types) or house specimens too numerous to send via an interinstitutional loan. Viewing specimens in this way is costly and time consuming. Taxonomists have overcome such hurdles through examining photographs of specimens, but these provide only a single view of the specimen. Technology such as remote microscope access overcomes these impediments. In the future, microscopes linked to museum or university collections could provide taxonomists with the opportunity to view the specimens in real time. Remote robotics used in medical sciences to perform live operations could be linked to such systems to give taxonomists the opportunity to examine, dissect, and rotate specimens without the need for interinstitutional loans or travel. Remote microscopy and robotics are a reality in the biological and medical sciences, and over time will be standard within all natural history museums. Advantages to institutions include having leading authorities study and photograph the specimens, contributing to online libraries of images that can obviate the need to examine the specimen again for many purposes.

The combining of both technologies in taxonomy will advance species exploration and attract students who will be able to be taught online. The full implications for educating taxonomists is yet to be realized, but the potential for students, teachers, and specimens to each be located in different cities or countries completely changes the educational possibilities.

Comparative Morphology Research and Visualization

Morphological descriptions require communication of complex visual information. A photograph with one focal point is rarely sufficient. Well-executed drawings will retain great value in comparative morphology as an artist is able to convey the meaningful parts of a structure and avoid "noise" from associated uninformative structures. A new species description contains a photograph of the type(s) and a detailed drawing or reconstruction of the specimen. The digital world of cybertaxonomy opens many additional options for creating, analyzing, sharing, and imaging morphological information. Digital images, whether from electron microscopes, digital imaging systems, or digitized artwork, are easily transmitted, and electronic monographs need not be constrained by printing costs associated with large numbers of images. Multiple focal depths can be sutured together into a single image for convex specimens. Computer-assisted tomography and other emerging systems permit fully digitized 3-D images that can be rotated or "printed" as 3-D models. Rapid progress is being made in new ways to visualize complex structures both in theaters and in single-user devices. All this promises to revolutionize the study and enjoyment of morphology for future generations.

e-Monographs and e-Revisions

An e-monograph is an online electronic document, such as a word processing file, that contains an embedded database. The document can be viewed by several authors who could edit the text simultaneously. The e-monograph can be published when the initial edition is completed, either as an electronic file or as hard copy with an assigned DoI. Any changes made to the e-monograph will be recorded for the next edition and updated on linked online databases such as EoL and GBIF.

Cybertaxonomy is the future of taxonomy. In 2006, Google recorded up to 10 hits. Within 2 years this had expanded rapidly to 1,600. Over a short period, taxonomists and the end users of taxonomy have adopted a new science, one that will define the future of biology and ways in which biologists will communicate and interact over time.

Malte C. Ebach and Quentin D. Wheeler

See also DNA; Evolution, Organic; Libraries; Museums

Further Readings

Appel, T. A. (1987). *The Cuvier-Geoffrey debate: French biology in the decades before Darwin.* Oxford, UK: Oxford University Press.

Encyclopedia of Life. (n.d.). Retrieved September 5, 2008, from http://www.eol.org

Global Biodiversity Information Facility. (n.d.). Retrieved September 5, 2008, from http://www.gbif.org

Hennig, W. (1966). *Phylogenetic systematics.* Urbana: University of Illinois Press.

Koerner, L. (1999). *Linnaeus: Nature and nation.* Cambridge, MA: Harvard University Press.

Nelson, G., & Platnick, N. (1981). *Systematics and biogeography: Cladistics and vicariance.* New York: Columbia University Press.

Wheeler, Q. D. (2008). *The new taxonomy* (Systematics Association Special Publication 76). Boca Raton, FL: CRC Press.

Williams D. M., & Ebach, M. C. (2008). *Foundations of systematics and biogeography.* New York: Springer Verlag.

D

Dalí, Salvador (1904–1989)

Salvador Dalí was an artist, self-publicist, showman, screenplay writer, poet, and clothing designer. His many occupations and interests took on his own unique style, which he considered to be true surrealism. As a surrealist, he expressed the unconscious mind such as what might be seen or thought of in dreams. Because time does not take on a solid form in the unconscious mind, Dalí found the idea of time fascinating and often used the idea in many of his paintings. Dalí was awarded the Grand Cross of Isabella the Catholic, the highest Spanish decoration. In December 1936, Dalí appeared on the cover of *Time* magazine.

Dalí was born to a middle-class family in the Catalan town of Figueres on May 11, 1904. Later in life, he and his wife, Gala, built their home in the nearby Port Lligat, where they would retreat for solitude and a chance to rejuvenate. The nearby scenery of rocks and cliffs often provided the landscape for the background in Dalí's paintings.

Although his father and mother did not encourage the youthful Dalí to pursue an artistic career, others—such as the nearby Pichot family and his drawing teacher Juan Núñez—encouraged him in his dream career. In the early 1920s Dalí went to Madrid to study painting and was drawn to the surrealist movement then attracting the attention of avant-garde artists. Many of his most famous paintings come from the late 1920s and the 1930s. In his paintings Dalí would invest an irrational object with symbolic significance, but no matter how bizarre the images in his paintings seemed, the technique and details of the objects were on an academic level of accuracy. For this, Dalí was considered a craftsman and a technical virtuoso.

Dalí used symbolism in his works referring to time. Many of the forms in his paintings are characterized by a certain fluidity, as if to demonstrate that nothing contained in the human mind is fully formed and rational. Grasshoppers or locusts, of which he had a particular phobia, appear in his works as symbols of fear and waste. Open drawers imply the presence of the unconscious mind, open for thoughts to come and go as they please. In many paintings he depicted eggs, which convey a sense of prenatal hope and love. Also, crutches, which symbolize the fragility of reality when in the mind, are a Dalí trademark. The crutches hold up and support reality so it can keep its form.

In the 1930s, Dalí spent time in Italy studying the art of the Renaissance. Many of his paintings show the influence of great painters such as Leonardo da Vinci, Caravaggio, and Velazquez. Later in his career, Dalí took a step toward mysticism. This step was influenced by the 1945 dropping of the atomic bomb in World War II, which engendered ideas concerning nuclear physics and the universe being made from particles. Many objects in his paintings would take fragmented forms as Dalí tried to show fragmented parts of an object coming together to create the one object as a whole.

Dalí not only wanted to show the unity of substance, but he also spent time during this era focusing on a spiritual theme. The iconography of

Christianity provided him a range of highly charged imagery. Many paintings focused on intermediaries between heaven and earth as representations of the spirituality of substances. To him, God was a concept that could not be grasped, and so he painted angels, heaven, and objects reaching up to the skies, such as elephants on long spindly legs.

Major Works

One of Dalí's most famous works is the *Persistence of Memory,* painted in oil on canvas in 1931. As is often found in surrealist works, there is a common image that is in some way irrational, such as the watches that appear soft and fluid in this painting. This idea of soft watches subverts the notion of a rule-bound order in nature and also focuses on the human preoccupation with time. Dalí claimed that the idea for this painting came while meditating upon the nature of Camembert cheese one night after dinner while Gala had gone out with some friends for the evening.

The background is composed of the Port Lligat scenery that he often depicted, and the painting took him only a few hours to complete. Dalí's dormant head, an image reoccurring from earlier paintings, such as the 1929 *Lugubrious Game,* is present in the painting underneath the center watch. In the bottom left corner are ants, a common symbol for Dalí of death and decay. In this case a watch covered with ants indicates that time is being devoured and is melting away, a sign that time is relative and not fixed.

Persistence of Memory *(1931) by Salvador Dali, is shown in New York's Museum of Modern Art, where it has been displayed since 1934. Perhaps Dalí's most famous painting,* Persistence of Memory *is widely viewed as a commentary that time is less rigid than most people assume.*

Source: Topham/The Image Works.

Dalí's *Crucifixion,* a 1954 oil on canvas, holds a hypercubic cross in which the body of Christ acts as the ninth cube in a grouping of cubes. This phase in his paintings indicates his turn toward mathematical conceptions. This idea of cubes may reflect the influence of Cubism, which was in vogue during the period when he was a student in Madrid. In that analytical phase, he arranged fragmented shapes in parallel formations in his paintings.

The Discovery of America by Christopher Columbus, painted in 1959, is another significant work of Dalí's. This painting came from a series in which Dalí decided to paint historical images metaphorically, in celebration of his fatherland. In this painting, earlier techniques are combined with a representation of his particle period, which stemmed from his thoughts on quantum physics and of small particles forming the matter in life.

The painting includes Saint James, the patron saint of Spain, and it is photographically precise. Columbus is depicted as a young adolescent to represent America as a young continent. The banner he carries has a painting of the Blessed Virgin on it in the form of Gala, Dalí's wife. Dalí often painted Gala and used her to represent the Virgin Mary in his paintings. In his famous painting *The Last Supper,* Dalí used Gala's face for the face of Jesus. At the front bottom center of this painting is a small sea urchin with an odd halo around it. This symbolizes the other planets that America would some day explore. With the passing of time since Dalí lived and painted, admiration and interest in Dalí's artistic creations has not diminished.

Bethany Peer

See also Consciousness; Memory; Michelangelo Buonarroti; Time, Subjective Flow of

Further Readings

Descharnes, R., & Néret, G. (1998). *Salvador Dalí: 1904–1989* (M. Hulse, Trans.). New York: Taschen.

Harris, N. (1994). *The life and works of Dali.* New York: Shooting Star Press.

Moorhouse, P. (1990). *Dali.* San Diego, CA: Thunder Bay Press.

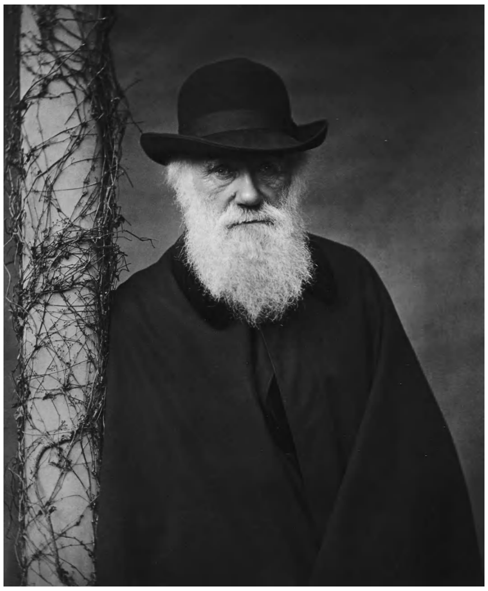
Daoism

See Taoism (Daoism)

Darwin, Charles (1809–1882)

Charles Robert Darwin is one of the greatest naturalists who ever lived. He was not only the father of evolution but also a remarkable scientist whose ideas and discoveries about the earth's history resulted in new areas for ongoing research in geology, paleontology, biology, and anthropology. His contributions to science, particularly concerning organic evolution, were possible because he would eventually embrace the vast temporal framework that was being argued for in the emerging disciplines of historical geology and comparative paleontology. Taking both time and change seriously was crucial for the young Darwin, as it resulted in his rejecting the fixity of species and, instead, accepting the mutability of life forms throughout the biological history of this planet.

Darwin's intellectual life evolved from his being a part-time naturalist, interested especially in geology, to his becoming a full-time scientist devoted primarily to biology. He developed a comprehensive orientation in geobiology, and his life was a long series of fortuitous coincidences that collectively propelled him to make major discoveries in the natural sciences. Whether speculating on the formation of coral reefs or reflecting on the similarities between the human species and the apes, Darwin came to see both geological structures and biological forms slowly changing due to the influences of natural forces on them over immense periods of time. His conceptual revolution of organic evolution also challenged the entrenched ideas of Aristotelian philosophy and the dogmatic beliefs of Thomistic theology. Consequently, as a result of Darwin's dynamic worldview, the modern thinker would never again see the earth, life forms, or humankind itself in terms of eternal fixity.



Charles Darwin at his home at Down House, Downe, Kent, United Kingdom, circa 1880.
Source: HIP/Art Resource, NY.

Before Darwin

Aristotle, the father of biology who contributed to embryology and taxonomy, had taught that plant and animal species are eternally fixed within nature. In accordance with his claim that experience reveals reality, it appeared to him that forms of life are static. Likewise, for Aristotle, the same species have always been and always will be on this planet, with none of them ever changing into a different form of life or becoming extinct. He held that, because nature is forever the same, no new species will appear on the earth. However, Aristotle maintained that the human intellect is capable of organizing biological types into a natural hierarchy of ever-increasing complexity and sensitivity; he referred to this order of species as the Great Chain of Being. Although he classified hundreds of organisms and was interested in the embryonic and postnatal development of animals, it never occurred to Aristotle that, through time and change, one species could evolve into a new species. The idea that life forms are eternally fixed dominated Western thought until the scientific writings of Charles Darwin.

Organic evolution was glimpsed in the thoughts of the Roman philosopher Lucretius, geological history was pondered by the Renaissance artist Leonardo da Vinci, and the fact that a species may produce varieties of itself was admitted by the biologist Carolus Linnaeus. Because these three thinkers held ideas that were outside the Aristotelian worldview, however, their concepts on time and change were not taken seriously.

The first major evolutionist was Jean-Baptiste de Lamarck (1744–1829). After long consideration of the geological column with its fossil record, he eventually concluded that the empirical evidence (admittedly incomplete) demonstrated that species had evolved throughout the earth's history. He presented his heretical interpretation of life in the book *Philosophy of Zoology* (1809), which first appeared in the year of Charles Darwin's birth. However, Lamarck was unable to give a satisfactory explanation for the mutability of species. His speculations on organic evolution were grounded in both the inheritance of acquired characteristics (through use and disuse), as well as a form of vitalism. However, there were no facts to support either explanation. As a result, Lamarck was unable to convince any other naturalist that species have evolved over time throughout the history of this planet.

Early Influences on Darwin

As a curious youngster, Charles Darwin had been interested in rocks and insects. He enjoyed taking nature walks into the English countryside, studying rocks, and collecting beetles. His inquisitive mind was inspired by these experiences, and it remained open to new ideas and challenging perspectives throughout his life. As a result of his activities in nature, Darwin continued to develop his acute powers of observation, description, and speculation. Years later, these mental powers would allow him to meticulously analyze organisms (e.g., barnacles, orchids, and worms) and synthesize vast amounts of empirical evidence. He was then able to derive both brute facts and those meaningful generalizations that are needed to explain complex phenomena in nature. Furthermore, over time, Darwin developed a disciplined imagination that would eventually allow him to envision the earth's history in terms of millions of years and, as a result, to accept the counterintuitive scientific truth of organic evolution.

Despite his studies in medicine at Edinburgh University and then in theology at Christ's College of the University of Cambridge, Darwin had no desire to become either a countryside minister or a medical doctor. He remained interested in geology and entomology. Like most naturalists at the time, Darwin thought that species were fixed and immutable throughout the earth's history. Although somewhat religious, he had not taken his theological studies seriously. Even so, Darwin found William Paley's *Natural Theology* (1802) to be intriguing in its argumentation. However, a few years later, he would reject its theistic premise in light of his own evolutionary explanation for life that replaced the assumed permanent design in nature. For Darwin, the alleged design in the world would be seen to be merely a temporary order rather than the manifestation of a preestablished divine plan. Of special consequence, Darwin was fascinated by the writings of the naturalist Alexander von Humboldt (1729–1781), who had made extensive travels in South America. Within only 7 years, as a result of his own trip to the southern hemisphere, Darwin's early conceptions of time and life would be turned upside down: Pervasive change would replace eternal fixity.

A Voyage of Discovery

After having accepted an invitation to join the H.M.S. *Beagle* on its 5-year voyage around the world to survey and chart the coastlines of South America, Charles Darwin anticipated studying rock strata, collecting fossil specimens, and describing wild organisms in their natural habitats. He could not have foreseen how his own view of time would radically change during this exceptional scientific journey of extraordinary discoveries. The major influence on his conception of earth history came to Darwin as a result of his reading Charles Lyell's three-volume work *Principles of Geology* (1831–1833). Lyell claimed that this planet is millions of years old, and over vast periods of time, natural forces have slowly altered its geological structures. The empirical evidence was so compelling and the rational arguments so convincing that Darwin came to accept Lyell's new interpretation of geological history. Furthermore, as climates and environments are always changing, Lyell's dynamic view of the earth's history in terms of geology now suggested to Darwin a dynamic view of the earth in terms of biology.

If, for Darwin, his voyage on the *Beagle* was the single most important event in his scientific life, then his acceptance of Lyell's geological perspective was the pivotal moment during this trip. Over the coming years, Darwin's piercing insights and a convergence of evidence would result in a paradigm shift in natural science from fixity to evolution.

Giving priority to science and reason, Darwin eventually rejected the age for this planet that had been determined through a strict, literal interpretation of the biblical story of Genesis. He now held the age of the earth to be in the millions of years (rather than being only a few thousand years old). Within this extraordinary time framework, Darwin was able to imagine the sweeping process of organic evolution.

As the *Beagle* sailed along the coastlines of South America, it frequently made stops at major ports. Some landings offered Darwin the opportunity to explore inland. In Brazil, he was delighted by the lush tropical jungles with their incredible diversity of insects. Next, in Argentina, working with crew members, Darwin helped to unearth the fossil remains of now-extinct giant mammals. Yet, these fossil specimens resembled a few of those mammals that were still living on the continent. This uncanny resemblance between past and present forms of life suggested to Darwin that there had been a historical continuity in life from prehistoric organisms to extant species (with extinctions occurring throughout the history of life on Earth). He subsequently wrote about the complex web of evolving life.

Captain Robert FitzRoy of the *Beagle*, a biblical fundamentalist, dogmatically believed the age of the earth to be no more than 10,000 years old; despite growing evidence to the contrary, he never doubted his religious opinion. In sharp contrast, for Darwin, several crucial experiences gave scientific evidence to support Lyell's dynamic interpretation of historical geology. In Chile, Darwin saw those geological changes that had recently been caused by earthquakes, tidal waves, and volcanic eruptions. These alterations to rock structures gave credence to Lyell's immense temporal framework, as it would take enormous periods of time for natural forces to significantly change the geological surface of the earth. Furthermore, Darwin had found seashells and fossil fish in the top rock strata of the Andes. He correctly reasoned that these geological layers must have once been below the surface of the Pacific Ocean and that slowly, over millions of years, natural forces had elevated these rock strata to form the mountain range of today.

For Darwin, however, the most important event of the *HMS Beagle* voyage was a 5-week stay on the Galapagos Islands in 1835. This unique archipelago consists of 15 major volcanic islands located near the equator, about 600 miles west of Ecuador. In his journal, Darwin wrote: "Hence, both in space and time, we seem to be brought somewhat near to that great fact—that mystery of mysteries—the first appearance of new beings on this earth." He was able to explore several islands, carefully describing and interpreting their geology and biology. He was surprised to discover that different species of finches, mockingbirds, iguanas, and tortoises lived on this group of islands. Moreover, these species resembled species on the mainland of South America. Nevertheless, he did not appreciate the far-reaching implications of these facts for evolution until after he had critically reflected on all the evidence from these islands when he was back in England after the trip had been completed. He concluded that the ancestors of the Galapagos species had managed to reach this archipelago from elsewhere ages ago, where they then speciated over time into different forms for different habitats. It had become obvious to Darwin that there is a direct relationship between the biological characteristics and behavior patterns of an organism and its environment in terms of adaptation, survival, reproduction, and evolution (or extinction). Even the Galapagos Islands and their unusual life forms have been changing throughout time.

The Theory of Evolution

It is very unlikely that Darwin would have developed his scientific theory of organic evolution without having read Lyell and taken the voyage on the *HMS Beagle*. When Darwin returned to England, he was convinced that species are mutable. The overwhelming scientific evidence, especially from paleontology and biogeography, clearly attested to the adaptive evolution of life forms throughout organic history on the earth; Darwin's biological framework supplemented Lyell's geological perspective. Darwin acknowledged both the creative and destructive aspects of organic evolution. Unfortunately, he still lacked an explanatory mechanism to account for the dynamic divergence and often extinction of species over unimaginable periods of planetary time.

In 1838, by chance, Darwin read Thomas Robert Malthus's monograph *An Essay on the Principle of Population* (1798, 1803). Suddenly, Malthus's description of life as a "struggle for existence" gave to Darwin his primary principle of natural selection, which would help to explain biological evolution. Despite being elated, the ailing and introverted naturalist had no plans to rush a volume on his controversial theory of evolution into print. Instead, he focused on those notes he had written during his groundbreaking trip and published them in *The Voyage of the Beagle* (1839). Furthermore, he wrote a 35-page abstract on evolution in 1842 and expanded it into a 230-page manuscript in 1844. Neither the abstract nor the manuscript was published.

The scientific philosopher Herbert Spencer (1820–1903) referred to natural selection as "the survival of the fittest," a phrase that Darwin himself would use and come to prefer in his later writings. Unlike Darwin, however, Spencer extended the evolutionary framework to include everything from the history of the entire universe to the development of human societies and ethics.

As a scientific theory, organic evolution by natural selection had enormous explanatory power. It accounted for the diversity of species on the Galapagos Islands. Organisms in different habitats required different physical characteristics and behavior patterns in order to adapt, survive, and reproduce. Over time, from a common ancestry, species would radiate into different varieties (or new species) to fill different environments. If conditions suddenly changed, then organisms were threatened with extinction; the fossil record shows the complete demise of trilobites and dinosaurs after their millions of years of successful adaptive evolution. All plants and animals, including the human species, are products of biological history in terms of organic evolution. Darwin's own interpretation of this ongoing process was mechanistic and materialistic; it rejected vitalism, essentialism, teleology, spiritualism, and a divine plan, as well as the fixity of species. For Darwin, the process of biological evolution had no meaning, purpose, direction, or final goal. He was correct in fearing that a bitter controversy would ensue over his theory of "descent with modification" (as he called it). For 20 years, his attention focused on numerous research projects ranging from domesticated pigeons to insectivorous plants, while his theory of evolution remained in the background.

The Evolution Controversy

In 1858, Darwin received a letter and manuscript from Alfred Russel Wallace (1823–1913), a naturalist who was living in Indonesia. Like Darwin, Wallace had read Lyell and Malthus and had spent time studying the biology of oceanic islands. Reading the manuscript, Darwin was shocked to learn that Wallace had independently discovered the theory of evolution by natural selection. Even so, on July 1, the members of the Linnean Society in London gave priority to Darwin for having fathered the scientific theory of organic evolution 20 years earlier.

Darwin finished his book on evolution *On the Origin of Species*, which was published on November 24, 1859. In this volume, he deliberately refrained from discussing human evolution and its disturbing ramifications. Darwin had only written: "Light will be thrown on the origin of man and his history." Nevertheless, anyone reading the *Origin of Species* could easily see that the theory of evolution should also be extended to account for the origin and history of the human species. As such, one may argue that the controversy over evolution was actually due to a topic that Darwin himself had consciously avoided including in his major work. As Darwin had feared, serious issues over evolution emerged in both academic and public circles. Of special significance was the 1860 confrontation held at the University Museum Library in Oxford (neither Darwin nor Wallace was present). Bishop Samuel Wilberforce ("Soapy Sam") pontificated on the biblical account of the 6 days of Creation, while the anatomist Thomas Henry Huxley ("Darwin's bulldog") defended organic evolution and its geological framework. Especially because of Huxley's informative and persuasive arguments, it was held that Darwin had won the day for evolution, science, and reason.

Along with Huxley in England, the biologist and philosopher Ernst Haeckel in Germany and the botanist Asa Gray at Harvard University in the United States championed the evolutionary perspective. However, interpretations of organic evolution ranged from materialism to spiritualism. Despite the ongoing controversy between science and religion, it was becoming increasingly difficult for other naturalists, as well as philosophers and theologians, to ignore the accumulating evidence for both the immense age of this planet and the great antiquity of the human species.

No radiometric dating techniques were available in the 19th century. Therefore, most naturalists did not share Darwin's sweeping geological perspective, which held that the earth must be at least 600 million years old. Darwin reasoned that his theory of evolution needed an awesome amount of time to account for the staggering diversity of life forms that had emerged throughout organic history. The slow evolution of vision, from a mere sensitive spot in a primordial organism to the complex eye in the human species, would take millions upon millions of years to accomplish through the gradual accumulation of slight but favorable individual variations and the mechanism of natural selection.

Human Evolution

Twelve years after his *Origin* volume appeared, Darwin published *The Descent of Man* (1871). Finally, the now world-renowned naturalist focused on the evolution of the human species; Huxley and Haeckel had already written on this contentious subject several years earlier. Darwin wrote that the human animal is closest to the two African great apes (chimpanzee and gorilla), with which it shares a common primate ancestor in the remote past. Furthermore, he reasoned that this common ancestor would be found in the fossil record of African rock strata. His rigorous consideration of comparative biology led him to claim that humans differ from apes merely in degree rather than in kind. For many thinkers, the philosophical implications and theological consequences of human evolution were disquieting. In fact, Darwin himself found his own pervasive materialism to be upsetting in its stark implications for human existence.

Darwinian evolution had dealt a serious blow to the alleged uniqueness of the human being; humans were now thought to be evolved apes rather than fallen angels. Consequently, as a result of scientific discoveries in the 20th century, the biological history of the human species was extended back millions of years to the apelike forms in the remote fossil record. Moreover, anthropologists also compared the genes, behavior patterns, and mental activities of humans with those of the living great apes. The results clearly demonstrated that humans are closer to the apes than Huxley or Haeckel or even Darwin himself could have imagined at the end of the 19th century.

For Darwin, even human feelings and emotions had their origin in the feelings and emotions of fossil apes. As such, he also grounded human morality in the distant past. Thus, from biology to psychology, humans are linked to the living apes through organic evolution. A remaining question about human evolution concerns when, in the early history of apelike forms, the successful split had occurred that resulted in a crucial distinction between the ongoing evolution of apes and the emergence of those proto-hominids that were ancestral to the appearance of true hominids, who were capable of both sustained bipedal locomotion and the making of stone implements.

After Darwin

After his return from the southern hemisphere, Darwin never made another trip outside of England. He spent his time thinking, writing, and doing research at Down House in Kent, near Bromley. Twice each day, Darwin would stroll the Sandwalk, a path through the woods and fields behind his residence. No doubt, during these walks, he reflected on his fortuitous voyage around the world on the *HMS Beagle* and his own theory of organic evolution. Lyell's persuasive thoughts had introduced the young Darwin to geological history with its awesome temporal framework. Subsequently, Darwin's own scientific theory had given the enlightened world an evolutionary perspective with its overwhelming views of time and change in terms of biological history. The complexity and unity of life on Earth are the result of organic evolution, and this ongoing process has encompassed millions of years. Even profound ideas, cherished beliefs, and social values have an evolutionary history. Nothing escapes the Darwinian revolution.

In his *Autobiography,* written in 1876 and published posthumously in 1887, Darwin admitted that his theory of evolution challenged the theology of Christianity. He did not speculate on the origin or the end of this universe. Furthermore, an explanation for the beginning of life eluded him, as did envisioning the distant future of the human species and the end of all life. Darwin's own mechanistic and materialistic interpretation of organic evolution was atheistic, while his cosmology remained agnostic. He simply left the philosophical questions and theological issues surrounding the fact of evolution for other thinkers to grapple with. One may argue that Darwin's crisis of faith, due to his own pervasive materialism, resulted in a failure of nerve, since he did not share his final thoughts on religion and theology during his lifetime. Unfortunately, not until 1958 was an unexpurgated edition of his *Autobiography* made available to the public; his devoutly religious wife had intentionally deleted all of Darwin's opinions on God and Christianity from the original manuscript before its first publication. For sure, there was a glaring contrast between Darwin's scientific understanding of evolutionary time and his wife's religious commitment to the biblical account of divine creation.

When Darwin died in 1882, he was buried in Westminster Abby near the tomb of Isaac Newton. Over the following years, his theory of evolution has been strengthened by ongoing advances in science and technology. New dating techniques have determined the age of the planet Earth to be 4.6 billion years old, and human-like fossils are now dated back over 4 million years. The discovery of endless specimens in the fossil record of the geological column has revealed both evolutionary patterns and periods of extinction throughout the vastness of biological history. Moreover, ongoing comparative studies in biology, from biochemistry and genetics to embryology and morphology, have shed new light on taxonomic relationships and common ancestries. Continuing studies in the biogeography of both plants and animals reveal the complex adaptive relationships between organisms and their environments. And, modern computers generate dynamic models of the phylogenetic histories of species, filling in the gaps of an admittedly incomplete fossil record. With all this growing empirical evidence, it is becoming more and more difficult for enlightened thinkers to ignore the fact of evolution and its obvious inferences for time and change.

Supplementing historical geology, organic evolution has greatly expanded the concept of time in terms of the origin and history of life forms on Earth (including all aspects of our own species, from religions to technologies). In the mid-20th century, with the discovery of the DNA molecule, scientists developed the so-called synthetic theory of organic evolution, which added genetic variations or mutations, found in dynamic populations, to Darwin's fundamental concept of natural selection. Furthermore, the evolutionary framework was extended to include the history of this universe. And, there is the probability that life forms, including intelligent beings, are evolving on planets elsewhere in other solar systems among the countless stars. In fact, the concept of time itself has come under rigorous scrutiny by scientists, philosophers, and theologians. No doubt, Charles Darwin would be surprised at, and delighted with, the modern awareness of time concerning both cosmic and biological levels of existence.

H. James Birx

See also Critical Reflection and Time; Darwin and Aristotle; Earth, Age of; Evolution, Organic; Experiments, Thought; Fossil Record; Geology; Haeckel, Ernst; Huxley, Thomas Henry; Lyell, Charles; Malthus, Thomas; Paleontology; Paley, William; Uniformitarianism

Further Readings

Aydon, C. (2002). *Charles Darwin.* London: Robinson.

Birx, H. J. (1991). *Interpreting evolution: Darwin & Teilhard de Chardin.* Amherst, NY: Prometheus.

Browne, E. J. (1996). *Charles Darwin: Voyaging.* Princeton, NJ: Princeton University Press.

Browne, E. J. (2003). *Charles Darwin: The power of place.* Princeton, NJ: Princeton University Press.

Darwin, C. (1991). *The origin of species.* Amherst, NY: Prometheus. (Original work published 1859)

Darwin, C. (1998). *The descent of man.* Amherst, NY: Prometheus. (Original work published 1871)

Darwin, C. (2000). *Autobiography.* Amherst, NY: Prometheus. (Original work published 1887)

Darwin, C. (2000). *The voyage of the* Beagle. Amherst, NY: Prometheus. (Original work published 1839)

Dennett, D. C. (1995). *Darwin's dangerous idea: Evolution and the meanings of life.* New York: Simon & Schuster.

Dupré, J. (2003). *Darwin's legacy: What evolution means today.* Oxford, UK: Oxford University Press.

Hodge, J., & Radick, G. (Eds.). (2003). *The Cambridge companion to Darwin.* Cambridge, UK: Cambridge University Press.

Keynes, R. (2003). *Fossils, finches, and Fuegians: Darwin's adventures and discoveries on the* Beagle. Oxford, UK: Oxford University Press.

Mayr, E. (1991). *One long argument: Charles Darwin and the genesis of modern evolutionary thought.* Cambridge, MA: Harvard University Press.

Tort, P. (2001). *Charles Darwin: The scholar who changed human history.* London: Thames & Hudson.

Weiner, J. (1995). *The beak of the finch: A story of evolution in our time.* New York: Vintage.

Darwin and Aristotle

Charles Darwin (1809–1882) and Aristotle (384–322 BCE) represent the greatest dichotomy of thought regarding the concept of time and its influence upon natural history (science) and philosophy. Separated by the vastness of time and intellectual advancements of their respective eras, the temporal concepts of finitude (infinity and the finite) are juxtaposed within both a cosmological and a human ontological and teleological framework. In the works of both thinkers, issues concerning the temporal nature of the universe, Earth, and humankind were explored for the ultimate understanding of both humanity and humankind's place in nature. With the combination of both acute observations of the natural world and rational speculation, Darwin's and Aristotle's individual contributions marked a theoretical shift that brought about a conceptual revolution that still reverberates in the modern world. A diachronic perspective, as in this entry, affords a comparative view of the conflicting metaphysical basis of time and the human experience as understood by these two key figures.

Aristotle, father of biology, taxonomy, and logic, provided a comprehensive view of nature that was separate from prevalent or traditional mythology or superstition. Although some works survive only in fragmentary form, his noted works titled *Physics* and *Metaphysics* provided essential clues as to the conceptualization of time, being, and ontological fulfillment within a logical and categorical framework. In this framework, matter and form became united within a developing and finite ontology and finitely directed teleology of the underlying substance (essence). The implications for species' ontogeny, especially with the human primate, become explicitly clear when examining the nature of change and humans' relationship within the natural world.

The relationship between a geocentric universe and nature was depicted as a series of processed actualization, such as an ebbing flow of potentiality to actuality, within the backdrop of the eternal and finite universe. Individual development, initiated and sustained by the "four causes" of change, results in the actualization of being. Categorically, each being expresses the qualitative "soul" that is essential in the Form for that particular living thing, example, vegetative, sensitive, and rational. Expressions of the soul, driven by the final cause, manifest themselves in terms of motion (e.g., spatiotemporal measurement of physical growth and development). Although physical changes are expressed (e.g., ontogenetic development), the substance and incorporated soul of living things remains fixed. For Aristotle, species are fixed within nature. However, it is important to note that the cosmological aspect of all motion is eternal and originated from the Unmoved Mover. It is the form and substance of the universe expressing a final cause from an eternal *logos,* or *nous.* The eternal and infinite intelligibility of the world reflects both the infinite and the finite nature of humankind.

Aristotle's depiction of humankind's place in nature is anthropocentric, whereby humankind is placed at the earthly apex within the Great Chain of Being. This placement is directly related to the human species' possession of a rational soul and the ever-present potentiality of reason with the possibility of actualization. In terms of the temporal nature of being human, Aristotle acknowledges the finite aspect of existence. The soul, by which existence is irrevocably linked to form, became viewed as temporally finite. Upon death, when animus ceases, the existence of matter and form are terminated in nonexistence. The psychological conception of time, on an individual level, is closely linked with the awareness of this mortality. In its totality, each species lives out its categorical existence within clearly defined teleological ends. For the human species, this Aristotelian perspective provides both psychological security and stability, that is, ontological and teleological justification for ethical and political structures. Furthermore, these ideas were later adopted and adapted for theological purposes by Saint Thomas Aquinas (1225–1274), whereby the conceptualization presented by Aristotle, along with scriptural interpretation and dogmatic thought, set the prevalent tone in the Western mind, in which the sciences operated. Nevertheless, changes in philosophical thought and the empirical sciences were established. The greatest divergence can be seen in the discoveries and theoretical perspectives of Darwin.

Charles Darwin, the renowned English naturalist, provided empirical evidence with rational speculation in support of a theory that was contrary to the established influences of Aristotelian thought within science and philosophy. Darwin's perspective directly challenged the traditional concept of the temporality of the universe, Earth, and the nature of species. Along with explicit differences, such as in taxonomical relationships, there are implicit metaphysical implications that challenge the conceptual security of humankind and humanity. It was Darwin's inquisitive mind and creativity that directed his early experiences as a naturalist on board the H.M.S. *Beagle* to postulate one of the most influential theories, the theory of organic evolution.

In the publications *On the Origin of Species* (1859) and *The Descent of Man* (1871), Darwin presented the accumulation of empirical observations from the Galapagos archipelago and South America, with the contextual influences of Charles Lyell, Thomas Malthus, and Jean-Baptiste de Lamarck. This resulted in the dynamic assessment in the age of the earth in terms of millions of years, dynamics of populations, relations among species within an environment, and the mechanism for the appearance of new traits in a species. Together, the origin of species is not only rooted within the ancient natural history of the earth, geologically speaking, but also affected by the arbitrary pressures of natural selection. The process of natural selection, resulting in species' proliferation or extinction, is temporally finite on an individual level and gradually finite on a species level, resulting in a gradual and nondirectional speciation. This illustrates the precarious nature of existence. The existence of each species enters into a spatiotemporal relationship that stresses not only the unity of life but also the common struggle for the continuity of existence as a species.

Contrary to Aristotle's position, Darwin held that humankind was a gradual product of evolution. Darwin speculated that humans share an affinity with primates (differing in degree and not in kind), and thus humans could no longer be considered the apex of life; rather, the human species, according to Darwin, is one part of a nondirectional continuum that is subjected to adaptation and the possibility of extinction. The process of change through time, not fixed within time, is key to the human species' origin, development, and future. Although Darwin did not explicitly comment on the human species' mortality, the metaphysical implications become evident. Humans were neither created nor designed, there is no teleological end, and a shared common ancestry (temporal continuity) with primates topples the Great Chain of Being. Furthermore, the metaphysical implications for theology are certain. Not only is the concept of the eternal soul rejected but also the theological underpinning of redemption and salvation of humankind's eternal existence in a destined afterlife (which also includes reincarnation). Aspects of ethics (morality) and beliefs (e.g., eternal soul) are psychological adaptations within the primate social structure.

Contrasting the views of Aristotle and Darwin shows that the influences of each thinker are extremely profound. The dichotomy of their thought, in each instance based on acute observation, illustrates not only the temporal nature of the human species but also the temporal nature of science. On an individual level, time is relative to human existence. Science, on the other hand, is relative to the precocious timing of scientific advancements set within a social framework. For the first time in human history, metaphysics and science intersect with the ability to direct the future and timing of human evolution. However, each instance of progress, with its metaphysical implication, is ultimately subjected to the pressures of natural selection within an evolutionary framework.

David Alexander Lukaszek

See also Aristotle; Darwin, Charles; Evolution, Organic

Further Readings

Aristotle. (1983). *The complete works of Aristotle, Vols. 1 & 2* (J. Barnes, Ed.). Princeton, NJ: Princeton University Press.

Darwin, C. (1964). *On the origin of species.* Cambridge, MA: Harvard University Press. (Original work published 1859)

Darwin, C. (1998). *The descent of man.* New York: Prometheus. (Original work published 1871)

Darwin, C. (2000). *The autobiography of Charles Darwin.* New York: Prometheus. (Original work published 1887)

Darwin and Nietzsche

The concept of time plays a fundamental role in Charles Darwin's theory of evolution as presented in his book *On the Origin of Species* because it answers one fundamental question raised by his theory. One critique Darwin anticipated when elaborating his theory of evolution was the the missing biological link; that is, the "absence or rarity of transitional varieties" If two species descended from common ancestors, then one should expect to find transitional varieties at the present time and in each region: "But in the intermediate region, having intermediate conditions of life, why do we not now find closely-linking intermediate varieties? This difficulty for a long time quite confounded me". According to Darwin, this phenomenon can be explained only by taking into consideration both the imperfection of the fossil records and the enormous time period that has passed since the first occurrence of life on Earth. This second point leads Darwin to widen the focus on human time. By comparing natural selection with human-made selection (domestication), Darwin exclaims: "How fleeting are the wishes and efforts of man! how short his time! and consequently how poor will his products be, compared with those accumulated by nature during whole geological periods". For Darwin, this insight implicates the necessity to widen the focus on the human time concept. When comparing "domestic" and natural instincts, Darwin remarks that the former are "far less fixed or invariable than natural instincts" because they have been transmitted in a much shorter period of time. Referring to Charles Lyell's geological research, Darwin claims that the denudation of certain areas of the earth's crust has required such a long and almost inconceivable period of time that the sheer attempt to envision this geological period of limited time is comparable to the vain attempt to envision eternity.

The other revolution of the time inspired by Darwin's reading of Lyell and other geologists is the rejection of rhythmic concepts of time. Darwin stated that the old notion of a recurring catastrophe sweeping away all inhabitants of the earth is generally given up by geologists. Instead, Darwin has shown that every new variety can become extinct because it is less favored than a competing one.

The question of how deeply the philosopher Friedrich Nietzsche (1844–1900) was influenced by Darwin, mainly by his conception of time, is hard to determine. On the one hand, Nietzsche polemized against Darwin's alleged "materialistic" and externalistic conception of evolution; on the other hand, he acknowledged Darwin for being one of the main exponents of a philosophy of becoming (*Philosophie des Werdens*). It is exactly in this regard that Darwin is seen as one of Nietzsche's antecedents. But at the same time, Nietzsche tries to downplay the actual meaning of Darwin by contrasting him with Jean-Baptiste de Lamarck and Georg Wilhelm Friedrich Hegel. In a posthumously published fragment written in 1885, Nietzsche remarked: "We are historical through and through. That is the great turnaround. Lamarck and Hegel—Darwin is only an aftereffect".

This short remark is characteristic of Nietzsche's ambivalent mind-set toward Darwin. Nietzsche honors the fact that Darwin's theory of evolution, especially his acceptance of the transformation of species, has proven that there is no eternal validity, neither of the concept of species nor of the logical categories. Nietzsche goes so far as to parallelize Darwin's transformationism with his own disbelief in eternal logical structures: Just as time transforms the species, it changes the logical categories, too. Hence, the main purpose of Nietzsche's reference to Darwin is to show that everything, even and especially the logical categories, is affected by transience.

However, much unlike the medieval *vanitas* thinking, this is not meant as a statement of the vanity of the fugacious earthly beings. On the contrary, Nietzsche points out that his insight—that everything, even the logical structures, is transitory—results in a deep affirmation of transience.

This motive pervades his entire thinking. It is already in his early work *Untimely Considerations* (*Unzeitgemaesse Betrachtungen*) that Nietzsche criticizes "antiquarian history" and pleads the art of oblivion. Thus, the early Nietzsche favors the unhistorical over the historical because the former refers to the "art and power to forget and to surround oneself in a limited horizon". In this early writing, Nietzsche still talks about the "hyperhistoric" manifested in art and religion that "bestows the character of the eternal and the continuous".

The connection between Nietzsche's theory of oblivion and remembrance on the one hand and his theory of becoming on the other hand is the chief motive for his concept of time. In his *Gay Science* (*Die fröhliche Wissenschaft*), Nietzsche points out this extraordinary importance of the concept of becoming: "We Germans are Hegelians [. . .] in so far as we instinctively attach a deeper value to becoming, to evolution than to that, what 'is'—we hardly believe in the authority of the concept of 'being'". At the same time, oblivion and remembrance are seen as organic functions. As Nietzsche points out in one posthumously published fragment from 1884, the process of life is made possible only by the embodiment of experiences: "the actual problem of the organic is: how is experience possible?"

At this point, Nietzsche refers not to Darwin but to Lamarck and this alleged theory of the "hereditary transmission of acquired characters" in order to support his own position. The notion that every action, every experience is transmitted to the following generations causes, in Nietzsche's view, the extraordinary relevance of physiology understood as an ethical doctrine.

The radical affirmation of transience is finally expressed in Zarathustra's "Yes-and-Amen-song" where each aphorism ends with the sentence "Because I love you, eternity!" However, this eternity is not made up of the everlasting and the immortal but by the affirmation of human transience and mortality. It is not by the belief in immortality or resurrection but by the affirmation of sexuality and siring first brought to mind by ancient mysteries that eternity is achieved.

This notion seems to be the inner meaning of Nietzsche's cryptic doctrine of the eternal recurrence of the same (*Ewige Wiederkehr des Gleichen*). The core of this doctrine (which was repeatedly modified by Nietzsche) is that every little thing, every moment repeatedly recurs in a long period of time—not similarly but *in the very same way* it was experienced the first time. The underlying time concept is clearly a rhythmic one. Nietzsche (who tried to prove this doctrine by referring to physical theories) often stated that the affirmation of the thought of eternal recurrence is the greatest challenge for every thinking being because the unreserved affirmation of a recurring eternity means to completely accept one's own transitory human existence. Thus, the affirmation of eternal recurrence is possible only for those who have first accepted the transience of human existence. Consequently, the doctrine of eternal recurrence can be considered as a touchstone for true salvation.

Dirk Solies

See also Darwin, Charles; Eternal Recurrence; Evolution, Organic; Lyell, Charles; Nietzsche, Friedrich; Time, Cyclical

Further Readings

Darwin, C. (1991). *The origin of species.* Amherst, NY: Prometheus. (Original work published 1859)

Nietzsche, F. (1967). *The will to power* (W. Kaufmann & R. J. Hollingdale, Eds. & Trans.). New York: Vintage. (Original work published 1901)

Nietzsche, F. (1974). *The gay science* (W. Kaufmann, Trans.). New York: Vintage. (Original work published 1882)

Dating Techniques

For as long as time travel remains the stuff of dreams and science fiction, archaeology will continue to provide the most direct means to gain access to the remote past. Historical sources (such as written texts) and ethnoarchaeology provide abundant and invaluable insights concerning ancient times, but even these approaches have significant limitations. For example, the earliest written sources date from only about 5,000 years ago, and such evidence is restricted to certain regions and found in a limited number of literate cultures. Thus, all of prehistory stands beyond the reach of historical research, strictly defined, and the radiometric (science-based) dating techniques, including the so-called radiocarbon revolution, are all the more valuable. The availability of written evidence (e.g., inscriptions in stone, clay tablets, coins, papyri) can provide firm dates for archaeological strata and artifacts by historical association with, for example, references to astronomical events or names of rulers. In principle, however, archaeological excavation, armed with a wide array of dating techniques, allows access to *any* period of prehistory and history in all parts of the world, even when and where no documentary evidence exists.

Of course, archaeology (the systematic recovery and analysis of the material remains from past cultures) faces its own limitations: theoretical, logistical, financial, and methodological. Archaeologists desire to bring order to, and understand, the various types of data that survive in the ground. Therefore, the search for better techniques by which to link sites and artifacts to particular periods and the need to understand them within a relatively narrow chronological framework remain important. Archaeology contributes to, and benefits from, chronometry (the scientific measurement of time). Many well-known scholars have contributed to a host of procedures used in archaeological dating (e.g., Jacques Boucher de Perthes, Christian Jürgensen Thomsen, Charles Lyell, William M. F. Petrie, Pitt Rivers, Andrew Ellicott Douglass, Willard F. Libby); the steady advance of chronometric techniques, especially those developed by physicists and chemists, promises even more precision for scholars who will examine the past in generations to come.

The field of archaeology emerged from a background that included several academic disciplines (e.g., geology, anthropology); its early practitioners included antiquarians from the Age of Enlightenment, whose views about the past ranged from naive to sophisticated. Once these early scholars accepted the idea of a past that differed from their own day, they began to develop means by which to date their discoveries and impose order on the past. As in all the sciences, progress depended on the development of reasonable methods of research and the invention of instruments to measure and analyze data. Because archaeology focuses on cultural changes through time, archaeologists have always sought methods that offer reliability and precision in dating materials from the past. Nowadays, archaeologists have access to many different dating techniques; these are the conceptual tools and instruments used to reach back in time to create a chronological framework for the prehistoric and historic eras.

In the broadest terms, these dating techniques fall into two categories: (1) *relative* dating, which identifies the sequence of archaeological materials (e.g., stratigraphy, ceramic typology), and (2) *absolute* dating, which assigns actual dates (however approximate) to sites, artifacts, and events (e.g., dendrochronology, radiometric dating [i.e., various techniques that determine age by measuring radioactive decay]). These approaches include some older, well-established methods that have demonstrated their value and a number of more recent scientific techniques. All of these dating methods have significant limitations (e.g., cost, kinds of materials that can be tested, span of time for which reliable results can be expected), and scholars who use these techniques must acknowledge problems where they exist (e.g., identification of variables, danger of contamination). Because dating is a pivotal aspect of archaeological analysis, archaeologists and scientists who work with multidisciplinary research teams must constantly work to refine dating techniques, improving the old standbys and perfecting the newer scientific methods, most of which were developed during the latter half of the 20th century.

As noted earlier, many different dating techniques are available, and scientists continue to invent new methods and improve the old ones. These different approaches focus on a variety of recognizable and measurable data, all of which allow archaeologists to date materials in relative or absolute terms. Sheridan Bowman has conveniently categorized the more science-based dating techniques and identified significant examples of each. The first category includes methods that are based on radioactive decay (e.g., fission track dating, potassium-argon dating, radiocarbon [carbon-14] dating, and uranium-series dating). Bowman's second category, dating techniques based on climatic change, includes calcite banding, dendrochronology, ice cores, oxygen isotope dating, and varves. The third type of dating method is based on special properties of materials (e.g., amino acid racemization, archaeomagnetic dating, electron spin resonance, fluorine uptake, thermoluminescence). Techniques based on diffusion processes, Bowman's fourth category, include obsidian hydration dating and nitrogen and sodium profiling.

Foundational Approaches

The most fundamental principle of archaeological excavation, borrowed from geology's focus on stratigraphy, is the law of superposition. On a complex archaeological site, this law provides the basis for the main concept of relative dating by noting that one normally finds older remains in the lower strata of a site, as they are covered by more recently deposited materials. The careful delineation of stratigraphic relationships provides invaluable information concerning site history (sequence of site occupation and use) and the relationships among all deposits, features, and artifacts in the site. As excavators soon discover, a variety of factors can complicate the picture and turn the site into something other than a picture-perfect sequence of easily defined strata. Nevertheless, the primary objective of excavation is the removal of layers (and their contents) in the reverse order in which they were deposited. More sophisticated approaches, like the Harris Matrix, lend precision to this process by forcing excavators to identify sequential, chronological links. Along the way, more precision becomes possible as researchers isolate and assign dates to features, materials, and objects through one, or more, of the scientifically based techniques, comparison with datable items from other sites (cross-dating/synchronisms), or through historical associations. Occasionally, evidence of well-known seismic or volcanic activity helps pinpoint a site's history, as in the case of Vesuvius's eruption in 79 CE.

Another foundational approach in archaeological dating is known as *typology.* Typology takes advantage of archaeologists' attention to detail and to their interest in imposing order on materials recovered from a site. The typological approach, applied to the full range of artifacts or even architectural features (e.g., stone or metal tools, gate plans, pottery), arranges archaeological materials into an order that reflects change and moves toward a hypothetical (relative) chronological order. Once a specific object, like a type of pottery lamp (distinctive in form, decoration, and manner of production), becomes linked with a fixed date at one site, the pottery assemblage of which that lamp is a part assumes a place in the optional dating tools available to the archaeologist (at least for a particular region). Though a ceramic typology can often provide fairly close dates, pottery and other materials arranged into typologies provide only relative dates (such as Thomsen's "three-age system" [stone, bronze, and iron], with elaborate applications to deal with cultures around the world). In fact, archaeologists make frequent use of the terms *terminus ante quem* and *terminus post quem* to distinguish between types of chronological evidence and to highlight the central role that relative dating continues to plays in interpretation.

Another type of relative dating is called *seriation,* a method that helps archaeologists arrange artifacts into chronological sequences by noting the "life cycles" of changes (in which typological features appear, experience extensive use, and fall into disuse). William M. F. Petrie first developed this approach in Egypt to provide a sequence for some 900 predynastic graves. He gave special attention to changes in ceramic forms, including wavy ledge handles that featured prominently on jars in the early ceramic repertoire. Petrie's use of the "concentration principle" makes this one of the earliest applications of statistics to archaeological research. In a period of research in southern Palestine, especially through observations he made during his brief excavations at Tell el-Hesi, in 1890, Petrie also recognized the nature of a stratified mound and laid foundations for the development of stratigraphy and typology.

Decades later, William F. Albright developed a significant ceramic typology ("ceramic index") on the basis of his work at Tell Beit Mirsim. Many scholars subsequently improved upon the perceptive observations made by Petrie, Albright, and others, but their contributions represent similar breakthroughs made around the world by many other pioneers in archaeological dating. Though it is not unique in this regard, ceramics has played a special role in providing a chronological framework for thousands of historic and late prehistoric sites in the Middle East.

Dendrochronology

Dendrochronology, which offers a genuinely absolute date, measures and links the annual tree rings of wood samples that comprise master chronologies for particular regions of the world. This technique developed out of climatic research, but anthropologists quickly recognized its potential in determining the age of ruins in the southwestern United States. Now species of trees known for their longevity, like the bristlecone pine and the European oak, provide a nearly continuous timescale that reaches beyond 10,000 years ago and serves as the primary component of the all-important "calibration curve" in radiocarbon dating. As with the radiocarbon analysis of wood samples, archaeologists must always consider the possible gap between the date assigned to, say, a roof beam and the actual use of that timber in an archaeological context (i.e., distinguish between the age of the wood and the date of the archaeological "event" itself).

Radiometric Techniques

The second half of the 20th century witnessed the invention and development of a host of scientifically based dating techniques, almost all of which derived from distinctive physical or chemical properties. Many of these newer methods are radiometric in nature; that is, they provide more-or-less absolute dates that are tied to known rates of radioactive decay and a precise measurement of isotopes. As indicated earlier, use of the term *absolute* requires some qualification, as laboratory results on any tested sample will include a margin of error, even when scientists are working with known rates of decay and the nuclides function somewhat like a clock. Scientists measure the deterioration of these radioactive substances in half-lives (e.g., the half-life of carbon-14 is 5,730 years). Precision is enhanced through multiple samples and cross-checking with other dating techniques, when that is possible.

Without a doubt, carbon-14 analysis of organic materials is still the best known radiometric dating technique; a by-product of research related to the Manhattan Project, this process was initially developed in 1949 by W. F. Libby and colleagues. After nearly 6 decades, research on the application of carbon-14 to archaeological dating and the resultant "radiocarbon revolution" continue at full speed, with no indication that the latter will slow down. The major journal *Radiocarbon* (published at the University of Arizona) and a regular series of related conferences provide invaluable international venues for discussion about carbon-14 and other isotope dating. As a result of this constant research and refinement, scientists have a much better understanding of the factors that have caused, and still cause, fluctuations in the carbon-exchange reservoir in the atmosphere, oceansphere, and biosphere. The radiocarbon "calibration curve," based on corrections provided by dendrochronology and uranium-series dating, promises much greater reliability and precision. Today's accelerator mass spectrometry (AMS) dating, which allows a direct counting of the carbon isotope ratios, has significant advantages over the conventional carbon-14 method, especially with respect to the small sample size that AMS requires. Even with carbon-14's relatively short half-life and the possible sources of error, the radiocarbon timescale gives good results for samples that date to 50,000 or even 70,000 years before the present. The recent application of Bayesian statistical analysis also enhances the usefulness of radiocarbon, and the future undoubtedly holds other improvements for the carbon-14 method of dating.

Other radiometric dating techniques, which have timescales that reach further into the past than the radiocarbon method, include alpha recoil dating, fission track dating, potassium-argon dating, radiocalcium dating, rubidium-strontium dating, and the uranium-series dating. The potassium-argon method achieved notoriety because of its early use in the study of hominid fossils at Olduvai Gorge (in research carried out by Louis Leakey, Mary Leakey, and colleagues) and other East African sites. By means of sensitive instrumentation, this geochronological process measures the parent-to-daughter decay of potassium-40 to argon-40, isotopes that appear in volcanic lava. The half-life of this potassium isotope is 1.25 billion years, and therefore this technique finds its primary application in geological dating.

Conclusion

Archaeology will continue to refine its array of dating techniques so that field research and laboratory analysis can provide more precise benchmarks in time and space, as well as offer a better understanding of past cultures. Better dating techniques also provide safeguards against fraudulent claims, as in disputes over pieces of art or even the infamous Piltdown hoax.

Gerald L. Mattingly

See also Anthropology; Archaeology; Boucher de Perthes, Jacques; Decay, Radioactive; K-T Boundary; Lyell, Charles

Further Readings

Aitken, M. J. (1990). *Science-based dating in archaeology.* New York: Longman.

Biers, W. R. (1992). *Art, artifacts and chronology.* New York: Routledge.

Bowman, S. (1990). *Radiocarbon dating.* Los Angeles: University of California Press.

Bowman, S. (2002). Dating techniques. In I. Shaw & R. Jameson (Eds.), *A dictionary of archaeology.* Oxford, UK: Blackwell.

Harris, E. C. (1989). *Principles of archaeological stratigraphy.* London: Academic Press.

Higham, T., Bronk Ramsey, C., & Owen, C. (Eds.). (2004). *Radiocarbon and archaeology: Proceedings of the 4th symposium, Oxford 2002.* Oxford, UK: Oxford University School of Archaeology, Institute of Archaeology.

Nash, T. (2000). *It's about time: A history of archaeological dating in North America.* Salt Lake City: University of Utah Press.

O'Brien, M. J., & Lyman, R. L. (1999). *Seriation, stratigraphy, and index fossils: The backbone of archaeological dating.* New York: Springer.

Renfrew, C., & Bahn, P. (2008). *Archaeology: Theories, methods and practice.* New York: Thames & Hudson.

Taylor, R. E., & Aitken, M. J. (1997). *Chronometric dating in archaeology.* New York: Springer.

Wagner, G. A. (1998). *Age determination of young rocks and artifacts: Physical and chemical clocks in quaternary geology and archaeology.* New York: Springer.

Walker, M. (2005). *Quaternary dating methods.* New York: Wiley.

Decay, Organic

When a living organism dies—be it a fungus, a plant, an animal, or a human being—decay is the final event to occur. The individual parts of the body decompose at different rates. In various ways and in numerous stages, they are reduced to small pieces, decomposed, and finally broken down to low-molecular-weight, inorganic basic substances (carbon dioxide, water, etc.). This process can happen through enzymes of the body itself; through animals, fungi, and bacteria as biotic factors; and finally through abiotic (chemical–physical) factors. The time required for the decomposition crucially depends on the temperature, humidity, oxygen content, pH value, and biological milieu.

Within an ecosystem, decomposition plays an important role. Not only do many organisms feed on the dead organic material, but through decomposition, nutrients that were once absorbed by living organisms can be released and used again by primary producers (most of all by plants). However, the decay process can also come to a standstill or it can slow down significantly—bodies can mummify, ice or amber can conserve them, bodies can form grave wax, or they can remain as skeletons or bog bodies for posterity.

Knowledge of the processes of decomposition and decay is important for forensics, archaeology, physical anthropology, ecology, and in the funeral and cemetery management industry.

Preliminary Remarks on Time

How long a body takes to decompose and what accelerates or decelerates this process depends on the nature and condition of the remains. At the death of a mammal, numerous circumstances have an impact upon the process of decomposition. Important factors can be whether the animal was slim or fat before death and also if it had a fever or any open wounds. In case of infection (sepsis), germs may have entered the body, thus accelerating the process of decomposition. Antibiotics in the body might have delayed the growth of bacteria and therefore may have slowed down the postmortal microbiotic decomposition. The time needed for the decomposition also depends on the ecological circumstances. It is therefore of utmost importance to factor in what animals, fungi, and bacteria had access to the cadaver as well as to consider the weather and soil conditions (moist/dry, warm/cold, acidic/basic). Another issue to be taken into account is whether the cadaver lay close to the surface of the earth, deep within the ground, or in water. Acidic, warm, and humid milieus (with a permeable soil) accelerate decomposition, whereas basic, dry, and cold milieus are usually more preservative. Due to the wide variety of these factors, the time given as an estimate of the relationship between time and the degree of decomposition in Casper's rule can therefore be used only as an approximation in a multifactorial process. Casper's rule provides an estimation as follows: The degree of degradation of a corpse that has been lying on the soil surface for 1 week corresponds to that of a corpse that has been lying in water for 2 weeks or buried in soil for 8 weeks.

Death and Dying

The death of multicellular organisms is a gradual process. For example, if the cardiovascular system of a human being collapses, the individual organs, tissues, and cells can still be vital for several hours or days. The proliferation activity of the epidermis is an example of such "intermediate life," which finishes at 20°C ambient temperature after 35 to 40 hours. It is possible that some cells and tissues are still viable, while other parts of the body have already started to display evidence of decomposition. Not until life on the cellular level has also been completely stopped can one speak of absolute death.

Processes of Decomposition

Autolysis

Autolysis is the self-digestion of cells and tissues caused by the body's own enzymes. In cells of a dying body, the defect cell compartments set free enzymes such as proteases or lipases. They attack the proteins of the cell itself and dismember and denature them. The degrading enzymes can also enter the intercellular spaces and destroy the connection between the different cells (tissue necrosis).

The tissues, which are sensitive to failure of the oxygen supply, and cells, which have many hydrolytic enzymes, are strongly affected from the beginning. Many autolytic enzymes have their temperature optimum at 34°C to 40°C; therefore, a warm milieu enhances autolysis (warm surroundings or fever before death).

Animals

A vast number of animals of different species and classes feed on dead plant and/or animal material (necrophages) or on excrements of other animals (coprophages), and so they are all part of the chain of organic decomposition. On the one hand there are animals that only occasionally feed on dead material, such as omnivore animals eating a carcass (e.g., rats, gulls, ants). On the other hand there are animal species that feed only on dead organic material or that depend on it during a certain stage of development. In particular, several articulates belong to these species. The larvae of snow scorpion flies, for example, feed on dead plant material and also on carcasses. Other animals may also particularly favor a certain species (e.g., the pine sawyer beetle on the pine tree). Certain remains, like the keratin of feathers, horn, or hair, can be utilized by only a few animals such as the fur beetle.

Not all species that take part in the decomposition process appear simultaneously on the dead substrate. In each case the point of time of their appearance depends on their requirement profile (e.g., fresh cadavers, intermediate products of the decomposition, or feces as feed). Therefore one speaks of a succession.

Bacteria and Fungi

Among the organisms of decomposition processes are bacteria and fungi, whose demands on the substrate are very different. Often they excrete exoenzymes, which disintegrate high-molecular-weight substrates (e.g. lignin, cellulose, protein) outside the organism to form more basic products that can be reabsorbed. The substrate is reduced by several species through many stages and is finally assimilated and/or transferred into an inorganic compound (so-called remineralization). In nature, whole groups of different organisms often work together by ingesting and feeding on decomposition or waste products so that their feces can then be used by another species as a feeding substrate.

Chemical–Physical Influences

The chemical milieu, the temperature, and moisture all have an effect on the time needed for autolytic, microbiotic, and animal decomposition. Besides the aforementioned indirect effects, abiotic factors also have a direct effect on the animal or plant material. Mechanical damage can be caused by wind and water. Frost can disperse tissue, variations in temperature and moisture can cause cracks to form (e.g., in bones), and pressure can also have an impact on buried substrate. Substances can dissolve in a moist milieu and can be carried away, especially in permeable sediments. The pH value of the soil can be preservative (depending on the composition of the body parts) or destructive; calcareous compartments (shells) can be affected by an acidic milieu, whereas in an alkaline milieu they are preserved for centuries.

Examples

There are many examples of the decomposition of organic materials (organic decay in the sea, in lakes, of insects, of a dung heap, etc.). Two types are discussed here.

Litter and Wood

The litter (leaves, needles) on the forest soil is disintegrated by articulates, by bacteria, and most of all by fungi. The decomposition takes place in many stages: In the first step the fallen but almost undamaged leaf and needle material has to be made accessible for the destructive microorganisms (destruents) because it is almost impossible for the microorganisms to get through the cutinized layer. An entry is primarily made possible for them through the damage caused by the macro fauna (arthropods and snails that tear the epidermis). Leaves that have fallen to the ground are mostly disintegrated by earthworms, which also eat intact foliage that they have pulled into their tubes during the night. The reduced pieces of the litter and the droppings of the primary decomposers can further be reduced by secondary decomposers such as springtails, mites, roundworms, and potworms. In the third decomposition phase, soil microorganisms (such as fungi; bacteria, especially actinomycetes) can totally decompose the rehashed litter of animal feces up to its inorganic elements.

Decomposition proceeds best under well-aerated, warm-humid conditions (e.g., in the tropical rainforest) because of quick and direct microbial oxidation to carbon dioxide, water, nitrates, and the like. Under cold, acidic, and partially anaerobic conditions, the decomposition is slowed down and peat accumulation can occur. In temperate soil the decomposition depends on the interplay of soil animals and microorganism. The better the soil fauna is developed (e.g., in deciduous mixed forests), the higher the level of decomposition that will occur.

In nature the wood of dead trees is mainly decomposed by fungi. Animal and bacterial decomposition does not play such an important role, but the decomposition through fungi can then lead to insects being able to digest the wood. As far as fungi are concerned, basidiomycetes with a hymeneal fruiting body are far more often involved in decomposition of wood than are ascomycetes and fungi imperfecti. Their hyphae grow into the wood, and during their growth they disintegrate the polymeric carbohydrates and the lignin (creating wood decay). Normally not all substances of the wood are attacked equally, and in fact the secreted enzymes affect the substances of the cell wall differently. This allows a classification of the wood decay by fungi. It occurs as brown rot, white rot, or soft rot.

In the case of brown rot, the fungi (exclusively the fungi of the basidiomycetes) feed on cellulose or hemicellulose so that the lignin part of the wood remains. For example, in 6 months the weight of sapwood can be reduced about 43% by the house fungus. The wood becomes brown, is transverse cracked, and molders cubically. Brown rotten wood parts can last for centuries within the soil because of the high lignin proportion.

In the case of white rot, which is often a very fast decomposition process, lignin, cellulose, and hemicellulose are being decomposed by releasing oxidizing enzymes. The rotten wood becomes white and long-stranded because of the bleaching process. It is possible to distinguish between simultaneous rot and selective delignification. In the case of the former, the carbohydrates and the lignin are being degenerated almost instantaneously; in the case of the latter the lignin is the first to be degenerated, whereas the cellulose is left for later decomposition.

The third type is soft rot. First of all the cellulose is decomposed to hemicellulose, whereas the lignin is more repressive. The wood becomes very soft in texture and gray to dark brown in color. In contrast to the brown rot, the soft rot is not caused by basidiomycetes but by ascomycetes and fungi imperfecti.

Human Corpse

Approximately 4 minutes after death, the decay of the cadaver begins with the process of autolysis. This can initially be noticed in the organs, which have a huge energy requirement, or many lysosomes, such as the intestine, stomach, and accessory organs of digestion. Without clear boundaries between the stages, this autolysis moves to decomposition by putrefactive bacteria and finally ends with skeletization.

The anaerobic conditions that develop within the body, and the nutrient-rich fluids released due to the autolysis, stimulate bacterial growth (especially endosymbiotic gut bacteria). Their emigration out of the gut is supported by the pressure caused by gases produced during decomposition. Bacteria can also enter the body via the skin (especially through open wounds), the mouth, the nasal cavity, and so forth. The bacteria disintegrate released carbohydrates, proteins, and lipids to different acids, gases, and other substances. They cause a change of colors and odors. The organs soften and finally become fluid. The detachment of the epidermis and its attachments and also the bloating of tissue are evident.

After the fluid produced during the decomposition has run off, normally the oxidative processes intensify. In this case the decay occurs in a rather dry milieu; organs and tissues decompose into peat, which is often supported by fungi, especially by molds.

In addition to chemical and microbacterial factors, animals can also be involved in the decomposition of a corpse. An example of a typical series of insects that would interact with a human corpse on the soil surface is as follows:

Shortly after death, attracted by hydrogen sulfide and ammoniac substances, blowflies begin to fly around the orifices and wounds. After oviposition, maggots hatch out of the eggs, they shed their skin twice, and after the termination of their feed intake, they usually leave the corpse to pupate. The speed of the development cycle depends mainly on the fly species and the ambient temperature. If these parameters are known, the time of the first colonization can be calculated (that is the job of the forensic entomologist). The dominant blowflies are accompanied by the fleshflies and the houseflies. As the decomposition progresses, cheese-skippers and latrine flies can be found, and later, fruit flies and humpbacked flies also appear. As the dehydration of the cadaver takes place, larder beetles and caterpillars of the clothes moths appear; these are responsible for the decomposition of the skin. The last remains are removed by the spider beetles and meal worm beetles.

Under "normal" conditions, that means in water-permeable and aerated soil and in 1- to 3-meter depth, the skeletization takes 5 to 7 years. The decomposition proceeds in order of anatomic strength and condition. Joint connections, which are held by a strong ligament and tendon apparatus, are preserved the longest, in particular, the pelvis girdle and the spine.

Concerning the decomposition of bones, once again biological, chemical, and physical factors contribute. The fragmentation of the bone can be caused by pressure of the soil or frost wedging. In acidic soil the hydrolysis of the mineral components (above all, hydroxyapatite) is accelerated. The big inner surface of the bone provides a large area for microorganisms, which are able to produce acidic metabolites and therefore to hydrolyze the apatite and finally to decompose the then unmasked proteins of the bone (above all, collagen). In this way the skeleton can finally decompose completely. Sandy soil indirectly promotes the decomposition of the bone because soluble components can dissolve, while loess soil, on the other hand, promotes the preservation of the bone.

Interrupted Decay

Normally a certain type of physical or chemical milieu is the reason that small animals and microbes are unable to decompose organic substances: high aridity, temperatures under the freezing point, exclusion of light and oxygen, high salt concentrations, or a low pH value. Some instances where organic decomposition under normal conditions is interrupted are described next.

Plants and animals that die in a cold season and cannot be reached by warm-blooded animals or articulata that produce warmth are either preserved or decompose more slowly than usual. Under the right conditions, dead creatures can be preserved for centuries within the ice as the low temperatures avert the microbial decomposition, just like a freezer. Prominent examples are the carcasses of mammoths that were enclosed in the Siberian permafrost (c. 10,000 years old) and the glacier mummy (called Ötzi by researchers) who died in the 4th century BCE in the Alps.

In an acidic, raised bog the soft tissue of animals can be preserved, too, because of the oxygen deficit and the high concentration of antibacterial humic acid. The humic acid also causes the decalcification of the bones and gives a tan color to skin and hair. Sometimes even inner organs are preserved. The most prominent examples for such preservation are the bog bodies of Northern Europe, which go back to the last ice age.

Preservation can also take place in resin that encloses plant parts or small animals. The hardened resin, which can turn to amber when pressurized, conserves the organic substances. Famous examples are the fossils found in amber from the Baltic Sea (c. 50 million years old) or in Dominican amber (c. 30 million years old).

Under anaerobic conditions in a moist milieu, grave wax (adipocere) can be formed. Bacterial activity transforms the unsaturated fatty acids of the corpse into saturated fatty acids (above all, palmitic and staritic acids)—a process that can take months or even years. Adipocere can be preserved for centuries. To a large extent the corpus of the dead body is preserved in its exterior layers (the fat tissue). The inner organs can also be well preserved if they are soaked with fatty acids. The parts of the body that contain less fat (often head and limbs) are usually skeletized. Grave wax corpses can form, especially if a fat corpse remains underwater or if water cannot drain from an earthen grave.

Mummification most commonly occurs where there is extreme dryness, heat, and especially draught. The tissues rapidly dry out and are therefore protected from microbial decomposition. It can happen at different stages during decomposition and can involve the whole corpse or only some limbs.

Finally, the hard parts of an animal body (shell, bones) can be preserved in basic and neutral milieus for centuries, even thousands of years. If secondary mineralization takes place, skeletons can finally form fossils.

Dirk Preuss

See also Chemistry; Diseases, Degenerative; Dying and Death; Ecology; Mummies; Thanatochemistry

Further Readings

Fiedler, S., & Graw, M. (2003). Decomposition of buried corpses, with special reference to the formation of adipocere. *Naturwissenschaften, 90,* 291–300.

Haglund, W. D., & Sorg, M. H. (Eds.). (1997). *Forensic taphonomy. The postmortem fate of human remains.* Boca Raton, FL: CRC Press.

Lavelle, P., & Spain, A. V. (2001). *Soil biology.* Dordrecht, The Netherlands: Kluwer.

Micozzi, M. S. (1991). *Postmortem change in human and animal remains: A systematic approach.* Springfield, IL: Charles C Thomas.

DECAY, RADIOACTIVE

In the early days of chemical manipulation, medieval and Renaissance alchemists sought means by which they could transform, or transmute, base metals into gold and silver. In the 20th century, scientists discovered that the transmutation of elements was not an impossible dream. In nature, radioactivity results from the spontaneous decay or disintegration of certain kinds of atoms (with unstable nuclei); these unstable nuclei emit energy (i.e., radiation) as decay particles or electromagnetic waves. Such subatomic changes have occurred naturally throughout Earth's history. Nowadays nuclear physicists artificially alter the composition and behavior of chemical elements for industrial, medical, and military purposes. Because each radioactive isotope decays at a definable rate (known as a half-life), the decay processes of radioactive substances can serve as "clocks" and offer unique opportunities for the measurement of time.

The closing years of the 19th century and the opening decades of the 20th century witnessed remarkable advances in our understanding of matter. Indeed, many famous names from the history of science are associated with early research into atomic structure and the nature of radioactivity (e.g., Becquerel, the Curies, Thomson, Rutherford, Soddy, Chadwick, Bohr). Although some of the terminology has changed over the years, many fundamental concepts related to radioactive decay appear in a brief overview of the early investigations into this phenomenon. Soon after Wilhelm Röntgen's discovery of X-rays, A. H. Becquerel accidentally discovered the phenomenon of natural radioactivity, in 1896, as he conducted experiments on the phosphorescence of uranium salts. As a result, Marie Curie and Pierre Curie dedicated years to the study of radioactivity and discovered the elements polonium and radium through their painstaking analysis of pitchblende (uranium ore); the Curies introduced the term *radioactive* to describe the emanations of uranium and these other heavy elements, which were much more "active" than uranium. Meanwhile, J. J. Thomson's 1897 discovery of the electron, coupled with these other breakthroughs, negated John Dalton's earlier views on the indivisibility and stability of the atom. (Modern particle physics examines the components, forces, and behavior of a subatomic world that is more intricate than Dalton's early 19th-century model, when chemists knew only 33 elements.)

One of Thomson's most productive students, Ernest Rutherford (through his research and experiments in New Zealand, Cambridge, Montreal, and Manchester), collaborated with other pioneering physicists and examined a number of significant aspects of radioactive decay. As a pivotal participant in the golden age of physics, Rutherford, with his curiosity and tenacity, was nothing short of inspirational. In 1898, he discovered that radioactive atoms emitted at least two distinct types of rays (later designated as particles), which he called alpha and beta. Rutherford and his colleagues used these decay particles (later identified as equivalent to the nucleus of a helium atom [a cluster of two protons and two neutrons] and high-speed electrons, respectively) in much subsequent research on the nature of radioactive materials. He also suggested that a third type of radiation might exist; Paul Villard identified the existence of the gamma-ray (electromagnetic radiation) in 1900. These major types of radiation have different properties (e.g., velocity, reaction to magnetic fields, penetrating power).

After discovering radon, a radioactive gas, Rutherford worked with Frederick Soddy and demonstrated that certain heavy radioactive atoms seek stability through disintegration (subatomic change). Rutherford, Soddy, and Otto Hahn conducted research on thorium and other elements that demonstrated their change from one form to another. This research into so-called decay chains resulted in a general, initially shocking, understanding of radioactive disintegration, namely, that elements are not immutable and that parent atoms of certain elements decay to daughter (and granddaughter) products through the loss of particles. For example, the radioactive decay series that begins with unstable uranium-238 ends with lead-206, a stable nuclide. In his study of the transformations that took place in these disintegration series, Soddy referred to atoms that had the same atomic number but different atomic masses as isotopes (also called nuclides nowadays).

Along with Hans Geiger and Ernest Marsden, Rutherford helped create a more accurate model of the atom, as their experiments directed alpha- and beta particles toward sheets of metal foil and observed patterns of divergence and deflection (as these particles reacted to an atom's positively charged nucleus). With Geiger, Rutherford developed an instrument to detect radioactive particles, a noteworthy advance in a field that depends on sensitive instrumentation. He also had a hand in the development of C. T. R. Wilson's cloud chamber, a relatively simple but effective detector that played a major role in the analysis of charged particles, including cosmic rays. (Physicists continue to develop hardware by which they can probe the subatomic cosmos, and much of this research focuses on high-energy particles and radioactive isotopes, e.g., reactors, accelerators, and cyclotrons.) Rutherford also used the versatile alpha particles to bombard light elements and brought about the first artificial transmutation of one element to another (the alchemist's dream) by disintegrating nitrogen nuclei and changing them into oxygen ("playing with marbles," as he described it). As representatives from a slightly later period of research on radioactive decay, Frédéric Joliot-Curie and Irène Joliot-Curie (the daughter of Madame Curie) worked on natural and artificial radioactivity and the transmutation of metals. Later, the Manhattan Project and the subsequent worldwide development of nuclear weapons generated a vast amount of research on fission and radioactivity, research that continues today for nonnuclear scientific and applied purposes.

Every radioactive element has a known rate of decay, or half-life, which is defined as the amount of time required for half of a sample's radioactive atoms to undergo decay. The half-life of some elements is extremely short while the half-life of other elements is extremely long, from a fraction of a second to several billion years. Isotopes whose half-lives are brief are quite radioactive, but elements with longer half-lives cause contamination for a longer period of time. Whereas the decay is random and spontaneous, the rate of decay (or activity) for a sample that contains a large number of the same atoms is predictable. As a result of their investigation of the radioactive decay of thorium, Rutherford and Soddy developed the exponential equation and the so-called decay constant used to calculate this decay rate. The international standard for measuring this disintegration or decay is the becquerel (= 1 disintegration per second).

Various nuclides are useful in radiometric dating, and, as discussed elsewhere in this encyclopedia, different techniques are applied to date archaeological remains and geological samples, from Earth and extraterrestrial sources. There are two kinds of radiometric dating techniques: (1) those based on the known parent-to-daughter decay rate of radioactive isotopes (e.g., radiocarbon [limited to organic materials], uranium–thorium, potassium–argon, uranium–lead), and (2) those based on the measurement of damage caused by the decay of certain radioactive elements (e.g., thermoluminescence, electron spin resonance, fission track). Of course, these methods provide approximate dates that include a range of error. Results from several methods of radiometric dating, applied to numerous samples (meteorites and lunar rocks), suggest that Earth and our solar system are some 4 1/2 billion years old.

Gerald L. Mattingly

See also Clocks, Atomic; Dating Techniques; Geologic Timescale; K-T Boundary

Further Readings

Asimov, I. (1991). *Atom: Journey across the subatomic cosmos.* New York: Penguin.

Bizony, P. (2007). *Atom.* Cambridge, UK: Icon Books.

Brown, G. I. (2002). *Invisible rays: A history of radioactivity.* Stroud, Gloucestershire, UK: Sutton.

Cathcart, B. (2005). *The fly in the cathedral: How a group of Cambridge scientists won the international race to split the atom.* New York: Farrar, Straus and Giroux.

Close, F. (2004). *Particle physics: A very short introduction.* New York: Oxford University Press.

Dickin, A. P. (2005). *Radiogenic isotope geology.* Cambridge, UK: Cambridge University Press.

L'Annunziata, M. F. (2007). *Radioactivity: Introduction and history.* Amsterdam: Elsevier.

Pasachoff, N. (1997). *Marie Curie and the science of radioactivity.* New York: Oxford University Press.

Wagner, G. A. (1998). *Age determination of young rocks and artifacts: Physical and chemical clocks in quaternary geology and archaeology.* New York: Springer.

Déjà Vu

The French phrase *déjà vu* is literally translated "already seen" or, less precisely, "already experienced." It refers to the uncanny sensation caused by an experience in the present that appears strikingly familiar to an experience from a vaguely defined past. The present feels as though it is being remembered. Often, déjà vu is used synonymously with paramnesia; however, there are terms for varieties of paramnesia having to do with other senses and similar sensations.

Explanations of experience similar to déjà vu arose in occultist and parapsychological circles prior to properly scientific investigation, and authors as far back as Pythagoras and Aristotle in ancient Greece examined the phenomenon. Such theories as hereditary transmission of experience, telepathy, precognition, or reincarnation were popular accounts of the sense of time transcendence experienced during déjà vu.

References to and descriptions of the déjà vu phenomenon have appeared frequently in fiction since the early 19th century, and it was first discussed in scientific literature of the late 19th century. Credit for coining the term is often attributed to Émile Boirac in a letter to the editor of *Revue Philosophique* (1876); however, some note that the topic was discussed by name as early as Arthur Ladbroke Wigan's *The Duality of the Mind* (1844).

With the rise of the Freudian psychodynamic perspective in psychology, many began hypothesizing that déjà vu is the result of remembering an unconscious wish, blurring of the boundary between one's self and external environment, or the rousing of a repressed memory. Gestalt psychologists believed déjà vu to be caused by structural familiarity of a past experience—lived, dreamed, read, or imagined—to the experience in which the déjà vu occurred.

As scientists found methods for examining the brain, their explanations moved farther away from phenomenological descriptions. The main causes purported in this community became epilepsy, temporal lobe abnormalities, and time lag between brain hemispheres or cognitive processes.

The development of even more advanced research methods in cognitive and biological psychology has sparked a resurgence of interest among those favoring these explanations. Often, contemporary theorists suggest that an adequate account of déjà vu must rely on an eclectic combination of these causes. Different causes might explain different experiences, for example, auditory or visual, and possibly even different occurrences of the same experience.

Social, cultural, and media studies theorists have also taken up interest in this topic today. Under the influence of psychodynamic theory's resurgence in continental philosophy and postmodernism, this literature may be seen as part of a broader interest in the study of culture and memory.

Kyle Walker

See also Cognition; Consciousness; Flashbacks; Memory; Psychology and Time; Time, Imaginary; Time, Subjective Flow of

Further Readings

Brown, A. S. (2004). *The déjà vu experience: Essays in cognitive psychology.* New York: Psychology Press.

Krapp, P. (2004). *Déjà vu: Aberrations of cultural memory.* Minneapolis: University of Minnesota Press.

Deleuze, Gilles (1925–1995)

In contrast to thinkers such as René Descartes and Immanuel Kant and the static world that they envisioned, Gilles Deleuze, a French philosopher who taught at the University of Paris, emphasizes becoming, contingency, irony, play, difference, repetition, and chance. Deleuze advocates becoming a nomadic thinker with neither past nor future. A wandering, nomadic, erring type of journey leads to the embrace of difference and repetition. Therefore, Deleuze constructs an anti-Kantian model of thought that is aconceptual, nonrepresentational, disjunctive, and inchoate. With this type of impetus, Deleuze's philosophy can be grasped within the context of the turn to difference that occurs in the 20th century with thinkers such as Martin Heidegger and Jacques Derrida.

If Deleuze is anti-Kantian, he is also anti-Hegelian in the sense that he is opposed to all closed or total philosophical systems. In a later work coauthored with Félix Guattari, titled *What Is Philosophy?* the job of philosophers is envisioned to be the creation of new concepts. Borrowing from Friedrich Nietzsche, Deleuze agrees that thought is a matter of creation, and truth is a creation of thought. This does not mean that philosophical concepts represent the truth independent of the plane of immanence upon which they are constructed. According to Deleuze, concepts are complex singularities and intensive multiplicities that do not represent anything. The creation of concepts occurs when a thinker determines a problem on a plane or set of pre-philosophical presuppositions, which he calls the plane of immanence. He also refers to it as the image of thought, by which he means an image that thought gives itself of what it means to think. The sources of truths are problems, which represent the differential elements of thought. More than merely questions to which thought provides answers, problems form the underlying and unanswerable questions that govern the creation of knowledge in a particular sphere.

Deleuze views his philosophy as a form of empiricism, which creates concepts in response to problems. Deleuze's empiricism is also experimental, by which he means introducing thoughts and acts that change an individual perspective. At the same time, Deleuze wants to find hidden differences and the destruction of illusions of permanence. The solving of a problem merely transforms it and offers new challenges rather than breaking the cycle of ever newer problems. Therefore, we must find a way to live with a problem rather than thinking that we can solve it for the foreseeable future. The problem of time is an example of a difficulty that begs for a new conceptualization.

Time in Deleuze's Thought

In his early major work *Difference and Repetition,* Deleuze considers three syntheses of time, which he considers in conjunction with the notion of repetition in each of them. By synthesis, Deleuze means a passive synthesis, or one that does not demand a representation of the sequence of moments to be synthesized within an active consciousness. Deleuze wants to overcome the representational mode of thinking because it is counter to the affirmation of real difference and is opposed to the eternal return. Therefore, Deleuze perceives a problem in the traditional way that philosophers have grasped repetition because it eventually culminates with identity, which renders it an equal, flat, and featureless timeline akin to a succession of moments.

The first synthesis of time is represented by circular time, which Deleuze identifies as the founding of time. Circular time is evident in mythical and seasonal time, which manifests a repetition of the same in the sense that it is a succession of instants governed by an external law. With circular time, a person experiences the present passing as moments cyclically because of the coexistence of past, present, and future. The repetition associated with circular time is concerned with habit, which is the passive synthesis of moments creating a subject.

Within this initial synthesis of time, repetition is not an objective property; rather, it is located in the experience, which is contradictory in the sense that prior moments are located in later instances. This scenario creates an expectancy because the repetition becomes synthesized in the present.

The second synthesis is identified with the foundation of time that Deleuze links with Kant, in which time is conceived as a straight line. With this second synthesis, the past coexists with the present, but it acts as a past that has been present. This scheme places events into time by not viewing a chain of events as constituting time because of the passing of present moments. If the present moment can pass away, it is because the present is already past, or it embodies a past element within it. From Deleuze's perspective, the present moment already possesses a past element in order for it to pass away. By passing away, a present moment becomes a past event for any future present. Repetition assumes an active sense because it repeats something in memory that was previously nonexistent.

Within this second synthesis of time, habit does not play a role because nothing returns. Deleuze refers to this second synthesis as memory, which is not connected to the present as is habit. Memory is associated with the past, or that which has never been present. By synthesizing from passing moments, repetition plays a role by repeating something in memory that did not previously exist, although this feature does not save it from identity. An important philosophical consequence is the radical bifurcation of the subject into the self of memory and a self of experience.

The final synthesis of time is identified as the unfounding of time, in which a pure and empty form of time unfolds. This pure form of time for Deleuze is repetition, which does not represent identity or the same. Repetition is related to difference in the sense that when beings are repeated as something other, their difference is revealed. This scenario suggests that Deleuze adopts Nietzsche's notion of eternal return, which is unrelated to habit. The advantage that Deleuze perceives in the eternal return is related to the fact that it does not suppress difference; rather, it represents a return of becoming and difference. In fact, it affirms difference even under the guise of multiplicity, becoming, and chance. This means that the eternal return is the repetition of that which differs from itself. This implies that whatever exists as a unity will never return; it is only that which is different from itself that can return.

Repetition possesses the power to accelerate or decelerate time, although this is something that cannot be intellectually grasped by an identity discovered in a concept or something similar in a process of representation. Being identified by Deleuze with the power of difference, the event of repetition disappears even as it happens because repetition lacks an in-itself, even though it possesses the ability to alter the mind that encounters it. Because repetition disappears as it appears, it is essentially unthinkable, incomplete, and cannot contain total reality.

If habit is the time of the present, or the always already becoming, and if memory, an old present, is the being of the past, repetition is the eternal return that is the time of the future. Pure repetition disturbs the repetitions of habit and memory and the paradox of the coexistence of past and present. This disturbance is related to the replacement of the linear succession of present moments and the cyclical recognition of revolving past moments by the eternal return of difference. Repetition is analogous to a dice throw, a risky act with an unknown result.

Moreover, Deleuze's notion of time possesses important implications for traditional philosophical modes of thinking. If the present and its previous presents are not similar to two consecutive instants on a linear line of time, Deleuze's conception of the nature of the present makes it difficult for representational thinking to work successfully because the present represents the former present instant and itself as a particular, and the past is presupposed by every attempt at representation. For the past and the future, representing dual asymmetrical elements of the present, this means that the past is caught between present moments, and it is futile to attempt to recreate the past from the present moments. Deleuze stresses the past as the foundation of time, and he acknowledges a basic paradox: the contemporaneity of the past with the present. A second paradox revolves around the coexistence of the moments of time, which results with the past being a synthesis of itself, the present, and future. This indicates that the present and future are mere dimensions of the past.

Another implication of Deleuze's position is related to time and being. Because repetition is unconnected to continuation, perpetuation, or prolongation of something with an enduring identity, Deleuze equates being with difference and repetition. Deleuze associates this equation with the ambiguity and deceptive nature of the notion of origin. For Deleuze, there is no union between being and time because everything is radically relative, without ground, depth, identity, or universality. According to Deleuze, the genuine character of being is the simulacrum in which everything is reduced to differences, which fragments them. If everything becomes simulacrum for Deleuze, there can be no resemblance of time to ontology or space.

Carl Olson

See also Derrida, Jacques; Descartes, René; Eternal Recurrence; Heidegger, Martin; Kant, Immanuel; Nietzsche, Friedrich; Postmodernism; Time, Cyclical; Time, Linear

Further Readings

Deleuze, G. (1983). *Nietzsche and philosophy* (H. Tomlinson, Trans.). New York: Columbia University Press. (Original work published 1962)

Deleuze, G. (1994). *Difference and repetition* (P. Patton, Trans.). New York: Columbia University Press. (Original work published 1968)

Deleuze, G., & Guattari, F. (1983). *Anti-Oedipus: Capitalism and schizophrenia* (R. Hurley, M. Seem, & H. R. Lane, Trans.). Minneapolis: University of Minnesota Press. (Original work published 1972)

Demiurge

Plato was concerned with the relationship between the eternal Demiurge as creator of the world and the birth of time. Time as becoming is understood by humans through astronomy and mathematics.

Plato's *Timaeus* picks up after the discussion in the *Republic* regarding the best form of society. It begins by recounting some of the major points of this discussion, beginning (significantly) with the point that each craftsman should be an experienced specialist and not interfere with the work of other craftsmen. In Book VII of the *Republic,* the education of those who are to guide the society (the guardians) is described; they move from arithmetic through geometry (plane and solid) to astronomy, which will make the soul "look upward"; the beauty of the patterns in the sky will provide a model for earthly patterns. The maker of the sky (the Demiurge) has provided a beautiful example of order for the earthbound craftsman to emulate. Socrates, content that they developed a good design for the ideal state the previous day, would now like to hear about it in action; this gives rise to a tale of the great island city of Atlantis, which sank beneath the sea. Critias finds remarkable the number of common characteristics between the "city in speech" and Atlantis. They then try to shift the comparison to the living city of Athens.

The first to speak in this endeavor is the astronomer Timaeus who, Critias tells us, will begin with the birth of the world and end with the creation of man. The world *does* exist, so there must be a reason, a cause for its existence. The world is a world of becoming, of coming-into-being and passing-away, so it cannot be perfect; but it *is* good. So it must have been fashioned after an eternal model; an account of the model can be (if it can be achieved) the truth, but an account of the sensible world, which is always changing, can be at best a "likely story"—"as being is to becoming, so is truth to belief (*Timaeus* 29b). The world has a maker (the Demiurge) who, like any good artisan, looks to an ideal model and creates the best copy possible. Some copies are better than others, and copies of copies are inferior (as in Book X of the *Republic*, Plato tells us how a painting of a bed is inferior to a bed made by a craftsman in imitation of the ideal Form of Bed). And a copy that has life and moves is superior to one that is static (just as Socrates and his companions desire to see the "city in speech" created in the *Republic* now in motion).

The Demiurge creates an order and harmony, according to mathematical principles and out of geometrical building blocks (the simplest of which are triangles). The created world is a living creature, with a body and a soul, made in the likeness of the ideal Form of Living Creature (the genus containing all the species). And it has a figure—it is spherical, the figure that contains all figures. The world needs a medium in which it comes into being; this medium Plato calls the Receptacle, the Nurse of Becoming. It is something like a room, or a womb; it is the mother to the creative father-force (energy) of the Demiurge copying the model. It is something like a mirror that takes on qualities. This space is eternal and "provides a home for all created things" (*Timaeus* 52b). It cannot be known through the senses (because it has no sensible qualities of its own) but must be apprehended by a kind of "bastard reason"; it seems we infer that it must exist. Qualities appear in the Receptacle, constantly changing, "without reason and measure"; the Demiurge brings order to this chaotic mix, fashioning "by form and number" (53b).

Just as the craftsman (consider a woodcarver) must wrestle with the resistance of the material he works in, the Demiurge is faced with the recalcitrance of his material (which Plato refers to as Necessity). Reason or Mind (represented in the Demiurge) must persuade Necessity to guide things for the best. The Demiurge is assisted in maintaining order by various lesser "gods" (the stars and planets, which are fiery). The need for the gods to bring about order by persuasion is represented in Greek mythology—at the end of the *Odyssey,* by the need for Zeus and Athena to intervene and wipe clean the memories of the families of the dead suitors, so peace can come to Ithaca; and at the end of Aeschylus's *Oresteia,* where Athena must persuade the Furies, who are frustrated because Orestes has been let go free, not to pour venom on the land but to accept a holy sanctuary and friendship mixed with worship. In both cases, the endless cycle of blood-vengeance must be stopped by reason; the analogy to the Demiurge bringing order out of chaos by reason is clear.

For Plato in the *Timaeus,* Space (the Receptacle) is a precondition of creation; but what of Time? Time is a different case; it comes into existence along with the world (he even refers to the "birth" of Time [39e]). The Demiurge desired to make his creation as much like its ideal model as possible. The model is eternal, and it is impossible for a generated cosmos, which is a realm of becoming, to be eternal as true being is. But he could have "a moving image of eternity" (37d); he made the image (Time) "eternal but moving according to number," whereas eternity itself "rests in unity." Thus we have the proportion (analogy)

$$\frac{\text{Time}}{\text{Eternity}} :: \frac{\text{Number}}{\text{Unity}}$$

Unity (the One) is the *arché* (generating principle) of number(s); eternity provides the model of which time is the image. The moving image of the model (eternity) generates time(s). Plato (or Timaeus) suggests that the heavenly bodies that reckon time teach humans to count and develop mathematics, "and from this source we have derived philosophy, than which no greater good ever was or will be given by the gods to mortal man" (47b).

Stacey L. Edgar

See also Becoming and Being; Creationism; Eternity; God and Time; God as Creator; Mythology; Plato; Space; Time, Emergence of

Further Readings

Benardete, S. (1971). On Plato's *Timaeus* and Timaeus' science fiction. *Interpretation, 2*(1), 21–63.

Pagels, E. (1989). *The Gnostic gospels.* New York: Vintage Books.

Democracy

Democracy is based on the idea of political self-determination. The emergence of democratic communities dates back to the ancient Greeks. Between 800 and 600 BCE, the political system of *isonomia* developed, a system of equality upheld by the willingness of its citizens to act in the interest of the common good. This lifestyle evolved as part of a cultural development, fostered by the interaction of a variety of factors, including geography and religion. Of particular significance was that in a Greek polis, the potential socioeconomic powers were relatively widespread. A tyrant was usually unable to stay in power for long; moreover, monarchy was not a generally popular idea in ancient Greece. So politics was a matter concerning a wide range of social classes in a polis (*demos*); it was not something "invented" by centers of power. However, this idea of integrating the masses has often been rejected by political philosophy. It is true that Aristotle (384–322 BCE) centered his concept of polis around the idea of free and equal citizens, and he emphasized that the ability to rule, as well as to be ruled, was a political virtue. Yet he rejected democracy as a political community under the rule of the rabble, as, for instance, Socrates (469–399 BCE) and Plato (427–347 BCE) had done before.

This perspective has proven most effective in the history of ideas: Until the modern era there was hardly a notable political philosopher who spoke out in favor of democracy, with the exception of Baruch de Spinoza (1632–1677). One of the reasons is that in earlier times democracy was often equated with direct democracy, such as in the writings of Immanuel Kant (1724–1804). So when democracy is discussed, it is always necessary to explain precisely what form of democracy is meant: Are there limits to democracy, for example, in a body of regulations? Is democracy seen as an end in itself, or does it serve other (higher) purposes? Are democratic decisions the immediate expression of the people's voice, or is the people's voice mediated by representative institutions?

Under the conditions of modern societies, democracy is typically temporary rule. The principle of political self-determination can be appropriately applied only by allocating power temporarily—first and foremost, by electing parliamentary representatives but also by selecting and democratically controlling government officials. The question of power separation and control was pointed out in the Federalist Papers, a series of articles in favor of ratifying the U.S. Constitution in 1787–1788. In Article No. 53, it is precisely described as follows: the greater the power, the shorter its reign; and vice versa. The lesser the power, the less dangerous it is to lengthen its reign.

In many ways, democratic elections are full of prerequisites. One prerequisite is that the political participants consent to prevailing conditions; another prerequisite is that the "loser" accepts the election results, and the "winner" is committed to carrying out his or her political responsibility for the common good during his or her term in office. However, using elections to achieve division of power represents nothing more than a temporary consensus that can be justified only in the light of a people's political self-determination, provided the democratic "rules" of the political system permit a real chance for a change of government. In this sense, the conditions governing the right to vote are of particular significance, as well as the structures of the party system, both of which determine whether all the relevant groups of a population are allowed to participate politically and essentially form a new majority.

The change of majorities is connected to the idea of creating an innovative contest among the pluralist concert of opinions to find a better argument, one that distinguishes the democratic system from other systems. This type of pluralism, which is upheld primarily by parties and political associations, binds time and therefore gives the impression of being "lethargic" with regard to democratic institutions' abilities to learn and respond. In fact, the cost of making decisions increases with the amount of time required, and that usually depends on the number of participants. As a result, democratic processes must be examined on a regular basis to evaluate the balance among the elements of participation, innovation, and efficiency. Yet, only such systems in which today's minority can become tomorrow's majority are capable of integrating political dissatisfaction and achieving reform. The key figures in this type of system-derived process are the floating voters. Nevertheless, a decisive prerequisite for this type of voting behavior is that decisions and responsibility are conveyed rationally (and, in that sense, topically), so that the voter can develop his or her own opinion on the matter in question.

Finding the right moment to make a political decision (*kairos*) is a question not only of luck but also of judgment that belongs, in an Aristotelian understanding of ethics, to prudence—a capacity that especially distinguishes the extraordinary politicians from the run-of-the-mill types. Following sociologist Max Weber (1864–1920), particularly democratic systems should have a strong interest in prudent political leadership, because the temptation is omnipresent that lures politicians to act in accordance with opinion polls to increase their own popularity (if only temporarily). Nonetheless, politics often require unpopular decision making, thus opening the way for a range of actions that are contrary to contemporary thinking or outside the spectrum of long-established routines. In view of accelerated developments in science and technology, not only has an alienation toward the past been growing but also the political responsibility not to submit to the linearity of events. It is important to retain the opportunity to reverse decisions. Otherwise, the limits of the majority principle are quickly reached: It loses its peacemaking character when decisions with irreversible results are made by the present generation for following generations—specifically in the field of risk technologies.

Just as democratic politics should not waste their energy dealing with the inherited problems of a former government's sins of omission, the horizon of political design should not be limited to one legislative period. According to the 20th-century German sociologist Niklas Luhmann, temporalized systems should always be capable of differentiating between reversibility and irreversibility. This challenges political systems to gain temporal autonomy with regard to the surrounding systems; the functionality of democracies depends primarily on the time available for negotiating decisions. Essentially this type of "limited government" is the result of a historical development, which also takes time. A democratic culture grows over centuries, a constitution begins to take shape only over decades, and several years are necessary to achieve governmental efficiency. If there is only "one" specific time period for the development of a democracy, it is, according to political scientist and sociologist Claus Offe, hardly possible to prevent the dilemma of simultaneousness. The transformational societies in Central and Eastern Europe during the 1990s fittingly illustrate this point; the failing attempts to democratize countries in the Middle East would be another case in point.

Failed attempts to implement democracy should not divert attention from democracy's almost inexorable triumphant progress. There is hardly a political system left that can refuse to justify its decisions democratically—or to at least create the impression of democratic legitimacy. This tendency is further promoted by the processes of globalization and particularly economic liberalization. In a modern state the relationship between a liberal economy and democracy may not be compulsory, but it has proven to be effective. With the increasing internationalization of political (as well as economic and ecological) challenges, the following question becomes more and more significant: How can democratic responsibility be organized on a global scale? History shows how democracy has been culturally bound to polis and the nation state. But what a democratic cosmopolis looks like remains to be seen.

Oliver W. Lembcke

See also Aristotle; Change; Enlightenment, Age of; Ethics; Kant, Immanuel; Law; Marx, Karl; Plato; Spinoza, Baruch de; Time Management; Weber, Max; Zeitgeist

Further Readings

Meier, C. (1990). *The Greek discovery of politics* (D. McLintock, Trans.). Cambridge, MA: Harvard University Press.

Riescher, G. (1994). *Zeit und Politik. Zur institutionellen Bedeutung von Zeistrukturen in parlamentarischen und präsidentiellen Regierungssystemen* [Time and politics. On the importance of temporality in parlamentary and presidential systems]. Baden-Baden, Germany: Nomos.

Rosa, H. (2003). Social acceleration. Ethical and political consequences of a de-synchronized high-speed society. *Constellations. An International Journal of Critical and Democratic Theory, 109,* 3–52.

Scheuerman, W. E. (2004). *Liberal democracy and the social acceleration.* Baltimore, MD: Johns Hopkins University Press.

Wallis, G. W. (1970). Chronopolitics: The impact of time perspectives on the dynamics of changes. *Social Forces, 49,* 102–108.

DEMONS

See DEVILS (DEMONS)

DERRIDA, JACQUES (1930–2004)

The Algerian-born French philosopher Jacques Derrida was a prolific writer whose influence extended to such varied fields as literary theory and semiotics as well as philosophy. Among the many issues addressed in his work is the concept of time. Noteworthy for his pervasive use of irony, Derrida is a master of playfulness. There is, for instance, an element of risk in his philosophy because he contends that his thought might not mean anything. Overall, Derrida offers no thesis and no philosophical position, because any distinctions that he makes he also undermines at the same time. Even though he leaves a reader with no identifiable philosophical position, he does adopt a method that he calls *deconstruction.*

Derrida's method promises to undo what he calls onto-theology, which can be identified with metaphysics, or what he calls *logocentrism,* which Derrida defines as the subordination of writing to the spoken word (*logos*). He equates logocentrism with the metaphysics of presence, which is the archenemy of deconstruction. As an expression of the metaphysics of presence, the fundamental error of logocentrism represents an illusion that reality and its categories are directly present to the mind.

Deconstruction is a method that does not produce anything, but it does reveal what is already present in a text. It is possible to grasp deconstruction as a simultaneous dismantling and building up because whatever position is taken is immediately negated. Deconstruction is exorbitant in the sense of exceeding the track of its orb. By passing through the line that it traces, deconstruction is a double crossing: a breaking through and a violation. Its exorbitant nature also means going beyond what is reasonable, just, or proper. In this regard, deconstruction undermines the propriety of reason.

Deconstruction is also a kind of double reading because it retraces a text to its limits, and it also marks the limits of a text. It is the trace that exposes the blank spaces of the text, that indicates what the text fails to constrain. At the same time, the process of deconstruction leaves tracks in the text in the form of remarks, that are like memory. This suggests that a track is already in a text, and it is only revealed by deconstruction, a process that also leaves a track in the original text. This implies that deconstruction leaves a text not dissimilar from its condition prior to deconstruction, but yet it is not the same. The remarks cut the text, and they perform an act of castration, so to speak, by clipping the logos of the text. The basic aim of deconstruction is to return to the metaphoric, poetic language where the power of signification has not been exhausted, in a process that leads to greater self-awareness. Being the deconstructionist, Derrida performs like a mime who occupies a position outside, or on the edges of the logocentric Western tradition. The mime's actions allude to nothing, reflect no reality, and produce merely effects of reality.

Because the concept of time is connected intimately with metaphysics and its concomitant presence, there is no alternative notion of time possible from the viewpoint of Derrida. As this is the case for Derrida, an alternative approach to the problem of time and its metaphysics of presence is his neologism *différance,* which is a finite movement preceding and structuring all opposition, that possesses a spatiotemporal significance for Derrida. *Différance* originates before all differences, and its "ance" ending indicates that it is neither simply a word nor a concept; it is neither active nor passive; and it is neither existence nor essence. It makes no appearance because it is not a phenomenal entity, whereas its movement represents a play of traces. This play of traces possesses no sense, because by presenting itself, a trace simultaneously effaces itself.

Différance is etymologically associated with the English term *differing,* which suggests a kind of spacing, and its association with *deferring* implies a temporalizing in the sense of a delay or postponement. Being simultaneously spacing and temporalizing, *différance* precedes time conceived as presence because the nothing of *différance* takes priority over being or time. This implies that absence precedes the presence of the present moment or being present, which suggests that presence is always deferred.

By thinking from the standpoint of *différance,* Derrida opposes any unity between being and time or place and time because their unity represents sameness, which suggests something static and unchanging. As Derrida thinks that there is no realm of *différance* because it subverts every realm, including its own, this implies that space and time are not intrinsically interconnected because spacing designates no presence, which is an irreducible exterior and a displacement indicating an irreducible otherness.

Because *différance* is in a constant state of flux, neither presence nor the present moment has a privileged place in Derrida's philosophy. This constant movement represents the play of traces, which is devoid of sense because the traces constantly efface themselves. The trace compromises the present moment and any residue of a past experience. In other words, the trace makes it impossible for a person to ever be located in a self-contained present moment.

Derrida's notion of time is also characterized by deferral, which suggests that what is happening is always to come. This implies that time is always slipping away. Nothing is ever stable or static; everything is subject to a process of change. Consequently, all past change can be recognized only from the perspective of the future, which is also subject to a process of transformation. For Derrida, the future is not something that will become present, but the future is rather that which makes all presence possible and at the same time impossible. A major consequence is that a self cannot become present to itself. Even though our existence is temporal, the experience of self-presence always eludes us. Instead of self-presence we must wait, or our experience is deferred, which Derrida refers to as messianic.

Derrida's notion of messianic must not be confused with the historical faiths of Judaism, Christianity, and Islam, because these monotheistic religions expect a Messiah with certain characteristics, such as maleness. Derrida calls and waits for the wholly other, or Messiah, to arrive. Derrida's Messiah, however, can never actually arrive, which is true even if the Messiah does come.

Because the futuristic Messiah is a completely ungraspable and unknowable other, we cannot truly know him even when he is present. Derrida thinks that our existence involves waiting expectantly for a messianic future event. We can wait actively or passively, but we must have openness toward a future that is noncircumscribable by any prior horizons of meaning that we impose upon the possible future. This is not a future that can ever become a present moment; it is forever deferred. We must thus remain open to an unknown and ungraspable futurity. For Derrida, time thus represents a disunity and uncertainty.

Carl Olson

See also Deleuze, Gilles; Futurology; Metaphysics; Postmodernism

Further Readings

Derrida, J. (1981). *Dissemination* (B. Johnson, Trans.). Chicago: University of Chicago Press.

Derrida, J. (1988). *Speech and phenomena and other essays on Husserl's theory of signs.* (D. B. Allison, Trans.). Evanston, IL: Northwestern University Press.

Derrida, J. (1992). *Given time: I. Counterfeit money* (P. Kamuf, Trans.) Chicago: University of Chicago Press.

Descartes, René (1596–1650)

René Descartes is one of the most important figures in the history of philosophy. Many of his ideas—for instance, his demand for a foundation of the sciences on an apodictic principle; his use of mathematics as a paradigm for natural science; his concept of science as a systematic totality; and his first principle of all philosophy, the famous *cogito, ergo sum* ("I think, therefore I am")—deeply influenced Western European philosophical and scientific thought. At the same time, Descartes articulated some general problems still contentious in today's philosophical discussions, such as the problem of body and soul, the irreducibility of the first-person perspective, and the problem of the existence of an external world. Descartes also earned much criticism for his dualist conception of human beings as consisting of two real, distinct substances (body and mind/soul) and his mechanistic model of the (animated) body.

René Descartes was born in 1596 in La Haye (today called Descartes), a village near Tours, France. Between 1606 and 1614 he was educated in the Jesuit College of La Flèche. Although this college was grounded on scholastic tradition, especially the philosophy of Aristotle, Saint Thomas Aquinas, and Francisco Suárez, it did not ignore the study of (natural) science. Descartes also came into contact with the works of ancient mathematicians, such as Pappus and Euclid. Deeply inspired by the validity and evidence of mathematical proof, Descartes became dissatisfied with natural philosophy based on Aristotelian principles, such as the doctrine of substantial forms and self-motion of animated bodies as being caused by their souls. He also disagreed with a foundation of philosophy on theological principles and stressed the necessity of a separation of reason and faith.

French mathematician and philosopher René Descartes (1596–1650). His views about knowledge and certainty, as well as his views about the relationship between mind and body, have been very influential over the past several centuries.

Source: Library of Congress, Prints & Photographs Division, LC-USZ62–61365.

After his time in La Flèche, Descartes studied law in Poitiers. In 1618 he enlisted in the Dutch, and later in the Bavarian, army. One year later, Descartes became acquainted with Isaak Beeckman, a Dutch scientist and mathematician, under whose influence he began working on mathematical studies of natural phenomena. Between 1619 and 1629, Descartes traveled widely and also frequented a circle of mathematicians and physicists gathered around Father Merin Mersenne in Paris. From 1629 on, Descartes lived in different domiciles in Holland for about 20 years. During this time, Descartes was working on optical, meteorological, and geometrical issues. At the same time, his concern was to find the final principles of the sciences and philosophy. In 1637 Descartes published his *Discours de la mèthode (Discourse on Method);* 4 years later his famous *Meditationes de prima philosophia (Meditations on First Philosophy)* appeared. The *Principia philosophiae (Principles of Philosophy),* Descartes' second main work, followed in 1644; his final work, the *Les passions de l'âme (Passions of the Soul),* was published in 1649. In the same year Descartes moved to Stockholm at the invitation of Queen Christina of Sweden, who employed him as philosophical and mathematical tutor. He died in 1650.

The Concept of Time in Descartes' Works

At first sight, the concept of time does not seem to play an important role in Descartes' thought. In both his major works, the *Meditations on First Philosophy* (Med.) and the *Principles of Philosophy* (PP), time seems to be of little interest. In Med. III Descartes discusses the *natura temporis* (nature of time) in a very short passage as a supporting argument for his first proof of God's existence; in the PP time merely serves as an illustration for general epistemological and ontological problems. At second sight, however, the issue is far more complicated. Although the singular passage in Med. III discussing the concept of time seems to be marginal because of its shortness, it nevertheless marks the zenith of the whole proof of God's existence; in the PP, the concepts of time and duration show an irritating ambiguity. The following sections discuss Descartes' reflection about time in the *Meditations* and provide an outline of Descartes' definitions of *time* and *duration* in the *Principles of Philosophy.*

Time in the Meditations

Descartes' aim in the *Meditations* is to establish certain and indubitable knowledge. For this purpose he starts scrutinizing the validity of the opinions he formerly had believed to be true. Descartes does not try to prove his opinions to be false; it is enough for him to show their doubtfulness, since "my reason convinces me that I ought not the less carefully to withhold belief from what is not entirely certain and indubitable, than from what is manifestly false, it will be sufficient to justify the rejection of the whole if I shall find in each some ground for doubt" (Med. I 1). Sensual perception soon appears to be no candidate for indubitable truth; first, the senses "occasionally mislead us respecting minute objects" (Med. I 4); second, Descartes perceives "clearly that there exist no certain marks by which the state of waking can ever be distinguished from sleep" (Med. I 5). In a third step, Descartes doubts the validity of rational and mathematical insight by constructing the concept of a "malignant demon [*genius malignus*] who is at once exceedingly potent and deceitful" and "has employed all his artifice to deceive me" (Med. I 12). However, although the result of the First Meditation seems to be "that there is nothing certain" (Med. II 1), in the Second Meditation Descartes soon finds "one thing that is certain and indubitable" (Med. II 1), namely, the fact of his own existence:

> Doubtless, . . . I exist, since I am deceived; and, let him [sc. the malignant demon] deceive me as he may, he can never bring it about that I am nothing, so long as I shall be conscious that I am something [*quamdiu me aliquid esse cogitabo*]. So that it must, in fine, be maintained, all things being maturely and carefully considered, that this proposition *I am, I exist,* is necessarily true each time it is expressed by me, or conceived in my mind. (Med. II 3)

An investigation of the question "what I am" and the consideration that the existence of bodies is dubitable—since bodies are the objects of sensual perception that has been doubted in Med. I—brings out the conclusion that all Descartes can be absolutely certain of is to be "a thinking thing [*res cogitans*]. . . . But what is a thinking thing? It is a thing that doubts, understands, [conceives], affirms, denies, wills, refuses; that imagines also, and perceives" (Med. II 9). In other words, Descartes cannot be certain whether the objects of his acts of consciousness, including his own body, exist independently of these acts, but he nevertheless can be certain that these mental acts themselves and he as the "thing" (*res cogitans,* mind [*mens*]) in which they are produced exist. The aim of the following Third Meditation is to transcend this solipsist perspective by working out the basics for the proof of an external world. This, however, cannot be done unless God's existence and truthfulness are demonstrated: "I must inquire whether there is a God, as soon as an opportunity of doing so shall present itself; and if I find that there is a God, I must examine likewise whether he can be a deceiver; for, without the knowledge of these two truths, I do not see that I can ever be certain of anything" (Med. III 4). For this purpose, Descartes analyzes the idea of God by focusing on two aspects: first, whether Descartes himself as a finite thinking substance could be the cause for this idea's existence within his mind; second, whether there is a need to ask for a cause for this idea's existence at all. The concept of time plays a crucial role in Descartes' discussion of the second question.

Descartes starts with a definition of God: "By the name God, I understand a substance infinite, [eternal, immutable], independent, all-knowing, all-powerful, and by which I myself, and every other thing that exists, if any such there be, were created" (Med. III 22). As a finite substance, Descartes argues, he cannot be the cause of the infinity involved in the idea of God. "For though the idea of substance be in my mind owing to this, that I myself am a substance, I should not, however, have the idea of an infinite substance, seeing I am a finite being, unless it were given me by some substance in reality infinite" (Med. III 23). Descartes also denies that God's infinity and perfection could be set within himself potentially, "for . . . although it were true that my knowledge daily acquired new degrees of perfection, and although there were potentially in my nature much that was not as yet actually in it, still all these excellences make not the slightest approach to the idea I have of the Deity, in whom there is no perfection merely potentially [but all actually] existent" (Med. III 27). In addition, Descartes argues that it is impossible to interpret the infinity and perfection involved in the idea of God as mere abstract negations of his (i.e., Descartes') finitude and imperfection. Nevertheless it is still possible that the divine features of God's idea do not require a cause for existing in Descartes' mind. Thus, Descartes asks himself "whether I, who possess this idea of God, could exist supposing there were no God" (Med. III 28). In this case, either Descartes was the cause of his own existence or there was no cause for his existence at all. Descartes tries to demonstrate the impossibility of both suggestions by discussing the nature of time:

> And though I were to suppose that I always was as I now am, I should not, on this ground, escape the force of these reasonings, since it would not follow, even on this supposition, that no author of my existence needed to be sought after. For the whole time of my life may be divided into an infinity of parts, each of which is in no way dependent on any other; and, accordingly, because I was in existence a short time ago, it does not follow that I must now exist, unless in this moment some cause create me anew as it were, that is, conserve me. In truth, it is perfectly clear and evident to all who will attentively consider the nature of time [*natura temporis*], that the conservation of a substance, in each moment of its duration, requires the same power and act that would be necessary to create it, supposing it were not yet in existence; so that it is manifestly a dictate of the natural light that conservation and creation differ merely in respect of our mode of thinking [and not in reality]. (Med. III 31)

The temporality of the "I" thus involves the metaphysical dependence of the finite self from an infinite cause, that is, God. Because time has no intrinsic continuity but appears as a series of relatively independent moments, any continuity of duration calls for a cause; and since continuity is equivalent with permanent creation, which needs a power that Descartes cannot find within his own existence, only God can be the cause for the permanent being of the "I." Thus, according to Descartes the mere fact of one's own temporal existence immediately indicates the existence of God in a way that knowledge of myself involves knowledge of God:

> When I make myself the object of reflection, I not only find that I am an incomplete, [imperfect] and dependent being, and one who unceasingly aspires after something better and greater than he is; but, at the same time, I am assured likewise that he upon whom I am dependent possesses in himself all the goods after which I aspire [and the ideas of which I find in my mind], and that not merely indefinitely and potentially, but infinitely and actually, and that he is thus God. (Med. III 38)

"Time" in the Principles of Philosophy

In the *Principles of Philosophy* Descartes takes a more objective perspective on time and duration. However, he seems to be irresolute where time and duration have to be located in ontological terms. He states: "Whatever objects fall under our knowledge we consider either as things or the affections of things, or as eternal truths possessing no existence beyond our thought. Of the first class the most general are substance, duration, order, number, and perhaps also some others, which notions apply to all the kinds of things" (PP I 48). "Duration" here seems to be a "thing" (*res*) just as a body or a mind. A few pages farther, however, the concept of duration is denied to designate a thing; it is merely the name for a mode (accident):

> We will also have most distinct conceptions of duration, order, and number, if, in place of mixing up with our notions of them that which properly belongs to the concept of substance, we merely think that the duration of a thing is a mode under which we conceive this thing, in so far as it continues to exist; and, in like manner, that order and number are not in reality different from things disposed in order and numbered, but only modes under which we diversely consider these things. (PP I 55)

Again the situation changes when Descartes discusses the relation of time and duration. Now duration seems to be something in the thing (substance) itself, while time now appears to be a mere mode of our thinking:

> Of these attributes or modes there are some which exist in the things themselves, and others that have only an existence in our thought; thus, for example, time, which we distinguish from duration taken in its generality, and call the measure of motion, is only a certain mode under which we think duration itself . . . [;] that we may comprehend the duration of all things under a common measure, we compare their duration with that of the greatest and most regular motions that give rise to years and days, and which we call time; hence what is so designated is nothing superadded to duration, taken in its generality, but a mode of thinking. (PP I 57)

While time is nothing but a measure of comparing the durations of things and thus a mode of our thought, not of the things themselves, duration itself cannot be separated from the enduring thing unless by abstraction—that is, as a mode of our thought: "For example, because any substance which ceases to endure ceases also to exist, duration is not distinct from substance except in thought (*ratione*)" (PP I 62). Descartes' indecision about the ontological and metaphysical location of time and duration results from a fundamental ambivalence of the Cartesian concept of substance, as the term *substance* can indicate one individual being among others of the same genus (e.g., one singular body) as well as the genus itself (e.g., "the extended substance" in the sense of "extension as such").

Descartes' concept of time and duration as a discontinuous series of moments and the temporal vagueness of the *sum* ("I am") has been extensively discussed and critiqued by other philosophers, in the 20th century perhaps most notably by Martin Heidegger.

Marko J. Fuchs

See also Aristotle; Augustine of Hippo, Saint; Duration; Epistemology; Heidegger, Martin; Kant, Immanuel; Metaphysics; Ontology; Solipsism; Spinoza, Baruch de; Time, Measurements of

Further Readings

Cottingham, J. (1992). *The Cambridge companion to Descartes*. Cambridge, UK: Cambridge University Press.

Gaukroger, S. (1997). *Descartes: An intellectual biography.* Oxford, UK: Oxford University Press.

Rorty, A. O. (Ed.). (1986). *Essays on Descartes' meditations*. Berkeley: University of California Press.

Williams, B. (1990). *Descartes*. Harmondsworth, UK: Penguin.

Design, Intelligent

Most broadly construed, intelligent design (ID) is the name chosen for a controversial strategy, combining both theory and practice, which is aimed at giving the ancient, philosophical design argument new life in the sciences, especially in U.S. public high school life science classrooms. More narrowly, the term is qualified so as to collect acts, persons, or propositions as elements related to the strategy—as in ID theorist, ID conference, ID tenet, or ID curriculum. The most contentious of these is surely ID science, or any connotation of the same. Indeed, ID flatly rejects contemporary science, including its thinking about time.

As theory, ID is the thesis that the sciences require an appeal to intelligent design to succeed at appointed explanatory tasks. As practice, ID embraces numerous forms of publicity for its theory, especially those that create the impression that the theory is, or ought to be accepted as, good science. These practices include television and radio appearances, private funding, journal articles, conferences, Web sites, rhetoric, sophistry, lawsuits, textbooks, mass-market books, curriculum packages, teacher-training programs, membership drives, campus events, and a host of religious, social, and political associations. ID theory and practice are carried out almost exclusively under the auspices of the Discovery Institute, a conservative think tank located in Seattle, Washington.

The full strategy of ID was described by Phillip Johnson in his book of 1997 and again in an online document, known as the *Wedge Document,* prepared for the Discovery Institute. Both treatments envision three phases scheduled over 20 years. The latter commits ID to the task of defeating "scientific materialism and its destructive moral, cultural and political legacies" and to replacing "materialistic explanations with the theistic understanding that nature and human beings were created by God." In the first phase, envisioned as a 5-year operation starting in 1999, ID proponents in the United States will publish 30 books and numerous articles. In the second phase, they will seek publicity for their work by contacting and cajoling U.S. broadcast media, lawmakers, congressional staff, and op-ed pages in newspapers. This phase is meant to prepare the public for reception of ID thinking. The third phase aims at "cultural confrontation and renewal." At this point the movement plans to use the courts to force their ideas into science classrooms.

ID and "Creation Science": Court Cases

A court case arose sooner than expected. In the 2005 case of *Kitzmiller v. Dover Area School District,* public school inclusion of the theory employed by the ID strategy was found to violate the establishment clause of the U.S. Constitution, and ID was legally ruled religion, not science.

The same fate befell ID's forebear, creation science, which was found to violate the establishment clause in the 1982 case of *McLean v. Arkansas Board of Education.* Like ID, creation science combined both theory and practice. As theory, it was strictly anti-evolutionist, embracing what is known as Young Earth creationism, which holds that the earth is between 6,000 and 10,000 years old. Its claim to scientific status was based on a dismissal of traditional earth and life sciences, including radioisotope dating and the accepted understanding of the geological and fossil records. In place of these it offered what is known as flood geology, which asserts that geological strata and the entire fossil record were laid down in the Great Flood described in the biblical story of Noah's ark. As practice, creation science pursued publicity, political connections, and a place in the science curriculum of public schools.

In their respective court cases, both ID and creation science were found to rely on a failed, two-model approach in which criticisms of one model are fallaciously taken as evidence in favor of the other model. Creation science pointed to weaknesses and omissions in evolutionary theory as evidence in favor of flood geology. In *Kitzmiller v. Dover Area School District,* the court found that ID did much the same. Omissions in evolutionary theory were adduced as evidence in favor of the ID theory that complete scientific understanding requires an appeal to intelligent design. Also in both cases, the supernatural was appealed to as an explanatory principle, in violation of the basic, naturalistic assumptions of science.

ID differs from creation science in that it does not assert a young earth; however, it does not officially deny one. ID is a broad movement, able to attract and accommodate both young earth and old earth creationists. In addition, ID does not rely on biblical literalism, though it carefully courts churches and flocks who do. ID is also importantly different from the thesis known as theistic evolution, which asserts that evolution is merely God's way of creating life forms. This view is officially held by most mainline Christian denominations; they necessarily accept an old age for the earth because they also accept the science of evolution. In addition, theistic evolution must accept evolution at all levels, whereas ID need not. ID accepts only what many creationists call microevolution, meaning that genetic anomalies can lead to prevalent changes within kinds. Many proponents of ID, such as William Demski, explicitly deny what is called macroevolution, that is, the mutation of kinds, or the fluidity of species—the whole notion of a common ancestry among fish, birds, amphibians, humans, and amoebas. Instead of macroevolution, these theorists assume what is often called special creation, the view that each species or kind was created in an individual act of creation, roughly as they are now barring microevolutionary changes. Thus, although it appears to accept an older earth than does creation science, ID is in fact compatible with a young earth and incompatible with theistic evolution.

Theory, Tenets, and Pseudoscience

In accord with the plans laid out by Johnson and the Discovery Institute, ID proponents frequently appeal to one another's publications and credentials to bolster their own individual cases. This echo chamber creates the impression of a wealth of expert agreement on the scientific value of ID theory. As a matter of fact, however, favorable expert evaluations of ID tenets are common only among cohorts of the Discovery Institute. Experts unaffiliated with that entity are unanimous in their agreement that ID's positive contributions to science are none, whereas its positive contributions to anti-intellectualism, misology, and sciolism remain inestimable.

ID practice centers on promoting the use of its textbooks and curriculum packages, most notably *Of Pandas and People,* which was originally a creation science textbook but was reinvented as an ID text more than a decade ago. Although ID publications and orators recommend this work, they make more frequent reference to Michael Behe's *Darwin's Black Box* and Demski's *The Design Inference* and *No Free Lunch*.

Behe, a microbiologist, claims to accept macroevolution, known in biology as common descent. But his pronouncement is at odds with his famous theory of the bacterial flagellum. According to this view, the flagellum would be useless if one of its parts was missing, and a structure that exhibits this property, dubbed "irreducible complexity," could not have evolved gradually, that is, from first having several of its parts to later having all of them. Instead, it must have been designed roughly as is, and Behe is stuck with flagellated bacterial species as deriving from special design, that is, from an individual act of creation. In that case, the common descent of these bacteria and any other life form is impossible, and Behe's position directly rejects the thesis of common descent. In response to it, the literature has developed numerous proposals about the evolution of the flagellum. The literature also reveals no serious modification of Behe's position since its publication and no interesting experiments or insights stemming from it.

Demski's contributions to ID theory revolve around the notion that eliminating chance and necessity as probable causes argues for intelligence as a probable cause. He calls "specified complexity" a property of objects that match an independently given pattern. For example, if you write down the opening of Hamlet's soliloquy, "To be or not to be," you reproduce a pattern that was specified by Shakespeare. Any random string of letters is complex, but some strings match independently specified patterns. When we see many of these successful matches, we conclude that intelligence is behind them, rather than chance (because the matches are not random) or necessity (because the matches obey no natural law). To the extent that organisms exhibit specified complexity, Demski holds, they too, like a sentence, must be understood as intelligently designed. He is impressed with the complexity of the flagellum described by Behe, seeing it as realizing an independently given pattern, a pattern that includes the kind of engineering we see in human contrivances, such as O-rings and a motor. The eye, he contends, exhibits the kinds of contrivances found in human camera design. Specified complexity, evidence of intelligent design, is all around us, waiting to be described. In *No Free Lunch,* Demski argues that mathematics suggests that the theory of natural selection lacks the power to do the things that biologists think it can do. Hence, the specified complexity he seeks to explain lies beyond the ken of conventional evolutionary biology—meaning that chance and necessity can be ignored as explanatory avenues, and intelligent design is all we really need. Although he is careful to avoid referring to his intelligent designer as a deity, and offers to not choose between its being either a deity or a race of sophisticated aliens, his works make clear that Demski is committed to an essentially religious conception of the sciences, in which, as he puts it, no theory has value "apart from Christ."

Some critics, such as Eugenie Scott, accuse ID proponents of relying on a fallacious appeal to ignorance, because one of the theory's premises asserts a lack of knowledge. "We lack a natural explanation in domain E; therefore, the phenomena in domain E were intelligently designed." Others, such as Mark Isaak, argue that ID proponents rely on a premise asserting incredulity, or disbelief, which inscribes a fallacy of the form: "It is inconceivable that X developed naturally; therefore, it must have been designed." ID can also be seen as an all-or-nothing mistake: Either historical biology can do all, or it cannot do enough in some domain, without recourse to the design thesis. This assumption yields fallacies of the form, "Evolution cannot fully explain Y; therefore, intelligent design helps to explain it." This is thoroughly mistaken because to assert that anything in the universe is the way it is because God or a race of sophisticated aliens made it that way is to offer an unscientific account, because it is an account that cannot be confirmed or disconfirmed empirically. In addition, the belief that a structure was intelligently designed does not help us to understand how it works. Hence, it explains nothing. These simple fallacies have been pointed out repeatedly, but the movement has not taken them to heart. Instead of modifying their thinking, and eliminating mistakes, they insist instead, and all the more loudly, that their ideas are being suppressed.

As described by R. T. Pennock, creationism has evolved from a crude attack on biology to a more sophisticated attack on the nature of science. Its new, ID thinking properly belongs more to the philosophy of science than to science proper. In contrast, Massimo Pigliucci treats ID as science in a weak sense that includes astrology, alchemy, and numerology, though it is unscientific in any stronger sense. ID is specifically not empirical because no observation or set of observations will ever prove whether an individual, an ecosystem, or the whole of nature is intelligently designed or not. In fact, the design thesis is widely understood to be consistent with any observation statement, making it metaphysical rather than scientific.

As described in the *Wedge Document,* a major strategy of the ID movement involves creating the public impression that scientific accounts of the origins of life are in serious crisis, and that those scientists who reject the notion that life evolved deserve a place in the sun. This impression was already worked on in the 1980s by Michael Denton. Of course, there are few scientific challenges to the thesis that life evolved, and cohorts of the Discovery Institute are not being suppressed. Nonetheless, the movement insists that there is a deep controversy over the evolutionary foundations of biology, and that the best way to treat dissenting scientists fairly is through the pedagogy of "teach the controversy," which would require that ID doctrines be taught in science classrooms. Because ID is not really science but rather a religious way of thinking, teaching the controversy over ID amounts to treating a theological or metaphysical debate as a proper content of high school science classes. Tellingly, religious neutrality is often invoked as grounds for demanding the inclusion of ID in the classroom. But of course, religious neutrality means treating all religious thought equally, which is most easily achieved by leaving all religious doctrines equally out of the science curriculum.

A simple and elegant solution like that will not satisfy proponents of ID, because their fundamental complaint is that science does not include God. Their project, on the basis of which they appeal for funding and political associations, is to put God at the beginning of science, as the beginning. Johnson has argued that knowledge is incomplete as long as the thesis that God created the universe is not accepted as the starting point of science. He misunderstands science, which can begin only when God and other supernatural agencies are left out of the picture. Johnson's position, along with the fact that there has been no modification of ID theory in the past decade, suggests that the pseudo-science published by ID theorists such as Behe and Demski exists merely to gain access for demolitionists of science, who plan to wreck and rebuild on religious foundations.

Bryan Finken

See also Adam, Creation of; Bible and Time; Creation, Myths of; Creationism; Earth, Age of; God and Time; God as Creator; Gosse, Philip Henry; Paley, William; Religions and Time; Scopes "Monkey Trial" of 1925; Teilhard de Chardin, Pierre; Teleology

Further Readings

Behe, M. (1996). *Darwin's black box: The biochemical challenge to evolution.* New York: The Free Press.

Davis, P., & Keaton, D. H. (1993). *Of pandas and people.* Dallas, TX: Haughton.

Demski, W. (1998). *The design inference: Eliminating chance through small probabilities.* Cambridge, UK: Cambridge University Press.

Demski, W. (2002). *No free lunch: Why specified complexity cannot be purchased without intelligence.* Lanham, MD: Rowman & Littlefield.

Denton, M. (1986). *Evolution: A theory in crisis.* Bethesda, MD: Alder & Alder.

Forrest, B., & Gross, P. (2004). *Creationism's Trojan horse: The wedge of intelligent design.* New York: Oxford University Press.

Isaak, M. (2005). *The counter-creationism handbook.* Westport, CT: Greenwood Press.

Johnson, P. E. (1997). *Defeating Darwinism by opening minds.* Downer's Grove, IL: InterVarsity Press.

Pennock, R. T. (1999). *Tower of Babel: The evidence against the new creationism.* Cambridge: MIT Press.
Pigliucci, M. (2002). *Denying evolution: Creationism, scientism and the nature of science.* Sunderland, MA: Sinauer.
Scott, E. C., & Branch, G. (2006). *Not in our classrooms: Why intelligent design is wrong for our schools.* Boston: Beacon.
Young, M., & Edis, T. (Eds.). (2005). *Why intelligent design fails: A scientific critique of the new creationism.* New Brunswick, NJ: Rutgers University Press.

DESTINY

Destiny is one of those subjects of interest in quests for the meanings of reality, human life, and the world at large. The term *destiny* can mean a predetermined occurrence of happenings, a future that is inevitable and unavoidable or not maneuverable, or an event fixed to take place at a particular point in time. It is also associated with a fate with which one is set up as one's lot. Destiny is a pattern of an occurrence of events that are out of the reach or control and in the hand of an external power. This notion of destiny thus entails a belief that there is an order that exerts agency over the happenings of events in the lives of human beings and the universe as a whole.

Among the various cultures, religions, and societies around the world can be found different notions and interpretations of destiny. The philosopher Messay Kebede, for example, in his book *Survival and Modernization,* formulates the central place of the notion of destiny in Ethiopian culture. According to him, destiny is referred to as *idil*—an Amharic term close to the meaning of chance, fate, or fortune. According to Kebede, the notion of destiny is embedded within the conception of time in Ethiopian philosophy.

For Ethiopians, according to Kebede, time is the doing and undoing of things, the ups and downs of life. Time is the good and the bad that may happen to someone or a particular group. Time is associated with fortunes and downfalls or failures. Thus people are said to have a favorable period of time when they attain power and access to authority and wealth and enjoy a good state of affairs of life in its various aspects. In all aspects of life, destiny is associated with the notion of time that success is viewed as a measure of the position of time being on one's side, whereas failure or loss is an indication of time being unfavorable, thus against. This can be in trade, war, a day in court, an accident, joy, sorrow, crop yield on a farm, or assuming or losing political position. Inherent in the notion of time, in Ethiopian culture, is the idea of promotion and downfall—time as the advent of destiny. Those who are bestowed with time in their favor are strong and unconquerable, whereas those who are disfavored by time are destitute and helpless.

Social orders and political systems and practices are all manifestations and reflections of time. It is time that gives power to those who are in a leadership position, and it is also time that causes others to be ruled and assume a lower position in the social hierarchy. From this perspective, Kebede argues, the Ethiopian conception of time is different from the Western notion. For Ethiopians, events are time or outcomes of time phenomena. Thus events and time are linked, and time is destiny. Time is the happening of events in a cyclical fashion—the ups and downs, not a linear progression from the past through the present into the future.

Claude Sumner, who studied Ethiopian cultures extensively and over many decades, outlines the notion of time in the Ethiopian culture. In his analysis of the *Book of the Philosophers,* a document considered to be an embodiment of Ethiopian philosophy, Sumner elucidates the various meanings of time. As a linear continuum, time is exemplified by what has happened that never comes back, like a spear that moves forward to its target. Accordingly, time is not cyclical; it is irreversible. This, Sumner presents, is a historical notion of the linearity of time, which has a past, a present, and an unknown future. Whatever happens never comes back, and life as events of time follows the same pattern. There is time for everything, and a wise person is one who knows the right time for the right actions. On the other hand, Sumner outlines the concept of time in association with the eternal, transcendental, and infinite notion of God in terms of creation—Creator versus creation. In this line of thought, human beings' choice in life leads to eternity, whereas the choice of falsehood results in death. Viewed this way, time is life and death, forms of the expression of destiny.

In conclusion, among other interpretations, destiny is understood as the series of events and happenings of life in the unfolding of time phenomena. In cultures such as that of Ethiopia, destiny is tied to time as the good and the bad of life. Be it cyclical or linear, time can favor or disfavor with consequences—fortunes and downfall.

Belete K. Mebratu

See also Becoming and Being; End-Time, Beliefs in; Eternity; Futurology; God as Creator; Predestination; Predeterminism; Teleology; Time, End of

Further Readings

Kebede, M. (1999). *Survival and modernization—Ethiopia's enigmatic present: A philosophical discourse.* Lawrenceville, NJ: Red Sea Press.

Levine, D. (1972). *Wax and gold.* Chicago: University of Chicago Press.

Sumner, C. (1974). *Ethiopian philosophy: The book of the wise philosophers* (Vol. 1). Addis Ababa, Ethiopia: Central Printing Press.

Determinism

The abstract noun *determinism* functions like a family name for a group of philosophical doctrines each of which asserts that, in one sense or another, events occur *of necessity* when and as they do. Different members of the family stake out different doctrinal territories, some construing the necessity involved in purely logical terms, some in causal terms, and still others in terms of predictability. Each has to do with necessary connections between past, present, and future.

Much confusion can arise from failing to distinguish one member from another. Much more can arise when they are taken to be identical with, or somehow allied with, other, less defensible doctrines: fatalism and predestination, for example. And still further confusion can arise when one or the other is taken to imperil such cherished beliefs as that in our own free will. It is important, therefore, to sort out the differences between them. We need to comply with the philosophical maxim, "Be careful with concepts and the words in which we express them." Sadly, there are some who bandy about the terms *determinism* and *deterministic*—often using them as terms of abuse—without saying exactly what they mean by them.

Three main members of the determinist family call for careful attention. The most basic is logical determinism, which asserts that future events (i.e., changes in states of affairs), like past events, are determinate and that statements about them are determinately true or false. It claims that if a statement about the future is true, then *of necessity* the events it is about will occur. It claims that the future will be what it will be, just as the past was what it was. These claims are evident tautologies. Yet, despite its evident logical credentials, this version of determinism has been called into question, often on the grounds that it seems to imply fatalism.

The term *determinism* is usually taken to refer to the doctrine of causal determinism. This holds that future events are caused by, determined by, or necessitated by, present ones and that these, in turn, are caused by past ones. It holds that nothing happens by "pure" chance. Causal determinism is an *ontological* doctrine: It makes claims about the contents and character of reality, holding that events that occur within it are connected in a temporal chain of cause and effect.

Unfortunately, causal determinism is often confused with predictive determinism, the view that if one *knew* in precise detail what events and states of affairs had occurred in the past, one could thereby predict present and future events and states of affairs. The 18th-century French mathematician and astronomer Marquis Pierre-Simon de Laplace (1749–1827) couched his concept of determinism in these terms, envisaging a hypothetical intelligence so vast that its knowledge of the laws of nature and the precise state of the universe at any given time would enable it to predict any future state of the universe with complete precision. Yet it is clear that this version of determinism adds an *epistemic* claim (a claim about our knowability of the world) to the ontological claim made by causal determinism. They are by no means identical.

Predictive determinism presupposes the truth of causal determinism, and that, in turn, presupposes the truth of logical determinism.

Logical Determinism

Logical determinists are committed to a realist account of truth. A statement is true if and only if reality is as the statement says it is. A statement's truth or falsity, therefore, does not depend on our perceptions or conceptions of reality, let alone on our knowledge (or lack of knowledge) of reality. By definition, there is only one reality (only one world), though there are many different conceptions of it. It is by virtue of this "correspondence" between true statements and the way the world is that logic gets its grip on reality. Hence the philosopher Ludwig Wittgenstein (1889–1951) claimed that logic is not just a body of human-made doctrine but is a "mirror image" of the world.

Logical determinists insist that the laws of logic apply to *all* statements, including statements about the future, for example, "A huge asteroid will destroy the earth in the year 2020." Logical determinists hold that the law of dentity (if P then P) shows that necessarily if this event is going to occur in 2020 then it will occur at that time; that the law of excluded middle (either P or not-P) shows that necessarily it will either occur or not occur in 2020; and that the law of noncontradiction (not both P and not-P) shows that it is impossible for it both to occur and not to occur in 2020.

Objections to Logical Determinism

Some people would object to the claim, on which the realist theory of truth is based, that there is only *one* reality. Such an objection is fostered by postmodernist and relativist claims about each of us having his or her "own" reality and, hence, that there are *many* different realities. It is doubtful, however, whether this sort of talk can be translated without loss of meaning into talk of many different conceptions or beliefs about the single reality that comprises all that was, is, or will be, the case.

Others would object to the realist account of truth, professing themselves to be deeply puzzled by the notion that true statements "correspond with" reality. But truth need not be explained in terms of correspondence. It suffices to say that a statement has the property of being true just when things are as it says they are. That formulation seems much less mysterious, as it focuses on the *conditions* in which a statement is true as opposed to wrestling with the abstract question, "What is truth?" It lets us understand what truth is by concentrating on our use of the predicate *is true* rather than on the abstract noun *truth*. The conditions under which a statement has the property of being true are different from the conditions under which we can *know* a statement to be true. Truth is not the same as verification (knowledge of truth). If it were, it would be absurd to suppose that there are undiscovered truths about the universe, awaiting discovery in such realms as the natural sciences, mathematics, or logic. It would be to suppose that we already know all the truths there are to know.

The notion that logic is a reflection of the basic structure of reality has also come under attack by those who suppose logic to be nothing more than a human-made doctrine about relationships between statements in human language. There isn't just one logic, they say, but many. We can invent new logical notations, including ones that abandon such traditional laws as the law of excluded middle. That "law" allows only two truth-values (being determinately true and being determinately false) with no allowance for intermediate truth-values. Hence, to escape from the threat of fatalism that logical determinism poses in the minds of many, some logicians have devised three-valued logics, allowing a statement to be neither determinately true nor determinately false but, in some sense or other, "indeterminate."

Formal systems for these and other multivalued logics can indeed be devised. But the question then arises as to the precise *meaning* to be attached to "indeterminate." In what sense of the word should we describe the statement that an asteroid will destroy the earth in 2020 as indeterminate? Can "indeterminate" coherently be understood as meaning anything other than "not known to be true or known to be false"? If not, then a defender of the law of excluded middle can reply that the proponent of these alternative logics is confusing truth and falsity with our knowledge of truth and falsity.

Similar questions can be asked about the proposal that we should adopt some nonclassical logic to handle problems in quantum theory. Is quantum "indeterminacy" to be construed in terms of anything more than a failure of our attempts to ascertain what the *determinate* state of a quantum system happens to be at a single point of time?

Causal Determinism

Logical determinists stake their claim on the truths of logic: truths that are said to be truths of reason, truths that we can come to know a priori, that is, without needing to appeal to experience. By way of contrast, causal determinism—roughly, the claim that the causal principle, "Every event has a cause"—makes a claim that we can certify, if at all, only *empirically,* that is, only by appeal to experience.

But is causal determinism in fact true? Certainly our everyday experience suggests so. "Things don't just happen," we say, meaning that things don't happen by so-called pure chance. Science, as commonly conceived, is the investigation of the unknown causes of various kinds of phenomena: the causes of asteroid collisions, the causes of global warming, the causes of physical and mental illnesses, and so on. That is to say, scientists try to discover hitherto unknown general truths (laws of nature) about how the universe works.

In principle the laws of nature seem to apply universally: not just to inanimate objects but to animate ones as well, including human beings. The more we discover about the mechanisms that make our bodies and minds work as they do, the more our behavior yields to explanation in terms of the interplay of a complex network of causes. Can *all* our behavior, mental as well as physical, be so explained? Are we just a product of nature and nurture? What are we to make of free will?

Belief in the universal reign of causality came under threat during the early 1900s with the development of quantum mechanics, the study of the behavior of the elementary constituents of the physical universe. The Danish physicist Niels Bohr had initially conceived of atoms as being like miniature solar systems, each with electrons spinning around a central nucleus in much the same way as the planets and asteroids revolve around the sun. But whereas in the case of the planets and asteroids about which, ever since Johannes Kepler and Isaac Newton, we have been able to formulate causal laws governing their behavior, in the case of electrons supposedly "spinning" around the atomic nucleus, we have not. Quantum theory, it turns out, does not yield strict causal laws about the behavior of the "ultimate" constituents of the universe. At best it yields only probabilistic estimates of how they will behave. Does this show that causal determinism is false? Or doesn't it?

Objections to Causal Determinism

Many thinkers think that the doctrine of causal determinism imperils the idea that we have free will. Indeed, it is often simply taken for granted, by those who haven't thought carefully about what "free will" means, that the two are logically incompatible. How can one be free, it is asked, if everything one does is determined by causes lying in the past? We cannot make the past other than it is. So if our present and future actions are necessitated by past causes, we cannot be free to do anything other than what those causes dictate that we will do. But we *are* free. Therefore, our free actions cannot be caused. So goes the argument of those subscribing to the libertarian's so-called contra-causal account of free will.

Some determinists agree with the libertarians that the ideas of free will and causal determinism are incompatible. But far from concluding that the doctrine of causal determinism must give way, they conclude that it is our beliefs in free will and responsibility that have to be abandoned. No one is ever *really* free or *really* responsible, they say. From their perspective, criminals deserve therapy and treatment, not blame and punishment. Such determinists are known as hard determinists.

Many philosophers, however, say that both the libertarians and the hard determinists have given a mistaken account of the conditions in which we are held to be free and responsible. On an alternative account, a person is free to act (roughly speaking) if he or she acts as he or she chooses, and does so without constraint or impediment. Only in those conditions can we properly hold people responsible. Such philosophers are known as compatibilists. Many well-known philosophers—John Locke, David Hume, J. S. Mill, F. H. Bradley, Bertrand Russell, Moritz Schlick, and A. J. Ayer, for example—have taken this position. A compatibilist can regard the question whether causal determinism is true or false as an open one, one that may yet be settled by further empirical inquiry. Some compatibilists, however, stick to their belief in universal causality. They are known as soft determinists.

Given this range of well-argued positions taken by philosophers on the issue of free will, it is naive to simply assume—as so many people do—that there are only two alternatives in the dispute: belief in causal determinism, on the one hand, and belief in free will, on the other.

Sadly, even sophisticated thinkers from disciplines outside philosophy may share this simplistic assumption. One of the founders of quantum physics, Werner Heisenberg, claimed that his newly discovered principle of indeterminacy opened the door for a belief in free will. How a lack of causality at the quantum level could be identified with responsibility-conferring freedom, he did not explain. Nor did he explain how we can be responsible for choices that occur, not from causal necessity, but just by *sheer chance*. The notions of freedom and responsibility seem as out of place in a wholly indeterministic universe as they seem to be in a deterministic one. Little wonder that compatibilists insist that these notions, when carefully analyzed, turn out to be compatible with both.

Predictive Determinism

Whether or not causal determinism is true, and whether its truth or falsity can in principle be established by quantum physics, one thing is clear: Current quantum theory does not enable us to make precise predictions about what is going on at the quantum, or subatomic, level of reality.

What, if anything, does this imply about the belief in universal causality? Remember that predictive determinism adds an epistemic thesis to the ontological thesis of causal determinism. This means that predictive determinism could prove to be false without causal determinism also being false. Albert Einstein's lifelong critique of quantum theory capitalized on this purely logical point. From our inability to measure the precise states of elementary particles, he argued, it does not follow either that they don't *have* determinate states or that those states are not *determined by* previous states.

Will physicists who are as philosophically well read and conceptually astute as Einstein eventually conclude that quantum physics provides a conclusive refutation of the ordinary belief in causality? Or will some future theory find a way of reinstating it? Perhaps time will tell.

Raymond Dynevor Bradley

See also Causality; Fatalism; Hume, David; Laplace, Marquis Pierre-Simon de; Predestination; Predeterminism; Quantum Mechanics; Russell, Bertrand; Time, End of

Further Readings

Bradley, R. D. (1962). Determinism or indeterminism in microphysics. *British Journal for the Philosophy of Science, 13,* 51.

Bradley, R. D. (1963). Causality, fatalism, and morality. *Mind,* October.

Bradley, R. D. (1974). The causal principle. *Canadian Journal of Philosophy, 4*(1).

Hook, S. (Ed.). (1958). *Determinism and freedom in the age of modern science.* New York: Macmillan.

Stebbing, L. S. (1937). *Philosophy and the physicists.* London: Penguin.

Van Inwagen, P. (1983). *An essay on free will.* Oxford, UK: Clarendon Press.

Devils (Demons)

Devils and demons have been ingrained in cultural and religious beliefs for thousands of years. Throughout time, the struggle between good and evil has been expressed through a belief in spirits, a belief that influences the manner in which we live our lives. Certain faiths expressed this theoretical concept as a tangible entity. Subsequently, demons were part of the physical and ethereal worlds and became both an explanation and advertence for certain human behaviors.

Demons initially referred to any spirits, whether or not they acted maliciously. The Greek word *daemon* (δαίμων) was often synonymous with *Theos* (gods). In pre-Islamic Arabic cultures no discrimination between gods and demons existed; instead the term *jinn* was used to describe inferior divinities. In the Islamic tradition, jinn are believed to be made of smokeless fire, whereas humans are made of clay. Evil jinns are *shayāṭīn,* or devils, and are led by Iblis (Satan), a former servant of God who became envious, arrogant, and defiant after the creation of humankind. Although God condemned Iblis to hell, He was additionally granted the ability to live to the end of eternity, misleading humankind and jinns. In addition to the jinns, the *guls* consume the bodies of the dead, the *sealah* inhabit the forests, and *skikks* are half-human creatures.

Within the Hindu faith there existed three classes of beings: *devas* (demigods), *manushyas* (humans), and *asuras* (demons). Asuras lived in Patala, the dimension between Naraka (hell) and

Bhu loka (earth), and were constantly in conflict with devas over supremacy. Asuras were once looked upon as divine creatures; when translated into early Iranian languages *asuras* becomes *Mahura,* the god in the Zoroastrian religion. However, the term *asuras* eventually became a reference to demons solely. In keeping with their belief in reincarnation, Hindus hold that if humans commit sinful and harmful acts in their lives, their souls (Atman) will be turned into evil spirits, such as *vetalas* (animate corpses), *pishacha* (vampires), or *bhutas* (ghosts). These Asian demons are depicted as being hideous creatures, with an extreme hatred of loud noises. A common practice to ward off oriental demons is to adorn hideous masks and light fireworks. This ritual is demonstrated during the Chinese New Year celebrations.

The modern Judeo-Christian system of demonology originates from the teachings of the prophet Zoroaster. One of Zoroastrianism's main influences upon demonology is with the concept of Ahura Mazda (the sole God figure) defeating his antithesis, Angra Mainyu or Ahriman (the Devil figure), in an epic battle of good versus evil. Alongside Ahriman is the queen of the demons, Lilith, "Mother of Ahriman." Lilith was later portrayed in the Jewish faith as having brought the demons, *lilin,* and evil spirits into the world with Adam while he was separated from Eve for 130 years out of penance for his sin. Later Lilith would be portrayed in certain texts as Adam's original wife.

Judaism incorporated the Zoroastrian class systems of demonology and angelology into the Hebrew Bible with the notions of the *se'irim* and the *shedim.* The se'irim (hairy ones) are satyr creatures, comparable to the Eastern religions' jinn. Shedim are spirits acting either in a benevolent or malevolent fashion. Three forms of shedim exist: Rabbi Loew's Golem is an example of the benevolent variety, *mazikin* (harmers) are the malevolent form often responsible for bodily possessions, and *ruhot* are evil spirits. The term *shedim* refers back to the *shedu,* the seven evil deities of the Chaldean mythology. These shedu are often depicted as protective winged bull figures outside royal places. Under some rabbinic sources, a king of the demons existed. This individual was either Samual "the angel of death," as described in older versions of the haggadah, or Asmodai. Satan is mentioned as well, though not as the king of the demons.

As Judaism and Christianity spread, the past religions and concepts were built upon and constructed into their own faiths. Their template for the devil comes from the Persian devil, whereas Lilith and winged angels are both copied from Babylonians. Due to the incorporation of Zoroastrian dualism, Satan changes from being the servant of god, distributing evil on behalf of God, to becoming God's adversary. As Christians overtook new lands, they also overtook the old temples. They integrated their own icons into the temples, changing the statues of Venus and Cupid into the Blessed Mother and Baby Jesus, and demonized the gods of their enemies. This demonization is apparent in the iconography of certain demons. Regularly a demon is portrayed with horns, hooves, and a pointed tail; this is evocative of the satyr god-creature Pan. Past gods are not the only demonized figures; the opponents of early Christianity were also labeled as being allied with the devil. Even Zoroaster himself was demonized as being Ham, the wicked son of Noah.

With the Judeo-Christian faith, new stories relating to the genesis of demons were introduced. The most widely known of these tales is that of the fallen angels. It is said that all those that sided with Lucifer were banished from heaven and became demons. The Book of Enoch provides another story: When the fallen angels slept with the daughters of man, giants and demons were produced. As the dynamic of the devil as the adversary grew, new religious beliefs resulted. On August 12, 1950, Pope Pius XII declared, in the *Humani Generis,* that Roman Catholics must regard the devil as a true person walking upon the earth. To resist Satan and his demonic forces, a strict adherence to cultural orthodoxy and religious dogma followed.

Derik Arthur Kane

See also Angels; Christianity; Evil and Time; Islam; Judaism; Satan and Time; Sin, Original; Vampires; Zoroaster

Further Readings

Ashley, L. L. N. (1996). *Complete book of devils and demons.* Fort Lee, NJ: Barricade Books.

Collin de Plancy, J.-A.-S. (1965). *Dictionnaire infernal.* London: Peter Owen.

Pagels, E. (1996). *Origin of Satan.* London: Allen Lane.

Dialectics

Dialectics is the formal study of change, of how everything changes over time. Dialecticians attempt to understand change by using universal and theoretical principles to analyze transformations over extended periods of time. With a comprehensive set of guidelines, the dialectical method can be used in the study of philosophy and in physical, biological, or social sciences.

Hegel and the Dialectical Method

The dialectical method, as used by Georg Wilhelm Friedrich Hegel (1770–1831), is employed to understand the history of rational thought or philosophy. Rational ideas are the creators of history. Using this method, we begin with an original idea. This is the *thesis*. The thesis has a limited life span because of its innate contradictions. Born out of this conflict is a new contrasting proposition, or the *antithesis*. The antithesis also contains contradictions. The solution between these rival influences fashions a resolution with a new thesis of the two opposing philosophies. This new philosophy contains its own intrinsic contradictions, and thus the process renews itself. By examining the basic contradictions of the new philosophy, we discover the inherited contradictions that begin the process of birth and death all over again. This is the way Hegel understood history. History has a pattern and not a hodgepodge of unconnected particulars.

Working with the concept of "essence of being," something is negated in the process of creating something new, which leads to what Hegel calls the "sum of essence." The new essence is only a manifestation of being, thus temporary and fleeting. This development is completely conditional; that only perceptible estimate of "being." The resulting contradiction is the negation-of-the-negation of the essence of being, leading to the "actuality" of a more advanced harmony. This brings together essence or "real meaning" with "existence." At each stage in this process, Philosophy is moving closer to the "absolute."

Dialectical Materialism

Dialectical materialism states that everything in the universe can be understood in terms of material substance, which occupies space and is in motion. The universe, nature, and human communities are natural and thus a part of a tangible process continually unfolding in a never-ending course of transformation.

Beginning with Karl Marx (1818–1883), the dialectic changes its orientation. The dialectic now becomes a materialist perspective that assumes matter in motion and change over time as the basis for all other understanding. The entire universe is interconnected and made up of interrelated parts. Matter neither vanishes nor is it formed anew. The physical field of material formations consists of interacting and interconnected particles transmitting movement from one body to another. This is the substantive reality of existence. Motion, space, and time are the basic expressions of matter.

According to Marx's collaborator Friedrich Engels (1820–1895), all of nature is continuously coming into existence and ceasing to exist at each moment in time. These changes are continuous. Trivial and hardly noticeable quantitative changes lead to a final break, followed by rapid and basic qualitative changes. Everything we can study is made up of opposing internal contradictions that break down the old while the new is being formed.

To summarize, there are three general laws of nature that constitute dialectics. First, the process begins with the law of unity and the conflict of opposites. Second, the slow accumulation of quantitative changes appears over time, until there is a final breakdown; this breakdown is followed by rapid qualitative change and the birth of something new. Finally, the law of the negation-of-the-negation occurs, which is based upon the Hegelian triad of thesis-antithesis-new thesis.

In the view of dialectical materialism, history begins with the material expression of actual people living their everyday lives. History moves forward with people living in association with nature. Through these relationships with nature, humans produce their own means of subsistence. Nature includes not only material nature but also the social nature of human communities. Each generation takes over from the past and provides for a new beginning with regard to their means of subsistence and then transforms it to fit their modified needs. "Human nature" of the individual is shaped by the specific historical and cultural setting of a particular group. Production determines how people are organized and how they interact.

Nature and Labor

Nature and labor are two critical aspects of the human condition. We are human because we labor. We take what we need from nature, and through our actions we change nature to fit our needs. This in turn changes us. Humans and human society are always a part of, and never separate from, nature. Our social world is merely an expression of the natural world. Human beings are seen in context as being fully integrated into nature, a part of nature. Humans are active, proactive, and interactive within our environment in a way that guarantees transmutation of humanity. This evolution of the human condition is continuous as we humans change and adapt to our environment.

The human condition, then, is set in the animal and social circumstances of people. This existential fact of our dual nature is found at the very beginning of hominid evolution and is a central concern of all human beings ever since. The human condition, which is universal and historically specific, includes biological necessity, social necessity, and the broad abstractions of psychological necessity.

We become human in a social setting. This setting is founded upon coming together to interact with nature. We call this interaction labor. Labor is our connection with nature, and through labor we create ourselves physically, socially, and emotionally. Through labor we become social beings, that is, beings that are culturally defined with individual personalities. It is through social activity that human life is possible. Labor is both social and material. Labor also symbolically and culturally manifests notions of self-expression. The human animal rationally develops into a culturally defined social being.

Labor, as seen in the perspective of dialectical materialism, is both symbolic and natural. Labor is born by combining symbols of creation with real human needs or wants. By working together in an existing environment, to take from nature and alter it in ways to meet our needs, we bring forth new needs by this action. This in turn changes our interaction with nature and each other. It is through this process of being human that society and cultures are created, and only in society are we fully human. In affinity with others, we can decidedly attain our power of creativity and of expression and fully maximize our humanity.

Modes of Production, Social Classes, and Culture

Human unity with nature exists through industry. Social science must reflect this if it is to elucidate the deeper underlying connections between specific social actions and global trends. In industry, commerce, production, and exchange establish systems of distribution, which in turn give birth to ideological possibilities. Along these lines, socioeconomic classes are determined by the mode of production. The needs of every class-society create its own ideological support. For example, with the evolution of bourgeois society, science developed to meet the needs of its mode of production. This was possible because the ruling ideas of any class-society are that of the ruling class. Those who control the material forces of society also rule the ideas of that society. Workers are subject to those ideas. The dominant ideology reflects the dominant material relations.

Manifestations of the human condition can be defined in specific social and cultural terms. These manifestations are continuously and historically in a state of metamorphosis, based upon the historical alternatives within the dynamic of an environment that is itself historically created. The appearance of the human condition is defined in specific social and cultural terms. Agency is the motor of this change. Agency is the instrument of the transmogrification of the social and cultural environment. Agency is defined as choice, which presupposes a limited free will, in a predetermined environment, with the options also predetermined.

Force of production is the natural environment combined with technology and the demands of population pressure. The relations of production are the sum of our social organizations, including work organizations, authority organization of work, property relations, and methods of product distribution. Political culture is reflective of this interaction, as is the ideological superstructure.

The forces of production set the limits of what is possible for the relations of production and in turn the relations of production offer continual feedback to the forces of production, thereby changing the nature of the forces of production. The relations of production generate the necessity of the specifics of a historically defined political culture. The political culture offers direction for the relations of production. The political culture creates, guides, and controls the ideological superstructure. The ideological superstructure provides the necessary knowledge for the operation of everything else, including the forces of production.

Culture is defined by the methods with which humans adapt to their environment and change that environment, thereby demanding and allowing humans to readapt to the changes in the environment. This dynamic operates within human communities as an interactive part of a larger world nature.

Thus we can say that because of the existence of humans as a part of the world and nature, humans and all other species in the greater ecosystem coevolved. Within this dynamic, the human condition specifically and historically defined the social, cultural, and biological, in order for the individual to survive and the community to meet its members' needs. These needs are met with specifics of the sociocultural setting that interact with nature and with other societies. This is carried out within the social setting of continual historical change and creates the individual, born within an historical setting that limits the options possible. Within this dynamic, the critical element is circumscribed free will, an assertion of choice.

Unfettered, unimpeded, lustfully creative, and aesthetically imaginative labor is fundamental to our human identity and a universal basic need of all people. Through labor, we become social beings, and through social activity, life is possible. Labor is thus both social and material. Labor also symbolically and culturally manifests notions of self-expression. The human animal rationally develops into a culturally defined social being. Truly free labor is a function of artistic creativity and aesthetic enjoyment.

The foregoing analysis blends the determinism of historical sociology with an element of inescapable freedom, made popular by the existentialists. When labor is introduced into this synthesis, labor becomes the unity of freedom and determinism.

This is the beginning of historical anthropology. Humans in fact create themselves and their society through their productive action, which we call labor, in the material world of nature. Productive powers are resources, including the ability to labor, which people use in that process. It is through the action of people using symbols, ideas, and objects to change nature that the historical core of the very production of society and its culture is created. We produce, alter, create, and ultimately bring forth ourselves through labor. Thought and action through labor produce new thought and action continuously. Culture, through communication and collective expressive validity, creates meaning. That meaning becomes basic to cultural explanations. Socially knowledgeable people in turn produce themselves by creating culture.

Productive powers are anything that can be used in production. Through production, people interact with nature. These forces and powers are used by people in such a way that material production occurs, because material production is organized to meet people's needs. This contribution to production is, in fact, planned. There must be an objective knowledge of how to use the tools of production, the process of production, and the needs that this activity satisfies. This interpretive composition of comprehension is within a culturally defined set of meanings, surrounded by a context that is relative to the conscious needs of a people. The processes of production are related to an interactive complex of meaning for the actors involved. This is central to the interpretation of symbols needed to carry out production. Productive powers include raw materials and technology, along with the skills and knowledge about the use of technology within that environment. All human social relations and their functions have an incontestable influence upon material production, and material production directly influences these relations.

Societies, to a certain degree, are internally consistent. There is a fundamental interactive relationship between economy, politics, and religion in a mutually reciprocal way that enables these institutions to be intellectually defined within a larger social whole. These "social totalities" have somewhat consistent arrangements of institutions that define the type of character a society has, in spite of the variation within the whole of that society. In any social and historical setting, there are limited options placed upon choices people make and the degree of social change possible by the formation of these structures. The types of societies form epochs. The epochs are shorthand for the basic themes of production of human social life in an entire historical era.

Humans need to realize themselves through labor. Through labor, people develop power and skills in an ongoing dialectic with nature. Productive knowledge is central to this actualization. Differing productive powers (forces of production) express themselves in different societies. Different relations of production give internal groups different interests in technological changes in these different societies. Most social revolutions would appear to preserve the level of productive powers achieved. Yet this tendency of expanding powers can best be seen at the world level, because local relations of production can prevent technical development beyond a certain point. The population size and average productivity of labor lies resolutely in the conditions of mass productive powers.

It is power that decides differing social groups' access to control over the means of production and the division of the fruits of labor of that society. Relations of production lead to productive inequalities. These relations of production are expressed through the affinity between groups within a society where some groups dominate and others remain subordinate in production and distribution.

Social beings determine social consciousness. This way of describing the material social life of people's productive activity, including the means of subsistence, lays the foundation for the intellectual, cultural, and spiritual life of a society. People, and only living people, make culture. Humans, as biological animals, create their own social life. Forces of production (including environment, technology, and population pressure) and exchange of material goods with other societies create the possibilities of what the relations of production or social organization will look like. This in turn limits the possibilities for the cultural world of a people.

Economics is the science of how people provide for their material and social needs and desires. This is historically determined within a specific environment, modified through trade with other societies. Each society is constantly changing as the environment changes. Each society has its own culture. The culture is formed through adaptation to an environment. By the use of culture, people adapt to an environment; through adaptation, they change that environment. The society and its culture become maladaptive to that environment and must alter culture to readapt to a new environment. In addition, all natural environments are changing naturally. Thus, the model used is both materialist and dialectical.

People are the authors of their social life within their societies. From the perspective of dialectical materialists, people create humanity and not God. Within communities, people make conscious choices. These in turn have real but unintended consequences. This establishes social phenomena beyond people's command. Social laws, like natural laws, exist outside people's control. Laws are intellectual constructs to explain these natural patterns. People collectively work as a unit to survive, and this creates the starting point for a social reality. Through collective labor, people interact with the natural environment and make human life possible. Thus, humans are not only social animals now but were always an interactive part of nature. People's changing relationship with nature is the foundation of a changing social reality they live with as a group. As there are changes in the natural environment and changes in the technology used to work with that environment, there are also changes in the social organization of that society. These changes then define the relations of production, which are the most basic part of a society. This is never a simple cause and effect relationship but a continual feedback system in which the cause is also the effect and vice versa.

Law, being heuristic, provides guiding principles that serve to indicate ways of allowing humans to make informed decisions. The laws of social reality, like the laws of nature, are knowable through careful observation and study. Through these studies, people learn about the multifaceted basics of social episodes. People can learn what is possible and what is not and thus make better choices instead of reacting blindly to those forces beyond people's control. Historical necessity provides the raw materials people work with in creating the choices they make. This, in turn, creates another historical necessity with new possibilities. With better information individuals can make better decisions, and the unforeseen consequences become less absolute. It is through the knowledge of objective necessity that people gain factual data. This deterministic model can elucidate the possible alternatives. True freedom within society, like within nature, is possible only if a deterministic model is used to explain the objective reality of society and the real options existing at any one time for people. Subjective free will is an illusion masking blind reactions to unknown outside forces that limit any real hope of freedom.

Until now, these changes operated as if they were blind forces of nature. Cultural and political structure reinforce the existing relations of production and become overpowering forces that individuals can never hope to change without precise information about what, in fact, exists. This is affected by understanding how society changes and by understanding the relationship between actions taken by a society and the social reality affecting those decisions.

*Michael Joseph Franciscon*i

See also Becoming and Being; Causality; Economics; Engels, Friedrich; Hegel, Georg Wilhelm Friedrich; Law; Lenin, Vladimir Ilich; Marx, Karl; Materialism

Further Readings

Afanasiev, V. G. (1987). *Dialectical materialism.* New York: International Publishers.

Cameron, K. N. (1995). *Dialectical materialism and modern science.* New York: International Publishers.

Engels, F. (1935). *Ludwig Feuerbach and the outcome of classical German philosophy.* New York: International Publishers.

Engels, F. (1977). *Dialectics of nature* (C. Dutt, Trans.). New York: International Publishers.

Engels, F. (1978). *Anti-Dühring.* New York: International Publishers.

Feuerbach, L. (1989). *The essence of Christianity.* New York: Prometheus.

Hegel, G. W. F. (1990). *The philosophy of history.* New York: Prometheus.

Lenin, V. I. (1970). *Materialism and empiriocriticism.* Peking: Foreign Language Press.

Marx, K., & Engels, F. (1970). *The German ideology.* New York: International Publishers.

Union of Soviet Socialist Republics Educational Bureau. (1974). *The fundamentals of Marxist-Leninist philosophy.* Moscow, USSR: Progress Publishers.

Diaries

The word *diary* is defined as a book or text in which one records one's own events and experiences, over time, most often on a daily or regular basis. The word *diary* comes from the Latin *diarium,* which is translated to mean "daily allowance."

There are no rules to diaries, as they include a personal collection of whatever suits their author: thoughts, feelings, complaints, poetry, art, and so on. Because of the private nature of diaries, individuals may be more candid about their feelings, relationships, and innermost thoughts.

To some extent, the words *diary* and *journal* have come to be used interchangeably, although many agree there are inherent differences. The largest difference between the two is probably that diaries, at least during their time of use, are intended more to be private, whereas journals, while personal, are often meant to be read by others.

Diaries have long been a part of human history, but in their beginning they were written only by those in the higher classes. Before the turn of the 20th century, only the highest-class citizens were literate and therefore were the only ones writing diaries. With greater industrialization and education, higher literacy rates meant more diaries were being written.

Over time, more and more diaries have been published. Published diaries offer a somewhat exclusive glance into the past. In addition to allowing a particular event or era to become timeless, published diaries can be one of the most intimate ways for history lovers and researchers to better understand the differences between contemporary living and times past. Diaries also offer a firsthand look into attitudes, feelings, and untold stories in times of economic depression, war, and other significant events. This may allow another side of the story to be told, offering a more complete glimpse into times of historical importance. One of the most famous diaries in this category is undoubtedly Anne Frank's *Diary of a Young Girl,* first published in 1947, as it offers a personal story and helps its readers gain a more complete understanding of the effects of the Holocaust.

More recently, the practice of writing "diaries" for immediate publication has become popular among political figures and celebrities. Many such works would be better categorized as memoirs or autobiographies, as they rarely are republished versions of actual diaries kept.

Reflective journals have become a popular teaching method throughout all levels of schooling, helping students to organize their thoughts and hone their writing skills.

Diaries have expanded well beyond the binding that once held them and have been transformed into more public than private texts. With the rapid growth of the Internet, online diaries quickly followed. Web logs, or blogs, are a popular place to capture one's own thoughts, opinions, experiences, and events. Although these certainly are not as private as diaries once might have been, they are growing in popularity, with as many as 8% of Internet users having created their own blog, and another 39% regularly reading blogs.

Blogs have allowed writers to reach a much wider audience, yet may still have the benefit of anonymity. Through the use of usernames or screen names, people can easily hide their identity but share their thoughts, feelings, and experiences.

As with most other media, the existence of diaries will likely continue, but with a change in times, education, and technology, they too will continue to evolve over time.

Amy L. Strauss

See also Consciousness; Education and Time; Memory; Novels, Time in; Proust, Marcel

Further Readings

Eicher, D. J. (2007). Primary sources: Handle with care—but DO handle. *Writer, 120*(4), 35–37.

Mallon, T. (1984). *A book of one's own; people and their diaries.* New York: Ticknor & Fields.

Sherman, S. (1996). *Telling time: Clocks, diaries, and English diurnal form, 1660–1785.* Chicago: University of Chicago Press.

Diderot, Denis (1731–1784)

Denis Diderot was foremost a philosopher and writer in France during the time of the Enlightenment. He is best known, however, for being editor in chief of the *Encyclopédie,* first published in 1751. It is believed that the *Encyclopédie* helped not only to promulgate the latest advances and discoveries in science and technology but also to spread the democratic ideas that sparked the French Revolution. Although it is debatable whether or not the creators of this work intended to incite social change, the consequences were far reaching.

Diderot was born October 5, 1731, in Langres, Champagne, France. His family was part of the bourgeois class that had been growing in France since the 15th century. Diderot's parents realized his academic talents at a young age and sent him to study with the Jesuits. His teachers saw a bright future for him in the clergy. At age 13 he became impatient with his schooling and decided to become an abbé at the local cathedral where his uncle was canon. After 2 years his uncle died and intended to leave his religious office to young Diderot. Unfortunately the church leaders gave the job to someone else. After this disappointment, Diderot moved to Paris and later attended the Jansenist Collège d'Harcourt.

While studying in Paris, Diderot worked as a tutor for wealthy families, wrote sermons, and did English translations, among other odd jobs. In 1732 he earned a master of arts degree in philosophy. He gave up his dream of going into the clergy and pursued a career in law. This was short-lived, and in 1734 he decided instead to become a writer.

In 1743, he married Antoinette Champion and had one child, Angelique. He struggled as a writer for many years, but through a bit of good luck, he obtained the post of librarian for Catherine II of Russia and earned a yearly salary to support his family.

As part of the growing Bohemian culture of Paris, he socialized with many of the period's greatest thinkers, such as Voltaire. Diderot's first philosophical work was titled "*Lettre sur les aveugles,*" published in 1749. It primarily describes the reliance of people's ideas on their senses. The works that followed dealt with the concepts of free will and relativism and gained him a good reputation among the thinkers of the day.

Diderot was asked to translate a dictionary of arts and sciences into French. Instead of accepting this task, he decided to create a new project that would do more than just define terms. He proposed the idea for the world's first modern encyclopedia. The publishers were excited by the prospect of such a project and named him editor in chief. In the *Encyclopédie* all of the ideas of this exciting intellectual period were compiled into one publication. The areas of history, philosophy, and poetry were included. For the first time it was possible for scholars, as well as the average citizen, to keep up with cutting-edge concepts. Some entries were seen as antiestablishment, and the encyclopedia was eventually suppressed and censored by the government in 1759, but volumes continued to be published until 1765. Diderot dedicated 2 decades of his life to this enormous project. He spent his final years writing plays and art criticisms and died of emphysema on July 31, 1784.

Jessica M. Masciello

See also Comte, Auguste; Democracy; Enlightenment, Age of; Materialism

Further Readings

Crocker, L. G. (1955). *The embattled philosopher: A biography of Denis Diderot.* London: Neville Spearman.

Furbank, P. N. (1992). *Diderot: A critical biography.* London: Secker & Warburg.

Dilthey, Wilhelm (1833–1911)

Wilhelm Dilthey was a German philosopher, pedagogue, and psychologist who is known mainly for his work on the foundation of the humanities and his philosophical theory of understanding (hermeneutics). Dilthey contrasts the notion of time of physical objects to the inner experience of time in human beings. He furthermore rejects Immanuel Kant's idea of time as a condition of perception and opts for a realistic interpretation of time.

Dilthey was born in Biebrich, Germany. After studying theology, philosophy, classical philology, and history both in Heidelberg and in Berlin, he became a professor of philosophy in Basel (1867). He then taught in Kiel (1868–1871), in Breslau (Wrocław; 1871–1882) and in Berlin (1883–1911). The main aim of Dilthey's philosophical works is to develop a systematic and historical foundation for the emerging *Geisteswissenschaften* (humanities). Following Kant, who presented in his *Critique of Pure Reason* a philosophical foundation for the empirical sciences, Dilthey aims at a project that he calls a *Critique of Historical Reason.* Whereas Kant takes the abstract rational subject as his starting point, Dilthey starts with the real, living, historically determined individual. Thus the categories of *Erlebnis, Ausdruck, Verstehen* (experience, expression, understanding) are the key categories of his work in the field of psychology and hermeneutics.

Dilthey analyzes and rejects Kant's highly influential philosophical understanding of time. Kant has argued that time is not an empirical object; that is, time is not a real thing within the world. It is rather (together with space) the form by which we structure our experience of the world. Time and space make experience possible; the world as such beyond our experience is completely unknown to us. Dilthey, however, argues in favor of a realistic interpretation of time. For him space and time possess a reality outside the subject and as real features of empirical objects. Time is therefore a real absolute condition of the existence of all objects that we find within the world.

Dilthey analyzes the notion of time not only in the context of physical objects but also as the inner experience of living persons. In opposition to the natural sciences, Dilthey emphasizes the subjective experience of time that cannot be measured with the help of the methods of the natural sciences. He distinguishes between objective time and time as related to the life of the individual. Dilthey considers the concept of a regular, mathematical objective time in natural science merely as a formal abstraction. He situates his understanding of time in the context of an analysis of the categories of human life: Our own inward experience is deeply linked to our temporal being that is structured in past, present, and future. Dilthey especially emphasizes the role of the past, which we experience in our memories and which we try to interpret as a part of our biography. The human concept of time therefore relates time to the idea of a unity of a life (*Lebensverlauf*), in which the different moments of our experience relate to each other and can be judged as "meaningful." By extension, Dilthey argues that the same objective time is not the same for different persons: "A year is not the same for a youth as for an old man."

Andreas Spahn

See also Bergson, Henri; Kant, Immanuel; Time, Objective Flux of; Time, Relativity of; Time, Subjective Flow of

Further Readings

Dilthey, W. (1985–2002). *Selected works* (R. A. Makkreel & F. Rodi, Eds.). Princeton, NJ: Princeton University Press.

Owensby, J. (1994). *Dilthey and the narrative of history.* Ithaca, NY: Cornell University Press.

Rickman, H. P. (1979). *Wilhelm Dilthey: Pioneer of the human studies.* Berkeley: University of California Press.

Dinosaurs

Dinosaurs are a highly distinctive group of vertebrates that played a dynamic role in terrestrial ecosystems for 165 million years of Earth's history. Fossils of their teeth and bones are found in abundance all over the world, sometimes along with evidence of soft tissues, nests, eggs, feces, and footprints. Collectively these remains comprise an excellent record extending from their emergence in the Triassic period up to the Cretaceous extinction, testifying to the great diversity of dinosaur species. First described in the early 19th century, dinosaurs were once thought to be sluggish, lizard-like reptiles. Our conception of these animals has changed with each new discovery; modern science shows that many dinosaurs were energetic, dynamic creatures more akin to birds and mammals in their activities. Their majesty and variety inspire perennial fascination, and scientific research on the group has vastly improved our knowledge of evolution and survival strategies in ecosystems under pressure.

Dinosaurs arose from archosaurian reptiles during the mid-Triassic period, approximately 230 million years ago. They became a hugely successful group, surviving several mass extinction events and evolving into a vast array of forms throughout their 165-million-year reign. During this time the dinosaurs achieved remarkable feats of specialization. The smallest were about the size and weight of a modern-day crow, while the largest attained lengths over 40 meters and weights up to 60 tons or more, the most gigantic land animals ever known. Some were quadrupeds, others bipeds, and some could move in either mode. Some were frightful, sharp-toothed carnivores; others were herbivores of such voracity that they altered the landscape with their feeding. Their range of forms and adaptability ensured that while not being the most abundant of terrestrial species, they ruled the top of the food chain in whatever niche they occupied and dominated their habitats over an exceptionally long period of life's history on Earth.

The term *dinosaur* is derived from the taxonomic group *Dinosauria,* a term coined by Sir Richard Owen in 1842. The fossils of many large and fantastic animals were being discovered in England at the time, including the carnivorous *Megalosaurus,* the herbivorous *Iguanodon,* and the armored *Hylaeosaurus.* Owen noted that the anatomy of these creatures differed significantly from that of modern and fossil reptiles but felt obligated to respect earlier research classifying the huge beasts as reptiles. He thus invented the name *Dinosauria,* meaning "fearfully great lizards."

One modern way of defining groups of organisms is through phylogenetic taxonomy, whereby organisms are related strictly by common ancestry. In this manner, Dinosauria can be defined as all members of the group descended from the most recent common ancestor of *Megalosaurus, Iguanodon,* and *Hylaeosaurus,* as these are all quite early forms of the two great dinosaur lineages Ornithischia and Saurischia. Dinosaurs can also be broadly defined as large terrestrial vertebrates that lived only during the Mesozoic era. Contrary to images in movies and popular culture, the prehistoric aquatic reptiles are not dinosaurs, nor are the flying pterosaur reptiles. Dinosaurs were predominantly terrestrial in nature, although fossil traces testify that some dinosaurs swam on occasion. Likewise, although the skeletons and feathers of certain species suggest some sort of flying ability, and theropod dinosaurs did indeed give rise to birds, this entry follows common usage in restricting the term *dinosaur* to nonavian dinosaurs unless specifically noted.

The earliest known dinosaurs were lightly built, agile bipeds with grasping hands. Although this body plan would later evolve immensely, certain important features defined at the start of the lineage were retained by all dinosaurs. All dinosaurs possessed a perforate acetabulum, that is, a hole in the wall of the hip socket that accepts the ball-like end of the upper thigh bone, the femur. This arrangement allowed dinosaurs to position their hind limbs closer to and underneath the body, allowing a full-time, "erect" stance compared to the more splayed-leg reptilian posture. The benefit of the more upright stance is that the limbs move within a vertical plane, with flexion and extension aligned to more efficiently convert muscular effort into forward movement. In either bipedal or quadrupedal mode, this improved mobility; dinosaurs could move around faster and stay active longer than most of their immediate ancestors. The upright stance is also capable of sustaining a greater body weight compared to a sprawled posture, allowing massive future growth potential. Other common characteristics of dinosaurs include an elongated ridge along the top of the upper arm bone and a hinge-like joint in the ankle. This last feature allowed dinosaurs to better adopt a digitigrade stance, where the longer foot bones and ankle are raised from the ground and weight is distributed over the toes and front "balls of the feet." Early dinosaurs also had "hands" with a semi-opposable thumb, grasping ability, and reduced outermost digits. This adaptation was coeval with their primary shift to bipedalism. Later on, when dinosaurs diversified further, some of these defining features were lost in some lineages. Most of these initial traits, however, were retained across all groups.

Dinosaurs are divided into two primary orders, originally based on the shape and form of their hip bones. The Saurischia ("lizard-hipped") dinosaurs have hip bones with the pubis pointing down and forward, similar to reptiles. The Ornithischia ("bird-hipped") dinosaurs have hip bones with the pubis pointing down but backward, almost parallel to the ischium. As this trait turned out to be a rather weak discriminator for subsequently discovered taxa, Ornithischia and Saurischia are now also defined by a range of skull and skeletal features. The essential division remains valid, however. It should be noted that the most bird-like theropod dinosaurs, while nominally lizard-hipped, in fact have a typical bird-shaped hip.

Within these general classifications dinosaurs evolved incredible adaptations, diversified into a wondrous range of sizes and shapes, and grew their formidable teeth and claws—in short, they acquired all those qualities of such fascination to humans. The diversity of their anatomy reflects a similar diversity of habitat; dinosaurs lived in cold polar regions and hot arid plains, by seaside cliffs and highland lakes, and their fossils are found on all continents. Dinosaurs truly dominated their time; new discoveries reveal there was likely a dinosaur in many of the ecological niches that are occupied today by small animals and mammals, including those that could burrow and climb, were active in darkness, and could not only glide but achieve true flight.

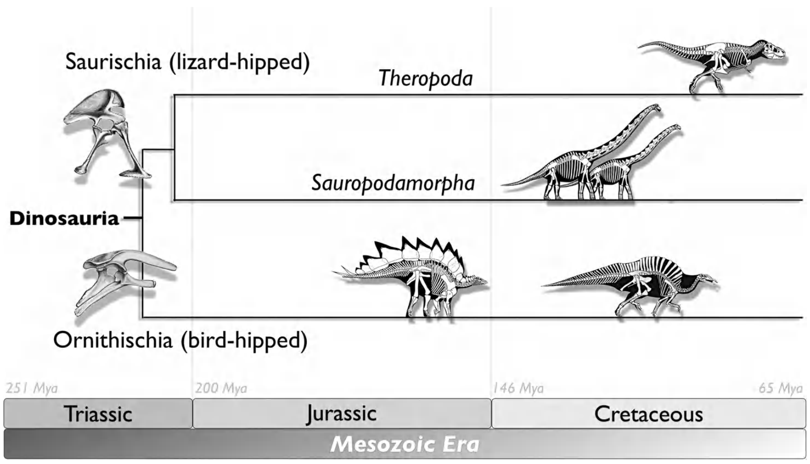


Figure 1 Basic dinosaur classification

Source: Courtesy of Mark James Thompson.

Notes: Basic classification of Dinosauria with timescale and geological periods. Dinosaurs are divided into two primary orders, originally based on the shape and form of their hip bones.

Evidence

Because there are no dinosaurs alive today, our knowledge of them comes exclusively from fossilized remains and traces. Fortunately, the fossil record is abundant and extensive. Several thousand largely complete dinosaur skeletons have been located and collected, not to mention hundreds of thousands of isolated bones and teeth. From these remains, many hundreds of genera and thousands of species of dinosaurs have been classified to date, with additional taxa based on fossilized footprints and trackways.

Nevertheless, it is clear that the fossil record is far from complete. Nearly half of the dinosaur genera are based on a single specimen, and complete skulls and skeletons have been found for only about 20% of the identified species. This is due to the process of fossilization being extremely haphazard, particularly for terrestrial vertebrates; only a minuscule fraction of any population will ever leave fossil remains.

This large fossilized femur of a sauropod dinosaur was discovered and excavated by Paleo-explorer Tim Quarles. The white portion along the top of the bone was exposed at the surface, leading to the discovery.

Source: Photo by Tim Quarles. Used with permission.

A rare collection of factors is necessary to preserve the body of an animal in fossil form. In even the best environments for fossil formation, such as a river floodplain, most animal remains are destroyed quickly by natural decay—scattered, trampled, and gnawed while being eroded by wind, water, and sun. The coalition of physical and chemical erosion is unrelenting—before long, no trace of the animal is left to join the geological record. The process of destruction may be temporarily halted, however, if a substantial flood breaks the river banks and sweeps over the plain, depositing a layer of sediment over any bones and remains, thereby protecting them from the surface elements. The completeness of the fossil record in this environment is thus largely determined by the frequency of flooding, which can occur at intervals ranging from tens to thousands of years. The resulting fossils form a series of snapshots in time rather than an ideal continuum. In less ideal environments where there is little chance of sedimentary deposition, the record becomes even more scant.

If the remains are deeply buried for a long enough period, the sediment may undergo diagenesis and transform into rock. It is during this process that bones fossilize; the forms of softer tissue are sometimes preserved as well. Later on, massive geological processes such as mountain formation are required to raise fossil-bearing rocks back to the surface. Just enough erosion is then required to expose the fossils, where with luck they may be discovered just prior to their terminal destruction, as weathering again conspires to convert the fossil to dust.

Given all these criteria, it is not surprising that the fossil record of dinosaurs is incomplete. Rather, it is astonishing that the record is so extensive and detailed. By recognizing the rarity of fossil formation, it then becomes possible to appreciate the sheer abundance of dinosaurs over time.

The best-known dinosaur remains are body fossils, which come from the physical remains of the animal itself. These are most commonly isolated bones and teeth, but sometimes articulated parts or even whole skeletons are found. Bumps, grooves, and scars on the fossil bones show sites of muscle attachment and let us make educated guesses regarding their body shape and abilities. The form of the jaws and teeth indicates preferred food types. In very rare cases the contents of a dinosaur's stomach are still intact, preserving not only its last meal but also a sample of the environment in which it lived.

Holes in the skull reveal the size and shape of their brain, ears, eyes, and nostrils. Indeed, the very shape of the braincase allows us to infer some of its functional capability by examining the size and location of specific lobes. For example, scientists might be able to recognize that a part of the brain used for olfactory processing was relatively large. From this evidence we can infer that the dinosaur had a well-developed sense of smell, and we may draw some conclusions concerning its potential behavior.

Occasionally traces of soft tissue are preserved along with the skeletal remains, usually as mineral replacements shaped like the original organic material (pseudomorphs). Spectacular examples of dinosaur fossils may display evidence of muscles and internal organs, skin, and feathers. Thanks to recent technological advances, researchers have even found preserved biomolecules in partially fossilized material. In these exceptionally well-preserved specimens, the molecules include bone-related proteins (collagen and osteocalcin) and blood proteins such as hemoglobin. Although much work remains before we fully understand the mechanisms of preservation, it appears that an exciting new area of dinosaur exploration may be opening up on the molecular level. Further progress may eventually lead to the recovery of DNA fragments, which can be used to directly demonstrate evolutionary relationships among taxa.

In addition to body fossils, there are trace fossils that also can provide useful information on dinosaurs and their environs. Footprints and trackways can tell us the animals' weight, stride length and speed, and the position of legs relative to the body. In some cases they also provide insights into behavior such as herding or predation. Fossilized dinosaur nests and eggs, some containing embryos, have been found on several continents. These provide important evidence on dinosaur reproduction and parental behavior. Coprolites (fossilized dung) are a good source of information on dinosaur diets and, in some cases, their habitat and distribution. Collectively the fossil record of dinosaurs is vast and detailed, allowing us to gain a deeper understanding of how they may have behaved and interacted as well as how they appeared physically.

Emergence and Ascent

Dinosaurs are members of Archosauria ("ruling reptiles"), a significant clade of terrestrial reptilian vertebrates of the Mesozoic that, during the mid-Triassic period, included two significant groups; the Crurotarsi and Ornithodira. Some members of Crurotarsi became quite large, cow or ox sized, and evolved into a range of diverse, mostly carnivorous forms that included phytosaurs, aetosaurs, rauisuchians, and crocodylomorphs (ancestors of modern crocodiles). The Ornithodira, by contrast, were smaller and acquired a more specialized upright stance, longer rear leg and foot bones, and an extended neck with an S-shaped curve. It is believed that the flying reptile Pterosaurs evolved from this branch of Ornithodira, while another branch further developed the fully erect posture and a new, hinge-like ankle joint, the Dinosauromorphs. From among these, the first dinosaur evolved.

The earliest known dinosaurs are *Pisanosaurus, Eoraptor,* and *Herrerasaurus,* whose body fossils are all found in 228 million-year-old (Late Triassic) sedimentary rocks of the Ischigualasto Formation in Argentina. These were lightweight obligate bipeds of small or moderate size. *Pisanosaurus* and *Eoraptor* were both about 1 meter in length, while *Herrerasaurus* was about 5 meters. Other early dinosaurs found slightly later in other parts of the world include *Staurikosaurus* and *Guaibasaurus* from Brazil and the ornithischian *Lesothosaurus* from South Africa.

As the oldest taxa are of similar geological age and lie close to the emergence of dinosaurs within Dinosauromorphs, identifying the first known dinosaur is a bit problematic. *Pisanosaurus* is regarded as the most basal ornithischian and already showed grinding teeth adapted for herbivory, with inclined tooth-to-tooth wear facets that assisted in slicing and processing plant matter. *Herrerasaurus* and *Eoraptor* were contemporaneous predators with adaptations for carnivory such as curved, serrated teeth and elongate hands specialized for grasping prey. They are generally regarded as the most basal saurischians, the great primary dinosaur lineage that later split into the herbivorous sauropodomorphs and the mostly carnivorous theropoda. Although the grasping, raking hands and curved teeth of *Eoraptor* suggest classification as a saurischian theropod, its lower jaw is not jointed like that of the slightly more derived *Herrerasaurus*. Because members of both saurischian and ornithischian lineages existed at this earliest time, the two divisions must have evolved from a common ancestor even earlier in

Eoraptor. The 228 million-year-old skull of the most ancient dinosaur yet found.

Source: Courtesy of Mark James Thompson.

the period, likely in the mid-Triassic. But this specific ancestor has not yet been found, if in fact it was ever preserved in geology. As *Eoraptor* exhibits fewer specializations that define saurischians and ornithischians, it is widely regarded as the first known dinosaur and is thought to be very similar to the original ancestor.

The world over which the first dinosaurs strode was a place of intense competition and major upheavals in the land fauna population. The dinosaurs' archosaurian relatives had diversified into a wide range of niche-dominating forms: terrestrial quadrupedal carnivores, semi-aquatic predators, and armored herbivores. Many of these animals were bigger than the earliest dinosaurs and existed in greater numbers. A huge variety of nonarchosaurs were also present, including early mammals and mammal-like reptiles. By the start of the Late Triassic, dinosaurs were only a small part of the total land fauna.

Yet from this humble start, dinosaurs had become the dominant land animal by the beginning of the Jurassic period 30 million years later. The reasons for their rise to eminence—and why their contemporaries faded away—have been the subject of much debate. Did the dinosaurs evolve some significant advantage that allowed them to overcome their competition, or did they just get lucky during oppressive environmental crises and extinction events?

It has long been thought that, once they had emerged, the dinosaurs swiftly replaced their closest relatives, the dinosauromorphs, and most other archosaurs. However, recent discoveries suggest that the rise of dinosaurs during the Late Triassic was a more gradual process. It now appears that dinosaurs coexisted with dinosauromorphs for a prolonged period, 15 to 20 million years, without establishing clear dominance. Although genetic and environmental factors must have prompted their evolution and emergence, dinosaurs clearly possessed no significant advantage over their contemporary land animals, as under normal environmental conditions they did not overpower their competition.

As the Triassic drew to a close, however, several global scale events occurred that caused mass extinctions of life. As with the more famous Cretaceous–Tertiary mass extinction, which occurred some 140 million years later, it has been suggested that one or more catastrophic events were involved. Global climate change due to sea-level fluctuations, severe volcanic activity, and bolide impacts have all been postulated with evidence for each hypothesis. The event probably best associated with the extinctions is the volcanic activity in the central Atlantic magmatic province. This was a rapid and massive outpouring of basalts and gases related to the rifting and breakup of Pangea during the Late Triassic that may have affected global atmospheric conditions and disrupted food chains.

The nature and timing of these extinction events is still poorly understood. There appear to be two phases of extinction defined by vertebrate loss. The first, around 220 million years ago, defined the end of the Carnian subperiod and wiped out the dicynodonts and basal archosaurs. The dinosaurs then continued to live alongside top predator competitors, such as the ornithosuchids and rauisuchians, for the remainder of the Triassic. By the end of the period, approximately 200 million years ago, 20% of existing families and about half of all species disappeared, both on land (the basal archosaurs and many mammal-like reptiles) and in the sea (all conodonts, most ammonites, and many bivalves). Indeed, almost all of the archosaurs perished at this time: Only dinosaurs, pterosaurs, and crocodylomorphs remained. Some aspect of anatomy, physiology, or distribution had contrived to allow Dinosaurian survival (see "Dinosaur Success," later in this entry), and the environmental bottleneck that depleted many of their competitors had provided a vast open ecospace in which to roam. Taking advantage of their "lucky break," dinosaurs expanded their territory, occupied new niches, and grew into worldwide terrestrial dominance.

The Triassic

The world that gave rise to and shaped the dinosaurs was quite unlike that of today. The Triassic period, so named because it naturally divides into three periods (from the Latin *trias*), spanned the period from 251 to 200 million years before the present. The early Triassic world possessed only one landmass, the supercontinent Pangea. While the dinosaurs were emerging, Pangea was splitting into Laurasia (North America, Europe, and Asia) and Gondwanaland (South America, Africa, India, Antarctica, and Australia), but this was not yet complete. The climate was warmer than it is today, with no really cold regions on land. The coasts and certain low mountain ranges hosted marshes and swamps, in which grew an abundance of moisture-loving ferns and horsetails. Pangea was so large, however, that rain struggled to reach its far inland regions. These were occupied by vast, arid deserts and dryland forests, where gymnosperms ("naked seeds") such as conifers, yews, and ginkgoes grew. Other tree-like plants such as cycads and bennettitaleans were also present at this time. Some evidence indicates that atmospheric oxygen levels were perhaps only 50% of modern levels.

The two main lineages of dinosaur evolution were already established by the Middle to Late Triassic, with representatives of both Saurischia and Ornithischia found in the earliest populations of dinosaurs. The saurischia evolved further into two major clades, the herbivorous sauropodomorpha ("lizard feet") and the mostly carnivorous theropoda ("beast feet"). The theropods were the major group of carnivorous dinosaurs for the entire Mesozoicera, although some later subbranches would adapt to be omnivorous or herbivorous. They possessed blade-like, serrated teeth and retained the bipedal stance of their ancestors. At this stage of the Triassic, some theropods appear to have dominated the sharp end of the food chain by force of numbers. Their abundance is evidenced by a mass mortality site at Ghost Ranch, New Mexico, containing many hundreds of individual *Coelophysis*.

Meanwhile the sauropodomorphs, long-necked plant eaters, steadily increased body size while retaining relatively small heads. Their leaf- or peg-shaped teeth and skulls indicate an unsophisticated feeding style, coarsely stripping and swallowing vegetation for major processing in the gut. Alongside them the smaller-bodied ornithischian herbivores were evolving a more specialized feeding anatomy, as seen in the primitive ornithischian *Eocursor.* They would crop vegetation and preprocess it with rows of shearing and grinding teeth, while muscular cheeks kept the food from spilling out. As the Triassic progressed, taxa of both herbivore lineages increased in average size and decreased using their hands for feeding, becoming more and more quadrupedal to better support their weight. Eventually the herbivorous dinosaurs would evolve the ground-shaking sizes that characterized the succeeding Jurassic period.

The Jurassic

The end of the Triassic was marked by several large extinction events, which severely weakened the archosaurs and decimated the dinosauromorphs. These catastrophes appear to have had little impact on the dinosaurs, however. This relatively new group survived and then thrived, radiating outward and diversifying, with a trend toward increasing size evident in most lineages. The Jurassic period ranges from 200 to 146 million years before the present and is named after rocks deposited at this time in the French and Swiss Jura Mountains. Pangea was rifting and breaking up, well on its way toward forming the continents we know today. Dinosaurs could still travel between the continents until quite late in the period, however. Geological activity was characterized by the steady deposition of sedimentary rock providing fertile beds for fossilization. The climate was still generally warm, with intermittent periods of extreme dryness. Shallow seas invaded much of North America and Europe, and rains reached lands that had been deserts in the Triassic. Plants grew thickly along the rivers snaking through seasonal floodplains. This period has been called the age of the cycads, but these palm-like plants were actually less successful at the time than their relatives the bennettitaleans. (The latter, however, are now extinct, so clearly the cycads were more successful in the long run.) Both groups flourished along with conifers, ferns, and tree ferns in the moister tropics.

During the Jurassic, dinosaurs underwent a massive rate of diversification within the main lineages laid out in the Triassic. This period is marked by the evolution of gigantism in some dinosaurs, and many early bipedal herbivores became obligate quadrupeds with their increasing size; the sauropods, in particular, became the largest land animals ever to have lived. Indeed, they pushed the boundaries of what is physically possible for terrestrial animals. Several clades of sauropods routinely exceeded 20 meters in length and weights over 15 tons, while some clades, such as the argyrosaurids, antarctosaurids, and brachiosaurids, became supergiants of greater than 30 meters in length and weights exceeding 50 tons.

Like elephants, the Jurassic sauropods possessed columnar limbs and a graviportal gait. They all had relatively long necks to a degree, but although some sauropods such as *Brachiosaurus* evolved necks set in the iconic upright pose similar to modern-day giraffes, this adaptation was relatively exceptional. Most sauropods had shoulders set lower than their hips and probably carried their necks in a horizontal posture, balanced beam–like by their rearward center of gravity and extensive tails. They would then sweep their heads from side to side, feeding over a radius of predominantly lower vegetation or were able to lean out over boggy ground for riverbank herbage.

Many dinosaur communities appear to have had several sauropod species at the same time, indicating a sort of niche partitioning where herbivores adapted to ground-feeding, mid-level feeding, or high feeding. At the ground to mid-level, sauropods likely competed with a radiating lineage of ornithischia that became very successful in the latter half of the Jurassic. The ornithopoda ("bird-feet") were herbivores with specialized skulls and jaws for more efficient grinding of foliage compared to other ornithischians at the time. They achieved this by utilizing a pleurokinetic hinge, a joint in the upper jaw and skull that allowed parts of the face to rotate and align both upper and lower tooth rows at the same time. There were no Early Jurassic ornithopods, but in the latter part of the period there were several clades expressed by such genera as the small delicate *Hypsilophodon* found in Europe, medium-sized *Dryosaurus,* and the larger-sized *Camptosaurus.* The ornithopods would go on to become a most successful group of dinosaurs, both abundant and globally distributed, later giving rise to the famous duckbill forms during the Cretaceous.

Another lineage of ornithischians sprouted armored nodes around the outside of the body to provide increased protection from the larger carnivores of the Jurassic. These Thyreophora included the earliest armored dinosaurs, *Scutellosaurus* and *Scelidosaurus,* and toward the end of the Jurassic this branch produced the famous plate-backed dinosaurs such as *Stegosaurus* and the thickly armored, tank-like *Ankylosaurus.*

It is not surprising that the plant-eaters evolved new ways to deal with carnivores, as the Jurassic marks a great diversification of theropods into a vast range of lineages around the world. Teeth and claws became highly specialized depending on habitat, and while there was an overall trend toward gigantism there was also the evolution of some smaller lineages. So while tiny theropods like *Compsognathus* or medium-sized *Dilophosaurus* chased insects and lizards, *Ceratosaurus* grew up to 8 meters long and *Megalosaurus* and *Allosaurus* were large enough to stalk large ornithopods or small sauropods.

The coelurosauria also appeared at this time, evolving larger brain-to-body ratios and longer feet, and some members appeared with protofeathers. This lineage produced a vast range of significantly smaller, hollow-boned theropods, with some groups having well-developed feathers and other characteristics that could be adapted for use in flight. Indeed, they later evolved the ability to glide or fly and eventually would give rise to the clade Aves, modern birds. One famous example of early coelurosauria is the flight-feathered *Archaeopteryx,* whose fossils are found in the famous Solnhofen limestones of the Late Jurassic. The stage was set for an explosion of small, feathered carnivorous dinosaurs, and the turnover of large dominant herbivores.

The Cretaceous

Starting 146 million years ago and ending 65.5 million years ago, the Cretaceous was the final and longest period in the Age of Dinosaurs. The landmasses of Pangea had splintered further to form numerous smaller continents. This process created new seas and expanded the old ones, further increasing the distances between continents. Weather patterns became more dynamic as the smaller landmasses had less stabilizing atmospheric influence. During this period the various dinosaur families became more geographically isolated and suffered from localized habitat fragmentation. This led to more intense competition for resources in some places, perhaps accelerating the process of specialization and encouraging greater diversity in both plants and animals.

By the start of the Cretaceous many of the sauropods had become extinct in North America and Europe, replaced as dominant herbivores by successive waves of beaked dinosaurs specialized for low feeding. Although sauropods continued to flourish in the southern hemisphere, where giants such as *Saltasarus* and one of the largest dinosaurs ever, *Argentinosaurus,* still roamed.

As plants and herbivores are always locked in an evolutionary struggle, it has been suggested that the increased pressure on plants by the voracious dinosaurian herbivores encouraged a takeover by plants that could grow and reproduce more rapidly. Such plants could colonize a grazed area quickly, producing a new generation before the herbivores returned to crop the area once more. One of the plant types best suited for such an environment was the angiosperms, or flowering plants. Today almost all the species we recognize as plants fall into this category, but in the Late Jurassic they were a struggling minority dominated by the slower gymnosperms. At about the same time that low-feeding dinosaurs were taking over as the major herbivores, angiosperms were flourishing. Worldwide, the great forests changed: The decline of gymnosperms accelerated and flowering plants multiplied. Broad forests of oak, hickory, and magnolia dotted the landscape, while swamp cypresses, giant sequoias, and China firs took over in swampy areas. Are the dinosaurs thus responsible for the flowers we know today, if only indirectly?

All families of ornithischia peaked in numbers and diversity during the Cretaceous, with specialized teeth for chewing the new plants with tougher leaves. One branch of ornithopods gave rise to the hadrosauriformes, such as the Early Cretaceous *Iguanodon* and mid-Cretaceous *Ouranosaurus.* By the Late Cretaceous this group evolved the clade hadrosauridae—the "duckbilled" dinosaurs, which were to spread widely and diversify extensively across the northern continents. Some species evolved large, elaborate cranial architecture, an extreme example being the trumpet-headed *Parasaurolophus.* The hadrosaurs attained large sizes (commonly up to 12 meters long and even longer for some Asian forms like *Shantungosaurus*) and became one of the dominant herbivore groups as the sauropods declined.

Theropod evolution also peaked in the Cretaceous, which saw a vast array of the largest carnivores ever to walk the earth. Each part of the world evolved its own version of gigantic carnivore: *Tyrannosaurus* and *Giganotosaurus* appeared in North and South America respectively, while *Spinosaurus* and *Carcharodontosaurus* stalked the wetlands of Africa. Meanwhile, at the other end of the scale, the small theropods exploded in diversity and abundance, from small feathered types to medium-sized "raptor" forms. Deinonychosaurs, dromaeosaurs, and troodontids were representatives of the many derived lineages of coelurosauria

Australia and the Dinosaurs

The land now called Australia was long thought to be too cold for dinosaurs in the Early Cretaceous. At that time Australia was only just beginning to break away from Antarctica, and parts of its landmass were within the Antarctic Circle. Nevertheless, early in the 1980s abundant hypsilophodontid remains and traces of an allosaur-like carnivore were unearthed on its south coast. Also found were isolated bones that may indicate various ceratopsian, oviraptorosaur, caenagnathid, and ornithomimid dinosaurs. Oxygen isotope studies indicate that the mean annual temperature at the time of deposition was about 5°C, perhaps ranging from −30°C in the winter up to +20°C in the summer. This discovery lent support to the hypothesis that at least some dinosaurs were endothermic, as ectothermic creatures would struggle to be active through such conditions. Being so far south also meant it was also quite dark for some 3 months of the year. Some dinosaurs, such as the little ornithopod *Leaellynasaura,* adapted larger optical pathways for enhanced low-light vision.

This small Cretaceous-period microraptor from Liaoning province in China displays an array of feathers on both arms and legs.
Source: Courtesy of Mark James Thompson.

that were part of the clade Eumaniraptora. These were small to medium sized bipedal carnivores, with specialized arms and some with feathers, including the infamous sickle-clawed *Velociraptor.* Some taxa such as *Microraptor* had well-feathered arms and also rear legs, displaying skeletal features indicating at least a gliding ability. Other branches of the eumaniraptorans underwent extensive miniaturization, tail reduction, and evolved shoulder girdles with potential for powered flight; the Avialae, the group that would evolve various groups of true winged dinosaurs and, ultimately, Aves—birds in the truest sense. In the latter part of the Cretaceous the flying reptiles were forced to share the sky with a vast array of essentially flying dinosaurs: primitive birds and their descendants. As the Cretaceous progressed, the marginocephalians also evolved extensively from their Late Jurassic ornithischian relatives. Marginocephalia—dinosaurs with extensions and protrusions of bone around the skull—further split into two main lineages: the pachycephalosauria ("thick-headed lizards") and the ceratopsia ("horned faces"). The ceratopsia lineage started in the mid-Jurassic, marked by basal members such as *Yinlong* from China, but during the latter part of the Cretaceous they evolved an enormous variety of frill-necked species, including *Triceratops* and its close relative *Torosaurus*. The latter has the largest skull of any land animal that ever existed. It seems that in some terrains the marginocephalians came to dominate the hadrosaurs, and at least in one location, the Saskatchewan province of southern Canada, the author has observed the last dinosaur remains occurring before the end of the Cretaceous are the marginocephalian *Triceratops*.

At the end of the Cretaceous period, approximately 65.5 million years ago, events occurred to cause apocalyptic environmental pressures to bear down on the planet. Despite the vast scope of the dinosaur spectrum, no member of Dinosauria outside the clade Aves proved capable of surviving the subsequent mass extinction.

Birds From Dinosaurs?

The phlyogenetic relationship between dinosaurs and birds has been intensely debated for at least a century, amid growing recognition of the many skeletal features found in both groups. Some theropod dinosaurs have a hand and wrist structure virtually identical to that of birds except in size, following a pattern found only within Dinosauria. They also have almost identical shoulders, hips, thighs, and ankles. Theropod dinosaurs have light, hollow bones as birds do, often with a dense system of blood vessels—a feature never found in reptiles. Birds and dinosaurs have a secondary palate—reptiles do not. Some dinosaurs are known to have uncinate processes, small extensions of bone on the ribs that assist high-flow breathing in nearly all modern birds. This feature suggests at least some dinosaurs had an avian type respiratory system. Likewise, the vertebrae of theropods and sauropods have pleurocoels: scoops and hollows in the bone that accommodate expanding air sacs in modern birds.

Dinosaurs also laid eggs, and although their eggs differ somewhat from those of birds, at least some dinosaurs are known to have nested in colonies and cared for their young in the nest. Incubation behavior has been supported by certain fossil discoveries, such as a large oviraptorid skeleton found in the classical brooding position on top of a nest containing eggs. The number of eggs found and the absence of eggs in the adult's body support the idea that the oviraptor was truly incubating the eggs, not simply laying them. There are many other interesting specimens, such as the small *Mei long* found with its tail encircling the body and head tucked around onto the back or wing, perfectly matching a typical sleeping or resting posture of living birds.

Even one of the most evident differences between birds and dinosaurs, the question of feathers versus scales, is no longer much of a difference at all. Many dinosaurs are now known to have evolved feathers, including asymmetric "flight" feathers, "downy" feathers, and other types that develop in different stages of modern bird life.

Several theories have been put forth to explain the similarities between birds and dinosaurs. One is that the birds are simply descendants of dinosaurs, as first suggested by Thomas Henry Huxley in the late 1860s. Another is the theory of parallel evolution—perhaps their similarities arose in response to similar environmental pressures as birds and dinosaurs evolved from an earlier separate ancestor. A third theory, originally proposed by Abel in 1911, is that dinosaurs are actually descended from birds rather than the other way around. The parallel evolution and birds-came-first theories had the majority of scientists convinced until 1973, when John Ostrom from Yale University successfully demonstrated that the skeleton of *Archaeopteryx,* considered by most researchers to be the earliest bird, was actually that of a coelurosaurian dinosaur with feathers. Ostrom later showed that other dinosaurs such as *Velociraptor* possessed the most distinctive of all bird-like bones: the furcula (wishbone).

Many of the difficulties in solving the bird versus dinosaur problem stemmed in part from the lack of skeletons of early birds. However, an explosion in the discovery of such skeletons in the 1990s has produced both early birds and "transitional" forms in large numbers. This evidence has greatly strengthened the argument that birds are descended from dinosaurs. The transitional *Unenlagia* ("half-bird") from Argentina is especially noteworthy, having arms that fold exactly as bird wings do. The Mongolian nesting oviraptorid dinosaurs demonstrate bird-like brooding behavior, or at least a protectiveness of their eggs not characteristic of reptiles. The dromaeosaurid-like bird *Rahonavis* from Madagascar also has a peculiar mixture of bird and dinosaur characteristics, with well-developed wings but also the sickle claw typical of the maniraptoran carnivorous dinosaurs.

However, undoubtedly the greatest discovery has been a number of feathered dinosaurs unearthed recently in China. Feathers were long considered a bastion of "birdness," and although the driving force behind feather evolution is not well understood (they likely did not evolve originally for flight; perhaps for insulation, display, or even as a metabolic clearance system for excess minerals), it had generally been considered that only the discovery of a genuine feathered dinosaur would provide definitive proof that birds had a dinosaurian origin. The announcement by Chinese paleontologists that they had discovered *Sinosauropteryx,* a basal coelurosaur dinosaur with evidence of an integumentary structure similar to feathers, thus sparked much debate. This revelation was followed by more Chinese finds from the same area, dinosaurs that were definitely feathered. *Protarchaeopteryx* and *Caudipteryx* were first announced as basal birds on this shifting disbelief. However, several investigators have since demonstrated that both are theropod dinosaurs—*Caudipteryx* is an oviraptorosaur, and *Protarchaeopteryx* is a maniraptoran dinosaur. Also discovered were a feathered therizinosaurid, *Beipiaosaurus;* the dromaeosaurid *Sinornithosaurus;* and a plethora of superbly preserved similar specimens. *Microraptor,* another dromaeosaurid, even displayed "flight"-style feathers on its legs. The resulting arrangement of wing surfaces almost resembles a biplane. Most paleontologists now accept that birds—Aves—arose somewhere within the theropod dinosaur lineage; the only remaining question is how far back they were present and so exactly where the split occurs. An emerging consensus seems to indicate that the common ancestor of theropods and birds may date back at least to the Early Jurassic.

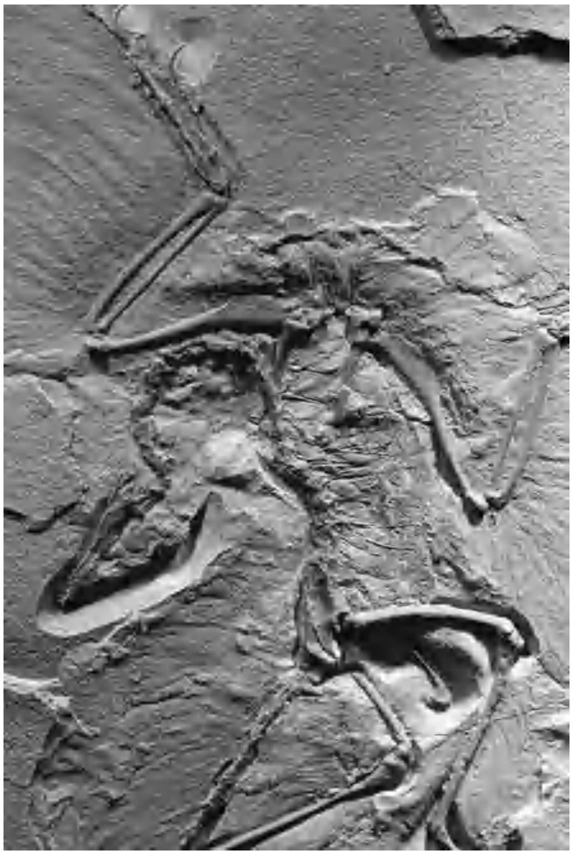
As more and more specimens are found, the evidence in favor of birds as dinosaur descendants continues to grow. At the same time, the dividing line between theropod dinosaurs and birds becomes less and less clear-cut. The gap between birds and dinosaurs has essentially been bridged—birds *are* highly evolved dinosaurs.

Dinosaur Success

It is now known that in the Triassic period, dinosaurs spent many millions of years competing with their archosaur and mammal contemporaries, without achieving dominance. Dinosaurs expanded and evolved at an easy tempo, and although they diversified early on, their adaptations were hardly unique among their contemporaries. Their erect gait, for example, was essentially shared by some other archosaurs (e.g., aetosaurs, ornithosuchids, and some crocodylomorphs) and the dinosauromorphs who also (presumably) shared similar physiology. But after the end of the Triassic extinction events, dinosaurs had assumed not only the roles of top predator and large herbivore but also most other roles all the way down. Only niches for very small animals remained to be filled by mammals and other reptiles. Why did dinosaurs survive when their closest relatives, which had a similar posture and many of the same anatomical adaptations, did not? And given that mammals have such an enormous advantage today, what are we to make of the whole Mesozoic era when, for 165 million years, the dinosaurs reigned supreme and few mammals could grow larger than a modern domestic cat?

One of the few measurable differences in the comparison of dinosaurs to their archosaur and dinosauromorph cousins was their limb proportions and foot posture. Dinosaurs have a longer fibula and tibia in relation to the femur and had better evolved the digitigrade stance. Could such subtle differences have provided a crucial advantage in the competition for food during periods of rapid environmental change? Possibly. The increased leverage of the legs may have allowed dinosaurs to get food resources faster or to retain energy during low food availability. But such anatomical differences do not explain how dinosaurs also managed to keep mammals subservient for so long, when we know that warm-bloodedness is a potent evolutionary advantage. We must therefore also consider the physiological characteristics of dinosaurs: that they may also have been warm-blooded, to some degree, and capable of significantly different respiration than that of their mammal and reptile competitors.

Among today's fauna, we find no large land predators that are cold-blooded. Crocodiles, the sole exception, occupy only one very specific ecological niche and are basically water dwellers.



Cast of the Berlin Archaeopteryx *specimen.*

Source: Courtesy of Mark James Thompson.

Central to any discussion of birds and dinosaurs is *Archaeopteryx.* First discovered in Bavaria, Germany, in 1861, it has been and continues to be the source of numerous controversies. Although there is now consensus that it lies somewhere close to the divergence of birds from dinosaurs, until recently there was still considerable disagreement as to which side of the divergence it comes from. Paleontologists tended to look at its skeleton first, which is almost indistinguishable from that of a small theropod. As the shoulder girdle was not derived enough to anchor flight muscles, they deemed it a ground-dwelling dinosaur. Ornithologists fought back by pointing out the feathers (which are identical to the flight feathers of today's birds), wings, claws, broad tail, and hollow bones. It seems likely that *Archaeopteryx* was capable of gliding, although to what degree and under what conditions are still open questions. At the moment it is generally acknowledged that *Archaeopteryx* is the oldest bird-like feathered dinosaur. Although it is certainly not a direct ancestor of modern birds, it testifies to the evolutionary pressures causing "birdness" to arise in the theropod dinosaurs.

During the entire Cenozoic era as well, virtually all large predators were warm-blooded. This is because the position of top predator is very competitive, and the ability to control and maintain body temperature (i.e., being warm-blooded) means that the animal is not as dependent on the environment for its activity rate. It can hunt at any time of the day (or night), in any season; warm-blooded animals can thus operate at maximum efficiency and tend to have a strong advantage on land.

Of course, the terms *warm-blooded* and *cold-blooded* are something of an oversimplification. Virtually all animals, if examined under the proper conditions, will appear to be "warm-blooded"; that is, their internal body temperature will be roughly constant over time. The more important aspect of this trait is the *mechanism* by which body temperature is maintained. The terms *endothermic* and *ectothermic* are more appropriate: An ectothermic animal relies on heat from the outside (i.e., the environment) to maintain body temperature, whereas an endothermic animal relies on the heat generated within its own body by metabolic processes. Endothermic animals will therefore have a higher metabolic rate, because they need to generate more internal heat. There are even animals whose metabolic processes fall in between endothermy and ectothermy. This is far from an either/or proposition, as a large number of physiological mechanisms are potentially involved. The enormous range of dinosaur sizes implies that they did not share a common physiology, nor did they use the same strategies and mechanisms to maintain their metabolic state. Given that all we have left are lifeless bones and footprints, is it even possible to produce evidence supporting the warm-blooded dinosaur hypothesis? Surprisingly the answer is yes, although such evidence must be largely inferential. For example, we can consider lines of evidence in bone structure, histology, and bone isotope composition, growth rates, posture, speed and agility, rate of evolution, similarities with birds, insulation, and the existence of Arctic and Antarctic faunas.

By comparing these aspects of dinosaurs, mammals, and cold-blooded reptiles, we find considerable support for the idea that dinosaurs were warm-blooded. At the very least, they clearly had a much higher activity level and metabolic rate than do modern cold-blooded creatures.

Not surprisingly, some counterarguments and alternatives have been presented as well. The question has yet to be decided, but on balance the likely outcome seems to be heavily weighted in favor of at least partially warm-blooded dinosaurs. The same tests for endothermy have been applied to the fossil remains of mammal ancestors (cynodonts, dicynodonts) and archosaurs. In both cases the results suggest that they were more warm-blooded than cold-blooded. Thus, it seems that endothermy may have evolved in both lines at an early period. In this scenario, dinosaurs were simply one group in a long line of warm-blooded animals.

An additional point of difference that may help explain dinosaur success is their increased activity potential as a result of evolving a unidirectional airflow lung and air sack respiratory system, as seen today in their avian descendents. Compared to mammals, which have a "piston" lung system whereupon the diaphragm does most of the work in sucking air into the lungs, at least some lineages of dinosaurs evolved a more avian-type respiration system that was "high flow" and more efficient at extracting oxygen out of the air. The evidence is in the pneumaticity of bones in sauropod and theropod lineages, uncinate processes on the ribs of some maniraptoran dinosaurs, and the astounding growth rates of some clades. During the Late Triassic extinctions, such potential may have been critical when atmospheric oxygen content was less than half that of present day.

Although much work needs to be done to confirm these lines of investigation, the combination of new fossil discoveries and modern-day technology are without doubt overturning the old paradigm of dinosaurs as sluggish, maladapted creatures. We now see that they represent an epitome of productive evolution; as a group they were innovative, adaptive, and successful long term. The ability to metabolize oxygen efficiently and maintain constant, high body temperature meant dinosaurs could remain active and successful during times of environmental stress. It required one of the greatest environmental catastrophes the world has ever known to bring them down and clear the way for our own ancestors.

The Great Extinction

Earth's geological record contains evidence of many different extinction events, some large enough to disrupt ecosystems on a global scale. Three such events occurred during the dinosaurs' reign. The first occurred in the Late Triassic and has been postulated as one of the main reasons for their rise to dominance. Another, at the end of the Jurassic, is associated with the disappearance of many large sauropods and ornithopods. This extinction may also have been related to the proliferation of flowering plants. Then we have what is probably the most notorious extinction of all time: the Cretaceous-Tertiary (K-T) event that destroyed all nonavialan dinosaurs 65 million years ago. Earth also lost a massive range of other taxa—terrestrial and marine, vertebrates and invertebrates. Floral communities also went through a dramatic turnover in abundance and diversity. The great reign of the dinosaurs was over, and no convincing evidence has ever been found that dinosaurs survived for even a short time after the K-T event.

The carnage has been attributed to several large-scale geological events occurring at or near the K-T boundary. This includes a period of massive volcanism, which poured out cubic kilometers of basalts to form the Deccan traps in India and Pakistan; global sea-level regression, which is notable in the sedimentary record of North America's western interior; and finally an asteroid impact large enough to form a 170 kilometer-diameter crater on the Yucatan Peninsula of Mexico. Individually or collectively, these events are thought to have invoked habitat loss and fragmentation, global climate change, and food chain disruption. The rapid environmental devastation overcame the abilities of many organisms to adapt and survive, causing one of the five biggest mass extinctions of life on Earth.

Whereas any of these cataclysmic events may account for the loss of life observed in the fossil record, all raise problems that have not yet been resolved. In particular, the apparent selectivity of the extinctions has yet to be explained. Large, nonavialan vertebrates such as dinosaurs were entirely wiped out, but so too were large marine reptiles. Amphibians survived very well, but many lizards and small reptiles did not. The avialae (birds and their closest relatives among the dinosaurs) survived, but flying reptiles such as pterosaurs did not. It can be recognized that life on Earth suffered a relatively rapid disruption that impacted ecosystems all over the world, if to varying degrees. As the selectivity applies to both land and sea, freshwater and saltwater, a successful theory of mass extinction must be able to explain why some survived and others did not.

Unfortunately, few areas of the world record this period of geological time in detail. Probably the best known and most studied are the upper Hell Creek and lower Tullock formations of eastern Montana in the United States. One research site produced more than a hundred samples of vertebrates from 12 major taxa: sharks, bony fish, frogs and salamanders, multituberculate mammals, placental mammals, marsupial mammals, turtles, lizards, champsosaur, crocodilians, ornithischian dinosaurs, and saurischian dinosaurs (not including birds). At this site it was observed that nearly half of the total species survived across the K-T boundary, but 75% of the extinctions occurred in just four of the groups: sharks, lizards, marsupials, and dinosaurs.

The same pattern of selective termination is seen worldwide in both animal and plant communities: Some life forms were entirely wiped out, whereas others, in seemingly similar conditions, remained untouched. Whereas the patterns of the K-T mass extinctions make the cause very difficult to interpret, the asteroid impact hypothesis has stood the test of time. For one thing, it has made predictions that have been supported by exploration and evidence, such as that an iridium-enriched layer of soil should occur globally and that extinctions should be not only global but relatively abrupt and synchronous. This turns out to be the case. It also has the advantage of being the most parsimonious explanation. While it fails to explain certain details of the selectivity, our understanding of the complex interactions caused by such impacts is still incomplete. Furthermore, the dinosaurs are known to have previously survived sea-level transgression/regression and volcanism on large scales. While acknowledging that these changes may have played a role, the asteroid impact better explains the scale and tempo of this environmental catastrophe. Although it may be attractive to invoke all the geological events in unison (the "everything that could go wrong did go wrong" theory), this solution is not necessary in light of the simple and effective asteroid impact.

Fortunately for Homo sapiens, the demise of dinosaurs freed up numerous ecological niches into which placental mammals could expand and diversify. The dinosaurs' death left behind a fertile world in which mammals could finally come out of the shadows and go on to become dominant terrestrial vertebrates.

Today, it is interesting to compare the K-T event to the mass extinction of life currently under way. Human activities are causing an impact of similar strength and rapidity on the habitats of many species, including birds. It would be ironic as well as tragic should our species go on to achieve what the K-T mass extinction could not: the extinction of birds, the last true descendants of dinosaurs.

Changing Interpretations

Sporadic work on fossils started as long ago as the 15th century, but it took hundreds of years for scholars to agree that fossils were even of biological origin. For one thing, recognizing this fact implies that extinction is real: that most of the organisms that have ever existed are now gone, leaving only their descendants. Researchers then (and now) had to deal warily with the extrapolations of their discoveries. Supporting the idea of extinction could be life-threatening in cultures where the dominant religion held that all animals were created at the same time to populate a world that looked much like it does today. It took a great deal of physical evidence collected from sites all over the world to raise the threshold of enlightenment.

During the 18th century, fossil marine reptiles and other "different" creatures such as pterosaurs were being found in quantity all over Europe. This led to swelling public interest, a passion that really ignited when a huge and viciously toothed *Mosasaur* jaw, the "Monster of Maastricht," was found in Belgium in 1770. The preponderance of evidence shone light on the debate over extinction and the origin of fossils, and the latter carried the day. Researchers soon moved on to classifying and interpreting the remains, a task made easier by the newly developed technique of comparative anatomy.

By the 1820s fossilized dinosaur bones had been found in English gravel quarries. Their strange appearance caused a plethora of interpretations. Various publications likened them to lizards, birds, mammals, and crocodiles. Scientists, artists, and the public proved insatiable, demanding more knowledge on what these long-lost animals looked like and how they might have behaved. But a combination of factors would collude to imprint one particular interpretation of dinosaurs on the public and scientific psyche.

The first dinosaur described by scientists was dubbed *Megalosaurus,* which literally means "big lizard." The next was named *Iguanodon,* simply because its leaf-shaped teeth are similar to those of the South American iguana. Having been tentatively identified as prehistoric ancestors to modern reptiles because of the shape of their teeth, dinosaurs quickly became associated with reptiles in every way. In 1842 Sir Richard Owen coined the term *Dinosauria* ("fearfully great lizards") for this growing group of strange creatures, and his work was published (almost as a footnote) in *Report on British Fossil Reptiles.* A side effect of this usage was that most subsequent dinosaur names were suffixed with *saura,* meaning "lizard" or "reptile."

Laypersons and scientists alike began to assume they were cold-blooded and sluggish, as some reptiles are today. Such an interpretation complemented other attitudes of the time, namely, that human beings were the pinnacle of nature. Any extinct life was necessarily more primitive, slow, and dim-witted than humans. Thus, the first complete dinosaur skeletons went on display as very large lizards with odd spikes and claws. This representation of dinosaurs as splay-legged, heavy-set quadrupeds would hold sway for almost the next 150 years.

Even at this early stage, however, several investigators realized that these animals strongly resembled birds. Thomas Henry Huxley in 1868 went so far as to suggest that birds might be descended from dinosaurs. He and other workers found considerable evidence in contradiction of the sluggish reptile theory, evidence supporting a more active and dynamic model of dinosaur behavior. But the dinosaurs-are-lizards paradigm was already entrenched; it would take time and several bursts of scientific endeavor to break it down.

In 1877 the hub of dinosaur discovery moved from Europe to North America. A vast number of complete pristine skeletons were discovered at Como Bluff in Wyoming and later on in Utah.

Some of the discoveries included dinosaur lineages recognized as bipedal, a distinctly unreptile-like trait, but this had little effect on the prevailing view. In 1925, however, Earl Douglas used the accumulated evidence in his collection of 350 tons of sauropod bones to mount and display the massive specimens in a parasagittal stance, with their legs oriented beneath the body like columns. This started a debate that was to last for decades. The argument was finally settled by the fabulous Paluxy dinosaur trackways, discovered in the bed of a Texas river. The careful measuring of the undoubted sauropod footprint tracks confirmed that sauropods indeed had a fully erect stance and not the previously accepted sprawling reptilian posture.

Another part of dinosaurs' reptilian image had been washed away, at least anatomically, but the entrenched idea of sluggish, cold-blooded behavior persisted. Andrews and Osborn found fossilized dinosaur eggs and nests while exploring the Gobi Desert in Mongolia during the 1920s, indicating dinosaurs' similar habits to modern birds. Theropod dinosaurs, such as *Velociraptor* later discovered in the same area, also beautifully displayed hollow bones similar to birds. Despite growing evidence that dinosaurs were more bird-like in their morphology, habits, and physiology, the concept was still not getting widespread traction.

In 1969 John Ostrom published detailed work involving the Early Cretaceous theropod *Deinonychus,* demonstrating that it was a lightly built and likely agile predator. This convinced many that at least some dinosaurs were very active and were more bird-like than reptilian in their behavior. Ostrom also investigated horned and duckbilled dinosaurs, reinterpreting them as sophisticated feeders rather than plodding primitives. This began a period often called the "dinosaur renaissance": Research accelerated amid a growing sense that dinosaurs were substantially dynamic animals. Earlier recognized but ignored aspects of the bird–dinosaur relationship were revisited and examined afresh, fueled by new discoveries. The Trexler family's 1978 discovery in Montana of hadrosaur hatchlings still within their nests led to the description of *Maiasaura* ("good mother lizard") by Jack Horner. This convincing evidence of postbirth parental care increased the growing perception of dinosaurs as dynamic animals with complex behavior. Then in the 1990s, a flood of small feathered dinosaurs with clearly bird-like attributes was discovered in China. These specimens helped confirm the new paradigm, and dinosaurs are now widely regarded as lively rather than sluggish creatures.

In some ways another wave of "dinomania" started around this time, to be inflamed later by blockbuster films such as *Jurassic Park* and the BBC television series *Walking With Dinosaurs*. Previously esoteric questions, such as whether dinosaurs were really warm-blooded and how they came to be extinct, became topics of interest to the public at large. People wanted to learn about how they mated, how they cared for their young, and what their migration patterns were. This trend of popularity seems set to continue with every generation.

New discoveries and further research continue to evolve our interpretations of dinosaurs, but old

Fossil Skull of Nigersaurus. This skull shows an amazing linear muzzle of teeth and other adaptations suggestive of low browsing or grazing, contrary to historical concepts of sauropod feeding strategy.

Source: Sereno, P. C., Wilson, J. A., Witmer, L. M., Whitlock, J. A., Maga, A,. et al. (2007). Structural Extremes in a Cretaceous Dinosaur. *PLoS ONE* 2(11): e1230. DOI:10.1371/journal.pone.0001230 habits die hard and many aspects of these fascinating creatures are counterintuitive. An example is the customary view that sauropods were high feeders, using their extensive necks to reach up and browse on trees similar to the modern-day giraffe. New discoveries and ongoing research show that although there were certainly some very tall sauropods that specialized in mid and high browsing, most seemed better adapted for low fodder.

The discovery and study of *Nigersaurus,* a medium-sized Cretaceous sauropod from West Africa displays extreme adaptations for a low-browsing feeding strategy first established among diplodocid sauropods during the Jurassic. The alignment of the cervical column, combined with an endocast of the braincase revealing the ear canals, indicates *Nigersaurus*'s head was held habitually pointing at the ground. In this ground-level posture it could nip off soft vegetation with its linear dental battery running along the front of its muzzle containing many hundreds of small teeth that continually replaced themselves at a monthly rate. Reinterpretation of the Jurassic sauropods *Apatosaurus* and *Diplodocus* has revealed they too were likely specialized for low browsing, including lacustrine feeding, based on their head-down attitude, neck pose and flexibility, specialized dentition, and a center of mass located back near the hind limbs.

Nigersaurus is an example of new dinosaurs that help broaden our outlook on all dinosaurian biology (beyond the fact that sauropods may not have resembled any living forms in how they carried out their lives). If we let the fossil bones tell their own story, these remarkable creatures help us critically reexamine preset rules of interpretation and thus dinosaurs have finally recovered from several centuries of the misplaced lizard stereotype to play an ongoing role as ambassadors of adaptability, complexity, and long-term survival.

The study of dinosaurs is now progressing at an unprecedented rate. Advances in the sciences of taxonomy, phylogeny, biogeography, paleobiology, and stratigraphic distribution have been providing frequent leaps of insight. Vigorous research programs are under way in many countries around the globe, many involving entirely new methods such as genetic sequencing and the search for biomolecules. Meanwhile, new detection and surveying technology has greatly accelerated the discovery and excavation of new dinosaur remains. There is also a trend toward more attentive excavation, which helps preserve fossil evidence of soft tissue. Finally, many researchers are choosing to focus on specific information that may assist us in dealing with our own biodiversity loss and climate change.

The total number of dinosaur types that have ever lived is estimated at 900 to 1,200 genera. If this is accurate, then the known fossil record of dinosaurs is presently only about 25% complete. This sets a tantalizing and challenging target for dinosaur paleontology. As research continues, there can only be one certainty—this perennially fascinating animal group has many more surprises in store for us.

Mark James Thompson

See also *Archaeopteryx;* Evolution, Organic; Extinction; Extinction and Evolution; Extinctions, Mass; Fossil Record; Fossils, Interpretations of; K-T Boundary; Paleontology

Further Readings

Chiappe, L. (2007). *Glorified dinosaurs: The origin and evolution of birds.* Hoboken, NJ: Wiley.

Dingus, L., & Rowe, T. (1997). *The mistaken extinction: Dinosaur evolution and the origin of birds.* New York: Freeman.

Farlow, J., & Brett-Surman, M. (1997). *The complete dinosaur.* Bloomington: Indiana University Press.

Martin, A. J. (2001). *Introduction to the study of dinosaurs.* Malden, MA: Blackwell Science.

McGowan, C. (2001). *The dragon seekers: How an extraordinary circle of fossilists discovered the dinosaurs and paved the way for Darwin.* Cambridge, MA: Perseus.

Psihoyos, L., & Knoebber, J. (1994). *Hunting dinosaurs: On the trail of prehistoric monsters.* London: Cassell.

Weishampel, D., Dodson, P., & Osmólska, H. (Eds.). (2004). *The Dinosauria.* Berkeley: University of California Press.

Diseases, Degenerative

The progressive deterioration or atrophy of tissue over time is the characteristic of a degenerative disease. Such conditions may be due to poor lifestyle choices, immune responses, genetic diseases, or just the wear and tear of time. Degenerative diseases also include those in which tissues change from a higher to a lower form, generally meaning a form that is less functionally active. Degenerative diseases are often contrasted with infectious diseases, diseases caused by pathogenic agents, including bacteria, viruses, and parasites. However, this comparison is not always straightforward, for infectious diseases often have degenerative symptoms, as in the case of tuberculosis.

General Degenerations

Many types of degenerative diseases are not tissue specific, affecting many different tissue types in the body. One such disease is dystrophic degeneration, in which the body as a whole degenerates as a result of poor nutrition. This is usually associated with various psychological eating disorders such as anorexia nervosa and bulimia. The malnutrition associated with these diseases may also lead to other degenerations, such as atrophic pulp degeneration, in which the pulpal cells in dental pulp degenerate. A classical systemic degeneration is senile degeneration, in which the age of the patient has caused bodily and mental degenerations, and the toll of time causes widespread changes. This includes the atrophy of muscles, declining sight (macular degeneration), dulling senses, a decrease in mental retention and abilities, and fibrous and atheromatous changes. Everyone experiences senile degeneration to some degree as they age and their muscles weaken through time; however, the rate of degeneration depends on many factors, including diet, exercise, familial history, and lifestyle.

The immune system also plays a large role in the degeneration of cells. Cloudy swelling degeneration occurs during the local inflammatory response of the immune system. Here, the cells take on water as the macrophages and fluids move to the offended site. This may also be called vacuolar degeneration, as the vacuoles tend to grow as well. If the injury has somehow affected the metabolism of the cell, this cloudy swelling degeneration may persist, but it generally goes away with time. A severe form of cloudy swelling degeneration is hydropic degeneration, in which water droplets can be visualized within the cell. This is also known as ballooning degeneration. Following the immune response, the body immediately begins the rebuilding process. The plasma protein fibrin migrates to the offended site and begins to aggregate to form a clot. This process is known as fibrous degeneration, or fibrosis. This is considered a degenerative process, as a lower form of tissue is replacing a higher one. This fibrous tissue is what forms scars and is a normal part of the healing process. However, when fibrosis becomes excessive, it can lead to many problems within the body. For example, if fibrin is activated within the bloodstream, it may form a blood clot within the vessel, which may travel as an embolus to the heart, causing a myocardial infarction (heart attack), or to the brain, causing a cerebrovascular accident (stroke).

If tissue is not repaired, it can lead to death of the tissue, or necrosis. Necrosis is characterized by several different degenerations, including the aforementioned fibrous degeneration. Another type of necrotic degeneration is caseous degeneration, or caseation. The soft, cheesy appearance of the necrotic tissue characterized by this degeneration earned it the name of "cheesy degeneration" as well. This is a common degeneration found in the lungs of tuberculosis patients. Necrosis of striated muscle is known as Zenker's degeneration, or waxy degeneration, in which the muscle cells die and take on a glassy appearance. This often is the result of a severe infection, such as typhoid fever.

Integumentary and Epithelial Degenerations

The skin, sweat glands, hair, nails, and the external covering of the body compose the integumentary system. The integumentary system is of course prone to senile degeneration like everything else, as the skin tends to become thinner and weaker, especially at the top layer, the epidermis. Epidermal atrophy has also been associated with lupus, hypothyroidism, and hyperadrenocorticism. Alopecia is the scientific name given to baldness. In certain types of alopecia, follicular degeneration occurs, in which hair follicles are destroyed and replaced with scar tissue. New hair cannot grow from these hair follicles, and hair growth is no longer observed. Colloid degeneration is when tissue is replaced by a gelatinous form. A common form of colloid degeneration is colloid milium, in which papules, or small hard elevations, are formed on the skin and give the appearance of amber acne. This disease has been linked to prolonged sun exposure. Colloid degeneration is not limited to the integumentary system, and benign colloid tumors or growths can occur throughout the body, including the brain.

The epithelial system includes the inner lining of all internal organs, most notably the gastrointestinal and pulmonary systems. One degeneration common to all epithelial systems is mucinoid degeneration; this includes mucous, mucinous, colloid, and myelinic degeneration. In mucous and mucinous degeneration, mucous is abnormally deposited in epithelial tissues. Increased mucous deposits may form in response to irritants and infections. An increase of mucous deposits is also a characteristic of cystic fibrosis, a recessive genetic disorder that affects all endocrine and exocrine glands but affects the epithelial cells most profoundly. This mucous degeneration is also a characteristic of mucinous carcinoma, an aggressive tumor. Research has indicated that tumors comprised of 60% mucus or more tend to be more aggressive than other forms of cancer. Mucous tumors are also called colloid tumors. Myelinic degeneration is characterized by a deposition of myelin and lecithin, important substances in the lining of the gastrointestinal tract. If this layer erodes, harmful stomach acids and enzymes may attack the intestinal wall, leading to infections and ulcers.

Muscular and Skeletal Degenerations

As a result of our evolutionary shift to bipedality, our skeletal system, especially our spine, is highly prone to degeneration. Degenerative disc disease of the spinal column is a perfect example of this, in which the spongy disc of connective tissue between the vertebrae is injured. This degeneration is often caused by trauma to the disc, which can occur from something as seemingly harmless as lifting a box. It can also be the sum of many small traumas over time. This disease is also known as spondylosis. Because the discs have very limited blood flow, they generally have a difficult time repairing themselves. Therefore, after the trauma, the discs dry out and lose their shock-absorbing capability. This can compress the nerve fibers radiating from the spinal column, causing a radial pain or numbness. These nerves may swell as part of an immune response, making the compression and pain even more severe. Surgery, most often a spinal fusion, is a frequent choice of treatment; this may be combined with physical therapy and anti-inflammatory medications. Experimental treatments are also available that attempt to rehydrate the discs; however, many of these are still in the early stages of development.

Another very common degeneration of the skeletal system is osteoporosis, in which the bone mineral density of the patient is significantly decreased. This disease is most common in postmenopausal women, but it also may be present in patients with chronic illnesses, especially hormonal disorders. This disease itself has no symptoms but is characterized by an increased risk in fragility fractures, fractures that would not occur in healthy patients. Fractures that reduce mobility, especially hip fractures, can lead to more threatening conditions, including deep vein thrombosis, pneumonia, and pulmonary embolism. This disorder can be treated with a combination of medications as well as an increase in vitamin D and calcium in the diet. Lifestyle changes that help to treat and prevent this disease include exercise and a reduction in tobacco smoking and alcohol consumption.

Degeneration in the muscles, or muscular atrophy, is a very common occurrence with age. However, muscular dystrophy is a group of diseases characterized by severe muscular degeneration, regardless of age. There are nine forms of muscular dystrophy and more than 100 diseases with similar symptoms. Duchenne muscular dystrophy is the most common of these dystrophies and is inherited by means of the sex-linked X chromosome. Duchenne muscular dystrophy and Becker's muscular dystrophy, the two most common forms, occur due to a mutation in the gene that codes for dystrophin, which, as of 2007, has the longest coding segment of any known allele. Dystrophin is a cytoplasmic protein that forms a complex pivotal to muscle form and function. Without this protein in its fully functional form, muscle function declines severely. Muscular dystrophy has no known cure, but physical therapy and orthopedic instruments may be helpful in treating the disease short term.

Gastrointestinal Degenerations

Many of the degenerative diseases of the gastrointestinal system were included in the epithelial degenerations, including mucous and myelinic degeneration. However, some of the most debilitating degenerative diseases of the gastrointestinal system are from abnormalities in the liver. The liver is responsible for the breakdown of fats into triglycerides, less complex substances that can be stored in the body. When this process is disrupted, it can lead to fatty degeneration of the liver, also known as steatosis. This condition is characterized by fat droplets (mainly triglycerides accumulating within the cells) as they cannot be broken down and stored by the normal processes. This is also known as adipose degeneration. This disease is most commonly caused by chronic alcoholism, but it also may be caused by pregnancy, malnutrition, or poisoning. Fatty degeneration usually has no outward symptoms; internally the patient's liver may grow to be up to three times the normal size, which may cause pain from crowding in the abdominal cavity. In more severe forms, the patient may appear jaundiced. This condition is generally reversible as long as the underlying problem, such as alcoholism, is corrected.

Hepatolenticular degeneration, or Wilson's disease, is characterized by a systemic accumulation of copper within the tissues. Patients with this autosomal recessive disease often initially present with liver problems at a young age (10–14 years) but may also have neurological symptoms as well. The mutant allele in Wilson's disease prevents the normal excretion of copper in the bile, resulting in excessive buildup in the liver cells. This leads to chronic hepatitis and eventual cirrhosis and may even lead to complete liver failure. Once the liver cells are significantly damaged they release the copper into the bloodstream, which then affects the entire body, especially the heart and nervous system. Treatment of this disorder includes medications such as trientine hydrochloride that remove copper from the tissues in combination with a diet low in copper and high in zinc and vitamin B6.

Genitourinary Degeneration

The deposits of uric acid throughout the body characterize uractic degeneration. This disorder is caused by the inability of the kidneys to regulate the amount of uric acid expelled in the urine. The uric acid is instead transported in the bloodstream and eventually forms crystals that deposit throughout the body, most commonly in the large toe. The condition is known as gout and is characterized by intense joint pain and inflammation. High levels of uric acid can also result in one form of kidney stone as well. Treatments generally focus on treating the inflammatory response in the joints as well as pain management, but an increase of vitamin C in the patient's diet as well as a reduced intake of purines help to lower the uric acid level in the bloodstream.

Degenerations in the uterus are very common in premenopausal women. One such degeneration is leiomyoma, which may be found in nearly 20% of all women. This degeneration is characterized by the formation of benign uterine growths or cysts in the smooth muscle of the uterus. Because estrogen and progesterone usually stimulate growth, leiomyomas tend to grow in size during pregnancy. Symptoms of this disorder include uterine bleeding, and if left untreated anemia and even infertility may result. Oftentimes leiomyomas undergo further degenerations themselves. The most common form of degeneration of leiomyomas is hyaline degeneration, in which the cyst takes on a glassy appearance. Other degenerations include mucous, fatty, cystic, and carneous or red degeneration, in which the tissue loses blood flow and becomes necrotic. Laser removal of these cysts is becoming a safe and common treatment of this degeneration. These cysts can also grow in the intestine, small bowel, and esophagus.

Cardiovascular Degeneration

Fatty degeneration also has a large impact on the cardiovascular system as well. Deposits of fat and cholesterol along artery walls are known as atherosclerosis, which is a potentially lethal condition. This condition is found in all patients to some degree, but large and numerous deposits become a major problem. If these deposits become too large, they may clog the vessel, preventing blood and nourishments from reaching all of the tissue the artery feeds. When this occurs it is known as an infarction, and if it occurs in the coronary arteries of the heart, it is known as a myocardial infarction, or heart attack. This deposit can also break off from the artery wall and travel, and an embolus may form, eventually blocking a new area of the vessel it reaches. Sometimes, the vessel may grow outward to allow blood flow past the deposit. However, this can result in an aneurysm or local dilation of the vessel wall, which may eventually rupture. Atherosclerosis is the most common underlying cause of heart disease and stroke. Treatment may include widening the affected vessel by inserting a stent or bypassing it using the patient's own vessels harvested from elsewhere in the body.

Calcium deposits may also contribute to arteriosclerosis and have strong implications in valvular diseases. Calcareous degeneration is any disease that is characterized by deposits of calcium in the tissues, the underlying cause of which may include problems with the parathyroid gland, which controls calcium concentration in the blood. Calcium is often deposited on plaque deposits in atherosclerosis, which helps to stabilize them within the vessel. This is known as Mönckeberg's degeneration or a form of angiolithic degeneration, in which mineral deposits coat vessel walls. When calcium is deposited on any of the four valves in the heart, it may narrow the opening, resulting in a condition known as valvular stenosis. The symptoms of this vary according to the valve the calcium is deposited on. For example, in aortic stenosis, narrowing of the aortic valve, the left ventricle must work harder to pump blood through the narrow opening and is thus larger in size, or hypertrophied. As the muscle thickens it needs more and more blood flow, most of which it is already not receiving. If this is not corrected, the hypertrophied muscle may become ischemic, resulting in chest pain. Syncope, or fainting, is also a common symptom, as less blood is being distributed throughout the body due to a decrease in cardiac output. One of the most serious implications of aortic stenosis is the possibility of congestive heart failure, in which the backflow of blood can cause shortness of breath, dizziness, widespread swelling or edema, and eventual heart failure. Pulmonary valve stenosis is characterized by a decrease in blood flow to the lungs. Patients have symptoms that are much less severe and may include hypertrophy of the right ventricle and cyanosis due to a decrease in oxygenated blood. Mitral stenosis by calcification is characterized by a decrease in blood flow between the left atrium and left ventricle. This results in a reduction in cardiac output and backflow of blood that can result in congestive heart failure and pulmonary hypertension. To compensate for the decreased cardiac output, the patient's heart rate may increase, a condition known as tachycardia, and may enter dangerous rhythms such as atrial fibrillation. Tricuspid stenosis usually is caused by rheumatic fever and rarely caused by calcareous degeneration. The treatment of all valvular diseases includes medical management, balloon valvuloplasty (which expands the valve), or valve replacement. Valve replacements may include mechanical, homograft valves from cadavers or heterograft valves from animals such as pigs. Mechanical valves last the longest; however, the patient must be on blood thinners for the rest of his or her life to avoid clotting.

Nervous System

Degenerations of the nervous system, or neurodegenerative diseases, are among the most widespread and the most debilitating. One of the best-known and most common degenerations of the nervous system is found in amyotrophic lateral sclerosis (ALS), or Lou Gehrig's disease, which develops in 1 to 2 people per 100,000 every year. ALS is characterized by the degeneration of motor neurons, which facilitate voluntary muscle movement. The net result of this degeneration is general muscle weakness, difficulty with movement (ataxia), muscle twitches (fasciculations), and an ultimate loss of voluntary movement (except for the eyes). Most patients ultimately die of respiratory failure due to an inability to breathe without the assistance of a ventilator. The majority of ALS patients (90%–95%) develop the disease sporadically or idiopathically, with no known cause. The remainder of the ALS patients show a genetic basis to the development of this disease. There is no known cure for ALS, although a new drug, Riluzole, was recently approved to slow the degeneration of motor neurons.

Another common and well-known neurodegenerative disease is Parkinson's disease, which is characterized by the degeneration of dopamine-secreting cells in the brain. This greatly affects motor control and results in tremors, rigidity, slowness in movement (bradykinesia), and postural instability or a difficulty with balance, among many other symptoms. Cognition is affected as well and may ultimately lead to dementia as the disease progresses. The majority of all individuals with Parkinson's disease develop the disorder idiopathically with no known cause. A very small number have shown a genetic basis to this disease. Most treatments focus on drugs that replace the lost dopamine in the patients. However, generally only 1% to 5% of the drug given produces the desired effect on the target area of the brain, with the rest being metabolized throughout the body, creating adverse side effects. Also, due to feedback loops, these treatments actually further the degeneration of dopamine-secreting cells, which are no longer needed due to the replacement therapy. Other treatments include dopamine agonist drugs and monoamine oxidase B inhibitors, which inhibit the breakdown of dopamine. Many treatments focus on treating the symptoms; these treatments include speech therapy, physical therapy, and deep brain stimulation, which acts as a "brain pacemaker," reducing tremors. Currently there is no known cure for Parkinson's disease.

Alzheimer's disease is also a very common neurodegenerative disorder and is the leading cause of dementia worldwide. This disease is characterized by a progressive loss of cognitive ability, including mood and behavioral changes, loss of language organization, and ultimately dementia. Plaques of amyloid beta, a misfolded peptide form within the brain, along with Alzheimer's neurofibrillary degeneration, in which protein aggregates form in neurons of the brain. This disease is also idiopathic in origin; however, early-onset Alzheimer's disease (before 65 years of age) has shown a genetic link. There is no known cure for Alzheimer's disease, and most patients die within 7 to 10 years after the onset of the first symptoms. As of 2004, Alzheimer's disease was the seventh leading cause of death in the United States. Treatments generally focus on treating the symptoms socially and include occupational and lifestyle therapies as well as psychosocial interventions. Other treatments, such as acetylcholinesterase inhibitors and ginkgo biloba supplements have shown to slow the progression of the disease, but they do not reverse its effects and do not slow it completely.

Special Senses

The loss of the special senses—taste, smell, hearing, and sight—is a normal part of aging. The number and sensitivity of taste buds on the tongue decrease over time from normal wear and tear. Thousands of tiny hairs within the cochlea of the ear are damaged over time, decreasing hearing sensitivity. However, these special senses also may degenerate prematurely, secondary to other disorders, especially those that affect nerve function, including the aforementioned Parkinson's disease and Alzheimer's disease, both of which affect smell, taste, and hearing.

Macular degeneration is characterized by the degeneration of the macula area of the retina and is the leading cause of blindness in the United States in patients over 50 years of age. In macular degeneration, yellow deposits called drusen form between the retinal pigment epithelium and choroid. This leads to atrophy of the retinal pigment epithelium resulting in a loss of photoreceptors in the offended area, generally the center of the eye. This is known as the "dry" form of macular degeneration. The "wet" form is caused by the formation of a small blood vessel within Bruch's membrane, the innermost layer of the choroid. This leads to blood leakage and scarring near the macula, destroying the photoreceptors, resulting in vision loss. Macular degeneration that forms at a young age (juvenile macular degeneration) is usually genetically linked and is found in many forms, including Best's disease (congenital macular degeneration), Doyne's honeycomb retinal dystrophy (Doyne's honeycomb degeneration), Sorsby's disease, and Stargardt's disease (Stargardt's macular degeneration). Treatments focus on slowing the progression of vision loss and incidence in high-risk patients and include dietary changes, drugs that reduce cholesterol, and, in individuals with wet macular degeneration, drugs that reduce the formation of new blood vessels.

The sheer number of degenerative diseases is considerable; volumes could be filled classifying and discussing the various degenerative diseases, as only the most common were briefly discussed in this entry. As modern medicine progresses, it is hoped that treatments will be discovered for many of these conditions. However, short of discovering the Fountain of Youth, with the passage of time all of us remain subject to the effects of aging.

Christopher D. Czaplicki

See also DNA; Dying and Death; Gerontology; Longevity

Further Readings

Huether, S. E., & McCance, K. L. (2000). *Understanding pathophysiology* (2nd ed.). St. Louis, MO: Mosby.

Lewis, M. A., & Tamparo, C. D. (2000). *Diseases of the human body* (3rd ed.). Philadelphia: Davis.

DIVINATION

Divination is an attempt to connect to a supernatural power in order to retrieve information. It is intended to allow participants to learn about the future or secret, hidden matters. Thus, divination is a process of gaining information through rituals with a specific intended outcome. The word can be traced back to *divinity,* which indicates a relationship to the gods. Anthropologists have debated whether the rituals surrounding divination should be classified as religious ceremonies or magical invocations; however, it is recognized that participants of divination do not make this distinction. In fact, it is an important component of both religion and magic. In the absence of scientific knowledge, early humans used divination to attempt to understand and manipulate their environment. Vital information concerning weather patterns, such as rainfall or drought, and animal migrations were "read" from their surroundings in "signs" that would indicate the future. Some of these included the flight of birds, the position of pebbles in a stream, or reading the entrails of small animals. Another notable use of divination was its prevalence in healing ceremonies. Historically, diviners were diagnosticians who were concerned with maladies put in a sociocultural context. They used psychosomatic and physical symptoms, everyday encounters, and supernatural influences to determine the source and therefore the treatment of illnesses. Divination also provided people with a map along their spiritual journey. People then, as now, wanted to know about paths to love, money, careers, and power. It is human nature to want to make the "right" choices and divination was, and is, regarded as a tool to see into the unknown.

Divination in History

Some of the best-known forms of divination include astrology, numerology, palmistry, runes, and tarot. Astrology is the oldest method of fortune telling; it developed as people followed the cycles of the stars. Though the Greeks and Romans were credited with the stories attached to the zodiac, by 3000 BCE the Babylonians and the Chaldeans were recording movements of constellations. In the Americas, indigenous astrologers used the stars to predict individual destinies. Today people still use birth charts and the movements of stars in everyday life; avid believers in these signs check their horoscopes to daily. Numerology uses numerical systems to discover the pathways that connect all things. This practice is almost universally evident and is concerned with understanding present circumstances. Pythagoras, a Greek of the 6th century BCE, believed that everything encompassed in the human experiences was related to the first nine numbers. His theory of harmonics is astoundingly similar to 20th-century wave theory.

Forms of Divination

Palmistry, also known as chiromancy, is the discovery of how a person's character, "read" through the unique lines on the palm, will influence his or her destiny. Modern palmists can trace their roots back to the Roma (gypsies) and Indian mystics, but again, the names and stories are derived from Greek mythology.

Another common form of divination is reading ancient German and Scandinavian runes. These hearty northern tribal groups left behind symbols that were carved into pieces of wood and stone that were cast to settle disputes, to ask for the gods' assistance, and to see into the future. Today, people still cast the runes as a form of divination. Booklets for interpreting meaning along with pouches of runic tiles are sold. The runes resemble letters but are not an alphabet; each figure has a meaning unto itself. Each represents a literal meaning such as "cattle," "gift," or "joy" and a prophetic deeper meaning like "wealth," "rewards," or "harmony." The most commonly used runes today are from the Germanic *futharks,* which contain 24 runes.

Reversed (upside down) runes indicate a blockage or frustration. Runes are read in 3 or 5 spread and in a Celtic cross pattern much like the tarot. The tarot deck was used in Europe to play card games as early as the 14th century and later became a deck for divination. Arthur Edward Waite is attributed with developing the most commonly used tarot deck, the Rider-Waite deck. Tarot meanings are variable and can be interpreted in a number of ways depending on the card reader. There are many less-familiar varieties of divination. Alectoramancy is divination by a rooster and involves a cock "spelling" a message by pecking at grains of wheat placed on different letters. Cleidomancy is the interpretation of movements of a key suspended by a thread from the nail of the third finger of a young virgin while a Psalm is recited. Omphalomancy is the analysis of the belly button.

Function of Divination

During the 19th century a divide existed between what were considered "primitive" and "modern" religions for those who analyzed the existence of religion. This approach was mostly rejected by social scientists in the 20th century. Social scientists such as Karl Marx, Max Weber, and Émile Durkheim were more concerned with studying how religious beliefs and practices are a part of a particular social, political, and economic force and what purpose they serve. They found that there were patterns of cultural universals among diverse groups. A spirit world existed, sometimes in the form of ghosts, spirits, or deities. Magic could be used to influence and manipulate the spirit world. Also, divination made it possible to connect with the supernatural as a means of discovering knowledge. This was believed to help people feel that they have some control over aspects of their lives over which, in fact, they have no control.

Today, there are many popular forms of what is referred to as "spontaneous divination." This includes the art of placement or Feng Shui, reading the energy field ("aura") that surrounds a person, or opening the Bible to a random page to receive a relevant, divine message. Some people also use "fairy" or "angel" cards to receive guidance and reassurance.

Luci Maire Latina Fernandes

See also Marx, Karl; Mythology; Pythagoras of Samos; Religions and Time; Weber, Max; Zodiac

Further Readings

Fiery, A. (1999). *The book of divination.* San Francisco: Chronicle Books.

Hicks, D. (2002). *Ritual and belief: Reading in the anthropology of religion* (2nd ed.). Boston: McGraw-Hill.

Lehmann, A. C., Myers, J., & Moro, P. A. (2005). *Magic, witchcraft, and religion: An anthropological study of the supernatural* (6th ed.). Boston: McGraw-Hill.

DNA

DNA (deoxyribonucleic acid) is a fascinating and compelling molecule that is responsible for expressing, storing, and replicating all of the genetic information in eukaryotic (nucleated) cells. This marvelous molecule is nothing less than a chemical history of all living things on our planet; its span extends throughout organic time and contains chemical documentation of the course of evolution in all species.

Ideas About Inheritance

In 1857, Gregor Mendel (1822–1884), an Austrian monk and biologist, was the first to illustrate that inheritable characteristics (such as height and color) were distributed from parent to offspring in a mathematically predictable pattern. He did these experiments using pea plants. As he analyzed his results, he noted that each character had variations (such as tall or small, and purple or white) that again were expressed in a mathematically predictable pattern. These predictable patterns could be expressed graphically. (Later, British geneticist Reginald Punnett arranged such patterns of inheritance in grids, which are now referred to as "Punnett squares"). Mendel's work stimulated much interest in the study of genetics; as a result of his work, he is known as the father of genetics.

Mendel had illustrated that characteristics are inherited through particles in a predictable fashion, but how does this happen? In 1928, biologist

Frederick Griffith theorized that a molecule for inheritance must exist. His experiments involved injecting virulent and nonvirulent strains of bacteria into mice. These experiments never assisted Griffith in his quest to discover the inheritance molecule, but they did prove that a characteristic (in this case virulence) could be passed on from one type of bacteria (which was virulent) to another type of bacteria (which originally was not virulent). He called this "transformation." Griffith's research on transformation proved that an inheritance molecule existed.

During this time, there were two prevalent theories on what the inheritance molecule was. The first theory was that it was a protein, which was a popular candidate because there were 20 amino acids. The second theory was DNA, which was a less popular theory because it was composed of only four nucleotides and because scientists could not yet conceive how a molecule composed of only four types of nucleotides could account for the complexity of an organism. Some theories proposed that other proteins were the inheritance molecules.

Identifying the Inheritance Molecule

Fourteen years later, a scientist named Oswald Avery attempted to identify the inheritance molecule based on Griffith's findings. In Avery's experiments, he used the same types of bacteria from Griffith's work. However, with newer technology and a deeper understanding of the knowledge of cellular biology and structure, he was able to use a different approach. Avery decided to selectively destroy different types of molecules (e.g., carbohydrates, proteins, lipids, and ribonucleic acids) in the virulent bacteria. He then administered the samples to mice to test for virulence. The results showed that all the bacteria maintained their virulence except for the bacteria whose ribonucleic acids were destroyed. Avery had identified the inheritance molecule, which was composed of nucleic acids: DNA.

Even though Avery had clearly illustrated that DNA was the molecule of inheritance, most scientists at that time rejected the idea. Many still found it too perplexing to understand how a very uniform molecule was responsible for the advent of something as complicated as a human being. In addition, this began to raise eyebrows in religious circles that a molecule, and not direct action by God, was at the root of an individual's inherited characteristics.

It took almost 90 years from Mendel's illustration that characteristics were passed on from parent to offspring in a predictable pattern to the idea that DNA, a molecule, was solely responsible for the occurrence of genetic diversity among all species. However, at this time, no one knew what DNA was—neither its structure nor how it worked.

Discovering the Structure of DNA

In 1953, biologists James Watson and Francis Crick, working in Cambridge, United Kingdom, accurately proposed a working model of the structure of DNA. They were able to do this based on results from two very important works. The first important work was research done by Erwin Chargaff, in which he proved that the DNA molecule was composed of four nucleotide bases: adenine (A), guanine (G), cytosine (C), and thymine (T). He demonstrated that adenine and thymine occurred in equal amounts, as did guanine and cytosine. Based on these findings, he postulated that adenine paired with thymine (A=T) and that guanine paired with cytosine (G=C).

The second important work that assisted Watson and Crick was the photography of X-ray diffraction patterns of crystallized DNA, which were completed by Rosalind Franklin and Maurice Wilkins. Their research showed that the DNA molecule had a helical shape made up of two strands connected by ladder-like rungs.

Based on these two studies, Watson and Crick proposed that the DNA molecule was a double-stranded helix and that those two strands were made of a sugar-phosphate backbone. They also concluded that the "ladder-like rungs" that were holding the two strands together were alternated A=T and G=C pairs. Watson and Crick were also able to utilize current molecular knowledge to discover that the reason why adenine and guanine paired together was because they both had two available hydrogen bonds, and the reason why guanine and cytosine paired together was because they each had three available hydrogen bonds.

They proposed that because one of the DNA strands was an opposite complement to the other (because of the pairing bases), the DNA molecule was composed of two "antiparallel" strands.

Now the inheritance molecule was identified, and a structure of its model was established. This changed the way scientists viewed genetics and heredity. The next perplexing questions were How does this molecule replicate itself? and How does it work to make a cell or an organism?

How Does DNA Work?

At this time it was generally accepted that DNA must replicate itself in order to reproduce new cells and for organisms to produce new offspring. In 1958, Matthew Meselson and Franklin Stahl utilized research involving radio-labeled nitrogen bases (which are what A, T, G, and C are composed of) to demonstrate that DNA replicated itself using what is known as a semi-conservative model. This model helped to illustrate that the two strands of DNA actually unzip, and one of the DNA strands serves as a template to reproduce another strand of DNA by pairing nucleotides. The template and new strand of DNA are separated, the original strands of DNA are reconnected (or zipped back together), and the newly created strand has a complementary strand attached (using Chargaff's rule) to it in place of the original template. This replication of DNA happens during cell replication, a process in which a cell makes a copy of itself, DNA and all. However, it must be noted that a cell cannot replicate an infinite number of times. A cell can undergo cell replication only a limited number of times while maintained in tissue culture; this phenomenon was illustrated in 1965 by Leonard Hayflick and was called the "Hayflick limit."

Besides replication, the DNA molecule is responsible for storing the information necessary to synthesize the basic building blocks called amino acids. There are 20 amino acids, which in different combinations make up proteins, enzymes, and other constituents that compose all cells and organisms. The DNA molecule achieves this by a process called transcription. During transcription, the DNA molecule unzips a small portion of itself and a messenger RNA (mRNA) molecule is made. This mRNA molecule will ultimately assist in the production of a protein molecule, a process called translation. Therefore what types of proteins are produced is determined by all the different sequences of DNA. These proteins are the basic building blocks for the cell's structure and organelles. The same cells conglomerate to form tissues, which become structured organs that can form organ systems. The organ systems (such as the digestive system and the skeletal system) are what make more complicated organisms, like human beings.

Understanding Human DNA in the Future

The DNA molecule exists today as a product of time. It is responsible for organic diversity and genetic evolution, in addition to accumulating and accelerating all human evolution. In the year 2000, after almost 10 years of research known as the Human Genome Project, scientists completed analyzing more than 3 billion chemical "letters" that make up all human DNA (which is referred to as the human genome code). This accomplishment will eventually revolutionize the diagnosing and treatment of disease and is one of the greatest scientific milestones. The concept of inheritance and what makes up all organisms has changed over time. This began as the idea of an inheritance molecule and evolved into attempting to understand and decipher the vast complexities of the DNA molecule, a task in where we are only just scratching the surface.

John K. Grandy

See also Chemistry; Dying and Death; Evolution, Organic; Medicine, History of

Further Readings

Alberts, B., Johnson, A., Lewis, J., Raff, K., Roberts, K., & Walter, P. (2002). *Molecular biology of the cell* (4th ed.). New York: Garland.

Grandy, J. (2005). DNA molecule. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (Vol. 3, pp. 753–756). Thousand Oaks, CA: Sage.

Watson, J. (2001). *The double helix: A personal account of the discovery of the structure of DNA*. New York: Touchstone. (Original work published 1968)

Dogen Zen

Japanese Buddhist tradition gives Dogen (1200–1253) credit for founding the Soto Zen school following his return from China after having attained enlightenment under the tutelage of Jü-ching (1163–1268) and having previously studied under Japanese Zen master Eisai (1141–1215). After being frustrated trying to spread Zen in Japan, Dogen settled in present-day Fukui Prefecture where he founded Eihei-ji. He spent the remainder of his life training monks and writing *Shobogenzo* (*The Treasury of the Eye of True Dharma*) and other works. It is especially in the *Shobogenzo* that he expounds his nondualistic philosophy and understanding of time.

To illustrate his notion of time, Dogen first discusses the conventional view of time by using an example of a person who lives in a valley, travels over a river, and climbs a mountain to its summit. Once the traveler attains his goal, there is a human tendency to relegate the valley, river, and mountain to things of the past that have no relation to the present moment. This suggests that time is measured by the movement from the valley to the summit of the mountain by now-points that are connected in a linear series. And when a person thinks that time flies away, that person separates himself from time as directly experienced.

In contrast to this everyday comprehension of time, Dogen substitutes primordial time, which he calls being-time (*uji*). He defines being-time as nonsubstantial, which means that it is not objective and forms a transpersonal basis for all activity without reference to an ego, subject, substance, or object. Being-time is also nonreductionistic, which suggests that it is a unity. Moreover, it is nonanthropocentric and nondifferentiated, which means in the initial instance that temporality is not limited to human experience because it encompasses both human and the natural, whereas the latter characteristic means that time is a unity of time and existence, truth and time, and is not independent of existence or beyond it.

Dogen identifies two perspectives, or basic individual responses to the presence of one's situation, of being-time. Each of these perspectives is an authentic reflection of the temporal mode of experience stimulated by a situation, and neither is more primary than the other. What Dogen calls *nikon* (right now) represents the now moment that is a completely spontaneous making present of being-time. This nikon extends simultaneously throughout past, present, and future. The second perspective is *kyoryaku* (totalistic passage), which refers to the nondirectional, continuing, and connected aspect of time that refers to an experiential continuity. This aspect of being-time engages all aspects and dimensions of the past, present, and future here and now and allows for their diversity, variety, and differentiation. Kyoryaku refers also to the continuously creative and regenerating dimension of being-time. Neither of these perspectives possesses priority over the other.

The difference between right-now and total passage is a matter of viewing either the surface (nikon) or the cross-section (kyoryaku) of a total temporal phenomenon. If one returns to the metaphor of mountain climbing, the now-moment (nikon) designates the act of ascent, whereas totalistic passage (kyoryaku) suggests the entire context of human events and the universe. This means that each moment is complete because it includes the full range of multiple perspectives and situations.

Being-time possesses important consequences for Dogen because things and events within the universe are time. Thus Dogen claims that mountains, oceans, and grass are time. It also means that time is both temporal and spatial, which implies that they inseparably interpenetrate each other. Moreover, each absolute now moment constitutes a unique whole of actuality, which suggests that the now moment is realized contemporaneously with activity. It can also be asserted that time is activity and activity is time.

If being-time is applied to the Buddha-nature (a nondual reality for Dogen), both future and past signify the present. This suggests that the Buddha-nature is not a potentiality to be actualized in the future, but it is rather an actuality in the present. According to Dogen, the being of Buddha-nature is time. This implies that every moment of illusion and every moment of enlightenment contain all of reality. Thus both enlightenment and illusion are Buddha-nature.

Dogen raises an interesting question: Can a person experience being-time? His answer is that we experience neither time nor being in themselves but rather temporal existence. What Dogen means is that we overcome the perception of things in terms of the three moments of time—past, present, or future. This suggests that we experience a phenomenon just as it is. With such an experience, we encounter a stream of ever-changing phenomena, which means necessarily that prereflective consciousness involves change. This change is located neither in the self nor in the object; rather, it is an aspect of phenomena as they are prereflectively experienced. By accepting the experience of change as it is without projecting anything onto it, there is simply an unending experience of flux. But when we project our experience of change onto some external self, we falsely assume the experiencing self to be unchanging. For Dogen, things cannot be experienced independently of change or time, which means that all things and all beings are impermanent, and Buddha-nature is the experience of impermanence.

Dogen's notion of time possesses important implications for his grasp of body and mind, which he also equates with time in a nondualistic way. According to Dogen's nondual position, mind, body, being, world, and time form a unity. Not only are entities time, and not only is time in me, but activities are time. Thus jumping into water or a pool of mud is equally time.

The unity of time is evident most lucidly in his grasp of Buddha-nature, whose being is time itself. Within the Buddha-nature, both future and past signify the present. Dogen stresses the now moment because there is never a time that has not been or a time that is coming. Therefore, time is a continuous occurrence of "nows." This makes the Buddha-nature a present actuality and not simply something potential to be actualized in the future. And if every moment of illusion and enlightenment contains all reality, Buddha-nature is both illusion and enlightenment. In summary, Dogen radically temporalizes being, opposes a quantitative view of time, views time as a lived reality, and contends that things and events of the universe are time.

Carl Olson

See also Becoming and Being; Buddhism, Mahayana; Buddhism, Theravada; Buddhism, Zen; Now, Eternal; Time, Phenomenology of

Further Readings

Dogen. (1975–1977, 1983, 1986). *Shobogenzo* (Vols. 1–4, K. Nishiyama & J. Stevens, Trans.). Tokyo: Nakayama Shobo.

Faure, B. (1991). *The rhetoric of immediacy: A cultural critique of Chan/Zen Buddhism.* Princeton, NJ: Princeton University Press.

Kim, H.-J. (1975). *Dogen Kigen, mystical realist.* Tucson: University of Arizona Press.

Donne, John (1572–1631)

John Donne is considered one of the finest poets in the English language. His works include a wide range of forms, including sonnets, love poetry, religious poems, epigrams, elegies, songs, satires, and sermons. Compared to the other poets of this period, Donne's work shines due to the language style he used and his expertise in using metaphors. One major theme in his poetry is the passage of time, as is evidenced in "Death Be Not Proud," in which he discusses how death is akin to sleeping and how it will be banished forever, due to God's bestowal of eternal life.

> And poppy or charms can make us sleep as well
> And better than thy stroke; why swell'st thou then?
> One short sleep past, we wake eternally,
> And death shall be no more; Death, thou shalt die.

Donne studied at Hart Hall, now Hertford College, Oxford, beginning at age 11. After 3 years at Oxford, he was admitted to the University of Cambridge, where he studied for another 3 years. He never obtained a degree nor did he graduate from either university; he declined to take the Oath of Supremacy, a requirement for all wishing to graduate. In 1591, Donne decided to study law and entered law school (they were Inns of Court at that time), and gained admittance to Lincoln's Inn, another "law school" of 16th-century England.

Donne longed for a career in diplomacy and by age 25 he was well prepared. He received status when he became chief secretary to Sir Thomas Egerton, the Lord Keeper of the Great Seal, and took up residence at Egerton's home, York House, which was in close proximity to the Palace of Whitehall, the most prominent social focal point in England. At some point during the next 48 months, he became romantic with Anne Moore, Egerton's niece, eventually marrying in 1601 (to his superior's consternation).

His early poems indicated a dazzling awareness of British culture attached to biting censure of its problems. His satires centered on ordinary themes, such as dishonest politicians and pedestrian writers, yet they maintain their comic strength even to this day. His early elegies were strikingly erotic, and he used eccentric metaphors (a biting flea is symbolic of marriage). A serious transformation occurred during the adverse years (1600–1610). He suffered financial setbacks and his closest friends died, leading to a more melancholy, but devout, poetic tone.

When he was young, Donne was skeptical of religious faith, but his views changed and he became pious. Although born a Roman Catholic, he converted to Anglicanism and eventually sought a position as a preacher. Soon thereafter, he grew prominent, and he was eventually appointed dean of St. Paul's Cathedral in London.

His later works challenged death, with the belief that those who die are sent to heaven to live eternally and thus, death should not be feared. Donne was expert in using the conceit, a figure of speech joining two opposite ideas into one, often using metaphors. His works are often witty, using literary devices like paradoxes, puns, and analogies; likewise, his works are frequently ironic and cynical, especially regarding the motives of humans and love. Donne used universal topics like love (more prevalent when he was young), death (primarily after his wife's demise), and religion.

In 1631, Donne preached his final time, giving a sermon detailing his belief in the Creator. Afterward, he returned to his bed and died quietly on March 31, 1631.

Cary Stacy Smith and Li-Ching Hung

See also Alighieri, Dante; Chaucer, Geoffrey; Eliot, T. S.; Eternity; Gibran, Kahlil; Milton, John; Poetry; Shakespeare's Sonnets

Further Readings

Carey, J. (1981). *John Donne: Life, mind, and art.* London: Oxford University Press.

Edwards, D. L. (2002). *John Donne: Man of flesh and spirit.* Grand Rapids, MI: Eerdmans.

Dostoevsky, Fyodor M. (1821–1881)

Fyodor M. Dostoevsky was a Russian novelist and short story author whose writings often focus on the psychological aspects of deep human emotion and suffering. His work is widely regarded as highly original and profound and has earned him a worldwide reputation as a literary artist. Dostoevsky's works profess extreme philosophical and psychological insights, including theories and practices in psychoanalysis. His writings are often categorized as existentialist. His characters face moral dilemmas and endure challenges as if their moral actions have no significance in terms of an afterlife. In the nihilist tradition, Dostoevsky's characters also struggle against all forms of tyranny and hypocrisy, negate all moral principle, and struggle to support personal and individual freedom. In this existential and nihilistic genre, the characters feel the only time they have is the time in which they are alive on Earth.

Dostoevsky was born to a middle-class family. His mother died before he was 16, and, allegedly, the household servants murdered his father while Dostoevsky was away at school. As a young man, Dostoevsky was arrested and convicted of political subversion because of his involvement with a political and intellectual discussion group. Although he was sentenced to death, his punishment was later commuted to 4 years hard labor and imprisonment in Siberia, followed by 4 years in military service. While imprisoned, Dostoevsky studied the New Testament, which led to his belief that redemption is achieved through extreme faith, suffering, and pain, a theme that occurs throughout his literary work.

His first major novel, *Crime and Punishment,* was published in 1866. This story is a psychological thriller in which its central character, Raskolnikov, a young, poor, and monomaniac student heinously murders an elderly pawnbroker and moneylender, whom he deeply despised as being a threat to the great moral and economic good.

The novel begins in medias res, 2 1/2 days before the murder, and it continues in time for approximately 2 weeks after the event. The story is told through a juxtaposition of events that occur at different times, thus creating connections between these events without intrusive explanations or detailed narrations. Time in the novel is felt through Raskolnikov's consciousness; it is a flow of time that exists through his personal experience or perception of time, rather than time measured on a clock. This narrative technique became widespread later in the century, as a result of Dostoevsky's influence. His influence also extended to philosophy, as a precursor to Henri Bergson's theory of the fluidity of time. He also profoundly affected philosopher–writers Friedrich Nietzsche and Franz Kafka.

Dostoevsky also uses an objective chronology of time, or *fabula,* a Russian formalist term used to describe time sequences as they are recreated for the novel. This motif helped compound and later illuminate or clarify Raskolnikov's motive for murder. Using a double time, Dostoevsky allows the actions occurring in present time to clarify the events that happened at a time in the past. For instance, in examining the novel, during present time, we begin to see that Raskolnikov had radical notions on crime and accountability as much as 6 months prior to the novel's beginning, when he wrote the significant article "On Crime." In this article, he tells of the ordinary and extraordinary personalities who are capable of either accepting the established order or those capable of mass destruction in the name of creating something better. These great men, such as Napoleon and Muhammad, Raskolnikov writes, possess a capacity to do moral atrocities for the sake of duty. Another example of a time-lapse technique in the novel includes the 3-day time period in which Raskolnikov falls into a semiconscious and feverish delirium, awakening in terror to wonder if he may have given away clues to his murderous act while suffering from his illness.

Debra Lucas

See also Bergson, Henri; Existentialism; Joyce, James; Kafka, Franz; Mann, Thomas; Nietzsche, Friedrich; Novels, Time in; Proust, Marcel; Tolstoy, Leo Nikolaevich

Further Readings

Dostoevsky, F. (2004). *Crime and punishment* (R. Pevear & L. Volokhonsky, Trans.). London: Vintage. (Original work published 1866)

Frank, J. (1995). *Dostoevsky. The miraculous years, 1856–1871.* Princeton, NJ: Princeton University Press.

Murav, H. (2001). Fyodor Dostoevsky. In J. A. Ogden & J. E. Kalb (Eds.), *Dictionary of literary biography: Vol. 238. Russian novelists in the age of Tolstoy and Dostoevsky.* Detroit, MI: Gale Group.

Doyle, Arthur Conan (1859–1930)

Sir Arthur Conan Doyle was a Scottish writer and physician who popularized the detective genre of literature with his creation of the Sherlock Holmes character and pioneered science fiction with tales such as *The Lost World.* Much of Doyle's work reflects his personal interest in, and unconventional approach to, the subject of time.

Conan Doyle was one of the most popular and prolific writers of his generation. His work spans several genres and includes both fiction and nonfiction. He is perhaps best known for his creation of the character Sherlock Holmes, the clever detective who appears in a series of novels and short stories along with his assistant, Dr. John Watson. Although many of the Sherlock Holmes tales, such as the *Hound of the Baskervilles* (1902), remain in print and are widely read today, Conan Doyle considered his historical scholarship to be his most important work.

Conan Doyle's interest in time is evident in *The Lost World* (1912), an adventure tale in which four men travel to a remote region of South America to investigate claims that dinosaurs inhabit a plateau there. On their journey they encounter dinosaurs and other prehistoric creatures, as well as quarreling ape-men and hominids. The notion of surviving dinosaurs and early hominids intrigued audiences then as it does now. By the early 20th century, even the most inaccessible regions of the earth were finally being explored by scientists and adventurers, and excitement and speculation were widespread as to what might be found. Conan Doyle's famous character Professor

Challenger makes his first appearance in the story, along with another scientist, Professor Summerlee; a journalist, Edward Malone; and nobleman adventurer Lord John Roxton. The characters Malone and Roxton were inspired by E. D. Morel and Roger Casement, founders of the Congo Reform Association, which Conan Doyle supported through his book *The Crime of the Congo* (1909).

Conan Doyle was born in Edinburgh, Scotland, in 1859; was educated in Jesuit schools in England; and studied medicine at Edinburgh, where he took his M.D. in 1885. Initially receiving few patients, Conan Doyle increasingly turned to writing, applying his medical training and deductive reasoning to his literary work. His first novel, *A Study in Scarlet* (1887), began the Sherlock Holmes series for which Conan Doyle is most celebrated, though he soon grew tired of the character. Conan Doyle was knighted by King Edward VII in 1902 for his scholarly defense of British involvement in the Boer War, as well as for other writings. During his later years, Conan Doyle increasingly supported spiritualism, including the belief that the living can contact the spirits of the deceased; he also became a strong defender of the existence of fairies, or "little people." It has been pointed out that these beliefs contrast sharply with the logical pragmatism of Conan Doyle's fictional characters, as well as with his own approach to historical writing. But this apparent inconsistency may also reflect the elusive and mysterious nature of time itself, which Conan Doyle approached by means of art as well as science.

James P. Bonanno

See also Bradbury, Ray; Clarke, Arthur C.; Novels, Time in; Verne, Jules; Wells, H. G.

Further Readings

Booth, M. (2000). *The doctor and the detective: A biography of Sir Arthur Conan Doyle.* New York: St. Martin's.

Coren, M. (1995). *Conan Doyle.* Toronto, ON, Canada: Stoddart.

Lycett, A. (2007). *The man who created Sherlock Holmes: The life and times of Sir Arthur Conan Doyle.* New York: The Free Press.

Dracula, Legend of

Count Dracula is the fictitious yet infamous vampire who lives a timeless and eternal life. In Bram Stoker's gothic horror classic *Dracula* (1897), Stoker created his vampire Dracula from various vampire folklore, myths, legends, and historical accounts of the vicious and blood-thirsty warlord Vlad Dracula, Prince of Wallachia. Stoker's story is the classic piece of literature that created a vampire legend that has only gained popularity and recognition over the past 100 years.

The popular legendary vampiric tale begins when the reclusive and aristocratic Count Dracula of Transylvania purchases real estate throughout London and meets Jonathan Harker, the law clerk sent to finalize the real estate paperwork. Dracula is described as an old man, clean-shaven, except for a long white mustache that nearly hides his ever-protruding long canine teeth. The Count's complexion is colorless, and he is dressed in black. His grip is firm yet icy, with hairy palms and long pointed fingernails. The Count's touch is like the touch of a dead man. His breath is foul and nauseating. Harker notices the Count casts no shadow, can enter and exit a room unnoticed, and has no reflection in a mirror. In a very short time, Harker becomes fearful for his life.

The story describes other legendary characteristics. Dracula must sleep in earth that is "unhallowed" or taken from his birthplace or native land. He is immortal, living forever, and unable to succumb to mortal wounds. Garlic, religious icons, and holy water can be used to repel vampires but not to kill them. Vampires such as Dracula become stronger as they age. Although a nocturnal creature, the Count can move in daylight, but his powers are somewhat diminished. He also can better tolerate Christian icons than novice or young vampires. In addition to transforming himself into beasts of the night, such as wolves and bats, Dracula can also force these beasts to do his will. He cannot enter a home unless invited. He can travel as mist or fog but is reluctant to cross a body of water, taking special care while traveling to and from London and Transylvania.

On its initial publication in 1897, *Dracula* was considered ordinary by the standards of that genre. It competed with several other superb tales of Englishmen conquering villains and monsters. To create the character of Count Dracula that has become a timeless icon, Stoker studied factual historical accounts of one of the best-known Romanian historical figures, Vlad Dracula, otherwise nicknamed Vlad Tepes (Vlad the Impaler). This Prince of Wallachia ruled in 1448, from 1456 to 1462, and again in 1476, the year of his death. Tepes was also called Vlad the Impaler because of his brute force and diabolical manner of impaling enemies, political dissidents, and Romanian citizens and criminals on long wooden stakes, where they would wither and die. He preferred to display his victims prominently, raising them in the town square for public viewing. Stealing was equally as offensive as murder, and in each case, the criminal faced public impalement. Under his rule, crime and corruption ceased to exist. Simultaneously, commerce and culture thrived, and Vlad Tepes became a highly regarded hero who fiercely demanded integrity and order in Wallachia.

The legend of Dracula is deeply rooted in vampire legends and folklore that spread from the Far Eastern trade routes, through India, the Mediterranean, Romania, and Transylvania. Belief in such legends of the undead was abetted by the lack of medical expertise that by modern standards diagnoses and treats illnesses. The spread of plague could wipe out entire communities as victims wasted away. An uneducated and unscientific populace rationalized that vampirism was the cause of such unfortunate deaths.

The spirit and appearance of Dracula have metamorphosed through time into countless derivatives. One of the earliest and most haunting vampire films, *Nosferatu: A Symphony of Horror* (1922), was a silent film and the German interpretation of vampirism. The legend of Dracula began haunting popular film and fiction during the 20th century, beginning with the Hollywood film release of *Dracula* (1931), staring Bela Lugosi. Films starring actors such as Frank Langella, Christopher Lee, George Hamilton, Brad Pitt, Tom Cruise, and Gary Oldman all showed a departure from Dracula prototypes. The undead creatures whose existence defiled all living souls would become transformed in the 1980s and 1990s and replaced with a sexier and more alluring Dracula. Hollywood film incorporated the American epitome of success into its later 20th-century film versions of Count Dracula. He is a sultry, debonair, aristocratic, and seductive man. Film vampires became beautiful, virile, and sexually irresistible. A modern Count Dracula is a distinguished, well-mannered, and youthful aristocrat who can show human emotion, including love for a woman and remorse for the inevitable death of those he feeds upon.

Although vampire stories existed before Stoker's novel *Dracula,* it has become the premier literary work or story that recorded the most widely held beliefs. The novel *Dracula* is a tale told through the letters, journals, diaries, and phonograph recordings of the novel's major characters, Jonathan Harker, his wife Mina Harker, Dr. Seward, and Lucy Westenra. The novel's characters all contribute to the legendary definitions of vampirism, in fact, doing a superb investigation and compilation of the facts each had learned through interactions with the Count, his servant Renfield, and his first female victim, the beautiful and seductive Westenra, who was later resurrected into vampiric life.

Dr. Van Helsing's expert knowledge, investigative techniques, and medical credentials help the cast untangle the mystery of Lucy's death, followed by the temporary disappearance of several small children who claimed that they had been playing with the "bloofer lady," the undead Westenra. Collaboratively, their observations of vampire characteristics and lifestyle habits later assist them in creating their plot to assassinate the Count.

Debra Lucas

See also Frankenstein, Legend of; Vampires; Voodoo; Werewolves

Further Readings

Auerbah, N., & Skal, D. J. (Eds.). (1997). *Dracula: Authoritative text, contexts, reviews and reactions, dramatic and film variations, criticism.* New York: Norton.

Day, W. P. (2002). *Vampire legends in contemporary American culture.* Lexington: University of Kentucky Press.

McNally, R. T., & Florescu, R. (1972). *In search of Dracula: A true history of Dracula and vampire legends.* Greenwich, UK, & New York: Graphic Society.

Twitchell, J. B. (1985). *Dreadful pleasures.* New York: Oxford University Press.

Dreams

Time plays a pivotal role in dreams. Much of the fantasy, incoherence, inaccuracies, and ambiguities of dream contents is owed largely to continuous weakening of the strengths of connections (synapses) between nerve cells of the brain over time. Considerations here relate mainly to this weakening influence. Emphasis is on the dreams of children, which are expressed in their purest form, minimally encumbered by the complicating influences that accumulate with age.

Dreams are the accompaniments or by-products of certain essential activities of the brain during sleep. They primarily occur as neocortical circuits (the most recently evolved brain circuits) become activated by spontaneous, self-generated, complex electrical oscillations. Superficially, these oscillations are expressed as the slow and fast scalp-waves of electroencephalograms (EEGs). A major role of dreams during sleep is the processing of phylogenetic and experiential memories, that is, inherited memories and memories of past waking events.

Memory Consolidation and Reinforcement

Regarding this processing, during nonrapid eye movement (NREM) sleep, recently acquired short-term memories stored temporarily in the hippocampus become converted into long-term memories stored in the neocortex by a process known as hippocampal replay. In addition, enormous numbers of already-stored fragments of memories in the neocortex become reinforced (strengthened). During rapid eye movement (REM) sleep, many already-stored, long-term memories in the neocortex also are reinforced to maintain their authenticity.

Because dreams usually are highly visual, the storage process for visual memories is used here for illustration, though essentially the same principles apply generally. Storage of memories in both the hippocampus and neocortex is sparse and distributed, sparse in the sense that only a fragment of the memory is represented at any one of the distributed physical locations. In the visual neocortex, sets of neurons having different response properties (fragments) for colors, textures, distances, orientation, positions, and so forth, are clustered together at the various distributed locations.

As an example of memory consolidation by hippocampal replay, consider the process for a new declarative memory, that is, for the conscious recollection or explicit remembering of a new scene or event. During replay, fragments of the memory, already sparse and distributed and stored in the hippocampus for the short term, become similarly established in the neocortex for the long term, by a repetitive interactive process. Such replay in humans might continue for as long as 3 years.

Spontaneous reinforcement of memories stored in neocortical circuits during sleep involves electrical activations by both fast and slow brain waves. Reinforcement often is accompanied by an "unconscious" awareness of the corresponding memories in the forms of static dreams, that is, isolated thoughts or perceptions. Narrative dreams are assembled from these thoughts or perceptions but, on any given night, only from a small fraction of them.

It is an intrinsic property of synapses of memory circuits that they need to be reinforced periodically. Otherwise the synapses weaken and the encoded memories deteriorate, in days, weeks, or little more than a month. Synaptic strengths (weights) persist for only limited periods, primarily because the macromolecules that are essential for synaptic function break down continuously (molecular turnover). Because sufficient numbers of these molecules are needed to preserve the specific synaptic strengths that encode given memories, if "lost" molecules were not replaced periodically, these strengths would gradually decline and the memories would deteriorate.

Dedicated Synaptic Strengths, Brain Waves, and Dream Contents

Dedicated (functional) values of synaptic strengths for a given memory become established and maintained by the memory's use or periodic activation. But for memories that are used only infrequently during wakefulness, most synaptic reinforcement has to occur spontaneously during sleep. The functions of such spontaneously reinforced circuits that would disturb sleep usually are not triggered because of decreased or absent muscle tone or temporarily reduced behavioral responsiveness.

Circuits for dedicated functions remain labile to the extent that they are susceptible to being updated (reconsolidated) in response to related new experiences. Whereas the updating process drives existing synaptic strengths to new dedicated values, mere repetitious synaptic activity in the course of a dedicated function, or reinforcement during sleep, merely maintains existing strengths.

During REM sleep, spontaneous gamma oscillations (30–100 cycles per second) trigger a process known as temporal binding (binding by synchrony). In this process, neurons of distributed neocortical memory fragments are activated synchronously by gamma oscillations. The different embedded stimulus features of the fragments constituting a specific memory are brought together transiently in this way. By this process, first advanced by Christoph von der Malsburg, memories presumably are recalled. These include the thoughts and perceptions of waking as well as dream memories.

It seems likely that certain slow brain waves of REM sleep—the hippocampal theta waves (4–8 cycles per second)—trigger the serial linking of individual memories, recalled as described earlier, to form connected, narrative dreams. Reinforcement of memories during REM sleep and of enormous numbers of memory fragments during NREM sleep presumably occurs continuously. On any given night, however, only a small fraction of the reinforced circuit contents rise to the level of unconscious awareness, that is, enter dreams.

For memories, this limitation probably is because too many of them exist to be accommodated in one night's sleep. For memory fragments, it is because the content of an isolated fragment is essentially meaningless. The existence of such limitations in the information conveyed by unbound fragments in the visual realm is illustrated by the "blind sight" of brain-damaged patients. Fragments of visual information are received and registered in the visual cortices of these patients, but because the fragments do not become bound, they are not accompanied by visual awareness.

For example, although certain patients cannot see a moving object in their visual field, they nonetheless become aware that movement is occurring there. In this connection, the activation of enormous numbers of memory fragments without temporal binding or awareness probably is how synaptic strengths in the vast majority of memory circuits become reinforced during NREM sleep.

Dream contents give clues to the brain's priorities for circuit reinforcement during sleep. High priority goes to consolidation of recent occurrences, particularly significant events of the same and previous days. Highest priority is given to recent emotional events and/or actions and perceptions with significant survival value.

Illusory Contents of Dreams

From 85% to 95% of REM dreams are ordinary and mundane, with authentic, highly visual, and dynamic contents. Waking perceptual experiences reappear with remarkably lifelike details. G. W. Domhoff asserted that the waking mind and the dreaming mind seem to be one and the same. The main thesis of this entry is that many failures of our minds, as exemplified by illusory dreams, also have "one and the same" immediate cause—defective synaptic strengths.

Defective synaptic strengths have their origin in two broad categories of disruptive influences. The first category includes failures of intrinsic origin, owing simply to system complexity. Such failures are common even in much simpler cellular and subcellular systems. Also included is a normal weakening of synaptic strengths in neocortical networks with time (normal processes of decay). The second category of disruptive influences, which is not treated here, is due to pathologically altered brain waves.

It is most relevant, then, to ask what occurs when the strengths of a small fraction of the synapses—of the millions that may encode a given memory—are weakened slightly from their dedicated ranges. In answer to this key question, one would not expect a scene, for example, to be degraded beyond recognition as such. Rather, novel, unpredictable, probably relatively minor alterations would be expected—distortions, background or location ambiguities, altered identities, and so forth. A face, for example, still would be a face, but the alterations might make it unrecognizable.

Synaptic strengths in some memory circuits, even though adequately reinforced during sleep, probably accumulate chance errors in their records of dedicated strengths with time. This would place our general forgetting of our oldest memories over the years on a firm foundation, probably owing to the accumulation of these synaptic defects. Such an imperfection might even be favored by natural selection, as it would tend to eliminate useless memories of the distant past, freeing otherwise encumbered cortical tissue for the storage of new memories.

Static and Continuous Dreams

Most frequently, compatible circuits addressed by dream-producing mechanisms have overwhelmingly authentic contents. Temporal binding of small numbers of circuits with weakened synaptic strengths might lead merely to such discrepancies as unrecognized people and places, altered times, slightly altered thoughts, and so on. These dreams would not be considered illusory.

Illusory dreams, on the other hand, probably trace to the inclusion of older, variously incompetent memories and their fragments, often harking back to childhood experiences. These would contain greater numbers of defective synapses, leading to the incorporation of faulty thoughts and perceptions (beyond the mere minor discrepancies mentioned earlier). But such direct effects are unlikely to be the only cause of illusory dreams. Disruptive indirect effects probably also occur when flawed memories become serially linked, which inevitably would lead to incoherent connectivity.

When memories remain isolated in dreams (i.e., unlinked), the dreams are said to be "static" or "thoughtful." Such memories typically occur in many dreams during adult NREM sleep, in children's dreams up to about 5 years old, and in the dreamlike experiences that accompany some seizures and artificial brain stimulation. The means by which the unlinked memories of static dreams become serially linked to form dreams with narrative continuity can be dealt with only in broad outline.

Consider a dream that begins when gamma waves temporally bind certain memory fragments into an initial memory. Activation of a second memory would be expected not to be random but to be biased toward including other memories formerly associated with the first one and similarly for subsequent selections. Serial linkages between these memories, then, would possess narrative continuity.

One expects biases to exist in the activation of memories being bound and serially linked. In forming some "day residues" of dreams, in particular, the linkages conferring continuity would have been in effect only hours earlier, while awake. Accordingly, serial links must leave traces (temporally fortified connections) that guide subsequent binding and linking mechanisms.

The same reasoning would apply to old memories in long-term storage. Their ordered arrangement in narrative dreams implies that great numbers of much older, favored memory associations also persist. But any influence that tended to randomize the activation of fragments to be temporally bound, and the serial linking of the resulting memories, would be expected to favor the production of illusory dreams.

The circumstances in which temporal binding and serial linking mechanisms are subverted, leading to illusory dreams, occur only rarely during waking. This is to be expected, as few circuits employed during waking are for very old memories. Were it otherwise to any significant degree, dreamlike hallucinations, bizarre thoughts, and false memories—such as those that occur in certain pathological states—might not be uncommon in normal, awake individuals.

To further consider the basis for activation of memories whose fragments enter dreams, the process is treated as a three-step affair. In the first step, NREM slow waves (up to 14 cycles per second) address and activate circuits containing fragments of memories, thereby reinforcing the strengths of their internal synapses. However, the contents of the vast majority of these fragments do not necessarily enter dreams. Such nonentry is the probable primitive condition in animals that sleep. Dreaming takes place only if the second step occurs. In this step, proposed to be the more advanced condition in sleeping mammals and birds, REM gamma oscillations temporally bind the fragments together to yield memories.

Were the process to terminate with the second step, only a static dream, an isolated thought or perception, would occur, as is typical in NREM dreams. In the third step, the building blocks become serially linked by the actions of REM theta waves, thereby producing continuous, often narrative, and authentic dreams.

Vital Clues From Children's Dreams

The conclusion that temporal binding can occur without serial linking has a compelling basis. Whereas bound memories always exist in dreams and dreamlike experiences, serial linking of them may fail. For example, up to the age of 5 years, the dreams of children consist largely of isolated occurrences, described as static thoughts and images (often of familiar animals). This finding suggests that serial linking mechanisms are not yet fully developed at 5 years. Because theta waves are present at earliest ages, some additional mechanism, perhaps functional completion of nerve-fiber myelinization, may be necessary for serial linking to occur.

Inasmuch as David Foulkes reported dreams by the typical child of 3 to 5 years old, in only 15% of awakenings from REM sleep and in none from NREM sleep, it appears that even the temporal-binding mechanism is only infrequently present at these ages during REM sleep and is absent during NREM sleep.

In a dramatic change, a "storylike" format in which characters move about and interact in a dynamic dream world closely modeled on the real world, often with the dreamer participating, begins to appear in children 5 years old. This format contrasts with the earlier static dream content, almost wholly lacking in social interactions and the presence of the dreamer. These changes accompany the well-known "5 to 7 shift" in children's cognitive competence and functional completion of nerve myelinization—probably also when the serial memory-linking mechanisms mature. These also are roughly the ages when sufficient competence for formal schooling develops.

The other major time of prevalence of dreams without connectivity is during adult NREM sleep, when only 5% to 10% of dreams are indistinguishable from REM dreams. The other 90% to 95% of NREM dreams (themselves of infrequent occurrence) often are described as less visual, less vivid, less emotional, less bizarre, or as static or thought-like, and containing more day residues. The finding that only 5% to 10% of NREM dreams have connectivity presumably reflects the very low level of oscillations in the theta and gamma ranges.

Young children's dreams portray activity of the same general kind that waking children perform or observe. Their dream maturation proceeds in an orderly manner, both reminiscent of and temporally associated with the unfolding of their other complex mental operations. With weakened or otherwise defective synapses accumulating with age, there should be relatively few weakened synapses in young children, whose dreams should reflect minimal or no memory-recall failures.

These deductions conform to Foulkes's findings with children 3 to 15 years old, as they reported no illusory dreams. But dream distortions—dreams containing unrecognized people, animals, and places—were common. These did not begin to occur until 5 to 7 years of age. Earliest dreams, at 3 to 5 years old, were constrained and impoverished by cognitive immaturity. Almost without exception, however, dream contents at those ages were authentic, containing some few recognized family members and familiar settings, but mostly animals familiar from fairy tales and cartoons.

Dreams containing highly authentic memories at 3 to 5 years of age can be understood in terms of the existence of relatively few weakened synapses. These years also are times of intense synaptic pruning, as circuits become fine-tuned for dedicated functions. Mere dream distortions at 5 to 7 years reflect the expected minimal weakening of synaptic strengths. The frequency of occurrence of unknown people and places generally increases with age through (and beyond) adolescence, doubtless reflecting the accumulation of defective synapses.

Evidence of small numbers of weakened synapses also characterizes adult dreams, for which unknown people and places are a hallmark. Subjects typically describe objects or persons that have specific unidentifiable visual features. In one study, for example, people were recognized and recalled in only 20% of dreams—usually the familiar face of a relative, friend, or colleague.

Some fanciful explanations proposed by Freud and others for children's dream distortions were discounted by Foulkes's studies. However, his alternative explanation appears no less fanciful. He regarded the distortions as tracing to children's increasing ability to imagine unfamiliar people and places as their cognitive processes mature. A more firmly grounded explanation would hinge simply on the presence of increasing numbers of defective synapses—the greater the numbers are, the older the child will be.

It follows that children experience less interference with the dream process than do adults because children have had less time for interfering influences to develop—the younger the child is, the less time and the less interference there will be. In consequence, time can be seen to play a crucial role in the authenticity of children's dreams as compared to those of adults.

J. Lee Kavanau

See also Amnesia; Consciousness; Dreamtime, Aboriginal; Memory; Sleep; Time, Subjective Flow of

Further Readings

Buzsáki, G. (2006). *Rhythms of the brain.* New York: Oxford University Press.

Domhoff, G. W. (2006). Dream research in the mass media: Where journalists go wrong on dreams. *Scientific Review of Mental Health Practice, 4*(2), 74–78.

Foulkes, D. (1982). *Children's dreams: Longitudinal studies.* New York: Wiley.

Kavanau, J. L. (2002). Dream contents and failing memories. *Archives Italiennes de Biologie, 140,* 109–127.

Dreamtime, Aboriginal

The Dreamtime, also commonly referred to as the Dreaming, constitutes the core of traditional Australian Aboriginal religion. It is the story of how animals, humans, and natural terrain came to be and why they have the particular behaviors and characteristics that they have; it is a code of conduct for all time. Before the period known as the Dreamtime, the earth was an endless, featureless plain devoid of all life. During the Dreamtime the Spirit Ancestors arose from under the ground and descended from the sky realm, creating human and animal life while journeying across the land. In doing so, they left behind evidence of their activities in the markings and contours of the natural landscape before disappearing back into the land and sky realms. The Dreamtime continues as an eternal moment that is accessed today, as it was in the past, through recounting the stories of the Spirit Ancestors, singing sacred songs, creating various forms of art, performing rituals, and totemism. The concept of time as neither linear nor cyclical, but rather as atemporal, is at the heart of this oral tradition.

Australian Aboriginal Culture

Numerous distinct cultural and linguistic groups span Australia, but with significant overlap in cultural practices and beliefs. The native people of Australia likely have the longest continuous culture of any group on earth. Archaeological sites throughout Australia provide evidence that indigenous people have occupied the continent for as long as 60,000 years. For most of this time they existed exclusively as hunters and gatherers. Men hunted animals such as kangaroos, emus, and turtles while women and children gathered fruits, berries, and plants. To prevent the overuse of any area of land and its resources, groups were mobile within a wide territory. According to Australian Aborigines, traditional lifestyles associated with existence as nomadic hunter and gatherers, as well as a newer way of life resulting from centuries of European contact, can be explained by reference to the actions and laws established by the Spirit Ancestors during the Dreamtime.

The Spirit Ancestors

The term *Dreamtime* is often misleading to Western thinkers who view time in a linear fashion and so mistakenly regard it as an event that was concluded in a distant past. But neither should the Dreamtime be thought of as time comprised of vast cosmic cycles, as found in many of the Eastern traditions. Rather, the Dreamtime may best be described with the term *everywhen,* coined by anthropologist and historian W. E. H. Stanner or, similarly, as the "all-at-once-time," in so far as past, present, and future coexist in an eternal now.

The Dreaming originated with the journeys of the Spirit Ancestors, who temporarily left their abodes under the ground and in the mystical sky realm to travel across the earth, creating the natural landscapes and living things that we see today. Taking a variety of human, animal, and other forms, the Spirit Ancestors endowed certain places with a particular power or sacredness while providing form to the landscape. These self-created Spirit Ancestors are not considered to be gods, but they do have significant power that can be used for either good or harm. For example, the Mimi spirits are described as tall, thin, stick-like figures that resemble humans. They live in rocky areas and although they may be mischievous at times, they are also credited with teaching the ancestors of today's Australian Aborigines how to hunt and cook as well as how to create rock paintings. Some indigenous groups maintain that particular rock paintings were left by the Mimi themselves.

After completing their journeys, many of the Spirit Ancestors transformed themselves into objects such as rocks, stars, or animals, and their powers still inhabit these objects. The journeys of the Spirit Ancestors still have relevance for today's people, with direct implications for why things are as they are. Explanations for how and why people and animals do the ordinary activities that they do, such as dancing, hunting, gathering food, and falling in love, are sought in stories of the Dreamtime that have been passed down orally for countless generations.

Stories of the Dreamtime

Knowledge of the Dreamtime was originally passed from older to younger generations in the form of oral stories rather than through the written word. Dreamtime stories are accounts of the journeys of the Spirit Ancestors as they moved across the landscape forming the natural geography and establishing the laws. Aboriginal groups who share a totem and territory are considered to be the owners of specific stories, songs, and ceremonies that pertain to the actions of the Spirit Ancestors in that territory. An individual's totem affiliation is derived based on the territory in which that person was conceived. Totems are animal or plant representations of a given Spirit Ancestor that link individuals to the group of other individuals who share that particular totem but also link the totemic group as a whole to the Dreamtime via their totemic Spirit Ancestor.

Dreamtime stories cover a wide range of themes and topics that vary from one group of people to the next, but they often contain significant overlap across the territories that span the continent. They tell of the period of the Dreamtime when all was created and so give reasons, for example, as to why we see particular geographic formations, why indigenous animals behave the way they do, why there are seasonal weather patterns, why we suffer, how people first learned language, why kangaroos have pouches, why and how the sun rises every day and retreats every night, how flat country came to have hills, and even how death came to be a part of human's lives.

The Rainbow Serpent is one of the most widespread figures throughout Aboriginal Australia. It is a large snakelike creature associated with the creation of watercourses such as rivers and lagoons that it formed while twisting and winding its way across the continent during the Dreamtime. The Rainbow Serpent is also attributed with producing the rain and storms of the wet season. As water is such an essential element throughout Australia, we see the Rainbow Serpent is revered as the source of life. However, if not respected, it can be a destructive force as well.

Another example of how Dreamtime stories explain the various contours of the landscape is found in the legend of a small lizard known as the Tatji and his actions at Uluru (Ayers Rock). At this site Tatji threw his kali, a curved throwing stick, which became embedded in the surface of the rock. In attempting to remove it by scooping it out with his hands, he left behind a series of hollows that continue to mark the rock face. Unable to remove his kali, he died in a cave where today his bodily remains appear as large boulders on the cave floor.

Given the importance of fire for traditional hunting and gathering groups across Australia, it is not surprising that another common theme found in Dreamtime stories is the origin of fire. Some Aboriginal groups attribute its origin to a strike of lightning or a small bird that brought it from a volcano. Others say that it was a gift from one of the Spirit Ancestors. One group traditionally located on the north coast of New South Wales claims that the Aboriginal people first discovered the benefits of fire for cooking and warmth long ago when the Spirit Ancestors accidentally set fire to the land. At this time in the distant past, only the Spirit Ancestors knew how to control fire, as they lived in the sky between two bright stars from which they could light fire sticks.

On one occasion the Spirit Ancestors faced a shortage of game in their sky world and were forced to seek food on Earth. During the hunt, two brothers carelessly left their fire sticks on the ground, whereby the two sticks began to chase one another leaving trails of fire in their wake. As the fire spread and overtook the cache of meat that had been hunted by the Spirit Ancestors, the people became excited by the wonderful smell of the cooked food and the warmth of the fire and so took the fire sticks for their own.

Ceremonies, Songs, and Art as Means of Accessing the Dreamtime

In addition to recounting stories, there are numerous means of invoking the Dreamtime and the Spirit Ancestors. Aboriginal religion is not centered on worshiping the Spirit Ancestors as gods but on reenacting the archetypal paradigms initiated by them. For this reason, Aboriginal beliefs about the creation of life and landscape on Earth and the laws set out by the Spirit Ancestors are conveyed in stories that are not only told but are enacted in ceremonial performance, art, dance, and song that allow participants to continually access the Dreaming. For example, people may perform ritual ceremonies at places in the natural environment that hold particularly potent power left by the Spirit Ancestors. Or, in different territories throughout Australia, such as Ayers Rock, we see rock art depicting the actions of the Spirit Ancestors that date back hundreds and, in some cases, thousands of years. These are typically painted with natural pigments of red, yellow, black, and white and may take a wide variety of unique stylistic forms. As Aboriginal culture continues to change to meet the demands of the 21st century, art associated with sacred totemic rituals endures but in addition to the traditional medium of sand, rock, or ground paintings, it can increasingly be found today in modern media such as acrylic and photography.

Catherine M. Mitchell Fuentes

See also Anthropology; Dreams; Mythology; Psychology and Time; Religions and Time; Sleep; Time, Subjective Flow of

Further Readings

Cowan, J. (1992). *Mysteries of the Dream-time: The spiritual life of Australian Aborigines.* Bridgport, Dorset, UK: Prism Press.

Elkin, A. P. (1964). *The Australian Aborigines.* Garden City, NY: Anchor Books.

Ellis, J. A. (1991). *From the Dreamtime: Australian Aboriginal legends.* North Blackburn, Victoria, BC, Canada: Collins Dove.

Flood, J. (1997). *Rock art of the Dreamtime: Images of ancient Australia.* Sydney, Australia: Angus & Robertson.

Stanner, W. E. H. (1979). *White man got no Dreaming: Essays, 1938–1973.* Canberra, Australia: ANU Press.

Duns Scotus, John (1265–1308)

John Duns Scotus, *Doctor Subtilis,* the Subtle Doctor, was a Franciscan theologian of the Middle Ages renowned for his defense of the Immaculate Conception and his writings on the soul. He also stands as an intermediary between Thomas Aquinas and William of Ockham. Although he sometimes is confused with Johannes Scotus Eriugena because of the similarity of their names, Duns Scotus lived at the end of the 13th century (1265–1308), whereas Scotus Eriugena lived in the 9th century (c. 810–c. 877). There is some debate as to Duns Scotus's origins, which may have been Irish, Scottish, or northern English. The English claim can be found in Duns Scotus's several years of service as a professor at Oxford. Part of the confusion stems from *Scotus,* which meant Irish in the Middle Ages. Some sources claim that Duns refers to a place in either Ireland or Scotland; *dun* is a Gaelic word for "fort," and it is a common prefix in place-names. It is perhaps significant in this regard that the Scotist school, of which he was the founder, found its greatest favor among Irish Franciscans. In the library of Saint Francis of Assisi, Duns Scotus is described as *de provincia Hiberniæ,* from the province of Ireland. Nonetheless, his grave inscription in Cologne says "Scotland bore me . . ." He is believed to have received his doctorate, titled *Quæstiones Quodlibetales,* at the Franciscan college in Paris, and from there he took up a professorship in Cologne prior to his death while still in his 30s.

The Scotist school, or the Later Franciscan school, is a theological and philosophical style that is derived from the Old Franciscan school of Augustinian theology (Platonism) and that combined the writings of Aristotle with those of Plato. Duns Scotus employed Aristotelian thought and Peripatetic ideas to a greater degree than had his predecessors, disagreeing with Saint Thomas Aquinas on some points, for example, the doctrine of necessity and the distinction between form and matter, yet he remained firmly entrenched within the Old Franciscan school.

His first work probably was his commentaries on Aristotle. Some of his other writings include *Reportata Parisiensia* and *De perfectione statuum.* The sobriquet *Doctor Subtilis* comes from his complex and subtly suggestive lines of thinking on subjects such as will, human freedom, universality, metaphysics, and theological language. This is evident in his *Opus Oxoniense,* his Oxford commentaries on Peter Lombard's 12th-century *Sentences* (*Quatuor libri Sententiarum*), which united the facets of theology from the Blessed Trinity through judgment to heaven and hell, into a unified whole. Duns Scotus's commentaries, although mainly theological in nature, cover the gamut of metaphysical, grammatical, and scientific thought and serve to display most of his philosophical system. Although Duns Scotus appears to have changed his position from his earlier acceptance of prevailing theology to his later individual insights, this cannot be certain because many of his essays remain incomplete, and he did not produce a *Summa.* His talent appears to have been criticism more than self-expression, or perhaps more accurately, self-expression through criticism.

Nonetheless, a philosophical system exists within the work of Duns Scotus. He distinguishes among pure intellectual distinctions, distinctions that are based in reality, and formal distinctions that lie between intellectual and realistic distinctions. This leads to the soul, the intellect, and the will, each with its own faculties and realities, yet which are different aspects of the same existence.

The Blessed Trinity exist of themselves regardless of externalities. It is in its wholeness as three persons in one existence that they create by their unified thoughts and will. Likewise, existence is not the same thing as substance; an accident can exist within substance yet not have substance of its own. Only things that actually exist have being. Prior to being, things have only essence but not existence, yet within the essence is contained the possibility of existence. Only God is perfect enough to exist without the need for material creation. Thus, when God gives existence to essence by his will, he makes it good and real because it comes from God. God's will is not limited by the laws of nature. Thus, being beyond the laws of nature, God is not bound by time, but he exists outside of it, making him eternal. Yet time itself exists solely dependent upon God's will, as he gives it existence. We measure time relative to lunar and solar movements put into motion as an expression of his will. From this we can infer God's infinity from his finite creations.

Ironically, the term *dunce,* someone who cannot learn, comes from later followers of Duns Scotus who were tied to his sophist teachings and would not accept the rise of humanism. Duns Scotus was elevated to Blessed by Pope John Paul II.

Michael J. Simonton

See also Aquinas, Saint Thomas; Aristotle; Christianity; God as Creator; Scotus, Johannes Eriugena; William of Ockham

Further Readings

Catholic encyclopedia (Vol. 5). (2003). New York: Appleton.

Reese, W. L. (1996). *Dictionary of philosophy and religion: Eastern and Western thought.* Amherst, NY: Humanity Books.

Rubenstein, R. E. (2003). *Aristotle's children: How Christians, Muslims, and Jews rediscovered ancient wisdom and illuminated the dark ages.* Orlando, FL: Harcourt, Brace.

Duration

The word *duration* refers to a length of time and can be broadly categorized into two types. A *filled* (or *full*) *interval* is the length of time of a single event (such as a speech). An *unfilled* (or *empty*) *interval* is the length of time between two successive events (such as two knocks on a door).

Human perception of time is sometimes referred to as involving both duration and succession. In this case, succession is defined as the fact that two or more events are perceived as different and occurring in a sequence. Duration is defined as the interval between the successive events. Duration is not a thing by itself, but it is a quality or characteristic. Without succession, there is no duration.

For events having an extremely brief duration, the perception of instantaneity is created. In this case, the perceiver is unable to distinguish between the beginning and the end of the occurrence. Studies have found differing thresholds at which humans can perceive a duration, but the minimum threshold is usually around 130 microseconds.

A number of variables can affect how humans perceive a specific duration, as shown in many clinical studies. Circumstances that cause strong negative emotions seem to last longer, because of the additional attention focused on processing the emotional stimuli. This effect is known as the *filled interval illusion.* Other factors that may make an event appear longer include using auditory (rather than visual) stimuli, greater intensity of a sound or light stimulus, and use of filled intervals (rather than unfilled intervals).

The theory of cognitive orientation states that events with greater variability and unpredictability also appear longer. This is because the participant is not able to anticipate what is coming next, and it takes longer to become oriented to the situation.

It should be noted that perception of duration differs from estimation of duration. When humans estimate a duration, they are considering an event that has already occurred and is in the past. When humans perceive a duration, they are considering an event that is presently occurring.

Duration in Music

In musical notation, *duration* refers to the length of time that a note is held. In this case, a note's duration is not absolute but rather relative to the whole note. For example, a half note has half of the duration of a whole note. The absolute duration of each note in a given piece is determined by the metronome marking (if given) and time signature. The time signature is made up of two numbers, one showing the number of beats per measure, and the other showing which note gets one beat.

The metronome marking is listed as a single number, indicating the number of beats per minute. In place of a metronome marking, some composers may use a tempo mark, which is a word or phrase indicating how fast or slow the music should feel. With this type of marking, the tempo is somewhat open to the interpretation of the conductor or performer.

Long Durations

Although much research about duration involves small periods of time, the word *duration* can also refer to lengthier events. For example, the age of the universe has been estimated at 13.7 billion years. One could see this time period as a filled interval (i.e., the duration during which the universe has existed). In this case, as the universe continues to exist, the duration will become longer, as there has not yet been an end point.

Jaclyn McKewan

See also Bergson, Henri; Consciousness; Music; Perception; Spacetime Continuum; Time, Subjective Flow of

Further Readings

Cooper, G., & Meyer, L. B. (1960). *The rhythmic structure of music.* Chicago: University of Chicago Press.

Fraisse, P. (1984). Perception and estimation of time. *Annual Review of Psychology, 35,* 1–36.

Durkheim, Émile (1858–1917)

Émile Durkheim, a French sociologist and anthropologist, is often credited with having established sociology as a distinct science. Much of his work is meant to explain how sociology is unique within academia and thus must be recognized as its own academic discipline. Consequently, he paved the way for sociologists and anthropologists of the

20th century. His major works include *Division of Labor in Society, The Rules of the Sociological Method, On the Normality of Crime, Suicide,* and *Elementary Forms of Religious Life*. Durkheim holds a special place in the historical development of social thought. Furthermore, he viewed human values from a temporal perspective; his investigations viewed the development of societies, institutions, and human beings over the course of time.

Durkheim was born in Lorraine, France, into a devoutly Jewish family; his father, grandfather, and great-grandfather had all been rabbis. Émile's outlook, however, was essentially secular; he was interested in studying religions objectively and thus never affiliated himself with any formal religion.

As a child, Durkheim was a bright and diligent student. He was awarded numerous prizes and distinctions. He earned his baccalaureates in letters (1874) and sciences (1875) at the Collège d'Epinal, as well as high distinction in the Concours Général. This facilitated his acceptance to the Lycée Louis-le-Grand in Paris. However, he was not content with having been accepted there and he studied fervently to be eventually accepted, after three tries, to the École Normale Supérieure, one of France's most elite schools.

At École Normale Supérieure, Durkheim studied alongside other scholars who would attain fame, such as Jean Jaures, Pierre Janet, and Henri Bergson, and he often discussed with them the Republican cause, of which he was a strong proponent. Durkheim admired Léon Gambetta, one of the founders of the French Third Republic, and Jules Ferry, who introduced the anticlerical reforms that made education mandatory, free, and secular throughout France. It was also in college that he read Auguste Comte and Herbert Spencer. Thus, he was exposed to the fathers of social science even though no such discipline was recognized by academia at the time. He majored in philosophy but was bored by the humanities that his college required him to study and therefore graduated second to last in his class.

Despite his apparent underachievement in college, he was not dissuaded from pursuing knowledge throughout the rest of his life. His own interest in education centered on teaching methods, which had long been literary but which he felt needed to be scientific, and it was this issue that drove him. He traveled to Germany, where social science was more accepted, and studied there for a year.

Durkheim received his first employment in 1887 in Bordeaux, teaching pedagogy and social science, which was still quite new and not fully legitimated within French academia. The social science part of the appointment had been tailored to fit his new ideas, and thus, sociology became part of the French academic curriculum.

Durkheim introduced several important concepts to the vocabulary of sociology. For one, he differentiated between two ideal types of society: the mechanical and the organic. Mechanical societies were small, simple, and traditional societies in which labor was not differentiated and in which norms were well regulated by collective consciousness and repressive corporal punishments. Organic societies were larger, more complex societies in which labor was differentiated and punishments for deviant behavior were aimed at rehabilitation. Durkheim also introduced the concept of *anomie,* which describes a lack of clear norms, leading to deviant behaviors within society. Also worth noting, Durkheim was one of the first to rigorously study and speculate upon the human phenomenon of suicide; he described anomie as the primary cause of one type of suicide (thus named anomic suicide), the three other types being egoistic, altruistic, and fatalistic, each with its own set of properties. Furthermore, he developed the religiosociological concept of collective effervescence, by which he theorized that humankind's belief in God emerges from wonder at society.

Perhaps most importantly for the future of sociology, however, he rigorously advocated an empirical method applied to sociology so as to differentiate sociology from the other sciences. Consequently, he introduced the concept of a "social fact" to justify the new science, a concept he said denoted the existence of some institution in society that was not dependent upon particular individuals for its continued existence.

Durkheim's thought, descended from that of the Enlightenment, helped to shape a new understanding of time and history. He made a point throughout his work of describing history as a process resulting from an intermingling of factors. He helped to further establish within Western society the scientific way of understanding time as a chain of cause and effect. For instance, Durkheim connected religious with social phenomena, suggesting that religious beliefs and practices, by influencing the way humans behave, also shape time. Social facts, in the form of large institutions such as religions or states, which span generations and exist independently of individuals, come to influence and shape not only individual lives but also the way time is viewed by human societies as a whole.

Mark Koval

See also Bergson, Henri; Comte, Auguste; Evolution, Social; Spencer, Herbert; Values and Time

Further Readings

Alexander, J. C., & Smith, P. (2005). *The Cambridge companion to Durkheim.* Cambridge, UK: Cambridge University Press.

Baum, G. (1980). *Sociology and human destiny: Essays on sociology, religion, and Society.* New York: Seabury Press.

LaCapra, D. (1972). *Émile Durkheim: Sociologist and philosopher.* Ithaca, NY: Cornell University Press.

Lukes, S. (1972). *Émile Durkheim: His life and work, a historical and critical study.* New York: Harper & Row.

Nisbet, R. A. (1974). *The sociology of Émile Durkheim.* New York: Oxford University Press.

Nisbet, R. A. (1965). *Émile Durkheim.* Englewood Cliffs, NJ: Prentice Hall.

Pickering, W. S. F. (2002). *Durkheim today.* New York: Berghahn Books.

Dying and Death

Dying is a process of time that all organisms undergo. From a biological standpoint, dying is synonymous with the concept of aging and metabolic degrading. The biological state or process of aging is known as *senescence*.

A phenomenon known as *cellular senescence* is a cell's apparent ability to divide (reproduce via cellular division) only a limited number of times in culture, negating the concept of perpetual cell replication. This phenomenon was illustrated in 1965 by Leonard Hayflick and was called the Hayflick limit. The aging process of an organism is known as *organismal senescence* and is typically quantified in terms of what is called a life span. A life span is defined as a length of time that an individual organism is expected to live. In humans, a life span is typically measured in years.

Death is the permanent end of the life of an organism. The principal causes of death are typically aging-related processes that cause a decrease in, and consequently the cessation of, metabolic actions. Other causes of death could include predation, environmental changes, and decreases in the availability of food. Overall, death is the inevitable consequence of aging. Although death may be viewed as undesirable, it is actually a natural part of the cycle of life.

Several factors influence the process of dying, thus slowing down or speeding up the process. Environmental factors most notably can affect the life span of an organism. A favorable environment can provide an organism with the proper food sources and ideal living conditions for it to attain a maximum life span. An unfavorable environment with insufficient food sources and hostile conditions (such as extreme temperatures) could directly cause an organism to die much sooner than its anticipated life expectancy.

Diet, or what an organism consumes for metabolic demands, can influence the rate of dying. For example, if an organism requires proteins and sugars to survive, where and how those two things are attained could have a positive or negative effect on that organism. If this food source is hazardous to procure or contains additional hazardous chemicals, then this could possibly increase that organism's rate of dying. However, if the food source is found in different forms that are safer to procure and/or contain less or no additional hazardous chemicals, then this would decrease that organism's rate of dying.

What type and how many predators an organism has can also affect its life span. An organism's ability to survive against predators depends on its genetics (inherited) and learned behavior. These two things give an organism a better chance of evading or fending off predation.

In essence the abilities of an organism to obtain food and avoid becoming food can increase its life span and prolong the dying process. These abilities would be favored by natural selection, a natural process by which favorable traits or genetics (that are inherited) become more common (by way of survival) in a population of reproducing organisms and, consequently, unfavorable traits that are also heritable become less common or eventually extinct.

Factors Affecting Human Life Expectancy

In humans, life expectancies (or the average life span of a group of organisms) have steadily increased. In the United States, the average human life expectancy was only 47 years in 1900, compared with 77 years in 2000. That is an average increase of 30 years. The global life expectancy in 2000, however, was 67 years, which is lower than in the United States and other industrialized nations but much higher than the global life expectancy in 1800, which was about 37. Five major factors are believed to have contributed to this increase in the U.S. and global life expectancies: improvements in general health, decrease in infant mortality, the advent of modern medicine, increased availability of food, and natural selection.

First and foremost is the improvement in general health, particularly the conditions of cleanliness and hygiene among large populations. In fact, one of the largest increases in life expectancies coincides with the advent of sewer systems. This greatly decreased both the spread of communicable diseases and the development of plagues that had wiped out massive numbers of people in the past.

Second, and often regarded as the most important factor in the increase of life expectancy, is the decrease in the number of infant deaths. This is more noticeable in industrialized countries, where the near elimination of infant mortality has been attained owing to improvements in prenatal health and medical obstetrics. From a mathematical standpoint, if you eliminate the number of zeros from your group of infant numbers, then the calculated results of your average life expectancy increases drastically.

Third, improvements and advancements in medicine have contributed to the prolongation of human life. For example, vaccinations against diseases like rubella, polio, and tetanus have allowed more individuals to survive beyond adolescence. In addition, improvements in diagnosing and treating diseases have also contributed to the increase in life expectancy. More interesting is that with the completion of the Human Genome Project, the physiology of aging may be better understood, and aging may perhaps be genetically halted or even reversed. This, of course, raises scientific, philosophical, and religious speculations.

Fourth, the increase in the availability of food has increased the life expectancy because of a decrease in the number of individuals dying from starvation. Just a century ago food was much scarcer and had to be grown or hunted if not bartered for. In those fragile times, if a crop failed or other unforeseen disasters took place that caused a shortage of food, people died of starvation. In modern times, hundreds of restaurants and grocery stores can be found in a single city, and in industrialized nations there is actually an overabundance of food. This could in turn have an adverse affect on life expectancy. Because of this overabundance of food, and the fact that much of this food is high in fat, cholesterol, and calories, industrialized nations like the United States are developing epidemics of obesity, diabetes, and increases in coronary artery disease. It has been postulated that in the near future we can expect to see a decrease in life expectancy for the first time in over 200 years.

Fifth, natural selection, in a theoretical way, may have improved human life expectancy, but perhaps only initially. In a given species, stronger individuals that live longer have more of an opportunity to reproduce, whereas genetically inferior members of the species die sooner and thus have less opportunity to reproduce. So initially when our species lived in more dangerous conditions, natural selection worked to improve the life expectancy, in general, by providing favorable genetics. However, there are newer philosophical speculations that have developed with regard to natural selection contributing to the improvement in life expectancy. Because our environment is not as hazardous as it once was, genetically weaker individuals are able to survive and reproduce, sometimes in large numbers. Therefore, because there are not as many natural factors to pressure the species to improve genetically, the gene pool is beginning to decrease in quality. This idea is known as "failure to improve the species" from a natural selection point of view.

Changing Views on Dying and Death

From a cultural standpoint, attitudes toward dying and death have changed over time. One major topic that has catalyzed moral and ethical thought about death and dying is euthanasia. There are two definitions of what euthanasia is. Passive euthanasia is the withdrawing or withholding of life-prolonging medical treatment, which in turn increases the rate of dying. This is typically done in what is believed or assumed to be in that patient's best interest because of the expected decrease in the quality of his or her life as a result of a current medical condition. Active euthanasia is the intentional act to end the life of a person who would otherwise suffer from a painful or incurable medical condition. Active euthanasia is illegal in most countries, whereas passive euthanasia is gaining more acceptance. Another factor influencing the acceptance of euthanasia is the cost of keeping terminal patients alive with little or no chance of their having a normal quality of life.

Understanding and Dealing With Death

The acknowledgment of death is the realization that another individual has ceased to exist. Mourning is the grief that an individual experiences as a result of the death of someone close or special to that individual. During this experience, an individual will undergo what is known as the grief cycle. The grief cycle, as originally outlined by psychiatrist Elisabeth Kübler-Ross, consists of five stages: denial (This can't be happening), anger (Why me?), bargaining (Please let me live to see [a particular event] happen first), depression (What is the point of going on?), and acceptance (He [or she] is in a better place now).

As we live, we witness the deaths that happen to others, but how do we come to terms with the fact that we too eventually will die? An organism's ability to comprehend that it is dying and will at some point cease to exist is known as death consciousness. This appears to be specific only to humans. Although some animals are reported to experience grief, it is uncertain if they are conscious of the fact that they too will eventually die. An animal's avoidance of death is driven more by instinct than by realization of a definite end.

In all likelihood, death consciousness was the driving force that motivated most religions to hypothesize the concept of the afterlife, which refers to the immaterial continuation of life or life after death once the physical processes of life have ceased. Every culture and religion has its own beliefs concerning what happens after an individual dies. For example, Christianity professes that when you die, your soul, which is immortal, goes to heaven if you were a good person or to hell if you were a bad person, based on the commandments of that religion. In many Asian philosophies or religions, it is believed that when you die, you are reincarnated into another type of life form. Other religions, such as Zoroastrianism, believe that the dead will be resurrected at the end of time. On the other hand, atheists and agnostics do not believe that there is life after death. However, all ideas about what, if anything, happens after death must remain speculative in the absence of proof or even of a universal agreement about what would constitute such proof.

Whatever religion or philosophy a person believes in, there is a general human tendency to want to remember loved ones or to be remembered after death. This is the purpose of a funeral, the ceremony that marks the death of an individual. In some cases, a monument is erected in remembrance. The burial of the dead is hardly a new concept. In fact, evidence discovered in the Shanidar Cave (in Iraq) establishes that Neanderthals buried their dead and adorned them with flowers. Some people, however, prefer not to be buried and choose to have their remains cremated instead.

Eternal Recurrence

The concept of eternal recurrence is a cosmological speculation based on the premise that the expanding universe has a limit, based on the current scientific assumption that there is a finite amount of matter. Once this limit is reached, it is believed that the universe may contract back to its origin, only to expand once again, then again to contract, and so on. Because the number of changes proposed through this model of expanding and contracting is believed to be infinite (which is another scientific assumption), there is a possibility that an exact state can occur an infinite number of times. In other words, this life may recur again an infinite number of times and may have already occurred an infinite number of times. In physics, an oscillatory model of the universe could illustrate and explain how the universe could cycle through the same events infinitely. Therefore the concept of eternal recurrence, from a scientific account, would be a function of energy and time. This also provides a model that death is not a permanent end.

The concept of eternal recurrence has its roots in ancient Egypt (c. 1600 BCE). The ancient Egyptian alchemy symbol, the *ouroboros,* which in Greek means "tail biter," is typically represented by a snake or serpent-like creature devouring its tail to form a circle. This also represents the concept that time is cyclical as opposed to linear. The idea of eternal recurrence was revisited by the German philosopher Friedrich Nietzsche, most notably in his works *The Gay Science* and again in *Thus Spoke Zarathustra.* Philosophically, eternal recurrence is a cosmological form of life after death.

John K. Grandy

See also Birthrates, Human; Diseases, Degenerative; DNA; Eternal Recurrence; Fertility Cycle; Life Cycle; Longevity; Malthus, Thomas; Nietzsche, Freidrich

Further Readings

Despelder L. A., & Strickland A. L. (2005). *The last dance: Encountering death and dying* (7th ed.). New York: McGraw-Hill.

Galor, O., & Omer, M. (2005, October 12). *Natural selection and the evolution of life expectancy* (Minerva Center for Economic Growth Paper No. 02–05). Retrieved July 20, 2008, from http://ssrn.com/abstract=563741

Riley, J. (2001). *Rising life expectancy: A global history.* Cambridge, UK: Cambridge University Press.

E

Earth, Age of

About 75 years ago, the best guess for the age of Earth was about 100 million years before the present. About 50 years ago, the best estimate was approximately 2 to 3 billion years. Now, the best estimate is that the earth was formed 4.75 billion years ago. In cosmic time, it may have taken another 14 billion years for the gases in the universe to coalesce into a liquid or plastic form. Scientific research and technological advancement improves with time, but how can such a huge amount of time be put into an understandable perspective? The archaeologist D. J. Mahony made an analogy with a walk down the avenue of time into the past, covering a thousand years at each step. The first step would take us back to the battle of Hastings, the second to the beginning of the Christian era, the third to Homeric Troy, the fourth to Abraham, and the seventh to the earliest traditional history of Babylon and Egypt. About a quarter mile would lead to the origin of the oldest stone tools found in Europe. To continue until we encountered the most ancient fossil organisms would mean a journey of more than 250 miles.

James Hutton, in the 18th century, was a farmer, a doctor, and, many believe, the father of modern geology. He perceived, from what he viewed and understood of the soils and the rocks, that the formation of the earth took a much longer period to happen than that postulated by Archbishop Ussher in the 17th century, who proposed that the earth was created on the evening of October 22, 4004 BCE. Charles Lyell, in the 19th century, using earlier works as well as his own observations, indicated that the earth was not only of great age but that its processes in the present could be used to illustrate the changes of the past. Early in the 20th century, Alfred Wegener presented the concept of continental drift, now known as plate tectonics, to his peers and to the world. These concepts by Hutton, Lyell, and Wegener were not readily accepted. But now we know that Pangea was truly a single continent about 200 million years ago and that that continent has become no fewer than six: Africa, Antarctica, Australia, Eurasia, North America, and South America. The geologic processes that we observe today have been recurring again and again. Some of these events and processes can be viewed in the geologic timescale in Table 1.

The study of Earth's origin is a work in progress. A multitude of geologists and other scientists for the past 500 hundred years or so have built the body of knowledge we have currently. Today, scientists are using new technologies to piece together how the earth was formed. It some ways, it is like building a structure from the top down, or as Hutton put it more than 200 years ago, "The present is the key to the past." Speculation concerning Earth's origin and its formation runs rampant. This continues today regarding Earth's formation, but with developing technologies, new, vivid, and more exact evidence has begun to appear.

Astronomers, seismologists, physicists, chemists, and biologists, among others, are accumulating the evidence necessary to reveal the history of Earth and its age. The interior of the earth, its core, consists of hot, molten material. The core is surrounded by a

Table 1 Geologic Timescale

Geologic Periods	*Time (YBP)*	*Major Events*
Quaternary	2–3 million	ice age, emergence of humankind
Tertiary	65–70 million	Cascadian orogeny, carnivores, mammals
Cretaceous	136 million	Laramide orogeny, some extinction, ice age
Jurassic	190–195 million	first birds and mammals, Nevadian orogeny
Triassic	225 million	first dinosaurs, Palisades disturbance
Permian	280 million	Appalachian orogeny ends, ice age
Pennsylvanian	320 million	Appalachian orogeny, swamps, first reptiles
Mississippian	345 million	Appalachian orogeny begins, conifers, ferns
Devonian	390 million	first amphibians, Acadian disturbance
Silurian	430–440 million	first plants, Caledonian disturbance
Ordovician	500 million	first fishes, Taconic disturbance
Cambrian	570 million	ice age, submergence, trilobites
Precambrian		Appalachia, Grand Canyon disturbances
Proterozoic		primitive marine plants, ice age
Archeozoic	4.75 billion	Laurentian orogeny, no life
Primeval gases		

mantle of more viscous material with variations in its fluidity. On top is the less hefty crust of the earth in two parts: the lower magnesium-silicate layer and the upper alumino-silicate layer, or the present landmasses. The crust consists of rigid materials such as silica (SiO_2) which is almost 95% of the total volume, followed by aluminum (Al), iron (Fe), calcium (Ca), sodium (Na), potassium (K), and magnesium (Mg), all of which add up to 98.59% by weight. In the core, below the crust, heat is generated and convected through the mantle. The heated material pushes forth and tends to weaken the crust, slowly moving it laterally, sometimes allowing molten material to ooze out, as in sea-floor spreading. This process of deformation has continued through time.

Landmasses built by volcanism, faulting and folding, and upheavals related to the collision of continents become exposed to the atmosphere, and they contribute sediments that are carried to lower elevations by moving water, moving air, moving ice, and currents and tides in bodies of water. Deformation of the crust has occurred repeatedly, producing a complex crustal surface.

Geological Eras

The Precambrian is divided into eon: the Archeozoic, which is characterized by primeval conditions, and the Proterozoic, considered to be the very beginning of primitive life. However, additional distinct eras during the Precambrian may emerge with the greater understanding afforded by newer technologies. During the Precambrian eon, considerable deformation has been noted with no fewer than three major orogenies and subsequent long periods of erosion and deposition, in addition to two ice ages. Every continent has Precambrian shields, many of which contain a wealth of minerals, including iron, copper, nickel, silver, and gold.

The Paleozoic era consists of the Cambrian through the Permian periods. This era begins with the appearance of trilobites and other marine fossils in vast shallow seas that came with climatic warming at the end of the Proterozoic ice age. The Ordovician was the greatest of all submergences, with reef systems and an abundance of marine fossils stretching from the tropics to the arctic regions of today. It must be remembered that the landmasses had different shapes and locations until about 200 million years ago. The rocks of this period offer gas and oil, as well as building stone such as marble, slate, limestone, and dolomite, and ores like hematite, lead, and zinc. The Silurian times were relatively calm as terrestrial life began, with the first air-breathing animals such as scorpions and millipedes, and marine life continued to develop. During the Devonian, which was relatively calm, some disturbances can be noted, as with other periods. Land plants flourished as did marine invertebrates; the ascendancy of the fishes began, including air-breathing fishes. The Mississippian and Pennsylvanian mark the millions of years of the carboniferous system with swamp vegetation, interspersed with sediments of clay, silt, and sand. The Permian marks a crisis in Earth history with major mountain building. Although deserts were widespread during this time, so were vast areas in the southern hemisphere covered with ice, and the decline of carboniferous floras can be noted.

The Mesozoic era includes the Triassic, Jurassic, and Cretaceous periods, during which the reptiles emerged. This was the age of dinosaurs measuring about 65 feet in length and more than 18 feet high at the hips. Also, smaller dinosaurs, birds, and mammals appeared in great quantities. The end of the era came with orogenic forces and a colder climate, with evidence of glaciers in Australia. It must be remembered that continents were not the same shapes or in the same locations as they are today.

The Cenozoic era is that of the modern world of the past 65 million years or so. The Mesozoic lasted about twice that long and the Paleozoic about five to six times longer. An appreciation for the magnitude and duration of the events of the Cenozoic era—including the birth of numerous volcanoes, the vast mountain ranges, the occurrence of earthquakes marking the faults, the array of hills, plateaus, and plains, the evidence of the great ice ages, and the broad expanses of oceans—brings into sharper focus the scale of time against which the existence of humankind can be understood.

Richard A. Stephenson

See also Darwin, Charles; Dating Techniques; Geology; Gosse, Philip Henry; Hutton, James; Lyell, Charles; Moon, Age of; Pangea; Sun, Age of; Time, Planetary; Wegener, Alfred

Further Readings

Ausich, W. L., & Lane, N. G. (1999). *Life of the past* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Dunbar, C. O. (1955). *Historical geology.* New York: Wiley.

Mahony, D. J. (1943). The problem of antiquity of man in Australia. *Memoirs of the National Museum, Melbourne, 13,* 7.

Tarbuck, E. J., & Lutgens, F. K. (2008). *Earth* (9th ed.). Upper Saddle River, NJ: Prentice Hall.

Earth, Revolution of

Planets are continuously "falling" toward the sun due to the gravitational effect of solar mass and the constant centripetal force that allows planets to remain at a consistent distance from the sun. Earth, like every planet in our solar system, orbits the sun elliptically. German mathematician and astronomer Johannes Kepler, collaborating with Danish astronomer Tycho Brahe, first noted this trend in 1605, when together they plotted the orbit of Mars. At that time in history, the geocentric model of the universe was common belief, although their discovery led to its ultimate demise some 40 years later by Galileo Galilei. As Earth progresses in its orbit, there are climatologic impacts on the surface.

Revolutionary Characteristics

Earth's orbital plane is known as the ecliptic plane. It is also the same apparent motion of the sun across the terrestrial sky on any given day. It is taken as the point of perspective from which all other planetary orbital inclinations are derived. Its name is derived from the occurrence when the lunar orbital plane intersects at new and full phases, causing an eclipse. Based on the definition of celestial north, the ecliptic is used as a reference point, and therefore all solar system objects revolve around the sun counterclockwise.

Earth's orbital position affects its surface as a result of its proximity to the sun and its axial tilt, or

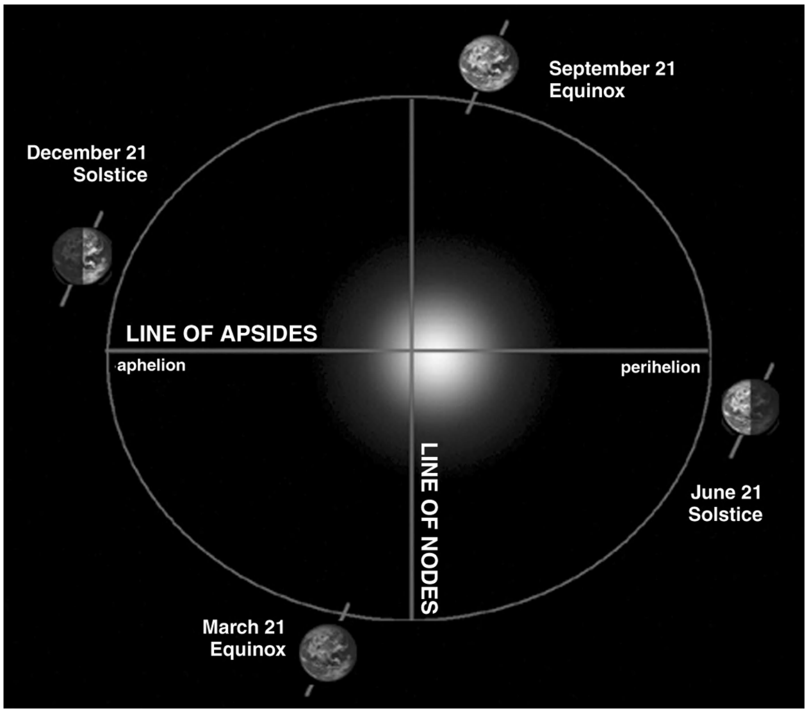


Figure 1 Generalized orbit of Earth around the sun

inclination. As a result, the sun is not at the true center of revolution but rather displaced from the elliptical center at a point called the focus. As part of his research, Kepler made this well known and discovered that orbiting objects in space exhibited predictable behavior. This research led in turn to Isaac Newton's discovery of modern physical laws.

Effects of Revolution

Climatologic effects on the surface of Earth are tied directly to its 23.5° axial tilt. Because the sun is not central, Earth then has points of closest and farthest distance from the focus, known as *perihelion* and *aphelion* (helio refers to the sun), respectively. Connecting one point to the other through the center of the ellipse yields a line of interest called the line of apsides. The line of apsides is the semi-major axis of any ellipse. Likewise, a similar line drawn across the semi-minor axis yields the line of nodes. The line of nodes is the point where the ecliptic and celestial equator intersect. These are the vernal and autumnal equinoxes.

Expectedly, Earth is most temperate at perihelion and, due to its angular inclination, the southern polar axis is pointed toward the sun during the southern hemisphere summer. Correspondingly, the northern polar axis slants away from the sun, so the northern hemisphere experiences winter. At aphelion, the seasonal reverse is true, and as a result, Earth's southern hemisphere tends to have warmer summers and colder winters than the northern hemisphere. At the nodes, Earth's axis is not a factor in climatology and a relatively equal temperature exists at the nodes (see Figure 1).

A common misconception is that because Earth is at its closest to the sun, a summer solstice is occurring for the warmer southern hemisphere. This is not necessarily the case. The points of perihelion (and aphelion) tend to precess over time because Earth's axis is subject to influence by other gravitational forces in our solar system, chiefly that of Jupiter. The net effect is that there is a cycle of where each solstice occurs.

Most planets tend to maintain their orbits and their order, except in the case of Pluto (which, as of August 2006, is technically no longer classified as a true planet by the International Astronomical Union). Every 228 years, Pluto falls inside the orbit of Neptune as it did between 1979 and 1999. However, each planet has differing distances across both the semi-minor and semi-major axes. The net effect of this event yields an eccentricity, or flattening, of the planetary orbit.

Timothy D. Collins

See also Copernicus, Nicolaus; Earth, Rotation of; Eclipses; Equinoxes; Galilei, Galileo; Leap Years; Planets; Seasons, Change of; Solstice; Time, Planetary

Further Readings

Danson, E. (2006). *Weighing the world.* New York: Oxford University Press.

Pumfrey, S. (2003). *Latitude and the magnetic earth.* Lanham, MD: Totem.

Earth, Rotation of

The rotation of the earth refers to the earth's spin around its own axis. The earth makes one complete rotation in 24 hours, during which the side of the planet facing away from the sun experiences night and the side facing the sun experiences day. The earth's axis of spin is inclined from the plane of its orbit, which causes seasons on the planet. The time required for one rotation has changed over history and is predicted to change in the future.

Characteristics of Rotation

Although Earth appears stable to humans, it is actually spinning rapidly. The velocity of a point on the equator is 465.1 meters per second, which is faster than the speed of sound at 335 meters per second. Objects stay on the earth's surface—despite the rapid rotation—because of gravity, a force that attracts objects toward the center of the planet.

The axis around which the earth rotates is not perpendicular to the plane of its orbit around the sun. It inclines from the perpendicular by 23.5 degrees, a geometric configuration that causes seasons on Earth. When the earth's axis points away from the sun, the northern hemisphere experiences winter because the sun's light hits the hemisphere at an angle. At the same time, the sun's rays are shining more directly at the southern hemisphere, which experiences summer. The seasons in the hemispheres reverse when the axis of rotation points toward the sun.

Astronomers have discovered that the position of the earth's axis is not constant over time. Every 14 months, the earth passes through a cycle known as the Chandler Wobble. A wobble, or precession, occurs when Earth's axis of spin oscillates around another axis; Earth resembles a spinning top that begins to slow down with its axis tracing a cone around a vertical axis. Scientists hypothesize that the 6-meter wobble is caused by changes in ocean currents or the atmosphere.

The Milankovitch cycles are patterns of rotation that occur over much longer periods. The axis inclination of the earth experiences a 41,000-year cycle, during which the axis moves from 21.5° of inclination to 24.5° and back again. Astronomer Milutin Milankovitch also identified a 21,000-year cycle during which the axis of spin wobbles and a 96,000-year cycle during which Earth's orbit becomes more and then less elliptical. Some astronomers hypothesize that the Milankovitch cycles caused the ice ages because when in conjunction, the cycles can vary sunlight reaching the northern hemisphere by as much as 20%.

Changes in Rate

Earth used to rotate more than twice as fast as it does in the 21st century. During the Archaean eon, 2,500 to 4,000 million years ago, the earth completed a rotation every 10 hours. One of the forces that slows Earth's rotation is the moon's gravity, which causes tidal activity. The friction of ocean tides actually acts as a brake on the rotation of Earth, causing the length of 1 day to increase by an average of 2.3 milliseconds per century. In the past 2,500 years, day length has increased by 42 milliseconds.

Erin M. O'Toole

See also Earth, Revolution of; Time, Planetary

Further Readings

Meissner, R. (2002). *The little book of planet Earth.* New York: Springer.

Redfern, M. (2003). *The earth: A very short introduction.* Oxford, UK: Oxford University Press.

Easter Island

See Rapa Nui (Easter Island)

Ecclesiastes, Book of

Ecclesiastes is the English designation for a book of the Old Testament, known in Hebrew as *Koheleth* (variously spelled). The canonical Hebrew Bible, or Old Testament—also part of the Christian Bible—is generally divided into three sections: the Law (or first five books, called the Torah); the Prophets; and the Writings. Ecclesiastes falls into the latter group and, along with Job and Proverbs, is considered wisdom literature, containing reflections on the meaning of life and righteous living. It is also described as poetic writing, characterized by parallelism and thematic refrains that repeat much like the rhythms of nature. In particular, Ecclesiastes compares the fleeting essence of human life with the everlasting nature of God and Earth. "One generation passeth away, and another generation cometh; but the earth abideth for ever" (1:4). Humankind is time-bound, but God is eternal. Ecclesiastes is traditionally read during the Jewish harvest festival of Sukkoth (Tabernacles) as a reminder of the transitory nature of life and an admonition against overreliance on material possessions. In this context, Ecclesiastes foreshadows a similar message of the New Testament warning against attachment to earthly matters, which pass with time.

Underscoring the ephemeral quality of life, the book begins, "Vanity of vanities, saith the Preacher . . . all is vanity" (1:2). The term *vanity,* translated from the Hebrew through the Greek, does not suggest the English understanding of self-absorption but variously the concepts of futility and meaninglessness, based literally on the Hebrew *hebel* (or *hevel*), meaning vapor, or mist. Life is, therefore, no more than a breath that forms quickly, evaporates, and is gone. The passage of time is an overriding theme: "To every thing there is a season, and a time to every purpose under the heaven" (3:1). There are no less than 45 direct references to "time" in the 12 chapters of Ecclesiastes and at least 6 admonitions to enjoy life in the present, not in the hedonistic sense but rather accepting both life and death as gifts from God. The present, then, takes on paramount significance, with the past forgotten and the future uncertain.

When the canon of the Hebrew Bible was defined at the Council of Jamnia (c. 90 CE), many Jewish scholars opposed the admission of *Koheleth* to the sacred, or inspired, collection of writings because of its pessimistic outlook; however, although not a book of praise, it ultimately affirms faith in God, God's Creation, and the Hebrew law. The English title of the book is derived from the Greek *ekklesia,* originally denoting a secular gathering. The term became associated with religious gatherings and then was exclusively applied in a religious context referring to "church" or church-related (ecclesiastical) matters. The Hebrew title *Koheleth* is also based on the Hebrew root meaning "to gather or assemble"; however, the English translation has come to be understood as "preacher," an honorific title referring to one who conducts or leads a religious assembly.

Some elements in the Jewish tradition hold the author to be King Solomon, who ruled Israel from approximately 970 to 928 BCE, as implied in the first line: "The words of the Preacher, the son of David, king of Jerusalem" (1:1). Tradition also attributes two additional Old Testament books to Solomon: the Book of Proverbs and Song of Songs. However, other scholars believe the opening of Ecclesiastes to be calling upon the credibility of Solomon's wisdom rather than identifying him as the writer and believe its style and language place authorship about 250 BCE in the post-Babylonian exile era, when most Jews lived under Greek rule and exercised no real political power. The skeptical tone of the book may also reflect the prevailing Greek philosophy and antipathy of the Greeks toward Judaism. Despite the author's viewpoint, he does not yield his faith in the face of adversity. The autobiographical first person is employed throughout from the perspective of a wise man who has lived fully and wishes to share his perspective on the purpose of existence. The maxims he advances are based on his own observation, but he is nonetheless cognizant of the limitations of human reason when he poses the question, "For who knows what is good for man in life, all the days of his vain life which he passes like a shadow?" (6:12).

Ecclesiastes comments on the futility of human accomplishments and the cyclical pattern of history over time: "What has been done will be done again; there is nothing new under the sun" (1:9). The narrator makes no reference to a hereafter, since the lives of both the righteous and the foolish end in death: "All go unto one place; all are of the dust, and all turn to dust again" (3:20), which echoes the words of Genesis (3:19). Similarly in the Book of Job, divine justice remains a mystery: "The race is not to the swift, nor the battle to the strong . . . but time and chance happenth to them all" (9:11). The meaning of life, then, must be found in the temporal sphere and living the brief interval of life to the fullest within the Hebrew law. Despite the seemingly hopeless tone of the book, the narrator affirms the existence of God and recognizes and encourages enjoyment and pleasure as divine gifts. "There is nothing better for a man, than that he should eat and drink, and that he should make his soul enjoy good in his labor. This also I saw, that it was from the hand of God" (2:24). The author cautions against pleasure becoming the goal of life, however, since he himself experienced wealth, luxury, and privilege but found them unfulfilling. While human endeavor appears futile, there is recognition of the value of life no matter how brief the interval: "For to him that is joined to all the living there is hope: for a living dog is better than a dead lion" (9:4–5).

In questioning the purpose of human life and endeavors, the author of Ecclesiastes expresses a practical ethic for the present, but without assurance of future justice. With the passage of time comes the inevitability of death: "For man also knoweth not his time: as the fishes, that are taken in an evil net, and as the birds that are caught in the snare; so are the sons of men snared in an evil time, when it falleth suddenly upon them" (9:12). This tone is in contrast to the more traditional books of the Old Testament, particularly the Torah, which place great importance on law and ritual as the guiding principles of a righteous life. But the universality and timelessness of the message of Ecclesiastes has made it an enduring source of allusion, especially in Western culture and literature. The acceptance of the cycle of life does not reinforce hopelessness but recognizes the balance in all things in observing that there is a time to weep and a time to laugh, a time for war and a time for peace. The inexorable passage of time and the cycles of life, death, and rebirth place a particular value on life for all its brevity and uncertainty. Life remains a mysterious gift to be enjoyed to the fullest but never completely understood. Accepting the infirmities of old age and his own imminent death, the narrator advises, "Rejoice . . . in the days of thy youth" (11:9), but to find fulfillment, "Let us hear the conclusion of the whole matter: Fear God, and keep his commandments: for this is the whole duty of man" (12:13). Only righteous living in the here and now, regardless of station in life, gives meaning to an otherwise unexplainable existence.

Linda Mohr Iwamoto

See also Apocalypse; Bible and Time; Christianity; End-Time, Beliefs in; Evil and Time; God and Time; Judaism; Parousia; Time, End of; Time, Sacred

Further Readings

Alter, R., & Kermode, F. (Eds.). (1987). *The literary guide to the Bible.* Cambridge, MA: Belknap Press.

Eaton, M. A. (1983). *Ecclesiastes: An introduction and commentary.* Leicester, UK: InterVarsity Press.

Sheppard, G. T. (1980). *Wisdom as a hermeneutical construct.* Berlin: de Gruyter.

Eckhart, Meister (c. 1260–c. 1327)

Dominican, philosopher, theologian, and mystic, Meister Eckhart was born outside of Erfurt, Germany, in Hochheim. His given name was Eckhart, yet became known as Meister Eckhart owing to an academic title he gained in Paris. Eckhart's ideas relate to a wide range of ideas and individuals, such as Immanuel Kant's critical idealism, the Eastern mystics, and pantheism. Eckhart's appeal is based mainly on his unorthodox understandings of how God works and interacts with creation; his unique view of time and God are foundational to this understanding.

Not much is known of Eckhart's early life. He entered a Dominican order in Erfurt and eventually attained the degree of master in Paris in 1302. He was evidently an exceptional preacher; some sermons are extant. He also gained fame as a teacher and author.

Later in life, Eckhart was accused of heresy. By 1309 Pope Clement V had decided to live in Avignon, France, and so Eckhart's heretical charge came to light during a contentious period within the Catholic Church. The Archbishop of Cologne wanted to try Eckhart in 1326, yet Eckhart appealed to Pope John XXII (who lived in Avignon). Eckhart affirmed his obedience to Catholic teaching in a letter dated February 13, 1327. He apparently died soon afterward because no further knowledge of his actions is recorded. John XXII issued a bull on March 27, 1329, in which he listed 28 heresies of Eckhart. The Dominican Order over time has attempted to reestablish Eckhart's Catholic orthodoxy. Although Pope John Paul II wrote favorably concerning Eckhart, the matter is still unresolved.

Eckhart's concept of time was counterintuitive to his milieu. From a medieval viewpoint, God worked within physical time and space. Yet Eckhart believed that time and space worked against a true understanding of God because it limited God to the physical world of time and space. He wrote, "For while the soul is occupied with time or place or any image of the kind, it cannot recognize God." Therefore, to Eckhart a true understanding of God must begin with God and not the Creation.

Eckhart believed in the importance of the union of the individual and God. Examples follow:

"Divine light enlightens me in everything I do." "Only God flows into all things, their very essences. . . . God is in the innermost part of each and every thing, only in its innermost part." "God . . . is the being of all beings." In each of these statements, Eckhart attempted to explain the mechanics of a union with God.

Since at least the time of John Climacus (d. 649), Christian mystics have attempted to explain how to grow in union with God; Eckhart attempted to explain how it worked.

Mark Nickens

See also Christianity; God and Time; Kant, Immanuel; Mysticism; Time, Sacred

Further Readings

Backhouse, H. (Ed.). (1993). *The best of Meister Eckhart.* New York: Crossroad.

McGinn, B. (2001). *The mystical thought of Meister Eckhart: The man from whom God hid nothing.* New York: Crossroad.

Eclipses

Eclipses are astronomical events during which light from the sun or reflected light from the moon is blocked from reaching the earth, causing temporary darkness. A solar eclipse occurs when the earth and the sun are in alignment with the moon positioned between them, and the moon casts its shadow on the earth. A lunar eclipse occurs when the moon and the sun are aligned with the earth positioned between them. In this case, the earth casts a shadow onto the moon. The timing of solar and lunar eclipses can be determined based on astronomers' knowledge of the orbits of the earth and the moon.

Periodicity of Eclipses

The earth completes an orbit of the sun in approximately 365 days, and the moon completes one orbit around the earth in 29.5 days. Both orbits are elliptical, but the moon's orbit is more elongated and the plane of its orbit is tipped by an angle of 5° from the plane of the earth's orbit. This configuration means that the moon is closer to Earth at some times during the year, and for most of the year, the moon is slightly above or below the sun as viewed from Earth. The nodes are the two points where the two orbits' planes intersect. Solar eclipses occur when the moon nears the node closest to the sun and comes into alignment between the sun and the earth. Lunar eclipses occur when the moon nears the node farthest from the sun, and Earth is aligned in between the sun and the moon.

Astronomers can predict eclipses forward and backward in time based on knowledge of the earth's and moon's orbits. In the 1880s the Viennese astronomer Theodor von Oppolzer calculated all of the eclipses that did and will occur between 1208 BCE and 2161 CE. Based on his calculations, solar eclipses occur 238 times per century and lunar eclipses are less frequent at 154 times per century. With current knowledge, astronomers have determined that the minimum number of eclipses per year is two solar eclipses, and the maximum number is seven eclipses with the ratio of solar to lunar eclipses being 5:2 or 4:3.

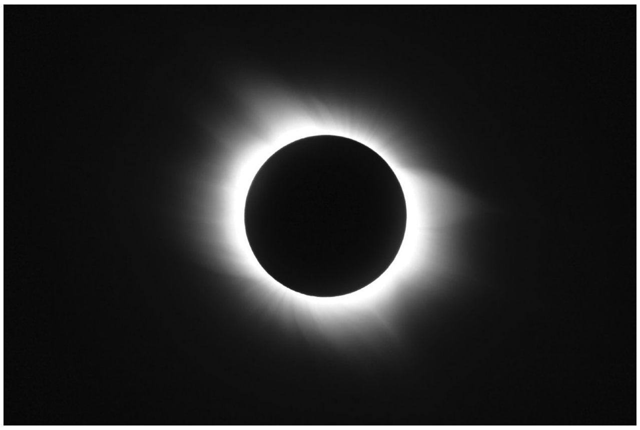
Another pattern in eclipse frequency is the *saros* series, which was first identified by the Babylonians. Any one solar eclipse has a specific geometric arrangement between the sun, the moon, and the earth, which determines its length and the location on Earth where it is visible. That precise arrangement repeats itself every 18 years and 11 1/3 days, meaning a solar eclipse of the same length results. However, the location is different because Earth has rotated for an additional 1/3 of a day. The eclipse will be at approximately the same latitude but will occur 120° west of where the solar eclipse did 18 years and 11 1/3 days earlier.

Solar Eclipses

There are three types of solar eclipses: total, partial, and annular. The first two depend on where an observer is in relation to the moon's shadow, and the last depends on the moon's distance from the sun. During an eclipse, the moon casts a total shadow, or umbra, over the earth in an area that is 60 to 100 miles in diameter. The penumbra, the area of partial shadow, encircles the umbra and has a much larger diameter of 4,000 to 4,500 miles. A person observes a total eclipse only when located within the umbra and when the moon is at one of its closest points to Earth. The moon appears to completely blot out the sun in this case, turning day to night. While the sun is about 400 times bigger in diameter than the moon, it is also 400 times farther from the earth than the moon; thus the perception is created that the sun and the moon are the same size. The frequency of total solar eclipses is one per 1.5 years, and the longest recorded period of total darkness is slightly more than 7 minutes. Although solar eclipses happen every year, a total eclipse can be observed in any one particular location on the northern hemisphere approximately only once every 330 years, and in the southern hemisphere only once every 540 years.

An observer sees a partial solar eclipse when located in the penumbra of the moon's shadow. The moon appears as a black disk moving over only part of the sun, so a partial solar eclipse does not have the dramatic darkness characteristic of a total eclipse. However, many more people can observe a partial eclipse because of the greater diameter of the penumbra. The frequency of partial solar eclipses is approximately 84 per century, or one partial eclipse per 1.2 years.

An annular eclipse occurs when the moon is aligned between the earth and sun and is approaching or leaving its apogee, the point in its orbit that is farthest from the earth. Then the moon appears to cover the sun only partially because it is closer to the much larger sun than it is during a total eclipse. When the moon and sun line up during an annular eclipse, the moon appears as a dark disk centered over the sun and ringed by its bright light.



Total solar eclipse, March 29, 2006. Eclipses occur when the sun, earth, and moon are in alignment. They are rare because the moon usually passes above or below the imaginary line connecting the earth and the sun.

Source: Petr Mašek/iStockphoto.

Lunar Eclipses

Lunar eclipses also can be total or partial depending on whether the moon passes through the earth's umbra or penumbra, respectively. The frequency of lunar eclipses is 1.5 eclipses per year. They are less frequent than solar eclipses at 2.4 per year because the moon is a smaller target for the earth's shadow to hit than vice versa. However, lunar eclipses have a longer duration than solar eclipses, lasting up to several hours, including total coverage of the moon for as long as 1.5 hours. This phenomenon occurs because the earth's shadow is much larger than the moon's, therefore it takes the moon longer to traverse the shadow than the earth does to cross the moon's shadow.

Erin M. O'Toole

See also Comets; Earth, Revolution of; Earth, Rotation of; Moon, Phases of

Further Readings

Dickinson, T. (2006). *NightWatch: A practical guide to viewing the universe.* Buffalo, NY: Firefly Books.

Golub, L., & Pasachoff, J. M. (2001). *Nearest star: The surprising science of our sun.* Cambridge, MA: Harvard University Press.

Steel, D. (2001). *Eclipse: The celestial phenomenon that changed the course of history.* Washington, DC: Joseph Henry Press.

Ecology

Ecology is a scientific discipline that focuses on the distribution and abundance of living organisms and how this distribution and abundance are affected by interactions between organisms and their environment. The term is derived from the Greek words *oikos,* meaning home, and *logos,* meaning study. Therefore, ecology might be described as the study of the home life of living organisms. The environment of an individual organism is composed of biotic factors, including other animals, plants, fungi, or microbes living in the same habitat, and abiotic (physical and chemical) factors, for example, local climatic or hydrologic conditions.

Ecology is commonly considered a branch of biology, but it might be better characterized as a multidisciplinary science. Because it also focuses on the interactions between organisms and their abiotic environment, many other scientific disciplines that help to explore environmental relationships contribute to ecological knowledge, like anthropology, chemistry, climatology, geography, geology, and physics.

Regarding distribution and abundance of living organisms, ecology deals with three levels: the individual organism; the population, consisting of individuals of the same species; and the community, comprising all populations living in the same habitat. Additionally, ecologists study the pathways followed by energy and matter through the interacting biotic and abiotic components that compose the so-called ecosystem and the relationships across multiple ecosystems. According to these levels of examination, the subdisciplines of ecology are commonly classified into autecology (also called species ecology), population ecology, synecology (also called community ecology), ecosystem ecology, and landscape ecology. Nevertheless, ecology can also be subdivided according to other categories. Different kinds of this scientific discipline can be defined, for example, by organism of interest (e.g., plant ecology), by habitat (e.g., urban ecology), or by application (e.g., conservation ecology).

Although ecology as a scientific discipline does not dictate what is right or wrong, the term *ecological* is also used as a synonym for environmental concern; because of this, it has acquired a positive connotation regarding moral judgments about human action in the nonhuman natural world. This meaning, tending to mix up results of scientific research and ethical values, emerged with the transformation of the ecological movement in the 1960s. For an exact distinction between ecology as a pure scientific discipline and the ideas and goals of the political movement of nature preservation, it is helpful to speak of ecology and environmentalism. Nevertheless, both try to see nature as a whole, and they continue to influence one another. Ecological knowledge provides a scientific basis for expressing and evaluating the aims of the environmental movement. Ecologists themselves also respond to the call of the environmental movement in directing much of their research to the environmental problems that have become increasingly pressing.

The concept of time is an increasingly important theme within the field of ecology, including both the science and the political movement. Both have their own history of development, which at some points are intertwined. Further, the history of ecology shows that for a long time, nature was thought of as being inherently balanced, wherefore it was largely ignored that history as one conception of time is applicable to the ecosphere. Such ideas were increasingly questioned after World War II, and nowadays it has become widely accepted that the natural world changes continually through time and that ecological and evolutionary processes affect each other. On this basis, the discipline of evolutionary ecology started to develop in the 1950s. But time does not only play a role in ecology in its historical sense: All organisms are embedded within the cyclical structure of the natural world. Ignoring the timescales of natural cyclical processes, like the flux of energy and matter through ecosystems, is thought to be a causal factor in the present environmental crisis.

History of Ecology

Ecology is generally spoken of as a new scientific discipline that has gained in importance in the second half of the 20th century and the beginning of the 21st. Nevertheless, prehistoric cultures probably passed down forms of ecological knowledge from generation to generation as a way of increasing their chances for survival. Information about the interactions between organisms and their environment was probably gathered from everyday experiences and closely intertwined with religious beliefs and myths.

The birth of modern natural sciences took place during the period of Greek antiquity. Presocratic philosophers (c. 600 BCE) went beyond myths in their attempt to explain nature. By studying phenomena of nature, they searched for the natural laws behind them and developed the first scientific theories. Later, Aristotle (384–322 BCE) developed biology to an independent scientific theme. Though ecological aspects can be found in his writings and in the writings of other philosophers and scientists of the ancient (e.g., Theophrastus, 371–287 BCE), medieval (e.g., Albertus Magnus, c. 1200–1280) and early modern (Carolus Linnaeus, 1707–1778) periods, the birth of ecology is generally dated to the year 1866. In this year, the German zoologist Ernst Haeckel (1834–1919) published his book *General Morphology* and with this the first definition of the term *ecology:* "By ecology we mean the body of knowledge concerning the total relations of the organism to its environment, to that we may reckon all conditions of existence. These are of both, organic and inorganic nature" Basically, the same definition is used today. Haeckel's definition was strongly influenced by the proto-ecological view the great naturalist Charles Darwin (1809–1882) provides in his 1859 book *On the Origin of Species* (1859). The theory unfolded here replaced the conception of the natural world as an enduring system with a conception of it as an open-ended historical process. Without using the word *ecology,* Darwin shows the ecological orientation of his thinking insofar as he refers to the impact of the inorganic and organic conditions of life on natural selection and therefore on the development of new species. The very fact that Haeckel's definition of ecology refers specifically to Darwin's theory of evolution indicates that time is an important factor in the study of ecology.

Haeckel did not elaborate the concept, and therefore the term *ecology* became an independent and established scientific discipline only after the publication of *Plantesamfund* in 1895 by the Danish botanist Eugen Warming (1841–1924). It is no surprise that this first significant textbook on the subject focuses exclusively the ecology of plants, because a second important strand in the development of ecology has been plant geography. Here ecological thinking can be recognized at least since Carolus Linnaeus published his writings, but the most important name in this context is Alexander von Humboldt (1769–1859), who explained the geographic distribution of plants with respect to geological data and went into the question of plant communities. For this reason, like Haeckel, he is called the father of ecology.

In the light of Darwin's theory of evolution and of plant geography, ecology developed into an independent scientific discipline in the second half of the 19th century. Around 1900, the first books were published under the headline ecology. Still, animal and plant ecology were explored separately in independent disciplines of zoology and botany, hindering a more synthetic understanding of their interdependence.

The first comprehensive works of ecology evolved within the field of hydrobiology—probably because a freshwater lake, for example, can easily be seen as a system. Therefore it is no surprise that the term *biocoenosis* (all interacting organisms living together in a specific habitat) was coined in 1887 by the German biologist Karl August Möbius (1825–1908). He was the first to describe in detail the interactions between the different organisms in the ecosystem of the oyster bank. In the same year, Stephen A. Forbes (1844–1930) published his paper "The Lake as a Microcosm." Two important ecological terms developed in response to Möbius. First, in 1908 the German zoologist Friedrich Dahl (1856–1929) introduced the term *biotope,* which means an area of uniform environmental conditions. Then, in 1935 the British botanist Arthur G. Transley (1871–1955) introduced the term *ecosystem,* which comprises "not only the organism-complex, but also the whole complex of physical factors forming what we call environment." Another important term not only in ecology but later on also within the theory of evolution, the *ecological niche,* was coined by the English animal ecologist Charles Elton (1900–1991) in 1927: "the 'niche' of an animal means its place in the biotic environment, its relations to food and enemies." The most important contribution to the development of a comprehensive ecology was made by the German biologist August Thienemann (1882–1960), who argued that autecology and synecology are just different steps of the ladder to ecological knowledge. Nevertheless, throughout the 1940s, 1950s, and 1960s, the debate continued regarding whether ecology is not more than autecology, or alternatively is not more than synecology. Intensive research under the title "ecosystem" began only in 1960, with the synthetic understanding of animal and plant ecology. It incorporated the advances from many scientific disciplines, such as pedology and climatology, but also statistics and informatics, expanding the options for ecological research by computer-aided modeling.

Already in the 1920s, some ecologists were aware of the fact that humans are a major ecological factor and advanced the view that ecology could help to solve environmental problems in the future. A conservationist movement also developed in the 20th century, parallel to ecology as a scientific discipline, inspired by such figures such as the American author and philosopher Henry David Thoreau (1817–1862). Thoreau argues in his 1854 book *Walden; or, Life in the Woods* that people should become intimately close with nature. Another American, the ecologist Aldo Leopold (1887–1948), claims in his famous and influential book *A Sand County Almanac* (1949) that humans should morally respect their natural environment. Nevertheless, environmental ideas reached public consciousness only after the 1960s, when the changes in the natural environment due to human influence began to be understood as the environmental crisis. At this time, the environmental movement was transformed, especially after the publication of Rachel Carson's (1907–1964) book *Silent Spring* in 1962. It emboldened a new generation of thinkers searching for an ethical basis for preserving the environment. This question has remained an issue within the philosophical subject of environmental ethics. The public desire for a better environment led to increasing financial support for ecological research, and the 1960s and 1970s were a period of rapid growth in both fundamental and applied ecology. Other indications of the developing public interest in ecology and environmentalism are, for example, the publication "Limits to Growth" (1972), commissioned by the Club of Rome; the research program "Man and Biosphere," which was launched by UNESCO in 1972; and the first international conference on the human environment, which was held by the United Nations in Stockholm in 1972. At the same time, in some countries political groups that are self-identified as ecological parties and environmental organizations, such as Greenpeace, were founded. The highly visible public support for the environmental movement declined during the 1980s, but recently it has been renewed by the concern over the effects of global warming. The increasing dangers of the greenhouse effect were recognized internationally at a conference in Kyoto in 1997.

In response to the interests of the environmental movement, the application of ecological thought to societal problems is one important direction in ecology today. This goes beyond the scope of ecology as a scientific discipline, but understanding human social behavior plays a role in some ecological research programs. To distinguish ecology as a pure scientific discipline from all other sciences that help to explore human environmental relationships, the term *environmental studies* is proposed. Nevertheless, the attention to scientific rigor is still an important direction in current ecology, in addition to a continued interest in interpreting ecological phenomena in terms of evolution.

Evolutionary Ecology

"Nothing in Biology Makes Sense Except in the Light of Evolution," the title of a 1973 essay by Theodosius G. Dobzhansky (1900–1975), applies to all disciplines of biology and therefore also to the study of ecology. However, whereas ecology is the field concerned with interactions between living organisms and their abiotic and biotic environments, evolutionary biology deals with the question of how populations change through time, split, and go extinct. So, how are ecology and evolution linked? Ecological and evolutionary processes affect each other. Interactions between organisms and their environment drive the evolution of populations by the pressure of natural selection, and this again leads to changes of the interactions and of the environmental processes themselves. Therefore, evolutionary and ecological biologists have a lot to say to each other, and the field where they meet is called evolutionary ecology.

Evolution, and therefore change though time, is one theme that tends to unite the different subdisciplines of ecology. Nevertheless, the use of the concept of evolution is not of equal intensity. Whereas it is strongly integrated into autecology, population ecology, and synecology, in ecosystem and landscape ecology the concept of evolution is a peripheral theme.

Balance of Nature, or Change Through Time?

The conception of ecological balance long precedes the development of ecology as a science. The ancient Greeks had ascribed balance to the natural world, whereas stability was thought rarely true for human societies. In most cases, this idea has its basis in the belief that this ordering is the work of a divine agency, but in some cases, the condition of equilibrium is described as an internal feature of nature itself. In Western cultures during the Middle Ages, the belief in divine order strengthened the belief in natural order and became a background assumption. Later, expressed in the metaphor of the great "chain of being," 17th-century rationalists continued to hold to the notion of a well-balanced nature but believed that laws accessible to human reason, and not a divine power, governed nature. Carolus Linnaeus assumed that harmonious relations between species according to the divine plan create order and stability; this he called the *economy of nature.* His hypothesis was later adopted by modern ecologists, who usually discuss the issue of balance of nature—using the term *ecological equilibrium*—in connection with segments of the natural world identified as communities or ecosystems. These terms indicate the existence of a certain structure ensuring order and stability. This seems surprising in light of Darwin's revolutionary theory of natural selection, which shows how the hereditary characteristics of a population change over time due to their differential reproduction arising out of their struggle for life. Though the emergence of a historical view on nature challenged the traditional belief of a divinely created world, even Darwin went along with Linnaeus's assumptions and considered equilibrium in nature. He wrote in *Origin of Species,* "Battle within battle must be continually recurring with varying success; and yet in the long-run the forces are so nicely balanced, that the face of the nature remains uniform for long periods of time, though assuredly the merest trifle would often give the victory to one organic being over another" The Scottish moral philosopher and pioneering political economist Adam Smith (1723–1790) contributed the idea that competition can lead to equilibrium in a community. From this point of view, Darwin's theory serves to explain the balance of nature and leaves intact the confidence that even in the evolution of life, order would prevail at last, and out of the tangled history of competitive struggle would come progress, harmony, and stability. The knowledge about periods of rapid changes within the course of evolution did not disturb the belief in the overall stability of the system, given that these are externally caused. Additionally, evolutionary change was sufficiently drawn out to leave the relatively stable world of ordinary experience intact.

In the 19th century, plant biologists began to focus on the roles of change and history of plant communities on smaller timescales. In 1899 the American botanist and ecological pioneer Henry Chandler Cowles (1869–1939) published a description of the patterns of vegetation change on sand dunes surrounding Lake Michigan. In his book *Vegetation of Sand Dunes of Lake Michigan,* he formalized the idea of dynamic vegetation succession. Nevertheless, his ideas did not lead to the notion that community change is an unceasing process. Influenced by Cowles's work and his own observations of prairie ecosystems, Frederic E. Clements (1874–1945) developed a comprehensive theory describing the mechanisms and patterns of successive change. This theory of succession, which was widely accepted by ecologists until the 1960s, hypothesizes an orderly sequence of changes in plant communities. One central assertion was that regardless of the types or varieties of disturbances that initiate successive change, succession inevitably leads to a single stable climax community whose composition is determined by the characteristics of the region's climate and has the potential to remain essentially unchanged forever. Though this theory postulates that plant communities change through time, it tends to support the conception of nature as balanced, because the changing occurs according to ascertainable laws and results in a steady state. Furthermore, it indicates that chance historical accidents and past disturbances in a community are erased by succession, whereas the composition of later successive ecosystems contains little or no information about their past history.

After the brothers Howard Odum (1924–2002) and Eugene Odum (1913–2002) developed and formalized the ecosystem theory in the 1950s, nature was conceived as an interlocking series of self-regulating and self-organizing hierarchically ordered ecosystems at various stages of development. Mature ecosystems—characterized by greater stability, increased diversity, and minimal loss of minerals and nutrition—were distinguished from immature ecosystems. Howard Odum even assumed a strategy of development in all ecosystems that is directed toward a world of mutualism and cooperation among organisms living in the same habitat. This goal, which is characterized by a no-growth economy, he called "homeostasis." His idea reappears in John Lovelock's (b. 1919) Gaia hypothesis, which proposes that biotic and abiotic parts of the earth form a complex interacting self-regulating system. This system can be viewed as a single organism promoting life, which Lovelock named after the Greek goddess of Earth.

Though reporters and even scientists persist in using words like *ecosystem, ecological equilibrium, balance,* and *fragility,* and many nonscientists still believe in the balance of nature, after World War II ecological thinking started to shift away from assumptions of order and stability. Until then, the few ecologists who were aware of the possibility of nonequilibria were ignored, but in the past several decades, a revolution has occurred in the worldview of ecologists. Soon after Clements published his influential works on plant succession, a few scientists challenged his theory of a stable climax. One of them was the American ecologist Henry A. Gleason (1882–1975), who worked largely within the theoretical structure of Clements's ideas, before he began to doubt his organic theory of the climax community. Gleason rejected the existence of balance, equilibrium, or steady state in nature and offered, as an alternative, "The Individualistic Concept of the Plant Association" (1926). In this article, Gleason argued that every plant association is nothing but a temporary gathering of strangers, a clustering of species unrelated to one another, and he advanced the view that we live in a world of constant change over time. Clements never responded in print to Gleason's objections and they were largely ignored elsewhere, but gradually some ecologists came to realize that the available data were not sufficient to support Clements's major assumptions. Research by a number of ecologists, for example, the American scientist Robert H. Whittaker (1920–1980) in 1953, supported Gleason's thoughts. In the 1950s, palynologists showed that the vegetation of North America has been in continual flux for at least the past 40,000 years, and the first serious contributions to the discipline that is now called evolutionary ecology were published. Increasing evidence suggests that succession may be governed more by external than by internal factors and that past events influence the properties of current ecosystems. Now it is generally recognized that natural disturbances are a normal part of most landscapes and that the evolution of a population or a species is not the necessary product of any natural laws but rather the outcome of a concatenation of chance events. In 1973 William Drury (1921–1992) and Ian Nisbet challenged not only Clement's but also Odum's theory seriously and rejected completely the assumption that there is a progressive development in nature and that organic nature tends toward order. Many ecologists will now admit that even the ecosystem concept is only a human construct. None of them ever succeeded in isolating one in nature. It is suggested that nature should be seen as a landscape of patches, a patchwork quilt of living things, changing continually through time and space, responding to an unceasing barrage of disturbances.

Scientists after World War II have been finding that contingency plays nearly as big a role in natural history as it does in human history, and instead of seeing a world in balance, most scientists nowadays see a world of flux and uncertainty and regard disturbances as the rule rather than the exception. This raises some questions: Why do the new ecological models seem more plausible to the scientific community than the former equilibrium models? And why do ecologists like Clements and Odum tend to dismiss disturbances as threats to the order of nature? Understanding these questions requires an understanding of how scientific concepts are culturally determined. One reason for the paradigmatic shift—besides empirical data that cast a scientific description of the natural order into doubt—could be the rapid political and cultural changes since World War II. Uncertainty today may seem more plausible than harmony. In addition, among ecologists, Social Darwinists are back on the scene generating new directions for ecology. For them a nature characterized by individualistic associations, unceasing disturbances, and permanent changes may be more ideologically satisfying. A third reason for post-Odum ecology could be the attempt of many ecologists to disassociate themselves from the environmental movement and some branches of environmental ethics, whose supporters still cling to the notion of natural balance as a last bastion of certainty, as a major argument for nature conservation, and as one last source of metaphysical absolutes.

The truth probably lies somewhere in between. Nature works in more than two modes, balanced and unbalanced, and some ecological systems persist in spite of centuries of disturbances—eluding ecologists' models and understanding. One important insight of modern ecology is that landscape patches have different levels of resilience to disturbances. Resilience relying on ecological relationships does not mean the absence of change, for it is defined as the ability to undergo change and then return to a similar but not exact configuration. If ecological relations are broken beyond a certain threshold by a major disturbance, the system may lose resiliency and form a new community. Finally, it has to be stressed that scientific attempts to answer whether nature is balanced or dynamic depend on the selected perspective and the scale of an analysis.

Temporalities of Nature and Culture

The passage of time is a basic experience of human existence; as such, it has been of concern to those interested in religion, philosophy, and science. As discussed previously, however, temporal aspects of the natural world had long been ignored while the focus of attention was on the role of time in human societies. Within the 20th century, the idea that history is not only a feature of human societies but also of the natural world became widely accepted.

Biological processes of change fundamentally entail cyclicalities, such as metabolic cycles, metamorphic processes, and life cycles. They range from the very fast to the very slow. Empirical studies of chronobiologists demonstrate the cyclical behavior of all living organisms, from single cells to mammals, including humans, and with this the importance of this temporal patterning of life. The varied cycles of the body's physiological activities, such as respiration, digestion, or activity–rest cycles, are orchestrated into a coherent whole and function as biological clocks. However, as Barbara Adam (b. 1945) declared in 1990, this "body symphony" of internal time programs is not played in isolation. It is—because of evolution according to the direction of the pressure of natural selection—embedded in the cycles of its environment. It exists as a kaleidoscope of different but connected timescales, constituted by the movement of the earth and its moon in relation to the sun. Therefore, it is the cyclical structure of the physical world that constitutes the cycles of organisms, populations, and ecological relationships. It appears, for example, in the form of circadian, lunar, or seasonal cycles.

The cyclical structure of nature seems to support the notion of an ahistorical natural world, but—contrary to the rhythm of a metronomic beat—cyclical does not mean invariant repetition. Rather it is in the very nature of those cyclical processes to differ in their recurrence. Something similar returns, instead of something identical, based on context-dependent adaptations. It is suggested that this openness of natural cyclic processes to variant repetition allows the evolution of the ecosphere. According to Barbara Adam, precisely these cycles of change, whereby past, present, and future can be experienced by humans, constitute time.

As with all organisms, human life is also ordered and regulated by internal biological clocks and external natural cycles. However, since the invention of mechanical clocks and notably since the use of electricity for industrial applications, social time has become more and more disconnected from the ecological choreography of planet Earth. This cultural decoupling from the cycles of nature in contemporary industrial societies, according to the time-is-money-principle based in the speeding up of social life and economic processes, is supposed to be associated with the current environmental crisis. Nowadays human action is structured not by the cycles of nature but by the context-independent and invariant metronomic beat. The 24-hour schedule of the machine dominates not only the temporal patterns of industrial work but also agricultural food production. One striking example is the acceleration of evolutionary processes by means of genetic engineering of plants.

Facilitated by the exploitation of nonrenewable resources such as fossil fuels, the speedup of production and consumption does not only affect human health but also has potent ecological implications, for it results in an increase of energy use and material flows. The industrial way of life and its approaches to time stand in conflict with the cycles of the natural environment, because renewable resources are used at rates incompatible with the rates of regeneration. One example is the degradation of soils, caused by erosion, salting, compaction, pollution, acidification, and sealing. Because soil takes thousands of years to develop, the recent human action on soils—literally the basement of life on Earth—converts this renewable resource to a nonrenewable one.

Additionally, the vast production of often toxic chemicals results in environmental pollution when those substances introduced into nature cannot be readily decomposed. The process of global warming is an example currently being debated. This process, also called the greenhouse effect, is thought to be the outcome of an increased concentration of carbon dioxide in the atmosphere, based on combustion of fossil fuels associated with accelerated industrial activity and other human activities, like tropical deforestation. Nitrous oxide is another gas that absorbs infrared radiation and, therefore, also contributes to global warming as human activity increases its concentration in the atmosphere. To date, humans have roughly doubled the input rate of fixed nitrogen into the ecosphere by combusting fossil fuels, planting nitrogen-fixing crops, clearing land, draining wetlands, and producing fertilizers. This not only has severe implications for the atmosphere. Nitric oxide is a principal cause of acid rain, which results in declines in soil fertility and acidification of freshwater lakes and streams. Nitrogen washed into aquatic systems has caused blooms of toxic algae and die-offs of fish associated with eutrophication.

These few examples indicate how economical timescales endanger ecological timescales. There are further consequences for ecological relationships. If the environment changes slowly enough, populations can ride with the tide of change by, for example, adapting via evolution or by migration. However, if the anthropogenic environmental changes exceed the maximal speed of adaptation, severe disturbances will follow. Ecological relations may be broken to the point that resilience of systems is lost and adaptation of the ecological processes to the new situation is no longer possible. Therefore, fast changes may destroy communities in a flash. This already takes place, as we have observed in the mass extinctions of species.

The environmental movement reacts to this acceleration of social life with its claim to conserve imperiled species and places. But this goal of conservation—though comprehensible given the fast anthropogenic changes of the natural world—may ignore the dynamic structure of nature as well as the industrial way of life. Environmental changes are the norm and occur across all timescales. Even natural catastrophic changes, such as triggered by volcanic eruptions or asteroid strikes, are able to destroy human resiliency. Nevertheless, the anthropogenic disturbances seem to be of a new quality and quantity. This raises an important question: What rate, quantity, and quality of change can be accepted? This is not an ecological but rather an ethical question.

To systematically recognize and establish the relevance of the temporal dimension of cultural time for the so-called ecological crisis, the Time Ecology Project was initiated 1991 at the Protestant Academy of Tutzing in Germany. One member, Barbara Adam, is the author of numerous publications on cultural and natural time and the founding editor of the journal *Time and Society.* In her monographs on time, she charts the importance of recognizing the multiple time frameworks of nature for our daily lives. The field of *time ecology* focuses on the mutual implications of time and ecology as one step toward ameliorative action with respect to environmental matters. In search of a time politics that shifts concern from the pursuit of total time control to the appreciation of the cyclical structure of nature, proponents of time ecology search for approaches to time that are sensitive to the temporalities of the environment. Human intervention into a natural system should allow a development of this system in its own timescale. Therefore, it calls for a balanced relationship between human technological interventions and environmental processes; it seeks a balance between the human timescale of consumption and resource depletion on the one hand and the environment's capacity for regeneration and reproduction on the other. This shift in human attitude toward nature, associated with awareness of the ecological significance of time, is a step toward achieving sustainable development, minimizing environmental degradation, and halting or reversing the process of exhausting natural capital faster than it can be replenished.

The Concept of Time in the Field of Ecology

In summary, the history of ecology as a scientific discipline shows that from its beginning, the concept of time played a central role. Early ecological thinking was especially influenced, for example, by Darwin's theory of evolution and his protoecological view. Nevertheless, for a long time most scientists ignored that history as one conception of time is not only applicable to human societies, but also to the ecosphere. They clung to the notion that nature is inherently balanced. It was thought that ecological communities have the potential to remain essentially unchanged forever and that serious changes occur only because of external disturbances. Even then, if climatic conditions persisted, a succession would lead inevitably to the former climax community. In this way, chance accidents of historical events were thought to be erased. Such ideas were increasingly questioned after World War II. Within the scientific community more recently, it has become widely accepted that the natural world changes continually through time and that evolutionary and ecological processes affect each other. On this basis, the discipline of evolutionary ecology developed.

Time plays a role in ecology in more than a historical sense as well. The evolution of the ecosphere is influenced by the cyclical structure of the natural world. Time-consuming cyclical processes, like the flux of energy and matter through ecosystems, exist as different but connected timescales. All organisms, including humans, are embedded within these cycles. Nevertheless, after the Industrial Revolution an increasing decoupling of social time from the cycles of the natural world can be observed. Ignoring the ecological timescales in favor of economic timescales is thought to be one important reason for the environmental crisis. The claim of the environmental movement to conserve imperiled species and places is a reaction to the fast anthropogenic changes of the ecosphere. Nevertheless, environmental changes are the norm and occur across all timescales. The extent of acceptable anthropogenic changes is an increasingly pressing question—not only for ecological scientists but also for environmental ethicists.

Sabine Odparlik

See also Darwin, Charles; Erosion; Evolution, Organic; Global Warming; Haeckel, Ernst

Further Readings

Adam, B. (1998). *Timescapes of modernity: The environment and invisible hazards.* London: Routledge.

Begon, M., Townsend, C. R., & Harper, J. L. (2006). *Ecology: From individuals to ecosystems* (4th ed.). Oxford, UK: Blackwell.

Dodson, S. I., Allen, F. H., Carpenter, S. R., Elliot, K., Ives, A. R., Jeanne, R. L., et al. (Eds.). (1999). *Readings in ecology.* Oxford, UK: Oxford University Press.

Hugget, R. J. (1997). *Environmental change: The evolving ecosphere.* London: Routledge.

Mayhew, P. (2006). *Discovering evolutionary ecology: Bringing together ecology and evolution.* Oxford, UK: Oxford University Press.

Economics

The term *economics* is derived from the Greek words *oikos* (house) and *nomia* (law). In ancient Greece, it was used to describe the management of the household. Today, the word is used in a much broader sense and describes the complex interactions of economic systems, including the production and exchange of goods and services. Economic evolution through time represents the different transitions from a subsistence economy, where people tried to satisfy only their basic needs, to today's highly industrialized and globalized economy. The evolution of economics as a social science attempts to describe the most influential persons, concepts, and theories in order to give some fundamental answers to the basic question: Why did it happen? Economic evolution, from prehistoric roots to the modern world, has been a multilinear process. However, complex developments may be broken down to several main milestones in human economic history. The starting point is the prehistoric developments that began the step-by-step economization of human life.

Prehistoric Developments

About 1.6 million years ago, the emergence of *Homo erectus,* a predecessor of the modern human, can be considered as the initial point for prehistoric economic development. *Homo erectus* was the first human who was able to use fire, which changed the life of prehistoric humans in a tremendous way: Apart from offering a better and a new method of hunting animals, fire also allowed for cooking meat. This then resulted in better nutrition because it made meat easier to chew and to digest. In addition to the use of fire, the creation of different tools made of stone and wood was an important characteristic of *Homo erectus* life. This reflected the ability to adapt to different needs and to the changing climate conditions of the Ice Age. Because they were foragers, their economic life consisted of hunting wild animals and gathering wild fruits and roots for only their own needs (subsistence economy). At this stage, there was no private property, and mobility was the key to consistently supplying the members of the community with food. It can be assumed that the foragers were already able to develop hunting strategies, which were realized in small groups of about 30 people. Tasks like observing, hunting, and carving could then be allocated among the different group members; this can be considered as an early form of the division of labor. Another advantage of organization in small groups was the possibility of hunting bigger animals to gain more meat with less effort. Hence, foragers already had to be efficient, productive, and innovative to survive.

The First Agricultural Revolution

From about 15,000 BCE to 10,000 BCE another economic transition took place: Specialized economic forms emerged in different geographic areas as a response to the various climate conditions marking the precondition for the development of early civilizations. Tools and weapons became more sophisticated, making hunting easier and more efficient, for example, with the use of bows and arrows, lances, or other long-distance weapons. Moreover, the foragers started cultivating plants or domesticating animals, and overproduction was stored. Hence, the economy changed slowly but consistently from subsistence to bartering and from a possessive to a productive economy. The improvements in food production led to higher population densities and to a change from nomadic to a more sedentary life. As a result, humans were no longer restricted solely to the locally given resources of nature but also created the environment themselves. Fostered by temperate climatic conditions about 8,000 years ago, fertile soil was created, and agriculture became the dominant economic form. Additionally, grazing land and water promoted the development of a high population density, which was the starting point of early civilizations. Food production was no longer driven by coincidence but by the cultivation of plants and the domestication of animals. The advantages of having a meat supply are obvious. Besides meat, other products could be gained, like wool, skins, and bones. However, agriculture was a seasonal activity, and the increasing demand for food due to the growing population resulted in strategies to stabilize the food supply. This resulted in new types of storage, transportation, and the development of lasting agricultural techniques. Consequently, the exchange of goods (e.g., nutrition, tools, and raw materials) was no longer limited to the immediate vicinity; the first interregional trade routes can be determined by archaeological findings. One example is the Fire Stone Route between Bohemia and Bavaria, dated about 7,000 years ago with a distance of 250 kilometers. However, these trade connections were, for the time being, of small importance. The revolutionary steps were to take place in agriculture.

The invention of irrigation systems and the plow, about 6000–5000 BCE in Mesopotamia and Egypt, can be seen as the First Agricultural Revolution (sometimes still called the Neolithic Revolution, even though it had been neither neolithic nor a revolution in the view of many prehistorians). The farmers were now able to dig up the soil, and the use of axes enabled them to clear the fields of wild plants and brushwood, which increased the efficiency of agricultural production. New technologies of storage were invented, like grain bins or jars, that allowed the people to retain the surplus of a harvest for lean times or to trade it against other goods and services. Pottery also played an important role for storage, plates, mugs, cooking tools, and art. Pottery was produced as early as 8000 BCE, but the invention of a fast rotating potter's wheel about 4000 BCE made pottery products one of the earliest mass products. Another innovation was animal domestication. Even though it is not quite clear how the domestication of animals began, the domestication of wolves to dogs, of wild to domestic goats and sheep, of aurochs to cows, and wild cats to domestic cats can be estimated to have occurred about 10,000 to 7000 BCE. A few millennia later, about 4000 BCE, horses and donkeys were domesticated. Not only were domesticated animals used for meat, wool, or milk supply, but they also played an important part in specialized tasks, such as plowing or transporting. As a result, agriculture and animal production became an important driver for the emergence of chiefdoms and the world's first states. Building permanent houses instead of using temporary camps as in of earlier times, resulted in stronger social links among the villagers, enhancing the development of human social complexity. Reciprocity and kinship ties became more important in agricultural societies, as it was no longer possible to move away in cases of social disputes. Additionally, the reciprocal networks of a clan's members helped them to survive in cases of crop failures or other emergencies, knowing that they would get assistance in turn if they would need it one day. The farming societies relied also on trade and exchange, as many commodities were not locally available.

Thus people who controlled the exchange networks were able to gain power and to become chiefs of the interconnected village societies. Whereas early forms of farming societies have been egalitarian without a social hierarchy, the new and more complex societies were under the control of the chief and his family, creating an elite. Inequality, with usually two or sometimes even three tiers of hierarchy, became common for these prestate societies. However, chiefdoms were a relatively unstable form of social organization, as leadership did not necessarily pass from one generation to another. Consequently, it was often a system of collapse and renewal. Chiefdom societies (e.g., Thy in Denmark/Northern Europe about 2300 BCE) emerged almost everywhere in the world, but none of them was able to gain control over more than a local or regional area. Thus state-organized societies must have had some institutional advantages, being economically superior to chiefdoms over time.

The Urban Revolution

Another technological breakthrough was the invention of metallurgy (e.g., copper, bronze, and iron) in approximately 4500 to 3000 BCE, making possible the invention of a wide range of new, improved tools, thus enhancing efficiency even further. New professions, such as craftsmen, arose, and the division of labor advanced. However, the new exotic raw materials were not accessible everywhere; this resulted in an intensification of long-distance trade. All this was the fruitful environment of what is sometimes called the Urban Revolution. The increasing complexity and the growing interactions would have required a certain form of organization to be efficient. This resulted in the formation of cities and, later, state-organized societies.

The first cities and state-organized societies came into existence between 4000 and 3000 BCE in Egypt and southern Mesopotamia, which is commonly referred to as the origin of civilization and was later the home of the Sumerians. Characteristic of civilized societies are literature, religion, and monumental structures (e.g., the pyramids). Being central in their respective regions, a city had the task of providing services to its citizens and to the surrounding area, being itself dependent on the food production of the rural area. Centralized institutions were necessary to organize the different needs, such as infrastructure or security. Whatever the complex factors that led to state-organized societies, they changed the way of life in a tremendous way. Development was not limited to new inventions such as complex irrigation systems, the wheel, or transportation by water, but led to institutional changes like state religion, taxation, and legislation. People such as priests, state executives, and soldiers could be taken out of the production process to serve society. Capital could be accumulated, which could then be spent for monumental architecture, for military purposes, or for the infrastructure. States therefore played an important role in the new economies. They purchased goods and services with tax revenues, employed people, and regulated commerce.

Additionally, pictography as a form of script was first used in Mesopotamia and was the basis for the cuneiform writing developed later by the Sumerians. Writing was another cornerstone in the economy, as it allowed formal record keeping and advances toward science and mathematics. Thus class societies evolved with some people forming the elite, accompanied by an increasing demand for luxury goods, which were often exchanged by long-distance trade (e.g., gemstones sourced by the Sumerians from the Indus Valley civilization). A famous ancient trade route was the European Amber Route, which led from Northern Europe to Italy. As important as these trade connections were for increasing wealth and enhancing economic growth, the instability in terms of the rise and fall of ancient states and cities resulted in unstable trade connections, both in domestic markets and in foreign trade.

Despite the remarkable progress made by these early civilizations, the subsequent era of classical antiquity, with its unique features, nevertheless represents a major shift toward civilization and has been most influential for the evolution of the Western world.

Economy of Classical Antiquity

The beginning of ancient Greek and Rome society, about 800 BCE up to the fall of the Roman Empire in 476 CE, marked the era of classical antiquity. Between 750 and 500 BCE the Greek states Sparta, Corinth, and Athens were on the rise, and democracy as a new form of state organization came into being. Even though democracy played only a rudimentary role in ancient Rome, the Roman Empire is known for establishing a code of law as the basis for a legal system and—when further developed—a constitutional state. Democracy and a trustworthy legal system are the foundations of modern civilization and economic growth, as they guarantee political, legal, and economic stability. Additionally, the first coin in ancient Europe was embossed about 650 BCE in Lydia (China had been using coin money since 2000 BCE). Earlier, noncoined forms of money of various kinds, like shell money, salt, or crops, were used to pay for goods and services. The advantages of exchanging goods for money instead of other goods include easy countability, less transportation, and suitability for storage. As a result, money facilitates transactions in the economy and is therefore a driver of economic development.

Philosophy evolved in ancient Greece, with Socrates, Plato, and Aristotle as its most famous exponents. Philosophers reflect human thinking and behavior with the aim to explain why the world and human beings exist. The theories of the ancient philosophers therefore built the basis for the worldview of the occident so that they developed even up to now. But, philosophy can also be seen as the earliest predecessor of economics as a social science. Aristotle, for example, gave economics its name (*oikonomia*). In his view, economics has the task to ensure the survival or subsistence of human beings. Thus it has only an assisting function for the well-being of a society. Besides expounding the importance of economics for a society as a whole, Aristotle also developed a monetary theory. Money, he recognized, can be used as a medium of exchange, as a measure of the value of a certain good, and as a measure for the intensity of wants and needs. According to his theory, money also has an intertemporal function, as it is possible to save it for future investments. It allows for the taking out of loans, which means that people can satisfy their needs now and pay for them later. Last but not least, Aristotle attributed a social function to money in the sense that without trade money, neither barter nor community is imaginable. Aristotle's seminal work on justice is likewise notably for economics. He was one of the first to develop a comprehensive theory of justice. His concepts of distributive justice (in Latin, *iustitia distributiva*) and commutative justice (*iustitia commutativa*) continue to influence social thinking. He realized that economic growth and fair distribution are the cornerstones of social living, thus linking economics and morality.

In classical antiquity, highly differentiated empires emerged in Greece, Rome, and China and were associated with an intensified intercontinental long-distance trade. The Silk Road, for example, an 8,000-kilometer ancient trade route on land and sea between China and the Mediterranean, shows that various goods like spices, gold, gemstones, ivory, glass, porcelain, and—where the name comes from—silk were traded bidirectionally. Not only were goods exchanged but also aspects of culture, religion, and information. Silk was nevertheless the most demanded luxury good by the Roman elite. However, safety was a crucial issue in ancient times, as pirates held up the caravans. Despite harsh conditions concerning safety, climate, and geographic barriers, the Silk Road was an important achievement of the ancient world, especially in terms of economic growth for the connected states, and it can be seen as an early form of globalization.

Besides, the early Romans recognized the benefits resulting from a good infrastructure. The construction of roads helped link together the far-reaching provinces of the growing empire, which accelerated the flow of information and supplies and facilitated the relocation of troops.

From the Middle Ages to the Scientific Revolution

After the fall of the Roman Empire, political and economic instability were the dominant features of the early Middle Ages. Those people who lived in a city for a certain period lost their status as serfs and were released from doing compulsory labor. Searching for liberty, many people migrated into the cities, fleeing from their lords and seeking better working conditions in the 13th and 14th centuries. In return, cities had to organize their markets and ensure safety. However, the intensified creation of marketplaces, which brought together supply and demand for goods, had helped boost trade connections among the medieval cities. The right to hold markets ("market rights") was usually restricted to cities with town status, that is, cities with certain privileges. Both market rights and privileges boosted the attraction of cities as working and living environments. Because of the growth of cities, the increasing demand for goods had to be satisfied. Thus certain occupation groups, like craftspersons and salespersons, syndicated into guilds. Guilds limited the access to their professions, as professionalism depended on the membership of the appropriate guildsman. As a consequence, guilds were able to restrict competition and keep prices high, which contradicts the economic concept of free markets. Accordingly, guilds succeeded in building power as they participated in municipal councils, which were responsible for trade legislation or regulation. In some areas the economic and political power of the guilds was used to create monopolies or even to take over the control of some cities. Famous examples are the Hanseatic League or the Fugger dynasty; both were able to dominate the commerce in northern Europe from the 13th to the 17th centuries. During that time, the city-states in northern Italy, like Venice, Florence, and Genoa, became the center of economic power in Europe. Their seaports were important trade connections between the Occident and the Orient, and to Africa, so that they could act as intermediary traders. Venice, for example, established a power monopoly with salt, which was a highly demanded good, as it was used for conserving meat and fish. While wealth and capital accumulation increased dramatically, the need for banks as an intermediary was also growing. Thus the foundations of a modern banking system with bookkeeping, cashless transactions, and new institutional structures were set in northern Italy in the late Middle Ages.

The era of transition from the Middle Ages to modern times is generally called the Renaissance, which took place between late 14th century and the 16th century, depending on the country. Art and education flourished as rich patrons supported artists like Rafael, Leonardo da Vinci, and Michelangelo Buonorroti. It was now feasible to draw more natural images and to paint more realistic copies of reality. Humanism became the leading idea of the Renaissance, driven by the thought that each human being is responsible for his or her own fate. Additionally, in 1450, the invention of movable-type book printing by Johannes Gutenberg is also considered one of the preconditions for the transition to modern times. It now became possible to print large numbers of books, thus driving the acceleration of knowledge transfer in Europe. Simultaneously, huge efforts were made to discover new land and resources by sea, driven by increasing imperialism. In 1492 the explorer Christopher Columbus discovered the New World (in fact, the Vikings landed on American ground around 1000 CE, and there is some evidence that 12,000 years ago Asiatic clans migrated over the Bering Strait and all the way to South America). However, all these events took place in the 15th and 16th centuries, which is sometimes called the Commercial Revolution.

Seeking economic expansion, European states tried to found colonies throughout the world and to link them together for international trade networks. Some historians argue that globalization, a concept used today to describe intensified international cross-links, can be attributed to developments in the 15th century. The discovery of the sea route to India by Portuguese explorers is another example of expanding international trade. Spices like pepper, cloves, and cinnamon, which were unavailable in Europe but of high value not only for flavoring food but also for medication or for conservation of food, were conveyed directly through the new sea route. From an economic point of view, the sea route broke the Venetian monopoly as an intermediary, which then resulted in lower prices. Demand and supply increased, enhancing economic growth. Lisbon and Antwerp were especially able to benefit from the new sea routes, establishing them as the new financial and commercial centers of Europe. Consequently, the first stock exchange was established in Antwerp in 1531. Later, Amsterdam became the new economic power and financial center until the Industrial Revolution.

Besides trade, important advances took place in the field of science around 1600, which is now referred to as the Scientific Revolution. The prevailing theories about physics and astronomy were revised, supported by inventions like the microscope and the telescope.

All of the previously mentioned developments were results of the so-called preindustrialized civilization, as they are based mainly on manual labor rather than the use of industrial techniques run by fossil fuels. The Second Agricultural Revolution prepared the ground for a drastic change in production techniques, which is known as the Industrial Revolution.

Second Agricultural Revolution

Not until centuries later did advances in agricultural techniques in Britain prepare the ground for the modern world. Taking place in the 18th century and also referred to as the British Agricultural Revolution, a series of developments resulted in an enormous increase in agricultural productivity. The selective breeding of livestock, enclosure (i.e., the conversion of common land to private ownership), and new farming systems such as crop rotation instead of the three-field system (e.g., wheat and barley in two, with the third fallow) and the cultivation of higher-yielding crops boosted the output of food. Furthermore, in 1840, the invention of mineral fertilizer by the German chemist Justus von Liebig also enhanced agricultural productivity. Thus the food surplus was now remarkably sustainable and able to keep pace with the expanding population, contradicting the influential views on population growth by the British economist Thomas Robert Malthus. In his "Essay on the Principle of Population" (1798), Malthus developed the theory that population increases at a geometric rate (1, 2, 4, 8, 16, etc.), whereas the food supply grows only via an arithmetic sequence (1, 2, 3, 4, 5, etc.). Hence, population growth, if uncontrolled, will unnecessarily lead to famine. However, Malthus failed to recognize the human ability for substantial technological advances, which took place as described earlier. As food output rose, fewer workers were needed for agricultural production, making them now available for industry.

Industrial Revolution

Technological improvements in agriculture enhanced industrialization and vice versa. This transition from an agricultural to an industrial society is also known as the Industrial Revolution, which had its starting point in Britain in the late 18th and early 19th centuries. Even though the complex factors that caused the Industrial Revolution are still a topic of debate, it can be assumed that changes in the social and political system were also helpful for the emergence of the industrial economy. The end of feudalism; colonial expansion; advances in medicine, accompanied by lower infant mortality and fewer epidemics; and local resources of coal, iron, and copper all resulted in excellent conditions for the development and expansion of the industrial sector. Thus Britain could be considered a relatively open society, allowing for the formation of a large middle-class society with the opportunity of social advancements. Entrepreneurship and the willingness to invest were high as capital accumulation rose. Additionally, a Protestant work ethic (or Puritan work ethic) influenced by Calvinism emphasized the necessity of an ascetic lifestyle. Economic success and the accumulation of wealth were seen as signs of personal salvation. The theoretical framework for the Protestant work ethic was later developed by the German sociologist and economist Max Weber (1864–1920). Liberalism became the dominant principle for the economic order, influenced by the seminal work of the Scottish moral philosopher Adam Smith (1723–1790). His influential treatise "An Inquiry Into the Nature and Causes of the Wealth of Nations" (1779) is commonly referred to as the rationale for capitalism and as a precursor to the academic discipline of economics, also called political economy. According to Smith, free trade and free markets will, in time, lead to the most efficient outcome in the sense that the right amount of various goods will be produced. There seems to be an "invisible hand" that brings together supply and demand, keeping prices low and therefore maximizing society's welfare. The economic concept of capitalism requires the private ownership of resources (i.e., labor, capital, land), assuming that everybody strives for profit maximization. Then, the allocation and distribution of goods is accomplished efficiently only by the market itself. Smith was opposed to guilds and government interventions (e.g., tariffs), even though he believed the state must play an important role by setting the legal and political frameworks for free markets and by providing goods, like public education or an army.

The complex interactions of geographical, economic, political, and social structures provided a fruitful base for the British Industrial Revolution. Here, it started with the mechanization of textile industries, especially the processing of cotton. In 1733 the clock maker John Kay (1704–1780) invented the flying shuttle, which carried the weft yarn mechanically from one side to the other with more speed and higher accuracy than it was previously done by hand. Hence, the speed of weaving accelerated and worker productivity more than doubled. As a result, the production of yarn posed a bottleneck problem, as it could not keep pace with the accelerated speed of weaving. New spinning machines were therefore necessary to solve this problem. First, James Hargreaves with his hand-operated spinning jenny (1764) and later Richard Arkwright with his water frame (1771)—a water-powered spinning machine—revolutionized the fabrication of cotton yarn. But it was Samuel Crompton who achieved a breakthrough in industrial yarn production by inventing the spinning mule in 1774—a combination of the spinning jenny and the water frame. These inventions marked the beginning of industrial mass production. Instead of small spinning and weaving companies, multilevel factories emerged. The cotton industry became the crucial sector and set the pace for economic expansion. Additionally, the factory as a new working environment was established. Although the textile industry played an essential role in driving the economy, other inventions and developments were important: First, the discovery of bituminous coal led to improvements in iron making. Second, both growing demands for resources and increasing trade required the expansion of roads, canals, and, later, railway networks (the first steam locomotive began operation in 1804). Last but not least, technological improvements in the steam engine were also a major source of economic growth. In 1769, James Watt succeeded in stopping the enormous energy loss inherent in early types of steam engines, thus improving the effectiveness and power output of these machines. Initially employed in mining to pump out water, the Watt steam engine was then used in other industries such as mills, breweries, and all kinds of factories, as it was able to produce mechanical work to a virtually unlimited extent. It is worth noting that industrialization occurred worldwide—even though at different times and with variations in length and process—and represented a major shift in human history. The gradual replacement of human hands by fossil fuels changed not only the technological but also the social and cultural conditions. More and more people migrated into the cities to find jobs; this resulted in an excess supply of labor, forcing workers to accept low wages and poor working conditions. Thus women and even children had to work for starvation wages to support their families. Moreover, the high migration into the cities caused a housing shortage and fostered the formation of slums.

Driven by these social grievances, the German philosopher and political economist Karl Marx (1818–1883) developed the economic concept of communism. In his theory, capitalism leads to an exploitation of workers, as entrepreneurs are able to make profits by paying low wages to their workers. As a result, workers feel alienated. The divergence of interests between owners and workers would inevitably result in a revolution. In the long run, communism would become the new order, including a classless society and the public ownership of resources. Even though Marx's ideas were controversial, debated, and commonly rejected, they initiated government intervention for the sake of improving the working conditions for the poor and, later, for bringing about social security legislation. However, the Industrial Revolution was the starting point for a sustainable period of enormous economic growth never seen before.

Today, historians prefer the term industrialization to describe the period of technological advancements lasting up to now, whereas the term *industrial revolution* generally refers to radical innovations within the process of industrialization leading to an accelerated growth in these industries. Hence, the control of electric power, groundbreaking advances in chemistry, and the invention of the automobile are also regarded as industrial revolutions.

Since 1911, these developments were also assisted by the efficiency movement. The American engineer Frederick W. Taylor (1856–1915) started analyzing workflows with academic methods to enhance worker productivity and is therefore credited as the founder of scientific management (or Taylorism). He thought that any workflow should be split into its separate components. Then, according to the "one best way" principle, precise work instructions are needed to assist the workers with the most efficient way to perform their task. For this purpose, Taylor conducted several comprehensive time and motion studies to find the least number of motions for a given task—a technique that is often cited in management textbooks. A few years later, the American entrepreneur Henry Ford (1863–1947) brought these concepts to perfection by inventing the assembly line in 1913 and thereby setting a new standard for mass production, particularly for large-scale manufacturing processes. With the standardization of production processes, less-skilled workers were needed, and it was the management's task to control and plan the working steps efficiently. Besides the advances in production technology and processes, two other inventions revolutionized not only the working environment but also the way of modern life: the digital computer and the Internet.

Digital Revolution

In contrast to analog technology, where signals can have infinite valences, digital technology can be used to transform analog signals into a binary combination of ones and zeros. Greater flexibility, lower cost, and the prevention of error propagation made digital technology superior and promoted the development of computers. The earliest digital computers can be dated back to the 1930s, but the most important developments were made in the 1970s, when the microprocessor and the personal computer were invented. Additionally, the invention of computer networking and the Internet, as well as digital broadcasting, also induced the Digital Revolution. The Digital Revolution marked the beginning of the Information Age and enhanced the emergence of new businesses and professions, such as software developers, computer technicians, and companies such as Google, eBay, and Amazon, whose business models rely on only the Internet. In contrast to the industry sector, the Internet-based and Internet-related businesses (the "dot-coms") are often summarized with the term *New Economy.* The Internet hype in the late 1990s caused a high demand at the stock markets for these companies' shares even though many of them had never made any profits. As a result, market capitalization of many New Economy firms far outreached their book value. However, the dot-com publicity peaked in 2000, at which time the speculative bubble at the stock markets burst, putting the whole world economy in trouble for years.

The Future

Today, the question remains: What might be the next revolution? Nanotechnology is a promising field as it allows the production and control of devices on a scale smaller than 1 micrometer. Further, new forms of generating energy, such as solar, wind, water, and biomass, could lead to an energy revolution. Colonization of space with interplanetary transportation is imaginable. This would probably require new social, political, and legislation structures and new innovations, resources, and professions for the space age environment. Even machines that accomplish all the work for us might be another revolutionary step in human economic future. Time will tell.

Christian Warns

See also Aristotle; Ecology; Egypt, Ancient; Evolution, Cultural; Globalization; Global Warming; Harris, Marvin; Industrial Revolution; Malthus, Thomas; Marx, Karl; Rome, Ancient; White, Leslie A.

Further Readings

Fagan, B. M. (2002). *World prehistory—A brief introduction* (5th ed.). Englewood Cliffs, NJ: Prentice Hall.

Harris, M. (1980). *Cultural materialism: The struggle for a science of culture.* New York: Vintage Books.

Hobsbawm, E. J. (with Wrigley, C.). (1999). *Industry and empire: From 1750 to the present day* (2nd ed.). New York: New Press.

Kennedy, P. (1994). *Preparing for the 21st century.* New York: Vintage Books.

Overton, M. (1996). *Agricultural revolution in England: The transformation of the agrarian economy 1500–1850.* Cambridge, UK: Cambridge University Press.

Scheidel, W., & von Reden, S. (2002). *The ancient economy.* Edinburgh, UK: Edinburgh University Press.

Stiglitz, J. E. (2003). *The roaring nineties—A new history of the world's most prosperous decade.* New York: Norton.

White, L. A. (1959). *The evolution of culture: The development of civilization to the fall of Rome.* New York: McGraw-Hill.

Education and Time

What is the never-ending task of education? This question has been asked and answered by inquiring minds throughout history. Not surprisingly, the responses have been complex. A credible reply is found in the autobiographical *Education of Henry Adams:* "From cradle to grave this problem of running order through chaos, direction through space, discipline through freedom, unity through multiplicity, has always been, and must always be, the task of education" The task does not change. The means to accomplish it are, however, many and varied.

In considering the task of education over time, it is well to examine how education has progressed over the years in representative nations across the continents. This entry considers the earliest vestiges of educational pursuits, as well as adaptations over the past 150 years, in Africa, Australia, the Americas, and Eurasia. Attention is given to the human and material price of progress.

Republic of South Africa

Historically, education in South Africa was centered in each village, where children were taught the survival skills necessary to subsist in a subtropical climate that is home to "The Big Five": buffalo, rhino, lion, leopard, and elephant. Early African education was not institutionalized, and black African families were multigenerational. Women were considered subservient and were often subject to spousal violence. For centuries, both boys and girls learned their roles from their elders in the language spoken in their own regions.

With the 17th century came white dominance. White Afrikaners (Dutch South Africans) reigned supreme, and in the mid-1800s ethnic-specific boarding schools were established with the dual purpose of producing laborers and precluding uprisings among the natives. Literacy was not a priority in these schools, cost was a factor to poor families, and children from rural areas had little opportunity to attend. In contrast, white children were educated in private schools, many of British origin. The disparity between black and white schools increased with the institution of apartheid in 1948. The Christian-based National Party denied blacks access to any white-only areas, particularly schools, and imposed Christianity on students regardless of their religious affiliations. Blacks were not allowed to travel freely. In 1953, the Bantu Education Act was passed, further discriminating against blacks and resulting in only 1% of all funding to reach black schools. Students were coerced into learning the Afrikaans language, and they continued to be educated to do manual labor. In 1976, while the United States was celebrating its bicentennial, 600 South African students were massacred in riots while protesting against inferior schools and the unwelcome heavy use of Afrikaans in the school system.

Since the fall of apartheid in the late 1980s, measures have been taken to integrate the schools and to revise the curriculum to include literacy, mathematics and science, life skills, history, and geography. Lessons began to be taught in English and in a native language of choice: Ndebele, Sepedi, Zulu, Setswana, Xhosa, Venda, Swazi, Xitsonga, Tsonga, or Sesotho. Budgets for educational improvements were astronomical. With the election of Nelson Mandela as president in 1994, marking the official end to apartheid, school populations grew to over 12 million black and white students in more than 30,000 schools. Presently, 87% of males and 86.7% of females over age 15 can read and write. Desmond Tutu coined the phrase "the Rainbow Nation" to illustrate the diversity of the South African people. And, so that they did not die in vain, President Mandela's new government declared June 16 as Youth Day in memory of the 600 protestors who died in Soweto.

Australia

Prior to the arrival of the English settlers in Australia, the Aboriginal people who populated the continent lived a pastoral life. Boys learned to hunt and to plant from their fathers, and girls learned to rear children and to maintain the home from their mothers. Institutional education did not exist until the early to mid 1800s when early English settlers and clerics established private schools for the purpose of domesticating the tribes. By the late 1800s each Australian state had passed public education laws that funded public governmental schools and, to a lesser degree, private denominational schools. Funding for private schools was fully guaranteed in 1964 when Parliament affirmed the practice. As the Commonwealth developed, there were major efforts to unify states in terms of common goals for education, but the outcomes of the conferences were only with regard to schools remaining free, compulsory, and secular in nature, with authority and funding to remain the responsibility of the states. Only in the Capital Territory, in and around Canberra, near Sydney, did the central democratic federal-state government determine educational processes and practice.

Australia is made up of six states and two territories; most people live in and around the large cities and work mostly in the manufacturing and tourist industries. Only 5% of the total workforce is involved in farming. Over time, interest in educating Aboriginal and other agricultural populations has become keen. An important innovation, facilitated to expand educational opportunities to the native people and to people in the remote areas of the outback, is a system of schooling named School of the Air. To communicate, two-way radios are used by teachers and students. Follow-up is carried out via the Internet, facsimile, or the mail. Instruction is done in an Aboriginal language and in English, and, in both the School of the Air and in city schools, Japanese is studied. Australia is a mecca of cultural diversity, and more than 200 languages are currently spoken there.

Unlike schools in the northern hemisphere that traditionally begin in September and end in June, schools in Australia begin the academic year in June and end in September. Students wear uniforms sewn of cotton, and children wear hats with a neck flap to shield their necks and shoulders from the sun. Sunnies (sunglasses) and sunscreen are required for students. Sometimes children are rewarded for their hard work and compliance to rules with little treats called *lamingtons,* small sponge cakes that are drenched with chocolate and topped with shredded coconut.

Throughout history, education has been strongly influenced by Western educational philosophy. Continual reformation has brought about dynamic and progressive change. Australia's literacy rate is currently 100%, and there are 20 colleges and universities on the continent. Australia is ranked high on the international stage for exceptional schools.

Mexico

Education in Mexico has changed dramatically over the years. Mexico has entered the 21st century with a national system of education dedicated to meeting the needs of all Mexico's children from the rural Mayas in the south to the Mestizo miners in the north. These ideals, however, have not as yet been fulfilled. Emanating from a society where only the elite attended school and education was the sole responsibility of the Catholic Church, a secular system of education was extremely costly and difficult to establish. The country was largely illiterate. Initial credit goes to President Benito Juárez. Juárez rose from poverty by way of a sound education. He focused on increasing the number of schools in Mexico, and by 1874 there were 8,000 schools, and public education was declared a universal right.

José Vasconcelos, director of education in the early 1900s, popularized the notion of education for the masses, and through his efforts, the education budget was more than doubled between 1921 and 1923 to 35 million pesos. Vasconcelos dispatched teachers, agriculturalists, home economists, and artists to remote villages to teach literacy, numeracy, and technology. Opportunities were advanced to women. A lively and enduring Mexican identity and cultural nationalism took hold.

For a time, the third article of the Mexican Constitution was amended to proclaim "State education will be socialist in nature." New curricula were written to emphasize the leading roles of the workers during the Mexican Revolution. Catholic education was basically tolerated, but great opposition was mounted against powerful landowners and foreign property owners. Revolution bore industrialism, and prosperity followed. Money became available for education, and literacy rates rose to 57% before World War II. The word *socialist* was removed from the Constitution. Catholicism remained, and still remains, the religion of 95% of all Mexicans.

Education continued to be a priority throughout the 20th century. Cost-effective prefabricated schools, furnished with teacher residences, were built to attract teachers to the rural villages. Free textbooks and workbooks, some in the 50 or more indigenous languages of Mexico, allowed more children to remain in school. Mexico became the first country in the world to offer *telesecundarias* (distance learning), and by 2004 the overall literacy rate reached 92%. This is significant because only one quarter of all students remain in school until age 16. Poverty plagues the society, and many poor Mexican families harbor detrimental anti-intellectual attitudes. Only a small percentage of high school graduates go on to higher education. Despite these problems, amazing progress has been made in the federal republic. Mexico City University, founded in 1551, is the oldest and largest university in all the Americas. Nonetheless, until students from the Mexican countryside have an equal opportunity with their counterparts in the cities to attend college or university, the absolute success of the Mexican educational system will not be realized.

Iraq

Iraq has a magnificent history of intellectual pursuit. What other country can boast the invention of the wheel, utilization of the first alphabet, or rank among the first to study mathematics and astrology? Indeed, the oldest university in the Arab world, Mustansiriya University, founded in 1234, is located in Baghdad. Relatively modern educational practices were introduced to Iraq by the British in the early 1900s, but student enrollment was low and the literacy rate was only 20% of the Iraqi population. Upon Iraq's becoming a republic in the late 1950s, great strides were made by the new government to construct schools, raise enrollment, and more than double the literacy rate. From kindergarten level to university level, tuition was free. The government provided all materials and texts. Teachers were paid well, and schools were in very good condition. More boys than girls attended Iraq's gender-segregated schools. Age-old gender bias existed, and Muslim women wore the *hajab* or the *burka*. It was believed that separating the sexes resulted in children's being better able to concentrate on their studies. Also of note is that more children from the populous areas went to school than those from rural areas. The nomadic and seminomadic people raised sheep, goats, cattle, poultry, and horses. School-age children were needed by their families to tend the livestock. Education was a luxury for them, not a priority.

According to Roger Wright, UNICEF representative to Iraq, "Iraq used to have one of the finest school systems in the Middle East." That is no longer the case. From 1979 to 2003, the pan-Arab and socialist policies of the Baath Party were enforced by Saddam Hussein. Iraq became a dictatorship where the people had little influence on the government. During this time, the Iraqi economy and its exemplary system of schools were adversely affected by neglect, underfunding, and war without end. The fall of Saddam Hussein in 2003 did little, however, to alleviate the deterioration of the schools and the school system. Harsh economic conditions caused some of the youngest children to drop out of school and beg on the streets of the cities. Parents feared sending their children to school. In Baghdad, alone, bombs destroyed, damaged, or burned hundreds of schools, and thousands of them were looted.

Even today, children who do attend school find the buildings in disrepair, with broken windows, weak foundations, and leaking roofs. Running water and sanitation facilities are defunct. Furniture, equipment, and materials are scarce. Teachers are disillusioned. They teach two and three shifts per day, and teacher salaries are at an all-time low. There is, however, reason for optimism. Much of the Baathist ideology has been removed from the curriculum. Reconstruction is slowly being carried out with the help of UN agencies, private sector companies, and the U.S. military.

Russian Federation

Education does not exist in a vacuum. It reflects the social, economic, cultural, and political posture of a nation. This is especially true in the former Union of Soviet Socialist Republics. The recently formed Russian Federation is the largest country in the world, spanning two continents. The land west of the Ural Mountains is located in Europe and the land east of the Urals is in Asia. In early times, Russia was an imperial state ruled by a hereditary monarchy. Education was reserved for royalty and the upper echelon of society. The masses were uneducated, poverty stricken, and subject to the restrictions of the czars. The abolition of serfdom under Alexander II in 1861 brought the Zemstvo reform. Rudimentary public schools were built in the countryside for the children of peasants. Twenty years later, the Russian Orthodox Church was granted jurisdiction over education, and by the dawn of the 20th century 50% of all school-age children attended the parish schools.

With revolution came innovation. The new phase of Russian education coincided with the rise of the Bolsheviks and the establishment of the Soviet Union in 1918. Led by Vladimir Lenin, and under the leadership of the Commissariat of Education, schools were deigned to become child-centered, interactive, and progressive. Instruction was to be rooted in students' interests. However, Lenin's idealistic vision for education was not well received at the local levels. Little change occurred, and tradition was defiantly maintained.

During the Joseph Stalin years (1931–1953), the schools became a vehicle for dispensing Soviet ideology. Schools were administered by the Politburo, the main organ of the Soviet state, and strict allegiance to the state was enforced. As often happens in a totalitarian regime, the curriculum was rewritten, in this instance painting Stalin as the Father of the Revolution. Suppression, fear, and numbing routine characterized the state and school. Yet the literacy rate under Stalin was reported to have risen to 95% by 1939 and was maintained throughout the century.

The year 1991 marked the fall of the Soviet Union and the foundation of the Russian Federation. With this came great hope and optimism among average citizens who believed that the far-reaching political upheaval would bring prosperity with democracy. Their hopes were dashed. Political and societal uncertainty and a weak economy prevailed. Schools were underfunded, teachers were underpaid, and conditions continued to deteriorate over time. Today, schools are in disrepair. Major heating, plumbing, and electrical repairs, as well as technological advances, are needed. New school construction is necessary to alleviate overcrowding and double sessions. New curricula must be designed, and "communist mythology" removed from textbooks. At this moment in time, Russian students are not encouraged to enter college or university because they can earn more money by entering the workforce. With hopes for immediate reform dashed, many Russians look to their current leader, Dmitry Medvedev, upon whom they depend to improve conditions in both society and in the schools.

Suzanne E. D'Amato

See also Evolution, Cultural; Evolution, Social; Lenin, Vladimir Ilich; Stalin, Joseph; Time, Teaching

Further Readings

Alwan, A. (2004). *Education in Iraq: Current situation and new perspectives.* Baghdad: Iraq Ministry of Education.

Bell, R. (2005). *A visit to Australia.* Chicago: Hinemann Library.
Ganeri, A., & Wright, R. (2006). *Country topics: Mexico.* North Mankato, MN: Sea-to-Sea Publications.
Hlatshwoyo, S. A. (2000). *Education and independence: Education in South Africa, 1658–1888.* Westport, CT: Greenwood Press.
Hollander, M. (2003). *Brazil: The culture.* New York: Crabtree.
Miesel, J. (1994). *South Africa at the crossroads.* Brookfield, CT: Millbrook Press.
Riasankovsky, N. V., & Steinberg, M. D. (2005). *A history of Russia.* Oxford, UK: Oxford University Press.
Schultze, S. (2000). *Culture and customs of Russia.* Westport, CT: Greenwood Press.

Egypt, Ancient

The concept of time was an essential part of life for the people of ancient Egypt because they believed that all things are connected in a continuous cycle of life, death, and renewal. This belief was a natural response to the phenomena that they observed in the world around them. They could depend on the annual flooding of the Nile River to renew the fertility of the soil. Ra, the sun god, was resurrected every morning following his nightly passage through the underworld, to continue his perpetual voyage across the skies. All around them was proof that the cycle of life was continuous.

This idea of continuity led the Egyptians to the belief that the world had been created in a state of perfect order that would never be changed. They worshipped the goddess Ma'at, who stood for order, balance, justice, and equality. This reverence led to the development of a moral code called *ma'at,* which served as a guide for everyone, beginning with the pharaoh and extending down to the common people. The goal for all Egyptians was to lead a sinless or virtuous life in order to be judged worthy of living on in the afterlife.

Development of Religion

As was the case in most primitive cultures, the earliest inhabitants of Egypt based their religious beliefs on the natural world. Before the unification of Egypt, each city-state worshipped its own local god, usually in the form of an animal. One example of this practice was the cult of the god Apis (or Hap) of Memphis. A single bull would be selected to be the sacred Apis bull on the basis of certain markings or coloring. The temple priests maintained the bull in luxury throughout its life. When the sacred bull died, it was mummified and received a royal burial. This cult existed well into the Ptolemaic period, so there were many tomb complexes where these bulls were interred. One such tomb is the huge underground cemetery called the Serapeum of Saqqara. Other animal burial sites have also been uncovered at Saqqara, with each tomb containing a different animal species.

Another animal cult, which originated in the city of Bubastis, was centered around the worship of the cat goddess, Bastet. The oldest known statues of Bastet represent her as a lioness. Her worship persisted and, over time, spread throughout Egypt. Around 1500 BCE, cats were first domesticated in Egypt and came to be considered sacred animals. They were greatly favored as pets, and mummified cats have been found in many tombs. Following the Roman conquest of Egypt, the worship of Bastet spread as far as Italy.

Beginning with the First Dynasty, the animal itself became less of an object of worship but continued to serve as the personification of the god. During this time, Egyptian gods also began to take on human attributes. Statues of the gods dating from this period portray them with a combination of both animal and human features. Assigning human features to a god or an animal is called *anthropomorphism.* An example of this is found in later representations of the goddess Bastet, in which she was depicted as a woman with a cat's head.

Many local gods were adopted as state gods as local beliefs were incorporated into a more formalized religious practice. The ruling pharaoh would often build temples in honor of his favorite god in order to promote the worship of that god, but Egyptian temples were never intended for public worship. They were constructed to house the image of a god and a staff of priests to serve the needs of the god. The full-time priests were the only permanent residents in the temple complexes. They were also the only ones who could perform the required rituals. However, all Egyptian men were required to work in a temple for 1 month out of 4 to fulfill their duty to the gods.

Daily temple rituals were performed beginning at sunrise. The statue of the god was usually housed in an inner chamber of the temple inside a sealed cabinet. At dawn, a priest would enter the chamber, unseal the cabinet, and remove the statue, offering incense and prayers before it. The figure would then be washed, clothed, and adorned with jewels. A meal was prepared, and the food was offered to the god. This ritual was repeated several times during the day until the image was retired for the night. The priest would then return the statue to the cabinet and reseal it with wax, sweeping away his footprints as he left the chamber. None of the general population was allowed to participate in these daily rituals at the temple, but small shrines in private homes were not uncommon.

The only time that the public was allowed to participate in religious observances was during a festival. Each of the primary gods had his or her own festival, and as there were many gods, there were multiple festivals throughout the year, usually at least one per month. Festivals were celebrated as holidays, days when no one was required to work. At the start of the celebration, the god's statue was brought out from the temple and carried to the Nile River by a procession of priests. This was the only time that the common people were allowed to see the god's image. The statue would be installed on a luxurious barge for the journey to the capital city, stopping at towns and villages along the way where the people celebrated with feasting and entertainment. When the statue reached the capital city, the pharaoh would assume the duties of high priest, ministering to the daily needs of the statue.

Not only was the pharaoh ruler over the civil workings of the country, but he was also designated as the high priest for all of the gods. Because he could not possibly fulfill his function as high priest at every temple, chief priests were appointed to serve as proxies in his place, and the pharaoh fulfilled his duties as high priest only during religious festivals. In addition to his birth name, pharaohs always carried multiple names and titles, both secular and religious, as did all high-ranking officials. The Egyptians believed that the pharaoh was not just a representative of the gods but the incarnation of the gods. Most importantly, the pharaoh was the incarnation of the sun god, Ra.

Beginnings of the Calendar

It was essential that these festivals take place on the same day of every year to ensure the goodwill of the gods who sent the yearly floods to sustain the land. To accomplish this, the Egyptians found it necessary to find a way to measure the passage of time. Temple priests first used the movement of the stars to mark the passing hours. They observed the stars nightly, appointing priests called "hour watchers" to monitor the heavens throughout the hours of darkness and record the movements of the stars in relation to a fixed point. Around 1500 BCE, the priests at the temple of the god Amon (or Amun) in Karnak began to use water clocks, or clepsydra, to determine set intervals of time for recording their astronomical observations. Over time, these observations revealed predictable patterns in the movement of the stars and planets, allowing the priests to predict the exact moment when the sun would rise and the daily temple rituals could begin. Another result of these nightly surveys was the division of the visible sky into 360°. Names were assigned to 36 star gods, or decans, each of whom occupied a 10-day period on a star chart that was similar to a horoscope. The first recorded use of star charts in Egypt has been dated to about 2100 BCE. Star charts became so important to the Egyptians that they inscribed them on the inside of a sarcophagus, or coffin, for use by the deceased in the afterlife.

The use of star charts led to the first calendar, which was used by temple priests to record religious observances. It was based on the lunar year of 12 months of 30 days with 5 additional, or epagomenal, days added at the end of the year to bring the total to 365 days. Epagomenal days were designated as birthdays of the gods and were celebrated as special holy days. Months of the lunar calendar consisted of 3 weeks of 10 days and were named for the god whose festival was held during that month. The Egyptians were the first to use a day that consisted of 24 hours, with 12 hours designated for daylight and 12 hours for darkness. Because the length of a day varies with the seasons, an Egyptian hour was not a set amount of time.

Instead, it was measured as 1/12 of the hours of daylight or darkness.

The first solar calendar came into use in Egypt around 2900 BCE. It was based on the appearance of the star the Egyptians called Sothis, which also signaled the imminent appearance of the annual flood. The solar year, like the lunar year, consisted of 12 months of 30 days plus the 5 epagomenal days at the end of the year. This was to become the civil calendar of Egypt and was used for all official business, such as recording the dates that grain was harvested on government land or how long workers served at civil building projects during the annual floods. Ancient Egypt had three seasons of 4 months each that coincided with the annual cycle of the Nile River. The season of Inundation would occur from June through September and was the time when the Nile River flooded the land. Because no work could be done in the fields, the people could make use of this time to work on civil building projects. The season of Emergence was the season when the fields emerged from the waters. The receding water was captured in holding ponds for later use, and seed was sown for new crops. Emergence lasted from October through February. Drought was the season of the harvest and took place between March and June.

Both lunar and solar calendars were inaccurate and, over time, the two calendars became asynchronous. Neither of them accounted for the full 365.25 days in a year. Using the lunar calendar, the first day of the New Year was the first day of the Nile flood. A year based on this calendar was problematic because it could vary by as much as 10 days, either shortening or lengthening the year, depending on when the start of the flood occurred. When the discrepancy between the two calendars became severe enough to cause religious festivals to be celebrated during the wrong season, the use of a lunar-solar calendar that combined the best features of both types was introduced.

In 239 BCE, Pharaoh Ptolemy III issued the Decree of Canopis to institute the use of a leap year. The Egyptian priests, however, refused to change their calendar. It was not until 23 BCE, when the Roman Emperor Augustus decreed that the Egyptian calendar was to be reformed, that the changes were actually made. This calendar became known as the Alexandrian calendar and was adopted in many areas of Africa and Eastern Asia. The calendar that we use today originated from the Roman calendar, which was heavily influenced by the Egyptians. When Julius Caesar initiated reforms to the Roman calendar in 46 BCE, he used the recommendations of Sosigenes, an Egyptian astronomer from Alexandria.

Beginnings of Astronomy

In their astronomic observations, the Egyptians noticed that certain stars and constellations remain stationary while others change their position in relation to the earth. Some of these stars disappear below the horizon for a predictable amount of time. When they reappear in the east, they are usually visible for a few moments just before the rising of the sun. This is called the heliacal rising of a star. If a star does not make its heliacal reappearance as expected, but remains invisible below the horizon for an extended period of years, the phenomenon is called precession. Both of these phenomena are caused by the rotation of the earth.

One of the most important heliacal stars for the Egyptians was Sothis, the star now known as Sirius, which is the brightest star in the constellation of Orion. Sothis was important because its heliacal rising signaled the immanence of the annual Nile River flood. It was also used to determine the beginning of the New Year for the civil calendar. Sothis and the constellation of Orion are closely linked with Osiris, god of the underworld. Osiris is one of the most important Egyptian gods because of his influence on Egyptian religious beliefs.

Osiris was one of the local gods who had moved up to the status of state god. He was a fully anthropomorphic god, being portrayed in human form, usually pictured as a mummified figure. The origin of the story of Osiris is unknown, but it seems to be a combination of a number of stories that have been found in various funerary texts that were discovered in Egyptian tombs. Plutarch, a Greek writer who lived in the 1st century CE, has left the only existing version of the story that brings together all of these myths. According to Plutarch, the story begins with Osiris, who is Pharaoh over all of Egypt. His brother Seth becomes jealous and plots against him. Seth lures Osiris into a sarcophagus, which he closes and throws into the Nile River. Isis, Osiris's wife, searches for and locates the sarcophagus. When Seth learns of this, he is so enraged that he cuts the body of Osiris into 14 pieces and distributes them throughout Egypt. Isis travels across the country to gather all of the pieces and, with the help of Thoth, the god of embalming, puts the pieces back together and embalms the body. Through the use of magical spells, Isis resurrects Osiris, who fathers a son with her and names him Horus. Osiris must then descend into the underworld, leaving Isis to rear the child in secrecy to protect him from Seth.

In the next portion of the story, Horus has reached adulthood and sets out to hunt for Seth. A battle ensues, during which Seth removes Horus's eye. Horus later retrieves the eye from Seth through trickery and the help of his mother. Horus descends to the underworld to present the eye to Osiris, who is granted eternal life because of it and, as a result, becomes ruler of the underworld. After these events, Horus rules over lower, or Northern, Egypt and Seth becomes ruler over upper, or Southern, Egypt. Horus, however, brings his case before the council of the gods, declaring that he alone is Osiris's rightful heir and should be the ruler over all of Egypt. The gods vacillate between the two claimants for 80 years before Horus is finally declared supreme ruler of Egypt.

What could be the significance of the 80-year court case of the gods? One modern researcher has advanced a theory. Using a computer simulation, he has discovered that the constellation Orion disappeared below the horizon of ancient Egypt for 80 years. Because the Egyptians believed so strongly in the divine order of the world, the extended disappearance of Sothis would need to be explained. This event may have been the source of the story of Osiris.

Burial Practices

One belief that may have originated from the story of Osiris involves the embalming process that is known as mummification. It was believed that if the pharaoh's body were embalmed in the same manner as Osiris had been and the correct magical spells were invoked, his immortality would be ensured. During his lifetime, the pharaoh was the person who was responsible for the welfare of the Egyptian people. He was supposed to continue to intercede with the gods on their behalf in the afterlife, making it imperative that the pharaoh achieve eternal life.

Was the story of Isis embalming her husband, Osiris, based on the practice of embalming, or did the embalming process originate with the story? Whatever the case, the process of mummification followed a strict ritual process. First, the body was cleaned and the internal organs were removed, with the exception of the heart. The brain was removed through the nostrils with no effort to preserve it because the Egyptians considered the heart to be the seat of knowledge. The four most important organs were stored in clay jars called Canopic jars. Each jar stood for one of the four sons of the god Horus, with each jar bearing a likeness of the head of its patron on the top of the lid. Imset was represented by a human head, and this jar contained the liver. Hapy was signified by the head of a baboon; he guarded the jar that held the lungs. Qebhseneuf watched over the intestines and was symbolized by a falcon's head. Duwamutaf protected the stomach and was denoted by a jackal's head. Each of these was watched over by a goddess from one of the four directions of the compass. After the removal of the organs, the body cavity was filled with resin or sawdust. Finally, the entire body was covered with natron, a salty substance, and was left to dry during the 70 days of mourning.

While the body was being prepared for burial, the tomb was being prepared and stocked with necessities. A tomb was thought of as the dwelling place of the deceased for eternity, so it needed to be equipped with everything that the deceased would need to live in the afterlife. This would include furniture, household utensils, a miniature funerary boat, food and drink, as well as small clay figures called *shabti.* Scenes depicting special times in the life of the departed one were painted on the tomb walls, and a statue of the deceased was nearly always placed in the tomb to serve as a replacement home for the *ka,* or spirit, in the event that the mummy was destroyed.

After 70 days, the body was removed from the natron, washed, and wrapped in linen cloths. When the entire process was complete, the funeral service was held. Cemeteries were usually placed on the west side of the Nile River and when a person died, they were said to have "gone west" where the sun "died" each day. The western horizon was thought of as the borderline between the land of the living and the underworld, the kingdom of Duat that was ruled by Osiris. Just prior to placing the body into its final resting place, which was usually a stone sarcophagus, a ritual called the "opening of the mouth" took place. In this ceremony, the priest would touch the mouth of the mummy with two special instruments while reciting magical incantations. The first was thought to give life and breath back to the body. The second was believed to enable the deceased to receive nourishment from the food offerings that were left in the tomb. In addition, it was thought that these incantations would enable the miniature funerary boat to enlarge for use by the deceased in the journey through the underworld. The spells were also supposed to animate the shabti figures to become the person's servants in the afterlife and were believed to enable the tomb paintings to come to life to serve the departed. This is the reason that tomb paintings always included everyday tasks, such as the harvesting of grain, the baking of bread, and the brewing of beer.

After a person died, it was believed that his or her soul must descend to the underworld to pass through certain tests and trials. Those who had lived a good life and had the proper answers to the questions of judgment would move on to an eternal existence. In the Old Kingdom, texts were written on the interior walls of tombs and pyramids to serve as a guide for the deceased. These are referred to as Pyramid Texts. During the Middle Kingdom years, these texts were written on the inside of the sarcophagus and are called Coffin Texts. Scrolls of papyrus with instructions for the deceased to use in facing the tests of the underworld were placed between the knees of the mummy in New Kingdom burials. These scrolls are known collectively as the Book of the Dead. One thing that was contained in the Book of the Dead was a recitation of the sins that had not been committed by the deceased. In addition to responding correctly to all of the questions posed by the gods, the individual's heart would be weighed against a feather in the Hall of Ma'at. If the scales balanced, the person would go on to eternal life. If the scales did not balance, it was believed that the heart would be eaten by Amment, the "devourer of souls." If this happened, there was no chance for an eternal existence, and it is likely that this was one of the reasons that the Egyptians devoted themselves to following the principles of truth and fairness that were expressed by the philosophy of *ma'at*.

During the early years of the Old Kingdom, only the pharaoh was expected to achieve eternal life. Smaller tombs for nobles and courtiers were usually constructed around the tomb of the pharaoh in the hope that they would be allowed to serve the pharaoh in the afterlife as they had during his lifetime. By the beginning of the Middle Kingdom, burials of nobles and courtiers reflected their expectation to live on in the afterlife in the same manner as the pharaoh. By the start of the New Kingdom, these beliefs seem to have included anyone who had the means to pay for embalming and an appropriate tomb.

The temple complexes that were commonly built around the tomb or pyramid of the pharaoh during the Old and Middle Kingdoms served a double purpose. Regular attention would keep his name alive, and the priests would continue to supply his mummy with regular food offerings. For everyone else, relatives were expected to visit the tomb with food and drink offerings to sustain the departed one. Those who were wealthy enough could hire priests to ensure that their loved one would have the necessary offerings in perpetuity. As time passed, it was not unusual for these agreements to be forgotten. If the food offerings were not forthcoming, it was believed that the needs of the deceased could be supplied by the tomb paintings that had been magically animated during the ceremony of the "opening of the mouth."

Another belief tied to the story of Osiris is the idea that a person who was deceased would have eternal life as long as his name was remembered. Tomb texts containing the name of the deceased were meant to ensure that the person would live on in the afterlife, just as Osiris had done. This belief, combined with the responsibility of the pharaoh for his people's welfare, made it important to record the pharaoh's name many times within his tomb, particularly on the sarcophagus. Carrying this belief one step farther, the Egyptians believed that if the departed pharaoh took on the name of Osiris, his name would be remembered forever, ensuring his immortality. Writings found in the tomb of Pharaoh Unas, who ruled from 2375 to 2345 BCE identify him as Unas-Osiris, showing that the funerary customs of that time were based on beliefs that had originated from the story of Osiris. The importance of keeping the name of the deceased alive also led to the construction of extensive temple complexes around the tombs of the pharaohs during the Old and Middle Kingdoms.

Tombs and Pyramids

The Egyptians practiced the worship of multiple gods, but the central principle in Egyptian religion was a belief in the continuation of life after death. To achieve eternal life, a person must have a properly prepared tomb where his or her *ka,* or spirit, would live forever. Consequently, temples, tombs, and pyramids were designed to last for eternity, and they were the only structures in Egypt that were constructed of stone instead of the traditional mud brick.

Sandstone was the stone of choice because it was easily worked with the available stone tools. However, sandstone's limitations include the fact that it cannot be used to span a large distance without support. Limestone came into use because, like sandstone, it was easy to work with, but it is also strong enough to withstand the stress of being incorporated into an arch. Everyday structures, such as houses, shops, and even the palaces of the pharaohs, were constructed of mud brick that has long since weathered away. As a result, most of what is known about ancient Egyptian civilization has come from the art and funerary goods that have been discovered in tombs.

At the beginning of the Old Kingdom, pharaohs were buried in mastaba tombs. These consisted of an underground vault, sometimes a suite of rooms, with a shaft to the surface. Above the tomb, a rectangular structure of mud brick was constructed to afford access to the vault below. A chapel was usually built inside the mastaba to provide a place for relatives to bring offerings for the deceased. Small funerary chapels slowly gave way to temple complexes.

In the 3rd century BCE, the style of tombs was changed forever when Pharaoh Djoser commissioned his chief architect, Imhotep, to design a tomb for him at Saqqara. Imhotep was an extraordinary man who served as the king's vizier but was also a priest, physician, astronomer, philosopher, and a gifted mathematician. The project began with preparations for a large, raised mastaba tomb. However, this tomb differed from those of previous kings in that it was built entirely of limestone bricks instead of the traditional mud bricks. In imitation of the former tradition of using organic building materials, the outer surface of the stone was carved to represent bundles of reeds and grass mats. After completion, the tomb underwent a radical addition. A second, smaller layer was added on top of the first, with two more added to form a step pyramid. Another addition followed the first, enlarging the base and adding two more layers to form a rectangular step pyramid of six layers. It was the first structure of its kind to be built in Egypt and was the largest stone structure in the world at the time of its completion. Tombs from this time period, including Djoser's step pyramid, had a north-facing entrance, pointing toward the polar stars, where it was believed that the deceased would spend eternity.

Pharaohs who followed after Djoser built tombs in a variety of styles. Some built step pyramids, but several of the kings who succeeded Djoser ruled only a short time and did not undertake such massive building projects. It was King Sneferu of the Fourth Dynasty who began planning an ambitious project for his tomb shortly after coming to power. The first attempt, built at Dahshur, resulted in the bent or rhomboidal pyramid. The second attempt, also built at Dahshur, resulted in the first classic pyramid, and became Sneferu's tomb. Its outer surface is covered with pink limestone that appears red at sunset, so it has been given the name Red Pyramid.

The largest of the Egyptian pyramids is the Great Pyramid at Giza, which was built by Sneferu's son, Khufu. Its base covers 13 acres. It measures 451 feet in height and its sides are aligned with the four directions—north, south, east, and west. Khufu's son, Khafre, built the second pyramid at Giza. Although it is smaller than the Great Pyramid, it seems larger because it was built in a higher position. The third pyramid was started by Khafre's son, Menkaura, who died before it was finished. His successor, King Shepseskaf, completed the building of Menkaura's pyramid.

Why did the Egyptians feel the need to build the pyramids? Pyramids, like the mastaba tombs before them, are thought to be symbolic of the primeval mound that was the first creation of Ptah, one of the creator gods. The entrance to the pyramid always faced to the east, where the sun god, Ra, rose every morning. It is thought that this practice reflected an emphasis toward the worship of Ra. The prevailing belief of the time concerning the afterlife was that the deceased would continually journey across the sky in the boat of Ra.

Pyramid construction occurred for a relatively short time during the Old Kingdom. In the Middle Kingdom years, tombs reverted to the mastaba style but were constructed of stone instead of mud brick. By the start of the New Kingdom, tombs were constructed entirely underground with a hidden entrance. This is the type of tomb that is found in the Valley of the Kings, which is located on the west bank of the Nile near Thebes. These tombs consist of extensive passageways and chambers that have been tunneled into the cliffs with the entrance hidden after the burial, most likely to discourage tomb robbers. This would be especially important to the Egyptians because they believed that if the tomb was robbed and the mummy was destroyed, the deceased could not continue to enjoy a life in eternity.

Conclusion

The Egyptians were a people who became obsessed with time and eternity. Although their religious beliefs changed over time, their belief in the afterlife came to dominate every aspect of life in Egypt. The primary purpose of the greatest Egyptian architecture and art was to construct a dwelling place for the deceased and the provisions that would be needed for life in eternity. Everyday life in Egypt was ruled by the tenets of *ma'at* in order to achieve eternal life. This obsession would eventually lead to the study of astronomy, the invention of timekeeping instruments, and the concept of a 24-hour day and the invention of the calendar. Although these discoveries were made thousands of years ago, the legacy of the Egyptians continues to influence people's lives today.

Corrine W. Koepf

See also Calendar, Egyptian; Mummies; Rameses II; Rosetta Stone; Seven Wonders of the Ancient World

Further Readings

Assmann, J. (2001). *The search for God in ancient Egypt*. Ithaca, NY: Cornell University Press.
Ikram, S. (2003). *Death and burial in ancient Egypt*. Harlow, UK: Longman.
Lamy, L. (1981). *Egyptian mysteries: New light on ancient spiritual knowledge*. New York: Crossroad.
Lippincott, K. (with Eco, U., Gombrich, E. H., et al.). (1999). *The story of time*. London: Merrell Holberton.
Richards, E. G. (1999). *Mapping time: The calendar and its history*. New York: Oxford University Press.
Ruiz, A. (2001). *The spirit of ancient Egypt*. New York: Algora.
Shaw, I. (Ed.). (2000). *The Oxford history of ancient Egypt*. Oxford, UK: Oxford University Press.
Wilkinson, R. H. (2000). *The complete temples of ancient Egypt*. New York: Thames & Hudson.

Einstein, Albert (1879–1955)

Albert Einstein was a German–American physicist who significantly changed the physical and philosophical view of time and space. The special and general theories of relativity are among his most seminal works. He also provided fundamental contributions to early quantum theory. For his quantum theoretical interpretation of the photoelectric effect, he was awarded the Nobel Prize in Physics in 1921. His most lasting contribution, however, is his theory of relativity, which changed our conception of time forever. As a pacifist, Einstein was actively involved with movements for peace, tolerance, and international understanding all his life.

Early Developments

Albert Einstein was born in Ulm, Germany, on March 14, 1879. His father was a moderately successful salesman in the electrical trade. The South German roots of Einstein's Jewish family reached back for centuries. Since 1880, the family had lived in Munich. According to Einstein, the experience that aroused his scientific curiosity occurred at the age of 6, when he was wondering about the invisible force aligning a compass needle. The stories often told about Einstein's underachievement in school are merely a myth. He earned average marks in most subjects but was excellent in the natural sciences. However, he showed a dismissive attitude toward dull authority from his early days on. Beyond school lectures, he was able to figure out the infinitesimal calculus on his own.

While his family moved to Milan, Italy, in 1894 for economic reasons, young Albert stayed back in Munich alone to finish grammar school. Ahead of time and without formal graduation, Einstein left school on his own decision when he became at odds with the school's authorities. "Your sheer presence corrupts the class's respect for me," his teacher remarked. On the basis of his attitude as a freethinker, he also resigned from the Jewish religious community. In 1895, he went to the Kantonschule Aarau (Switzerland) where he passed the Matura (the Swiss grammar school diploma), qualifying himself for the Confederate Polytechnical Academy Zurich (today's ETH). In 1900, he achieved the teacher's diploma for math and physics. He applied for an assistantship at the Zurich Academy, but his application was rejected, so he eked out a living as a substitute teacher at first. In 1901 Einstein submitted his dissertation on the theory of thermal equilibrium and the second law of thermodynamics to the University of Zurich; the dissertation was declined.

During his years of study, Einstein fell in love with his Serbian fellow student Mileva Maric. In 1902 she gave birth to their illegitimate daughter, Lieserl, at Mileva's parents' home in Serbia. The subsequent fate of the child is uncertain; it is stated in various sources that she was given up for adoption at Einstein's insistence in order to preserve moral standards; some sources state that she suffered from trisomy 21 (Down syndrome) and died at the age of almost 2 years.

Annus Mirabilis: An Explosion of Creativity

In 1902, after a recommendation from his friend Marcel Grossmann, Einstein got employment as "third class expert" at the Swiss patent office in Bern. Half a year later, on January 6, 1903, he married Mileva. Their sons Hans Albert (1904–1973) and Eduard (1910–1965) were born from this marriage.

Along with his time-consuming but nevertheless regular work, Einstein concentrated on theoretical physics and prepared for his graduation at the University of Zurich. With his friends Maurice Solovine and Conrad Habich, he founded a sort of philosophical discussion circle, the Akademie Olympia. After leaving work, they would study and discuss the works of Immanuel Kant, Ludwig Boltzmann, Henri Poincaré, or Ernst Mach. Einstein's wife Mileva was among the intellectual discussion partners.

Einstein's ambitions, advanced beyond the academic establishment, first culminated in a scientific "eruption of genius" in 1905, often referred to as his annus mirabilis, or miraculous year. Within a few months, the 26-year-old Einstein published four papers of historical relevance in the prestigious journal *Annalen der Physik*. In mid-March, he explained the photoelectric effect and laid one of the cornerstones of quantum mechanics by ascribing a corpuscular nature to light; in 1921 Einstein would win the Nobel Prize for this work. Two weeks thereafter, he resubmitted a dissertation titled *A New Way to Determine Molecular Dimensions*. This work contained essential hints on the atomic nature of matter. With this publication, he succeeded in referring the Brownian motion in fluids to the thermal motion of molecules. He thus established the kinetic interpretation of heat.

Foremost, however, the name of Einstein is associated with the idea of relativity. The first and most constitutive work on this topic was the "Electrodynamics of Moving Bodies" paper, which he submitted on June 30, 1905. The paper is particularly remarkable in that it does not contain any academic references, unthinkable for a scientific paper today. Finally, in September, he provided a sort of extension to the electrodynamics paper culminating in the equation $E = mc^2$, the most famous physical formula in history. Both works set up the special theory of relativity, Einstein's revolutionary new theory of time and space.

Scientific Reputation

In January 1906, Einstein received his Ph.D. Shortly thereafter he was advanced to a "second-class expert" as a patent office employee. Until 1908, he made his living from passing expert opinions on patents. Later on, his weighty contributions would pave the way for a scientific career. Meanwhile, qualified as a professor and now possessing a certain reputation within the scientific community, Einstein delivered lectures beginning in 1908 and was appointed to an associate professorship at the University of Zurich in October 1909. During the following 5 years, he changed his academic affiliation several times. After working in Prague for a short period, he returned to Zurich. Finally, in 1914 he was enticed by his elder colleague, Max Planck, into going to Berlin, and he worked there without teaching commitments. Einstein's departure from Zurich was impelled by more than scientific reasons; his marriage to Mileva was breaking up, and in Berlin, he had begun an extramarital relationship with his second cousin Elsa Löwenthal in 1912.

After the outbreak of World War I on August 1, 1914, Einstein began to care about political concerns more intensely. He joined the group Neues Vaterland (New Fatherland), which was based on a decidedly pacifistic attitude. Despite lucrative offers by other German and international universities, he would stay in Berlin until his emigration to the United States in 1933.

Quanta and Relativity

Einstein's 1905 works provide not only the general basis of his theoretical framework but also, in particular, a radical new view of space and time. Until his death, Einstein would criticize the new quantum theory. "God doesn't play dice": With these words, he summarizes his pessimistic attitude toward the probabilistic "Copenhagen interpretation" of quantum theory developed by Nils Bohr and Werner Heisenberg in 1926, even though in 1905, Einstein had provided a fundamental contribution to the quantum concept. "On a Heuristic Aspect Concerning the Creation and Transformation of Light" is the bulky title of the very paper postulating the particle character of light. In a letter to his friend Konrad Habicht, Einstein announced his own work to be "revolutionary."

The quantum concept had been introduced 5 years earlier by the physicist Max Planck, also in the context of electromagnetic radiation. However, Planck was referring only to the radiation energy being emitted and absorbed in discrete packets, denoted as quanta.

Around the mid-19th century, the French physicist Alexandre Edmond Becquerel discovered the effect that an ultraviolet-irradiated, negatively charged metal plate emitted negative charge carriers in a characteristic manner. The energies of the individual electrons emitted do not depend on the radiation's intensity, but only on its wavelength. Moreover, the effect sets only in as soon as the radiation wavelength drops below a certain limit. These observations were not compatible with the conventional and established wave picture of electromagnetic radiation.

Einstein took on the challenge and postulated that both light and electromagnetic radiation consist of tiny portions of "light" particles called *photons*. However, the wave properties of light had been proved experimentally in Newton's era. In this respect, Einstein introduced the duality of light, which is still considered valid today: Though excluding each other, both natures obviously coexist in electromagnetic radiation. Many years after Einstein's work, the concept of duality was applied to any kind of matter when two beams of electrons were observed to interfere. This is considered as conclusive proof of waves acting.

Einstein would apply himself to quantum theory all his life. After the publication of his light-quantum hypothesis, however, his investigations on the nature of space and time came to the forefront.

Around 1900, the classical disciplines of physics had been completed in their main features. What one knows as classical mechanics today was provided as a complete theory by Isaac Newton (1643–1727) more than 300 years ago. Meanwhile, it turned out to be a valid border case of Einstein's theory of relativity. James Clerk Maxwell, on the other hand, united the broad domains of electric and magnetic effects within a single theory of electromagnetism, based on four fundamental equations that provide the undisputed classical frame to this day.

After the turn of the 20th century, insurmountable problems arose at the borderland between mechanics and electrodynamics. Elegant attempts at solutions were suggested by Hendrik Antoon Lorentz and Henri Poincaré, but these turned out to be mathematical gimmicks rather than plausible physical explanations.

Again, it was Albert Einstein who brought about a rebound in 1905. To conserve the universal validity of the principle of relativity (PR, the equivalence of any uniformly moving frame of reference), and without further ado, he ascribed physical reality upon the Lorentz transformations (Lorentz's mathematical gimmick). At the same time, he declared dispensable the concept of the ether that had been postulated centuries earlier; this substance was believed to pervade all space and bodies though it had never been detected. Light and electromagnetic waves should propagate through this ether like sound waves through the air. Last but not least, ether was to provide an absolute frame of reference in Newtonian space.

Together with the universal validity of the PR, the new ideas called into question the classical Newtonian concepts of space and time. They individually lose their rigid, absolute characters and turn from passive subjects to active objects depending on the physical circumstances. Simultaneity becomes relative and depends on the observer's state of motion: Two events, appearing simultaneous to a (say) resting observer A, happen successively to a moving observer B. Following the theory of relativity, clocks run differently for two observers moving with respect to each other; likewise, spatial length measures are different. "From now on space and time apart shall reduce to shadows and only a kind of a union shall keep autonomy," the German mathematician Hermann Minkowski stated. This bizarre issue is frequently illustrated using the twins paradox. An astronaut says good-bye to his twin brother prior to his interstellar flight. In his spacecraft, he would travel through space at 99.5% the speed of light. He returns 10 years later and is greeted by his brother, whereupon both brothers realize they have aged unequally. While the earthling is older by 10 years, there passed only 1 year for the space traveler!

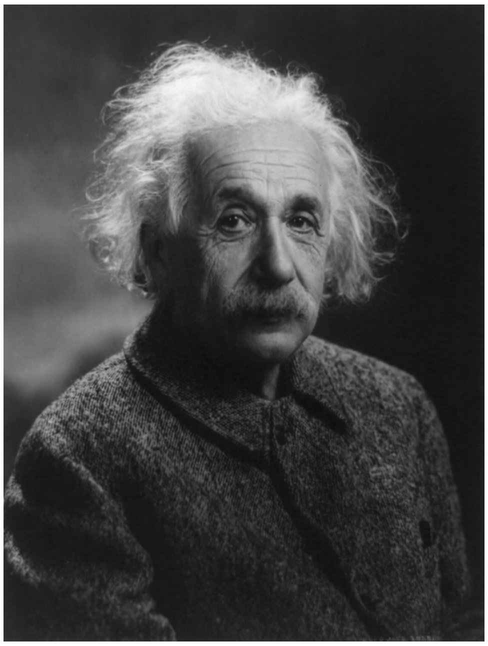
Furthermore, Einstein showed that the new theory implies that the mass and energy content of a body are equivalent. This is expressed in his most famous equation, $E = mc^2$. The relativistic effects of length contraction and time dilation are proved by many experiments today.

Starting in 1907, Einstein tried to generalize the PR for accelerated frames of reference. The PR in the special theory of relativity says it is not possible for an observer to distinguish whether he is placed in a resting or a uniformly moving frame of reference. As a generalization, Einstein introduced the principle of equivalence, the "most felicitous idea in [his] life." An observer in a closed room, such as an elevator or a windowless spaceship, is strictly unable to tell whether he is accelerating in free space or resting in a gravitational field (like on the surface of the earth).

From this principle, Einstein finally overthrows the concept of time and space even more radically than before. Gravitation turns out to be an intrinsic curvature of spacetime. This curvature is in principle comparable to a spherical surface but, beyond any human imagination, in three dimensions instead of two. The curvature of spacetime is caused by the presence of mass-afflicted matter. Vice versa, the curvature causes a body to accelerate. A direct and verifiable implication of the general theory of relativity (GTR) is the deflection of a light beam passing near a massive body (like a star). Einstein's article "The Foundations of the General Theory of Relativity" was published in the *Annalen der Physik* on March 20, 1916.

Three years later, following the war's end, a British expedition led by Sir Arthur Eddington left for West Africa to observe and measure the exact positions of stars appearing close to the obscured sun during a total eclipse. Einstein remarked that his theory would be incorrect if it were not able to correctly predict the deflection of light (and thus the shifted positions of the observed stars). It turned out that the deflection of the starlight passing the gravitational field of the sun was in close agreement with the predictions of the GTR. This verification of Einstein's theory was the onset of his international fame and myth. One week after the confirmation of his theory, Einstein married his cousin (the daughter of his father's cousin), Elsa Löwenthal. In December 1919, he published a popular science book titled *The Special and General Theory of Relativity, Generally Understandable.*

During the following years, many physicists and mathematicians attempted to find solutions for the GTR field equations. Particular significance in this context was achieved in the works by Georges Édouard Lemaître (1894–1966) and Alexander Friedmann (1888–1925). Their solutions



At 16 years old, Einstein tried to imagine what it would be like to ride on a beam of light. Could he travel as fast as light or could he travel faster? In 1905, nearly a decade after this first "thought experiment," Einstein answered these questions with his special theory of relativity.

Source: Library of Congress, Prints & Photographs Division, LC-USZ62–60242.

for homogenous and isotropic spaces constitute the foundation of the cosmological standard model to this day.

Berlin and Princeton

Einstein left Switzerland the year before he submitted his GTR. In Berlin, he was accorded respect by the Prussian Academy of Sciences and given a professorship. He would never re-enter Germany after his emigration in 1933, and he expressed disgust with the "brutality and cowardice" of the Nazi Germans. He states about Berlin: "There's no city ever, I'm more associated to by human and scientific connections."

Though he was exempted from lecture commitments in Berlin, Einstein gave numerous public talks. Sometimes there was such an enormous crowd of attendees that only the largest auditorium in the university could accommodate it. Among his various leading positions within the academic community, perhaps the most noteworthy was his being the chair of the German Physical Society, a position he held as the successor of Max Planck from 1916 to 1918.

In the year of his move, Einstein was sensitized to politics through the outbreak of the Great War. Contrary to the initial national enthusiasm for the war, he pleaded in public for international understanding and called for an immediate end to the war. He campaigned for democracy and pacifism and engaged himself for the Bund Neues Vaterland (New Fatherland Alliance), later renamed the League for Human Rights. After the war, he embraced the anti-monarchic German November Revolution and the ensuing Weimar Republic.

In a famous statement that offended many, Einstein expressed his contempt for war and soldierhood:

> If someone feels pleasure marching lock-step to music in rank and file, he has already earned my contempt. He has been given a big brain by mistake, since for him a spinal cord would be quite enough. This disgrace to civilization should be done away with at once. Heroism on command, senseless violence and deplorable "fatherland" blubbering, how passionately I hate it, how mean and ignoble war seems to me. I would rather be torn to shreds than take part in so base an action! It is my conviction that killing under the cloak of war is nothing but an act of murder.

Being more in the public eye and as a committed advocate of humanistic values, Einstein more and more became a focal point of anti-Semitic hostilities, which occasionally arose even from his circle of colleagues. In particular, Philipp Lenard and Johannes Stark excelled with subjective debates against "Jewish physics" and declared the theories of relativity "degenerations of common sense." As anti-Semitism flourished in Germany and elsewhere in Europe, Einstein reflected on his Jewish roots and joined the Zionist movement. Together with its leader Chaim Weizmann, he traveled across the United States for 2 months. In a show of solidarity in the face of hostility and persecution, he rejoined the Jewish religious community, which he had quit in his earlier days. In 1921, Albert Einstein was awarded the Nobel Prize for his light quantum hypothesis (not for his theories of relativity).

Einstein undertook three more extensive, scientifically motivated journeys to the United States. During his last one, starting in December 1932, Adolf Hitler came into power; immediately Einstein declared that he would not return to Germany. After a trip to Europe, he moved to his adopted city of Princeton in the United States, where he would work at the Institute for Advanced Studies until the end of his life.

In 1939, alerted by the outbreak of the war in Europe, Einstein wrote a letter to the president of the United States, Franklin D. Roosevelt, and advised him to develop a nuclear bomb, in anticipation of the Germans' attempt to do so. Thereupon, Roosevelt initiated the Manhattan Project, culminating in the dropping of two nuclear bombs on the Japanese cities of Hiroshima (August 6, 1945) and Nagasaki (August 9, 1945).

After the end of World War II, shocked by these terrible incidents, Einstein intensively campaigned for armament control and suggested that a world government be established. In November 1952, the Israeli President Chaim Weizmann died. Einstein was immediately offered the presidency, but he declined: "Equations are more significant to me. Policy is for the present but equations are for eternity," he was said to have explained. As one of his last contributions for a peaceful world, he signed a manifesto, written by the British philosopher and mathematician Bertrand Russell, calling for all nations to abstain from nuclear weapons.

On April 15, 1955, Albert Einstein was taken to Princeton Hospital because of internal bleeding. He died on April 18 at the age of 76. In keeping with his wishes, his body was burned to ashes on the same day, but not before a pathologist purloined Einstein's brain during the autopsy.

"God Doesn't Play Dice": Criticism of Quantum Mechanics

In 1926, the young German physicist Werner Heisenberg had published the so-called uncertainty principle. It is the preliminary climax in the evolution of quantum theory, initiated by Max Planck (1900) and Einstein (1905). With the uncertainty principle, Heisenberg expressed the innermost character of quantum mechanics: the turning away from classical strict determinism and the wave–particle duality, which Einstein prepared the ground for with his light-quantum hypothesis. A year later, Heisenberg and his Danish mentor Niels Bohr developed a probabilistic interpretation of the theory (the Copenhagen interpretation), accepted by most physicists today.

Einstein disliked this idea from the beginning. During the Fifth Solvay Meeting, he led a legendary series of lively disputations with his friends and colleagues Niels Bohr and Max Born, but both of them emerged victorious in each case. Some of Einstein's objections to quantum theory Bohr could parry using Einstein's general theory of relativity. But until his death, Einstein was unwilling to accept the dual character of matter, the renunciation of determinism, or the introduction of randomness into physics.

Search for a Unified Theory

The pursuit of structural unity in physical theories arose with the birth of theoretical physics itself. In his historic work *Philosophiæ Naturalis Principia Mathematica* (1687), Isaac Newton had developed a single unified theory to explain the fall of an apple and the journey of a planet around the sun. Another great success of theoretical physics was the unification of electric and magnetic phenomena, developed around 1864 by the Scottish scientist James Clerk Maxwell.

Of the four fundamental forces that physics now recognizes, only two were known in Einstein's time: the electromagnetic and, exhaustively investigated by Einstein, the gravitational force. After the publication and experimental confirmation of his GTR, Einstein for the first time addressed the problem of describing both within a common scheme. He provided a first paper in 1922 and a second one in 1929, accompanied by high expectations within the scientific community.

Like his lifelong but unsuccessful criticisms of quantum mechanics, Einstein's enterprise was to lead to a scientific dilemma that Carl-Friedrich von Weizsäcker called the "tragedy of his late years." Neither Einstein nor any other physicist ever succeeded in unifying gravitation with any other fundamental force. Three of the four forces known today (including the weak and strong interactions) are so far unified in the so-called grand unified theory. To this day, gravitation, with its completely different mathematical structure, resists any such attempt at being unified with the three other forces.

Nature of Time in Relativity

It is by far the most significant effect of relativity that space and time lose their absolute and independent character. *Absolute* means that time intervals do not depend on the observer's state of motion and the presence of gravitational fields. In particular, the term *simultaneity* loses its meaning beyond the context of a certain frame of reference (i.e., a certain observer). Because there is nothing like one frame of reference in the universe being superior to any other, there is no absolute, universally valid measure of time, but only some observer's inherent time or proper time. The loss of independence means that time cannot be considered as a physical quantity independent of space. Rather, time and space generate a four-dimensional coordinate system called spacetime, providing the stage for any physical phenomena.

The twins paradox in principle demonstrates the possibility of time travel to the future in terms of special relativity. However, this would require technical conditions (far out of reach today) for traveling at almost the speed of light over a significant period of time. Furthermore, it would not be possible to travel back to the present, which would require superluminal velocities.

Finally, going back to the general theory of relativity, one insight is that time has (at least) one universal border. Within the framework of the big bang cosmological theory, time begins with the big bang event, which is held to have occurred about 13.7 billion years ago. There is no moment "prior" to the big bang, just as, according to Stephen Hawking, there is no point "north of the north pole." Today, cosmologists maintain that there will be no end to time in the form of a big crunch, as the "reversal big bang" is frequently called. In fact, there are many hints pointing to an eternal, even accelerated, expansion of the universe.

Helmut Hetznecker

See also Cosmogony; Einstein and Newton; Galilei, Galileo; Hawking, Stephen; Light, Speed of; Newton, Isaac; Planck Time; Quantum Mechanics; Relativity, General Theory of; Relativity, Special Theory of; Spacetime, Curvature of; Spacetime Continuum Time, Relativity of

Further Readings

Davies, P. (1995). *About time: Einstein's unfinished revolution.* New York: Touchstone.

Einstein, A. (1961). *The special and general theory* (R. W. Lawson, Trans.). New York: Three Rivers Press.

Folsing, A. (1998). *Albert Einstein: A biography* (E. Osers, Trans.). New York: Penguin.

Greene, B. (2004). *The fabric of the cosmos: Space, time, and the texture of reality.* New York: Vintage Books.

Hoffman, B., & Dukas, H. (Eds.). (1981). *Albert Einstein: The human side.* Princeton, NJ: Princeton University Press.

Isaacson, W. (2007). *Einstein: His life and universe.* New York: Simon & Schuster.

Kaku, M. (2004). *Einstein's cosmos: How Albert Einstein's vision transformed our understanding of space and time.* New York: Norton.

Kaku, M., & Thompson, J. (1995). *Beyond Einstein: The cosmic quest for the theory of the universe.* New York: Anchor Books.

Neffe, J. (2007). *Einstein: A biography* (S. Frisch, Trans.). New York: Farrar, Straus, and Giroux.

Richardson, S. (Ed.). (2008, March). The unknown Einstein [Special issue]. *Discover.*

Einstein and Newton

Albert Einstein (1879–1955) and Isaac Newton (1642–1727) are scientists best known for their contributions to the field of physics in relation to space, time, and other forces within nature. To Newton, space and time were constants, and his philosophy formed the basis of classical physics. Einstein, however, in his famous theory of relativity, proved that space and time were not so easily defined.

Isaac Newton

Isaac Newton was born on Christmas Day, 1642. Newton grew up on his family's agricultural estate, Woolsthorpe, and spent his time working the farm land when he was not in school. Under the supervision of a local apothecary near his boarding school in Grantham, Newton studied Latin, and he constructed wooden models, clocks, and sundials in his spare time. Though he sometimes neglected his schoolwork, his analytical intellect landed him a place at Cambridge's Trinity College in 1661, relieving him of the daily tedium of rural life.

At Cambridge, Newton devoted much of his time to independent study. He read books by René Descartes and Galileo Galilei, reflecting on them in handwritten notebooks. His study of Descartes also led him to read about "analytic geometry," and before long he received a scholarship to continue his studies at Cambridge until he received his B.A. in 1665.

Later that summer, Cambridge shut down because of an outbreak of the bubonic plague, and Newton was forced to return to Woolsthorpe. It was here that he made the discoveries for which he is most famous. The observation of fruit falling from trees let him to deduce that a force attracted them to the earth. From this he pieced together the laws of universal gravitation and developed corresponding formulas for these laws based on the assumption that space and time were unchanging absolutes. Newton used these formulas to estimate the relation between objects in the universe, including the gravitational forces that keep the planets in orbit.

Newton had difficulty proving his calculations to the scientific community, and it was nearly 20 years before he published his findings. He first achieved renown through his experiments with prisms, light, and color. Once accepted as a notable scientist, he published his famous *Principia Mathematica,* and his laws of universal gravitation finally received the acclaim they deserved. Newton also used his knowledge to assist the astronomer Edmund Halley, who utilized Newton's formulas to predict the arrival of the comet that is now named after him. Newton retained a noble status in the scientific community until his death in 1727. Before he died, he was working to find a unified theory to explain matter in relation to the universe.

Albert Einstein

Albert Einstein was born in Ulm, Germany, on March 14, 1879, to a middle-class Jewish family. One of his earliest memories was of his father, showing him a compass with its precise dials and needles, and Einstein wondered about the invisible forces that imparted motion to the magnetized needle. However, he was temperamentally unsuited to submit to the harsh discipline and rote memorization required in the German education system of the day and ended up dropping out of school and leaving Germany at the age of 15.

He joined his parents in Milan, Italy. Einstein thrived in Milan, which was much more open to his free thinking, and it was here that he first formulated visualizations of what would later become his theory of relativity. Although he failed his first attempt at the entrance exam for the prestigious Swiss Federal Institute of Technology in Zurich, he passed the examination a year later and was accepted. At the Swiss Federal Institute of Technology in Zurich Einstein excelled at physics, but he was still a poor student in French and history and only graduated with the help of his classmates.

Einstein was unable to find steady work until 2 years after he graduated. He finally found a stable job in a patent office in Bern, Switzerland, which allowed him spare time to test his physics theories. Einstein worked on his ideas constantly and would even record his thoughts in a notebook when taking his son out for walks.

His efforts soon paid off. He published six papers by early 1905, particularly impressive considering his unsuccessful postgraduate stint. The year 1905 is known as his "miracle year," when his publications changed scientists' ideas of both the Brownian movement (how particles move within water) and the photoelectric effect. In the latter, Einstein proved that light travels as both waves and particles, giving the first evidence of the existence of atoms and earning him the Nobel Prize in 1922.

Einstein's final two papers of 1905 are his most famous; these papers enabled him to expand on what Newton had already discovered. For instance, Newton's laws were able to predict the precise movements of all the planets except Mercury. Einstein's theory of relativity revealed that because Mercury is the planet closest to the sun, it is more affected by the sun's gravitational pull, which causes distortions of space and time within its orbit. These calculations proved that space and time are relative, and they helped astronomers better predict the movements of various objects in the universe. Einstein verified that gravity is also relative, demonstrated in his famous $E = mc^2$ formula, which proves that larger objects have more energy and gravitational pull than smaller objects.

Due to persecution by the Nazis in pre–World War II Germany because of his Jewish heritage, Einstein was forced to relocate to the United States, where he was offered a professorship at Princeton University. Afraid that the Nazis were constructing a powerful bomb, he wrote a letter to U.S. President Franklin D. Roosevelt and encouraged him to launch efforts in building a similar bomb. After U.S. military forces dropped an atomic bomb on the city of Hiroshima in 1945, however, Einstein was emotionally devastated by the terrible loss of human life, and until his death he spoke out passionately against the use of nuclear weapons. He died in 1955, absorbed until the end in his efforts to construct a unified field theory to explain the behavior of all matter within the universe.

Though Newton's findings were based on absolute motion and Einstein's were based on relativity, the two scientists led similar lives. Both had "miracle" years during which they formulated theories that explained the complexities of the universe in a way that enabled scientists to better predict its various phenomena. Both also tried but failed to find a unified theory to explain the behavior of matter within space and time. Most importantly, their theories are still used by scientists to examine the universe's history and nature.

Karen Long

See also Cosmogony; Einstein, Albert; Newton, Isaac; Space, Absolute; Space and Time; Spacetime Continuum; Time, Absolute; Time, Relativity of

Further Readings

Clark, R. W. (1971). *Einstein: The life and times.* New York: World.

Isaacson, W. (2007). *Einstein: His life and universe.* New York: Simon & Schuster.

Mandelbrote, S. (2001). *Footprints of the lion: Isaac Newton at work. Exhibition at Cambridge University Library, 9 October 2001–23 March 2002.* Cambridge, UK: Cambridge University Library.

Pasachoff, N. E. (2007). *Albert Einstein: With profiles of Isaac Newton and J. Robert Oppenheimer.* Chicago: World Book.

Westfall, R. S. (1983). *Never at rest: A biography of Isaac Newton.* Cambridge, UK: Cambridge University Press.

Eliade, Mircea (1907–1986)

As philosopher, historian of religions, novelist, professor, and editor, Mircea Eliade was an extraordinarily erudite scholar whose writings, methodology, and personal biography continue to generate debate in various academic disciplines. Several of his well-known books reflect a fascination with the concepts of time and history, in particular, and still influence the contemporary discussion.

Born in Bucharest, Romania, where he also received his university education, Eliade's interest in philosophy led him to study for 4 years in Calcutta and to spend several months in a Himalayan ashram. These experiences helped to make Eliade an expert on yoga—the subject of his 1933 doctoral dissertation and later book—and broadened his comparative horizons; other writings reflect Eliade's study of Eastern religions, including the Hindu and Buddhist concepts of time and history. His political affiliations caused him to leave Romania after World War II began. Following the war, Eliade taught comparative religion for 10 years in Paris, where he developed many of his seminal ideas. In 1957, Eliade came to the United States and began teaching at the University of Chicago, where he exercised tremendous influence as chair of the history of religions department for nearly 3 decades. By all standards, Eliade was a gifted and prolific writer; he published over 1,300 items, including a number of popular and influential books—two of which incorporate his major treatments of time and history, namely, *Cosmos and History: The Myth of the Eternal Return* and *The Sacred and the Profane: The Nature of Religion.* Creative and energetic, Mircea Eliade's life and wide-ranging scholarly perspectives remain provocative and controversial.

Repeated use of a technical vocabulary, some of whose terms Eliade created or used in an idiosyncratic manner, reflects his fascination with the concepts of time and history. Among the world's ancient (or "archaic") and modern cultures, he identified two different perspectives on time. On the one hand, a religious person (*homo religiosus*) divided time into two categories: "sacred" and "profane." The former refers to time associated with religious festivals and other occasions (hierophanies) that recall and regenerate (or "reactualize") the mythical time of origins. On the other hand, a modern, nonreligious person does not experience this sacred time but lives in the mundane world of ordinary historic time. Members of this secular (or profane) society do not have access to *illud tempus,* the mythical, ideal time that gives meaning to life. In Eliade's analysis, myths reach across time and provide explanations of what took place and how things came into existence at the beginning of time (*ab origine*) and provide examples for human behavior. Eliade also emphasized the distinction between cultures that perceived time as cyclical and allowed for periodic reoccurrences of sacred, primordial time ("myth of the eternal return") and those that did not. The latter saw history as linear and irreversible, and Eliade emphasized the special place of history in the noncyclical perspective of the Judeo-Christian tradition.

Time—its passage and our experience of it—is also a major theme in Eliade's fiction, as seen, for example, in the character Stephane in *The Forbidden Forest.* Eliade advocated a new humanist agenda and wanted his readers, who live in a desacralized world, to rediscover the sacred in their lives—including its manifestations in space and time.

Gerald L. Mattingly

See also Anthropology; Cosmology, Cyclic; Eternal Recurrence; Evolution, Cultural; Mythology; Nietzsche, Friedrich; Religions and Time; Time, Sacred

Further Readings

Allen, D. (2002). *Myth and religion in Mircea Eliade.* London: Routledge.

Eliade, M. (1954). *Cosmos and history: The myth of the eternal return.* Princeton, NJ: Princeton University Press.

Eliade, M. (1959). *The sacred and the profane: The nature of religion.* New York: Harcourt, Brace & World.

Rennie, B. S. (Ed.). (2000). *Changing religious worlds: The meaning and end of Mircea Eliade.* Albany: State University of New York Press.

Rennie, B. S. (Ed.). (2006). *Mircea Eliade: A critical reader.* Oakville, CT: Equinox.

Rennie, B. S. (Ed.). (2007). *The international Eliade.* Albany: State University of New York Press.

Eliot, T. S. (1888–1965)

Anglo-American poet and critic, Thomas Stearns Eliot exerted a major influence on modern English poetry and became a prominent literary figure during the post–World War I to World War II period. His poetry opposed the major intellectual worldviews of modern Europe, going against the current of modernism in philosophy. Eliot's concept of time develops and plays a prominent role in several of his most popular poems: "The Love Song of J. Alfred Prufrock" (1917), "Gerontion" and *The Satires* (1920), "The Waste Land" (1922), "The Hollow Men" (1925), "Ash Wednesday" and the *Ariel Poems* (1930), and *Four Quartets* (1943). The themes of time, timelessness, and eternity, as they relate to the Christian concept of salvation, reappear in his works as he questioned the disintegration of modern European culture and approached the concept of time according to his own faith. Eliot also founded the journal *Criterion* in 1922 (which he edited until 1939), worked as an editor for the London publisher Faber and Faber, and wrote plays and literary criticism. His most popular drama, *Murder in the Cathedral* (1935), depicts the events surrounding the death of Saint Thomas Becket.

Born in St. Louis, Missouri, in September of 1888, Eliot received his education and training as a writer from Harvard University and Merton College, Oxford, and during brief studies abroad in France and Germany. Eliot studied the French symbolists, the English metaphysical poets, Elizabethan drama, and Dante. In September 1914, Eliot became friends with the American expatriate writer Ezra Pound, who supported Eliot as a rising poet and helped him to publish some of his earlier poetry; Eliot would later dedicate *The Waste Land* to Pound. In 1915, Eliot married a British woman, Vivien Haigh-Wood, and he became an British subject and member of the Anglican Church in 1927. The marriage was troubled and ended in separation; the couple had been apart for several years at the time of Vivien's death in 1947. Eliot received the Order of Merit and Nobel Prize in Literature in 1948. In 1957 he married again, to his long-time secretary, Valerie Fletcher.

Throughout Eliot's poetry, one can see a transformation in the treatment and interpretation of the concept of time. The characters in his earlier works were conscious of the passing of time and the recurring patterns of monotonous daily routines. For Eliot, the modern temporal world offered no hope or salvation, and these early poems reflected that despair, loneliness, and sense of meaninglessness. He perceived 20th-century Europe's concept of progress as offering people false hope and deceiving the world about the reality of life beyond the temporal. Therefore, his later works explore the possibility of transcending earthly existence and finding timeless eternity, full of meaning, purpose, and hope.

One of Eliot's most complex works, *Four Quartets,* offers the best expression of his concept of time. *Four Quartets* is a collection of poems that offer a different and changing perspective on time and how humans experience that time. In "Burnt Norton," time is eternally present with no beginning or ending; in "East Coker," time represents cycles with seasonal and life changes; in "The Dry Salvages," the mood shifts to a meaningless view of time without purpose or direction; and in "Little Gidding," the theme of time reappears as eternity but is seen as past, present, and future time. In Eliot's personal experience, the faith of Christianity offered hope and gave meaning to the temporal world. Although he did not openly identify Christianity in his poetry, the language and ideas reflect Eliot's emphasis on humanity and God, timeless eternity, and the Incarnation of Christ.

Leslie A. Mattingly

See also Christianity; Donne, John; Novels, Time in; Poetry; Salvation; Shakespeare's Sonnets

Further Readings

Bergsten, S. (1973). *Time and eternity: A study in the structure and symbolism of T. S. Eliot's* Four Quartets. New York: Humanities Press.

Eliot, T. S. (1952). *The complete poetry and plays 1909–1950.* Orlando, FL: Harcourt Brace.

Gish, N. K. (1981). *Time in the poetry of T. S. Eliot: A study in structure and theme.* Totowa, NJ: Barnes & Noble Books.

Weitz, M. (1952). T. S. Eliot: Time as a mode of salvation. *Sewanee Review, 60*(1), 48–64.

ELIXIR OF LIFE

According to legend, the elixir of life is a potion created through alchemy that grants immortality and perpetual youthfulness or creates life. The word *elixir* comes from the transliterated Arabic *al-iksir* meaning "essence." The concept of the elixir of life is associated with Eastern traditions, namely, those of China and India; the Western traditions are more closely associated with the concept of the philosopher's stone.

There is some uncertainty as to where alchemy began, but in China and India the elixir of life was the primary object of alchemical research. Although the focus was on life extension, the transmutation of base metals (mercury and lead) to higher or noble metals (gold and silver) was a by-product in these countries. This was probably due to the culture: Although acquisition of wealth was discouraged, the extension of life was considered a dignified pursuit and could therefore be researched.

Within both the Eastern and Western traditions there are two perspectives: internal (spiritual or philosophical) and external (via elixir, potion, etc.). In China, Taoism influenced both perspectives, and over time the internal perspective became more important. This has been attributed to the rise of Buddhism and the failure to find a less-than-dangerous potion of immortality.

As in all alchemy, metals and other substances were transformed, transfigured, subsumed, and converted into other metals and substances. At this time in China, consuming precious metals or minerals, such as gold, cinnabar, and even jade, was thought to extend one's life. Other substances were added to these mixtures, some dangerous (like lead, arsenic, or quicklime) and others that are not (such as gold and silver). Owing to its various properties, mercury was a highly prized metal that was added to many elixirs, potions, and other alchemical mixtures. We know today how highly toxic mercury is to the human body, and with large doses sometimes added to potions that were eventually consumed, these elixirs actually had an effect opposite to the intention.

In India, as in China, the quest for the elixir of life combined both the internal and external perspectives. But because many Indian alchemists were also priests, they were familiar with the Vedas (the sacred texts of Hinduism), which describe *soma,* a sacred drug that was believed to impart divine qualities to those who drank it, including immortality. Because the Vedas discuss soma at length, the external perspective concentrated more on medicinal herbs and mixtures for healing and rejuvenating. Such experimentation eventually led to the modern science of pharmacology and the global pharmaceutical industry. (In recent decades, with the rise of "alternative" medicine, herbs and other natural remedies have become the focus of renewed interest.) It has been suggested that the elixir of life in India was soma, which today is believed to be caffeine, ephedra, ginseng, or one of many other botanical extracts.

The search for the elixir of life declined in these two countries when the focus turned inward, to the spiritual and philosophical, based on a growing belief that the path to immortality was not achievable through an external source but only through an inner transformation.

Timothy Binga

See also Longevity; Shangri-La, Myth of; Youth, Fountain of

Further Readings

Holmyard, E. J. (1957). *Alchemy.* Baltimore, MD: Penguin.

Thorndike, L. (1953). *A history of magic and experimental science.* New York: Columbia University Press.

Emergence

See Alexander, Samuel

Emotions

Although emotions did not play a significant role in modern philosophical discussion up to the 1970s, today they form an important subject of philosophical inquiry. If one considers a broader historical context, however, this discovery of emotions in practical philosophy turns out to be a rediscovery. From antiquity to the Middle Ages, a discourse on "passions" and "affections" was an integral part of moral philosophy and ethics. Although Aristotle, the Stoics, Saint Augustine of Hippo, and Saint Thomas Aquinas had widely diverging opinions about the role emotions should play in ethics, they all agreed upon the importance of emotions for the moral life. Up to the 18th century, when the English and Scottish moralists (Shaftesbury, Butler, Hume, and Smith) centered their moral philosophies around "moral sentiments" and when Rousseau traced back any sort of moral behavior to the pure feeling of "commiseration," emotions continued to be at the core of morality. Yet, with the triumph of positivism in the social sciences and the birth of scientific psychology in the 19th century, emotions were reduced to mere biophysiological phenomena that had to be dealt with in a purely functional sense. Against the background of the Cartesian distinction between spirit and matter, emotions were categorized as belonging to the body without having any cognitive content. Emotions as a whole were thus reduced to what the classical discourse on emotion had classified as "appetites" and "passions." From such noncognitive drives, the classical discourse had distinguished more subtle emotional phenomena like "affections" or "sentiments" that belonged to the higher parts of the soul.

The contemporary revisionist discourse on emotions has taken up this strand of thought. The now-prevailing cognitive approach to the emotions distinguishes emotions proper from mere physical drives like bodily appetites by their cognitive content. From the cognitivist's viewpoint, emotions are individuated by reference to their characteristic beliefs. One cannot describe the pain that is peculiar to fear without saying that it is pain at the thought of a certain sort of future event that is believed to be impending. It is this intentionality, or "aboutness," of emotions that sets them apart from mere biophysiological reactions to an external or internal stimulus.

This new conception of emotion as a cognitive phenomenon has several consequences for the conception of the interplay of emotionality, sociality, and morality. First, because emotions are no longer seen as mere passive responses to given stimuli, their productive role in shaping and constructing social reality can be addressed. Second, emotions do not only structure social interactions but are, in turn, shaped by social circumstances. They are social constructs. Third, the question of how development and emotionality are linked on the personal and societal level arises. Fourth, the role of emotions in rational decision making and moral reasoning has to be reconsidered. In all of the four points, special emphasis is put on the relationship between emotions and time.

Emotions and the Social Construction of the World

Mainstream sociology stresses the role of cognition and action in the social construction of the world. With a cognitive conception of emotion in mind, however, an emotional construction of the world becomes no less plausible. How emotions structure our apprehension of reality can be made clear by reference to the first cognitive theorist of the emotions, namely, Aristotle. In Book Two of his *Rhetoric,* Aristotle treats emotions (*pathé*) as "that which causes people to change with respect to their judgement." For example, becoming ashamed of a person involves being led to view that person as involved in misdeeds that bring dishonor. Anger involves the view that somebody has insulted one, and so on. To be moved to a certain emotion involves making the judgment constitutive of the emotion and excludes other judgments. Being moved to envy does not allow one to be moved to pity toward the same person at the same time. The judgment implicit in an emotion influences the way in which we view the world.

In addition to this cognitive modulation of our worldview, emotions affect our perception. As common experience shows, one is easily deceived about perceptions when one is in emotional states. What something is perceived as differs for people moved by different emotions. Ronald de Sousa thus compares emotions to paradigms, which are how we see the world.

This insight in the role of emotions as partly constitutive of our way of viewing the world is most clearly expressed in Martin Heidegger's *Being and Time,* in which he refers to Aristotle's *Rhetoric* as the first account of our necessarily emotional being-in-the-world. For Heidegger our "affectedness" is constitutive of our cognitive and performative ways of being in the world. Hence, for Heidegger, the emotional construction of the world is the most fundamental one.

If our emotions are at the core of the social construction of the world, what then is their relation to time? Three points can be made. First, emotions shape our subjective experience of time. While we are depressed or bored, for example, things seem to be stretched in time. On the contrary, our being angry, stirred up, or stressed results in an acceleration of time-experience. Second, emotions can be differentiated as to their relatedness to the past, the present, or the future. Past-directed emotions like gratitude and guilt relate to something that occurred in the past. By contrast, present-directed emotions like love, hatred, courage, anger, joy, and sorrow are feelings that relate to something that, although it may have happened in the past, continues to affect us. Although, as in past-directed emotions, one may love somebody in part for what he or she did in the past, love also demands that we love the person as he or she presently is. Future-directed emotions, such as hope, despair, and fear, refer to states of affairs that have not yet happened but that are expected to come about with more or less likelihood (fear, hope) or with certainty (despair).

According to Heidegger, a third claim can be made. Because emotions have a temporal structure, it is through the experience of emotions that the temporality of time is grasped. Emotions make accessible to us the fact that our being-in-the-world is in principle embedded into temporal horizons. Experienced time necessarily has an emotional quality.

Emotions as Cultural Concepts

On the noncognitive scientific account, emotions are biologically determined reactions that are (more or less) universally dispersed among humans and primates. Charles Darwin and other 19th-century biologists and psychologists tried to conceptualize emotions as biologically determined patterns of instinctive behavior. Recent anthropological and ethnological research, however, has uncovered the cultural diversity of emotionality. Darwin and his fellows were right insofar as some basic emotions, like hunger, fear, anger, sorrow, and joy, seem to be universal and in fact do have an innate type of bodily expression. But more sophisticated emotions like envy, compassion, and guilt are clearly socially shaped and differ from culture to culture. Opinions diverge on whether these culturally shaped emotions retain a robust essence untouched by social and cultural context or whether they are socially constructed through and through. Yet, no matter whether the emotions themselves or only the emotion-triggering stimuli are culturally determined, it is well established that emotive cultures vary strongly over time. Every culture establishes certain "feeling-rules," which regulate the expression of emotions and which have to be accommodated by "feeling-work."

Emotion and Development

It is a commonplace that an individual's life is emotion-laden in its earlier stages and becomes calmer as one gets older. This is one reason why wisdom is usually attributed to old people. In developmental psychology, the formation of our cognitive capacities is associated with the balancing of our emotions. In Piaget's genetic epistemology as well as in Freud's psychoanalysis, the development of our cognitive structures goes hand in hand with the formation of affect-control.

Sigmund Freud, the founder of psychoanalysis, applied this conception of individual development to the evolution of collective entities. According to Freud, civilization may be understood as a collective process in the course of which affect-control is established on the level of society and its institutions. Whereas for Freud this process is a fragile one, because the natural drives cannot be fully tamed, Norbert Elias develops a much more optimistic view in his influential work on the *Civilizing Process*. According to his interpretation, Western history since the Middle Ages can be reconstructed as a progress in the history of manners and morals. For Elias, the state's monopolization of the use of legitimate physical force and the emergence of a capitalist economic system bring about the gradual abandonment of the emotional laissez-faire that was characteristic of the medieval warrior societies. Already in the high court society (*höfische Gesellschaft*) governed by a code of etiquette, the unstable emotional life is partly overcome by regulations of civility. The absolutist society of the 17th century and the modern nation-state are further steps in the process of civilization, which is marked by the internalization of constraints and the strengthening of affect-control.

Elias's teleological and overly optimistic account of history has been criticized from various perspectives. Some contemporary sociologists maintain that at least since the 1970s, the process of civilization as defined by affect-control has been reversed. The liberalization of sexual morality, the stirring of emotions by mass media reporting, and the emotionalization of politics have reintroduced emotions into public and political life. Whereas critics urge that this trend toward re-emotionalization be seen as a process of de-civilization, cognitivist theorists of emotion argue that this need not be so. To judge whether the resurgence of emotions poses a threat to the current state of civilization, the relationship between emotions and rationality must be explored.

Emotion and Rationality

The reconstruction of occidental history as a process of progressive civilization rests upon the underlying assumption that emotions are irrational forces that have to be suppressed, canalized, or transformed by rational institutions. In Max Weber's terminology, the "rationalization" of society presupposes the mastery of reason over emotion. In this perspective, the civilizing process can be seen as a process of rationalization precisely in that it involves the strengthening of affect-control. Rationalization, then, is coextensive with the de-emotionalization of public conduct.

The view that emotions are the opponents of rationality is one of the constitutive tenets of occidental philosophy. Even Plato and Aristotle, although more attentive to the positive roles of emotions, put forward a reason versus passion dichotomy that has been deeply influential ever since. Yet, whereas in the reason/passion dualism, the passions were still seen as properties of the soul (if only of its lower part), the emotion/cognition dichotomy employed by current mainstream psychology is even sharper. On this account, emotions are bodily disturbances without any cognitive content whatsoever.

The presumptive irrationality of emotions that is implicit in this dichotomy can be put down to emotion's relationship to time. According to Aristotle's *On the Soul* (III, 10), the supremacy of reason over passion is established by virtue of its broader temporal horizon. Because reason, unlike emotion, takes into account the future benefits that rational action may bring about, rationality entails the capacity to distance oneself from the present emotional states.

In Hobbes's *Man and Citizen* (*De homine*) this argument is taken one step farther. According to Hobbes, humans are rational animals to the degree that they are capable of transcending the present. Thus they are rational animals only because they are providential animals.

By contrast, emotions seem to have an urgent, pressing character (they are, however, not entirely contained in a present-related point of view, as has been pointed out earlier). Because of their shortsightedness, emotions are treated as impediments to rational decision making in classical rational choice theory. As urgent and pressing, they affect the probability and credibility estimates of the agent. Consequently, they lead to irrational belief formation and interfere with the cost–benefit calculation of the agent.

The claim that emotions always hinder rational decision making has been cast into doubt by modern theorists of emotion. De Sousa points out that emotions can actually promote rational behavior. In situations of rational indeterminacy or in cases of indifference, they serve as tiebreakers and promote decisions where no decision could be made by rational deliberation alone. According to de Sousa, emotions are "patterns of salience" that help us find out what is rational at a given moment because they represent to the actor his or her preferences. If it is required that the action be chosen quickly, emotions offer a guide to rational decision making.

The neurologist Antonio Damasio has offered an argument that heads in the same direction. He draws on findings from patients with specific brain lesions that render them emotionally flat. Although these patients retain their other cognitive powers, along with their capacity to react emotionally, they lose their ability to make decisions. Based on these findings, Damasio makes the strong claim that "reduction in emotion may constitute an important source of irrational behavior."

In Damasio as well as in de Sousa, rationality cannot be separated from the emotions. Rather, in order to be rational in a meaningful sense, rationality has to draw upon emotion's capacity to represent to the agent his or her preferences (de Sousa) or to give meaning to otherwise senseless cognitive operations (Damasio).

Emotions and Morality

The relation between emotions and morality can be addressed from the three following perspectives. First, on the *epistemic level,* emotions take part in the formation of moral knowledge. De Sousa's characterization of emotions as patterns of salience and his proposal to illustrate the function of emotions with reference to the role that paradigms play in the formation of theoretical knowledge suggest that only emotions allow us to recover what is morally required. One can even go so far as to maintain that emotions constitute the moral context of our actions. On this account, one does not become angry because a comment is offensive. Rather, the comment appears offensive by virtue of its being an object for anger.

Second, on the *axiological level,* emotions influence our moral evaluations. With a view to the history of ethics, this claim can be illustrated by pointing to the Scottish moralists of the 18th century, David Hume and Adam Smith, whose ethical systems center on the notion of moral sentiments. Critics of this tradition of ethical thought argue that although emotions may serve as the basis of moral evaluations in communitarian contexts, they are incapable of instructing moral action in more complex situations and de-localized contexts. This criticism is in part inspired by the idea that emotions have a narrow temporal horizon and thus cannot transcend the here and now. However, this need not be so. Consider once again the case of past-directed emotions like guilt or future-directed emotions like fear, which play an important role in the contemporary ethical discourse on collective guilt or the rights of future generations.

Third, on the level of the *theory of action,* emotions constitute an important subgroup of motivations for action. The crucial question here is whether emotions as motivations are stable enough to constitute a reliable ground for moral behavior. Two types of emotions can be distinguished by virtue of their timely dimension. Short-lived emotions (mere affects) may instigate a single moral deed. However, they cannot be relied upon because they depend on a situation that serves as a trigger for the emotion. By contrast, a standing emotion (passion) is characterized by its continuity in time: It is a permanent disposition for certain attitudes. For Aristotle, insofar as an emotion is part of a permanent state of mind (*hexis*), it may become part of what he calls "ethical virtues." In his account, a virtue is a "mean" (middle ground) disposition with regard to both passions and actions. Because the right emotional state is an integral part of an ethical virtue, an apparently correct action would cease to count as a virtuous action if it were chosen without the appropriate motivating and reactive emotions.

Florian Weber

See also Aristotle; Darwin, Charles; Ethics; Heidegger, Martin; Morality; Humanism; Values and Time

Further Readings

Aristotle. (2004). *Rhetoric* (W. R. Roberts, Trans.). Mineola, NY: Dover.

Heidegger, M. (1996). *Being and time* (J. Stambaugh, Trans.). Albany: State University of New York Press.

Damasio, A. (1999). *The feeling of what happens: Body and emotion in the making of consciousness.* New York: Harcourt Brace.

De Sousa, R. (1987). *The rationality of emotion.* Cambridge: MIT Press.

Elias, N. (1994). *The civilizing process* (E. Jephcott, Trans.). Oxford, UK: Blackwell.

Hobbes, T. (1978). *Man and citizen* (B. Gert, Trans.). Atlantic Highlands, NJ: Humanities Press.

Empedocles (c. 495–435 BCE)

Empedocles was a Presocratic philosopher, poet, and mystic whose theory of cosmogenesis marks his fame. He was born in the ancient Greek city of Akragas (recently renamed Agrigento) on the coast of Sicily. Popular lore claims that Empedocles was offered the kingship of Akragas after having overthrown the previous oligarchy. Though Empedocles is often cited as being extravagant, and even making claims that he was immortal, he refused the kingship in order to support a democracy. His ideas embraced a temporal framework.

Empedocles was a pupil of Pythagoras and a disciple of Parmenides, two other major Presocratic figures. Borrowing heavily from Parmenides' concepts of the nature of reality and theory of being, along with the Pythagorean theory of opposites, Empedocles applied these principles to his cosmogony and the universe's cyclical nature. Owing to Empedocles' belief in the transmigration of souls, which also stemmed from Pythagorean tradition, he remained a strict vegetarian, believing meat-eating to be a sin, an act of cannibalism. In fact, Empedocles believed his fall from being a potentially divine being (or daimon) stemmed from a past life's sin of eating meat. To complete his catharsis, Empedocles is forced to journey the earth through continuous reincarnations, being rejected by the various combinations of elements, until one day being reunited with the gods, free of pollution.

According to Empedocles, all matter is composed of four primal elements (*stoicheon*). These elements—Earth, Air, Fire, and Water—are each attributed to a god: Hera, Aidoneus, Zeus, and Nestis, respectively. The elements are timeless and indestructible and therefore can be considered divine. To explain the creation of the universe, Empedocles introduces two cosmic forces known as Love (Philia) and Strife (Neikos), which in turn are likened to the gods Aphrodite and Aries. Love is responsible for the unity of the elements, while Strife is responsible for the division of the elements. Because the elements can never be annihilated, only separated and united, all things are eternal, including life. Death, as one knows it, is merely a separation of the elements by Strife, which will soon be rearranged and united by Love.

This elemental theory applies to all aspects of the universe and is undoubtedly what led to Empedocles' evolutionary theory and ideas of natural selection, in anticipation of later philosophers and naturalists such as Herbert Spencer and Charles Darwin, respectively. Empedocles claimed that Earth was responsible for the birth of living creatures, each imbued with portions of Water and Fire. In the beginning, however, all were masses of disembodied organs. Through the force of Love, the organs would join together in different combinations. These combinations would result largely in mutation, filling the world with beings with two heads and human-faced animals, though sometimes perfect combinations would result and would survive and multiply.

Empedocles delivered these postulations in the form of epic verse, which can be found in his two extant works, "On Nature" (*Peri Physeos*) and "Purifications" (*Katharmoi*), the largest body of fragments that remain from any Presocratic philosopher. Whether or not these two works are separate entities has long been a source of scholarly debate, though a recent find of papyrus fragments at the University of Strasbourg may link the two works as part of one larger work.

In addition to being a philosopher, poet, and crude scientist, Empedocles was well known for his mystical feats. There are many accounts of Empedocles performing miracles, healings, and even being consulted for cures. Although these ideas may originate from Empedocles' poems, where he describes himself as a celebrated mystic, one cannot help but believe that Empedocles was often consulted for help because of his knowledge of cosmic affairs. His skill in the art of rhetoric was, without a doubt, another impetus for him to be well received.

To prove his immortality, according to a much celebrated tradition, he threw himself into an active volcano on Mount Etna, the mythical forge of the Greek god Hephaestus, leaving nothing behind but a sandal, which revealed the farce. Most likely a legend, this particular account of Empedocles' death has been dramatized in a play by Friedrich Hölderlin and in the poem "Empedocles on Etna" (1852) by Matthew Arnold. Though Empedocles may not have proved his immortality to his contemporaries, his ideas and notions remain immortal and timeless.

Dustin B. Hummel

See also Anaximander; Anaximines; Heraclitus; Parmenides of Elea; Presocratic Age; Pythagoras of Samos; Thales; Xenophanes

Further Readings

Birx, H. J. (1984). *Theories of evolution.* Springfield, IL: Charles C Thomas.

Visnovsky, E. (2006). Empedocles. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (pp. 809–810). Thousand Oaks, CA: Sage.

End-Time, Beliefs in

As stories of the beginning are provided by any number of religious or secular belief systems, so too are stories of the end. End-time beliefs broadly understood are those things believed about the eschaton, or the end of things: the end of an individual life, the end of a community, the end of the universe, or the end of time itself. End-time beliefs reflect a cultic system's explanation of how the end

This is the third and most famous woodcut from Dürer's series of illustrations for The Apocalypse. (c. 1497). *The* Four Horsemen *presents a dramatically distilled version of the passage from the Book of Revelation (6:1–8).*

of things will come about. These beliefs are based on canonical sources, folk sources in the absence of canonical sources, or creative reinterpretation, willful denial, or simple ignorance of received wisdom whether from folk or canonical sources.

Doctrinal beliefs often differ from popular beliefs. For example, often in the popular Christian imagination the death of the saved is directly followed by their heavenly welcome. However, in the canonical Christian account found in the Book of Revelation, the death of the saved is directly followed by their long wait, along with the damned, for the worldwide bodily resurrection, final judgment, and arrival of God's heavenly city into which the saved are only then finally welcomed.

Varieties of End-Time Beliefs

Literature that reflects end-time beliefs that describe a final catastrophe resulting in the general destruction of life on Earth is generically, though somewhat imprecisely referred to as "apocalyptic" literature. However, the word *apocalypse* is simply an artifact of the Christian influence on world culture. The Book of Revelation (or the Apocalypse of Saint John) in the Christian Bible contains an end-time narrative in the ancient Near East tradition that the writer (or writers) inherited from the Hebrew Bible's Book of Daniel. The word *revelation* rendered in Greek is *ἀποκάλυψις*, or "apocalypse." Based on the influence of this book on Christian and therefore Western literature, a text that follows the style or content of the Book of Revelation, whether written before, during, or after the closing of the Jewish and Christian canons, became referred to as "apocalyptic." The Jewish–Christian form of apocalyptic literature properly includes particular identifying elements such as angelic visitation, numerology, catastrophe, judgment, and final punishments and rewards. Yet narratives that lack one or another apocalyptic element still have been considered apocalypses in the generic sense as long as they include catastrophic events that are to accompany the end-time.

Canonical and noncanonical end-time literature presents a diverse array of end-time beliefs, not all of which contain catastrophe and ultimate destruction. Zoroastrian Persia developed rich and complex end-time scenarios. Here the writers of scripture produced two apocalyptic narratives that provide examples from two decidedly different historical moments. The writers of the more ancient apocalypse recorded in the *Greater Bundahišn* described a general cataclysm that would result in general happiness. Mountains would empty themselves of molten lava enough to cover everything on a newly flattened Earth. "Followers of truth" would experience the molten rivers as a bath of warm milk. "Followers of evil" would experience them as molten rivers but with miraculous results: First, everyone would survive, and second, the experience would occasion a transformation not only of the entire earth but of all humankind. All would begin to speak the same language. All would become followers of truth. Worldwide apocalypse would be followed by worldwide bliss. This particular narrative developed during a time of relative strength and security in the Persian Empire. After the Roman conquest, however, Zoroastrian end-time narratives themselves became more menacing. Writers of the *Oracles of Hystaspes* revealed the catastrophe and chaos that would reign as the end-time drew near; but rather than a worldwide transformation resulting in a happy family of an egalitarian humanity, this end-time scenario resulted in a devastated Rome, an ascendant Asia, and rewards and punishments meted out by a just, mighty, and decidedly pro-Zoroastrian God.

This latter type of end-time belief resembles more the end-time narratives of another kingdom of little strength and even less security: ancient Judah, the seat of Judaism. The appearance of Jewish apocalyptic literature followed the conquest of Judah by the Persian Empire, whose state religion was Zoroastrianism. The apocalypse in the Hebrew Bible's Book of Daniel provided a standard for apocalyptic visions that later Jewish and Christian writers were to emulate. In this likely pseudonymous book, Daniel, the famed Jewish hero, saw visions, received angelic visitations, described fantastical images and events ripe for interpretation, invoked numerical and quizzical secrets, and, like the latter Zoroastrian narrative, ended the scenario with punishments for the evil and rewards for the good.

Over time, a variety of Jewish sects gathered in the hills around Jerusalem and in the Near East, some complete with their own messiahs and all evidently anticipating impending doom. Apocalyptic communities included those at Qumran and the Dead Sea who are known because they left records that have survived. Common end-time beliefs among such groups included the rain of destruction on establishment temples and the divine formation of a new regime and new temple of which the sectarians themselves would be the primary beneficiaries.

During this era, the newly founded Christian sect developed similarly heightened end-time expectations. Early Christian canonical and noncanonical end-time and apocalyptic texts from Matthew to Paul to John the Revelator included the almost immediate return of Jesus, their messiah, who would inaugurate the end-time. But whereas some of the texts referred to the return as happening within the lifetime of the writer or reader, other writers avoided more precise dating than that. Medieval Christian end-time anticipation saw the occasional popular apocalyptic deadline come and go. In the European settling of North America, the Puritans saw the Christian conquest of the continent as proof of the impending end, so they evangelized accordingly in order to speed the apocalypse on.

Islam developed its own apocalyptic narrative that, like the Christian one, owed much to its Jewish prototype. Here again there would be a general resurrection, judgment, and punishments for the evil and rewards for the good. But unlike the many canonical and noncanonical Christian apocalyptic texts, there was little by way of timing the event, much less characterizing it as "soon."

End-time beliefs include a variety of expectations that exist apart from a unifying narrative, written or oral. In Hinduism, for example, although there are certainly texts that include scenarios of the end-time, Hinduism itself contains within it such diverse belief systems that it is virtually impossible to speak of a single Hindu end-time belief. Some Hindu end-time visionaries described cataclysmic ends to the current universe; some, an all-consuming fire; some, an avenging Kalki who would ride on a white horse to transform a holy remnant of humanity and begin a new golden age referred to as the *Krta yuga*. Other, though not mutually exclusive end-time beliefs focus more sublimely on the cosmic closing of Vishnu's eyes that would bring the resolution of the current universe, just as the next opening of his eyes would inaugurate yet another new universe through the "Golden Embryo" that is Brahma. Commonly included in most of these end-time beliefs has been the notion that, of the *yugas* (time units that last hundreds of millions of years) of this universe, the world currently exists in its last and most corrupt phase, the Kali yuga. Precisely how many solar years a yuga includes and where the universe lies in the span of this yuga has provided a source of considerable speculation. Because of this lack of agreement on when the end-time may arrive, Hinduism's long history has been punctuated by incidents of apocalyptic fervor whenever believers have expected that the end was at hand.

Buddhist end-time beliefs have been established primarily among Mahayana Buddhism and have focused primarily on the Maitreya Buddha. Writers of Mahayana Buddhist scriptures looked forward to the Maitreya Buddha, who would bring in his wake the end of the world as we know it, with or without a catastrophic prelude. End-time beliefs of Mahayana Buddhism do not appear to necessitate widespread immorality or decay but do anticipate the complete abandonment of Buddha's teachings or *dharma*. In the wake of a world that would completely forget Buddha Shakyamuni's (also spelled *Sakyamuni*) dharma, the Maitreya Buddha would arrive as the new and final Buddha. Some of the end-time visionaries anticipated that the final Buddha would be the world's ruler, who would teach pure dharma that would bring an end to war, disease, and even death, effecting a transformation of the world as we know it but not its end.

End-time beliefs exist not only within universalizing cultic systems but also within the religious imagination that is more local in scope. Local or regional cults, however, offer the added interpretive challenge of distinguishing between indigenous and colonizing beliefs. Native American end-time narratives, for example, stubbornly frustrate attempts to separate original elements from Christian incursions. End-time beliefs that have incorporated obvious influences from the colonizing cult of Christianity include, perhaps most famously, the multitribal Ghost Dance of the late 19th century. This apocalyptic cult developed from the vision of a Paiute shaman named Wovoka, who prophesied the final coming of Christ, a new Earth that would be inherited by Indian peoples, and, in some accounts, the obliteration of all white peoples.

Other end-time beliefs appear to have less explicitly Christian influence. Originators of the White Buffalo Calf Woman legend of the Lakota Sioux, for example, spoke of the promise of her return. Far from being apocalyptic, this "return" would encourage transformation through human, cultic, or environmental renewal on the rare occasion of the birth of a white buffalo. Yet, although centuries-old versions of the story lack any accompanying end-time expectation, the mere fact of the explicit "return" narrative has fueled end-time speculation when white buffalos have been calved.

Modern end-time cults offer a blend of secular anxiety and New Age interpretations of traditional religion that results in the cult's particular recipe for apocalypse. Rather than developing their own end-time narratives, these cult systems have usually accepted the inherited end-time narratives of the predominant religious tradition and have modified that narrative depending on the cult's own doctrinal particularities. In this sense they can be seen as amalgam cults that not infrequently include conscious or subconscious accommodation to modernity. Examples include Japanese end-time cults based in Buddhism, Shintōism, Christianity, new religious movements, or combinations thereof; and American end-time cults being based in Christian apocalypticism onto which New Age elements can be grafted. Like their historic Christian predecessors, non- or quasi-Christian cults such as Heaven's Gate, People's Temple, and the Branch Davidians of Waco, Texas, have had immediate end-time expectations. Some of these expectations have been realized through cult members' own actions, for example, when People's Temple or Heaven's Gate members realized their own communal end-time through mass suicide.

In addition to explicitly religious end-time beliefs, nominally secular environmental activists have taken on quasi-religious fervor in their beliefs that the end-time is near. These beliefs have included the idea that humanity actively perpetuates the species' own demise or even ecocide. Such beliefs have inspired some to work to interrupt or reverse the environmental degradation. Others have sought to promote the environmental decay, hastening the decimation or destruction of the human species in order to save the planet for other, more benign life forms.

Apocalypticism

Fervent belief in the apocalypse, no matter its religious or secular origin, can take on characteristics of being a religion itself. A belief system that focuses on an apocalyptic end-time is sometimes referred to as apocalypticism. In a world where end-time books and films have proliferated and record numbers of Americans have believed that some Christian apocalyptic vision would be realized in their lifetime, apocalypticism carries tremendous cultural, social, and political power.

Throughout the history of apocalyptic movements, the marginalized, colonized, and persecuted have been attracted to apocalypses that could promise the destruction of the persecutors and the reversal of the social hierarchy. Ancient Persian Zoroastrians provided a classic example of end-time beliefs from both of these divergent cultural contexts: An ascendant Persia produced an end-time narrative resulting in blissful global family reunion, and an occupied Persia produced an apocalypse ending in bliss for the Zoroastrian faithful but doom for their Roman invaders. Currently, however, it has been leaders and significant numbers of people in the wealthiest and most powerful countries who have been vigorous promoters of apocalypticism, with some of these leaders controlling the military wherewithal to create an apocalyptic reality. This makes understanding apocalypticism a serious if not urgent area of study.

American Christian apocalypticism has continued the tradition inherited from early Christianity, the medieval church, and the Puritans that the end-time is near. Two thousand years figures prominently in the mythology of the Christian eschaton, based on the most liberal interpretation of the end-time timeline in the Book of Revelation. After the year 2000 CE arrived without the anticipated apocalypse, some Christian apocalypticists extended that 2,000-year marker, revising it to some time within a generation of the turn of the millennium. Due to some perceived problems with the accuracy of the Christian calendar, some have extended the coming apocalypse to centuries in the future.

Concluding Remarks

Topics common to end-time beliefs have included (1) timelines; (2) speculation on the origin of the end-time; (3) dualistic elements of (a) particularity versus universality, (b) bliss versus punishment, and (c) global transformation versus annihilation; and finally, (4) the appropriate cultic responses to the coming end.

Timelines of end-time beliefs vary from "soon" to "far in the future." Rare is the end-time vision that has provided precise names and dates. And when that has occurred, their followers have been prone to find room for interpretive liberality once that date has passed or the history of the named person has failed to fit the prophecy.

Speculation about the ultimate source of the end-time itself varies in connection with the theological commitments of the believer. End-time beliefs of theistic cults favor divine or semidivine retribution. Nontheistic cults such as Buddhism and secular beliefs such as those of environmentally committed activists often invoke themes of a humanity that would bring about its own destruction.

Dualistic elements such as universal bliss versus universal punishment abound between competing narratives as well as sometimes within the same end-time scenario. The writers of the Book of Revelation, for example, seem to have invited various and self-contradictory interpretations regarding whether sinners would be permanently tortured, fatally extinguished, or miraculously renewed and made ready to enter a new Earth where the only distinction between the renewed sinner and the saint would be the inability of the former to enter the heavenly city. Thematic elements also vary such as whether the apocalypse would result in a complete or a partial catastrophe and whether the destiny of the planet would include total destruction on one extreme versus complete renewal on the other, with interim possibilities including partial renewal or partial destruction.

Finally, end-time beliefs have inspired various responses from their believers in the form of cultic or social action. Some end-time beliefs simply demand that their particular end-time story be read or told. Others encourage cult members to ritually enact the main elements of the narrative. And, rarely, still other belief systems encourage the instigation of actions to effect the conditions for the beginning of the end-time itself. Some believers act to forestall the end-time. Others work to speed the end-time along.

David V. McFarland

See also Apocalypse; Bible and Time; Christianity; Ecclesiastes, Book of; Judaism; Nirvana; Parousia; Revelation, Book of; Time, End of; Time, Sacred; Zoroaster

Further Readings

Cohn, N. (1993). *Cosmos, chaos, and the world to come: The ancient roots of apocalyptic faith.* New Haven, CT: Yale University Press.

Lincoln, B. (1983). The earth becomes flat: A study of apocalyptic imagery. *Comparative Studies in Society and History,* 25(1), 136–153.

Strozier, C. (1994). *Apocalypse: On the psychology of fundamentalism in America.* Boston: Beacon Press.

Thompson, D. (1996). *The end of time: Faith and fear in the shadow of the millennium.* London: Sinclair-Stevenson.

Engels, Friedrich (1820–1895)

Friedrich Engels was born on November 28, 1820, in Barmen, which was, at that time, part of Prussia. Engels's father was a prosperous German industrialist. Young Engels attended the *Gymnasium* (secondary school) in Elberfeld in 1834. Liberal freethinkers directed the school. By 1837, Engels openly expressed sympathy with radical humanism and militant democratic ideas. In 1838, Engels moved to Bremen, Saxony, to train as a factory manager for the firm of Heinrick Leupold. Engels found that liberal ideas were more openly articulated in Bremen.

In 1839, Engels published an article that attacked the absurd mysticism of pietism. Engels claimed that this ideology was closely linked to the major social ills of Germany and that it justified the wealth of the moneyed elite. Owners who were deeply religious were morally responsible for the pain of child labor. It was justifiable to blame the owners for the poverty and suffering of the working class.

In November 1842, Engels moved to Manchester, England. He went to work at the Victoria Mill office of Ermen and Engels in Manchester. This operation manufactured yarn and sewing thread. During the working day, Engels was a hard-working industrialist. At night, he became a social researcher and labor militant, hanging around the grimy, perilous streets of the Manchester working-class slums. Manchester was, at this time, a major center of the most revolutionary elements in the Chartist movement. Though born into a capitalist family and working as a manager in his family's business, he openly sided with the revolutionary proletariat. Engels began his famous study on the conditions of the English working class. This became the data for his book *The Condition of the Working Class in England in 1844*. This book detailed the life of the industrial proletariat in an advanced industrial capitalist nation. Under such conditions, antagonisms with the bourgeoisie were open and strong. The Industrial Revolution converted tools into machines. Tools, which were extensions of the workers, distorted the worker into an extension of the machine. Because of the dehumanization of the industrial proletariat, the middle class, which became the new ruling class, found that its enemy was no longer the feudal aristocracy but its own workers.

Next, Engels began a serious study of the history and evolution of the sciences. The philosophy of the 18th-century materialist philosophers of France and England provided the connection between philosophy and science. However, the materialism of the 18th century was seriously limited. Materialism needed to be merged with the dialectical logic of Georg Wilhelm Friedrich Hegel. Engels, along with Karl Marx, also wrote in refutation of both the young Hegelians and their master Ludwig Feuerbach. This radical secular humanism would not provide the ideology needed to organize a working-class movement in its struggle for socialism.

The Thesis

This was the thesis of the emerging German ideology: The real history of humanity begins with people providing for their material necessities of life through their practical activities of taking care of their physical needs. It is through labor that people connect with nature and with each other. This link between the forces of production and the relations of production set into motion all the changes in history. When forces and relations of production no longer support each other, revolutionary changes in society take place. The production of material life defines the possibilities of the social, cultural, and political life of a people. In a stratified society, all ideas have class content. The ideas of the ruling class are the ruling ideas. These ideas reinforce the economic and political power of the ruling class. Private property and a market economy come together over time to concentrate the resources and products of production under the control of a very few wealthy owners. The majority of the population of direct producers is forced, by fear of hunger, to sell their labor power in order to survive. The workers can end this oppression by abolishing private property.

It was at this time that Engels and Karl Marx became close colleagues and partners. Over the next 50 years, Engels would carry out his close collaboration with Marx. Engels's contribution to the intellectual traditions of Marxism was based upon his initial proficiency in economics and science.

Engels wrote about science and social science. The writing of *Anti-Dühring* was a defense of historical materialism against not only a watered-down eclecticism but also an insipid assortment of idealism, materialism, and fabrication. The study of an object or event in the context of its larger historical and environmental setting, scientifically and methodically, was central to materialism. This study recognized that change is always happening and that it can be understood dialectically. The unity and conflict of opposites and the transformation of quantity into quality were Engels's explanations of how all this was achieved.

Materialism states that physical matter is reality and humans are a historical product of the environment, both social and physical. However, if one does not recognize the dialectical nature of everything, the research will miss the mark. Constantly changing reality, with a material basis, is true for history, sociology, biology, or physics. Through historical materialism, it is possible to understand the conditions that were elemental for the origins of capitalism. It now becomes possible to understand the subsequent development and changes of capitalism as a world system.

Capitalism expanded from its homeland to the rest of the globe, demolishing, integrating, or containing preexisting economic systems. Class conflict, economic crisis, colonialism, and nationalism were natural consequences of private property, expanding markets, production for profit, and the culture of individualism. Industrial markets expand and transform every nation. Private ownership and competition in a world market lead to increased productive resources being concentrated into fewer hands. When companies become larger, more people are stripped of their resources; with the exception of their ability to work for wages. This leads to the majority of the world's population being controlled by a socially organized system of production and exchange. Historically, the social role of the capitalist changes over time from entrepreneur to investor and from innovator to parasite. The contradictions between the forces of production and the relations of production lead to a revolution not only in technology and social organization but also in the culture of everyday life.

Dialectical Materialism, Science, and History

Engels was seriously interested in advances made in all the sciences. Knowledge of mathematics and the natural sciences was essential in order to comprehend a materialist method that would also be dialectical. It was implicit that anything studied was in a process of change, coming into existence and ceasing to exist at the same time. Matter in motion is seen everywhere. The universe itself is changing, evolving, dying, and being born at every moment. In the process of change, what exists is being replaced by something new, fashioned out of what went before.

Because of this, science itself is founded upon philosophical materialism. As science evolves, teleological arguments are harder to justify. Interconnections can be observed and then presented as facts. Problems like biological evolution, conservation, the transformation of energy, and new discoveries in organic chemistry are better understood from a model that is both dialectical and materialist.

Science best matures as an interaction between theory and practice. From observation, we derive scientific experiments, and then we develop theories that have practical applications. From these applications, new observations and experiments are conceived. Philosophy is never superseded by science, but science itself is historically and culturally embedded in a set of specific historic preconditions. Freed from religion and magical beliefs, science is founded on materialist philosophy that uses the dialectical logic of understanding.

In *The Part Played by Labor in the Transition From Ape to Man,* Engels argues that human evolution had a long historical development in which labor and early use of tools, once being established among our hominoid ancestors, played an important role in further human biological evolution. This interaction between human creation and the physical evolution of humans demonstrates the importance of using a research model based on interaction of parts rather than simple unidirectional cause and effect.

Engels gathered a copious amount of notes on what was current in natural science. These notes would become *Dialectics of Nature,* posthumously published in 1924. Following is a summary of the book's argument.

Central to the evolving universe is a conflict of opposites merging continuously into something new. Objectively, these movements follow law-like patterns. Subjectively, these patterns are interpreted and reflected in a people's ideology and consciousness (culture). At any time everything is coming into being and ceasing to exist. The subjective reflection of this, while seen as absolute and unchanging "truth," is in fact continuously reinvented and reinterpreted.

The universe consists of matter in motion, changing through time and space. The earth and all the bodies in the cosmos arose from a random collection of atoms, acting in the course of objective law, like patterns that can be discovered by the use of the scientific method. Because all parts interact and modify all other interacting parts, change is constant everywhere in the universe. Thus, any method of inquiry should be both materialist and dialectical.

People evolved from less-developed biological organisms. Because human consciousness is a function of the human brain, consciousness is also a function of human evolution. Ideology and culture result from this consciousness and are a part of human evolution. Slowly, the transition from simple neural response to external stimuli to complex cultural awareness evolves.

Engels would claim that walking upright was central to the evolution of the highly complex human consciousness necessary for human society. An effect of freeing the forelimbs was to make tool-making easier. With more comprehensive tools, a more multifaceted consciousness naturally evolved. The human brain evolved from a common ape ancestor. Humans, through their collective labor, created humanity in a natural environment.

Forces of production, as in technology, environment, and population pressure, are always in conflict with the relations of production, which is the social organization of a society. Conflict in competing ideologies reflects this. Struggles within a society are expressed as opposing values, which reproduce competing interests over production and distribution. Production and redistribution are needed resources of subsistence. Each class within society has its own interpretation of the dominant ideology.

Specifics of history reflect changing historical trends, because of these conflicts. With the constant disintegrations of the old, the raw material for the construction of the new is constantly being created. Small changes accumulate until there is a rapid break with the old order. There are small quantitative changes until there is an abrupt qualitative transformation. This is completed by natural causes, though the ideas of cause and effect are only intellectual tools to understand these changes. Something fundamentally new is created out of the leftovers of the old; these occasions are called "nodal points." Motion arises from this continuous interaction of elements of divisions of a larger whole.

Humans are biological, social, and cultural animals. The production of the means of subsistence at any point in history is the foundation for the creation of culture or ideological superstructure. This being said, the histories of most societies are mapped out by class struggle. Political tussles arise over political control of economic resources. The older classes try to maintain domination of society, and newer emerging classes attempt to obtain that power for their own benefit. The fight is over control of material resources and how they are used in the productive process of a society.

This is an ongoing struggle. The relationships between classes are always in flux. Because of the continuing struggle, changes in the social organization of society reflect the varying ideas. Ideas change to reflect the changing economic needs and relative strength of the competing classes in society. In this evolving culture of conflict, social and political relations in turn change to reflect changing economic relations between the various groups in a society. Given this context, religion, philosophy, art, and culture are produced within a historical context.

In any class society, it was the "small privileged minority" that controlled both the means of production and distribution. The minority benefited from the productive activity of the majority. The wealth of the minority was created by the poverty of the majority. Because of this, control over the direct producers was the primary issue of government and law. All of history is the history of class struggle. Each government reflects a specific mode of production (economy) and the needs of a small ruling class. This is the real foundation of all political, religious, and social conflicts and change.

When people make fallacious assessments about the world, those assessments are not based on rational assumptions that are in turn based upon correct data. When these same people inescapably arrive at goals that are contradictory to a chosen purpose, then no matter how we protest that their decisions were based upon rational assumptions and empirical data, they always lead to unforeseen consequences. It is those choices that lead to the experience of a world beyond our control.

In *The Origin of Family, Private Property and the State,* Engels came to the conclusion that the type of family in any society reflects the property relations and class structure of the society being studied. The family type is, then, historically determined. The type of state that develops when a state society is formed also reflects the specific property relations and is also historically determined. The state is the real meaning of oppression. Each new ruling class overthrows the previous ruling class and creates an all-new state to reflect its interests. The state, then, is always the instrument of oppression. This is true even though every state claims to represent the interests of all people.

Michael Joseph Francisconi

See also Dialectics; Evolution, Cultural; Evolution, Social; Lenin, Vladimir Ilich; Marx, Karl; Materialism

Further Readings

Cameron, K. N. (1995). *Dialectical materialism and modern science.* New York: International Publishers.

Engels, F. (1955). *The condition of the working class in England.* New York: International Publishers. (Original work published 1844)

Engels, F. (1965). *Peasant war in Germany.* New York: International Publishers. (Original work published 1850)

Engels, F. (1970). *The role of force in history.* New York: International Publishers. (Original work published 1895–1896)

Engels, F. (1975). *Origin of the family, private property and the state.* New York: International Publishers. (Original work published 1884)

Engels, F. (1977). *Dialectics of nature.* New York: International Publishers. (Original work published 1883)

Engels, F. (1978). *Anti-Düring.* New York: International Publishers. (Original work published 1887)

Marx, K., & Engels, F. (1970). *The German ideology.* New York: International Publishers.

McLellan, D. (1977). *Friedrich Engels.* New York: Penguin.

Enlightenment, Age of

The Age of the Enlightenment describes a time and a movement rare in history because of the fact that the movement's thinkers actually gave the title to their own period of time. Roughly, the Enlightenment covers the period from 1750 CE to 1800 CE. Enlightenment thought emanated from Europe, especially France, but its consequences spread throughout the world and, pertinently at the time, to the colonies of North America that were to become the United States of America. The changes wrought by the Enlightenment include a rejection of traditional religious and metaphysical ideas, as well as the insistence upon the virtues of freedom, equality, moral dignity, science, and reason. Tied in with these Enlightenment values, however, was a particular conception of time as a continually unfurling process by which progress was made. Thus, time was of crucial importance to Enlightenment philosophers because the passage of time would bring progressively superior ideas about religion and metaphysics as well as greater freedom, equality, moral consciousness, ethical action, and understanding of the universe.

Early Enlightenment

To understand the Enlightenment one must first acknowledge its antecedents. The Enlightenment could not have occurred if not for the historical foundation that buttressed it. This historical foundation includes the accomplishments of reason and logic dating back to ancient Greece. It was in ancient Greece that logic had been used to turn traditional beliefs upside down, and the thinkers of the Enlightenment sought the same outcome in Europe.

Most emblematic of the Enlightenment is the appreciation of reason. Thus, the roots of the Enlightenment in Europe can be traced back as far as Saint Thomas Aquinas, who reinvigorated the ancient Greek logic of Aristotle, attempting to demonstrate harmony between reason and faith. It was at this point in the 13th century that reason began to vie for center stage in European thought, rivaling the religious faith that had been venerated since the fall of Rome and throughout the Dark Ages. The conflict may be seen not just in the philosophy of Aquinas but in literature as well, particularly in Dante Alighieri's *Divine Comedy.*

From the 13th century on, reason vied to sway the European mind, as can be seen by the unfolding of European history afterward. The 14th and 15th centuries saw the rise of the Renaissance and particularly the humanist thinkers who fueled this movement. The humanists defied traditional power structures not just by championing reason but by taking a new attitude toward God, humanity, and the universe. Instead of gloomily dwelling on original sin, they took a more positive and cheerful attitude, arguing that to worship God one must worship his creation, the most beautiful of which was humanity. In fact, the new humanist paradigm envisioned humans as being like God not only in literal image but also in his image in the sense that they too had creative powers. Thus, the outpouring of intellectual and artistic achievement during the Renaissance was rooted in the idea that such works were not sinful but were means of worshipping God.

Also demonstrating a new appreciation of humanity were the changes that came during the Reformation, which followed the Renaissance. The primary change was the appreciation and acceptance of human interpretation of the Bible. This new insistence upon human powers to create and interpret formed the foundation upon which the Enlightenment could unfurl. Furthermore, the emphasis on worshipping God through worship and appreciation of his creation evidences the roots of deism, which was the religion embodied by the Enlightenment.

Finally, the third major social transformation that allowed for the Enlightenment after the Renaissance and the Reformation was the Scientific Revolution. The Scientific Revolution marked a new method of thought, aptly named the scientific method. It was the method advocated by Francis Bacon (1561–1626). It involved observing, questioning, hypothesizing, and experimenting. The Scientific Revolution's impact was felt first in the realm of physics. Nicolaus Copernicus, Johannes Kepler, and Galileo Galilei successfully changed the way that humans thought about the earth and about their relationship to God. No longer was the earth at the center of the universe as had been taught throughout the Dark Ages. It merely revolved around the sun, which was situated in the center. These first scientists who established the heliocentric model as humanity's universal paradigm were followed by Isaac Newton, who made yet another grand leap for science, uncovering natural laws that governed the universe, the most important of which was gravity. Once Newton established the existence of natural laws determining the movements of the universe, humans reasoned that natural laws might govern not only celestial bodies but human populations as well. Thus, the search was on for natural laws that could guide the development and progress of human society.

The Value of Reason

The stage was set for the Enlightenment over a number of centuries that preceded it. New values were championed, such as appreciation of the individual and human power to create, choose, interpret, and act freely. It was only a matter of time before these changes inspired a large and organized movement for social reform. Optimism about the human condition and the grand undertaking to discover natural laws that ordered and directed the progress of society are what would come to characterize the Enlightenment.

Thus, the Enlightenment was an optimistic period marked by the belief in reason, secularism, and progress. The Enlightenment was characterized by the belief that there was a logically deducible reason for everything and that humans could unravel the mysteries of the universe by using the faculties of their own minds. It was believed that with time, the accomplishments of humankind in science and morality would be limitless. Through the use of reason, humans could learn how to manipulate the universe to their every advantage and thereby make the world the most optimal place for human existence. It was believed that through the employment of reason, humans could perfect society and could subsequently perfect themselves as individuals as well. According to Enlightenment thought, human potential was limitless, and in the world there was a correct answer for everything; it was only a matter of time before the answer was found. Thus, a belief in the inevitable fulfillment of people's potential to govern themselves and the world characterized the Enlightenment.

With the Enlightenment came the embrace of subjectivity and freedom as well. Attached to these came a decline in the power of traditional religion and monarchical state authorities. After the Reformation, modern individuals could stand alone in the world, independent and self-reliant, in the sense that they could directly mediate their own relationship to God, bypassing the previous mediator that had existed in the Catholic Church. The Enlightenment marked a leap even grander than this, as many began to abandon Christianity completely in favor of more rebellious ideas such as those of deism, or even naturalism, in which assumptions of divine intervention and guidance are laid to rest. In addition to the religious shift came an economic shift as well, as people during the Enlightenment stood to gain greater economic freedom. Rational theories of self-interest guiding the economy, such as Adam Smith's theory of the invisible hand, worked to erode mercantilism and justify capitalism. Thus, people came to be free and self-directed not only in their religious beliefs but in economic adventures as well.

In many ways, the thinkers of the Enlightenment believed that they were involved in an act of creation: the creation of a new and better world order, based upon reason and the study of individuals and societies. As with any act of creation, this of course necessitated destruction. In the case of the Enlightenment, this meant the destruction of the church and the destruction of the monarchical state. Thus, the philosophers relentlessly scrutinized and criticized the dogmatic theology that buttressed both. Instead, they championed open inquiry and new forms of government. Some, such as Voltaire (1694–1778), believed enlightened despotism to be the ideal means of government. Much like Plato, Voltaire felt that only philosophers could rule in the most rational way, and thus the king ought to be informed by philosophers such as himself. Symbolizing his distaste for democracy, Voltaire is often cited as saying that he would rather obey 1 lion than 200 rats of his own species. In other words, one enlightened despot is better than a whole democratized country of uninformed fools. Thus, it was through a monarchy directed by philosophical reason that Voltaire thought progress and change would occur.

Enlightened Despotism

To understand the Enlightenment, one must understand the governmental models that its thinkers found ideal. Enlightened despotism, also known as benevolent despotism or enlightened absolutism, was championed by Voltaire, and its enactment was catalyzed by Voltaire's close contact with several monarchs of the time. Enlightened rulers identified themselves as such and differed from traditional rules in their emphasis upon rationality as a means to better government and their espousal of modern notions such as religious toleration, freedom of speech and the press, and the right to hold private property. Subsequently, these rulers often cultivated learning in their lands more than traditional rulers had.

Determining the enlightened despot from the mere despot is not a matter of black and white, however. Both tended to believe that their right to rule was granted by birth and thus were not apt to make unwarranted compromises such as the allowance of constitutions or the proliferation of legislative bodies that would serve to check monarchical power. Determining whether or not a ruler was enlightened depended in large part upon the judgment of the historian and upon a broad examination of a ruler's reign. For instance, Holy Roman Emperor Joseph II embraced the social contract, whereas Catherine II of Russia rejected the concept but demonstrated her enlightenment by sponsoring the arts and encouraging a committee revising Russian law to incorporate the ideas of Montesquieu. The two differed in the ways in which they showed themselves to be enlightened, yet both are regarded as such by historians.

Essentially, enlightened monarchs wished to improve the plight of their peoples without relinquishing their own hold on authority. It is no coincidence that serfdom was abolished during the Enlightenment. Emperor Joseph II encapsulated the ideology behind enlightened despotism by saying, "Everything for the people, nothing by the people."

While enlightened despotism was the preferred form of government for most Enlightenment thinkers, some, such as Jean-Jacques Rousseau, expressed a different opinion. Rousseau argued for something closer to democratic revolution. Unlike Voltaire, who took inequalities among men for granted, Rousseau believed all men ought to be equal under the law, obviously an underpinning of the democratic governments that followed the Enlightenment. Particularly, this type of thought materialized into the United States of America and the French Revolution.

Metaphysics and Ethics

Government was just one of the realms in which thought changed during the Enlightenment. Another realm was metaphysics and ethics. It was during the Enlightenment that some of Europe's first materialist atheists gained prominence and fame. One of these enlightened thinkers was Julien Offray de La Mettrie. He was the earliest materialist thinker of the Enlightenment and is credited with being the founder of cognitive science. He observed that bodily circulation was hastened upon thought, which led him to theorize that physical phenomena were caused by organic changes in the brain and nervous system in his books *Histoire naturelle de l'âme* (*Natural History of the Soul*), *L'Homme machine* (*The Human Machine*), and *L'Homme plant* (*The Human Plant*). In the ethics he derived from this, which he detailed in *Discours sur le bonheur, La Volupté* (*Discourse on Happiness, Exquisite Delight*) and *L'Art de jouir* (*The Art of Joy*), he concluded that the purpose of life was pleasure of the senses and thus that self-love was virtuous. He believed that the theologians had deceived humanity into believing in a fictitious soul and that humans ought to reject this metaphysics, instead opting for atheism and a morality based in hedonism. His earth-centered metaphysics and ethics exemplify the new paradigms espoused by many of the revolutionary thinkers of the Enlightenment.

Another thinker whose ideas closely mirrored those of La Mettrie was Paul-Henri Thiry, Baron d'Holbach. He was also a materialist and an atheist, and his morality would be described by most as hedonism, as he argued that if virtue made a person unhappy, then that person should love vice. In 1761 he wrote *Christianisme dévoilé* (*Christianity Unveiled*), in which he charged Christianity with being counterproductive to man's moral development. This was followed by an even more famous and controversial book, *Le Système de la nature* (*The System of Nature*). Unlike other Enlightenment thinkers, however, he did not call for revolution but rather warned the educated classes against it, arguing that reform was necessary to prevent mob rule.

While the Enlightenment marked changes in realms of thought such as government, metaphysics, and ethics, it also marked new achievements in academic production. Perhaps the greatest achievement of academic production was by Denis Diderot, editor of the world's first encyclopedia. The project began as something meager. Bookseller and printer André le Breton solicited Diderot to translate Ephraim Chambers's *Universal Dictionary of Arts and Sciences*. Diderot accepted the project, but after undertaking it, persuaded le Breton to allow him to undertake an original work, which was to be a compendium of all active writers, new ideas, and new knowledge of the day. Soon Jean le Rond d'Alembert joined Diderot as a colleague. The project was announced to the world in 1750, right at the commencement of the Enlightenment. By 1751 the first volume was published, and by 1765 the last was completed, although it was not until 1772 that subscribers received the final volumes of the *Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers* (*Universal Dictionary of Arts and Sciences*).

The encyclopedia was more than a mere academic work. The significance of the encyclopedia reverberated in social and political realms as well, which cost Diderot numerous friends. The supporters of the church opposed the encyclopedia, as it championed the very Enlightenment values that challenged ecclesiastical authority. The aristocracy opposed the project as well because it took for granted modern notions of justice such as religious tolerance, freedom of thought, and the value of science and industry. Furthermore, it asserted the democratic doctrine that the state existed to serve the people, not vice versa. Diderot's subscribers grew to 4,000 by 1757 and continued in the same direction afterward, a trend that offended and frightened the enfranchised classes of Europe. Resultantly, rumors were spread that the encyclopedia was the work of conspirators against society, and in 1759 the encyclopedia was formally suppressed, but by that time Diderot's mind was set to keep the project moving, although at a slower pace due to the complications of working in secrecy. Unfortunately, d'Alembert withdrew from the enterprise and other knowledgeable colleagues such as Anne Robert Jacques Turgot, Baron de Laune, declined to contribute further to a book that had developed a bad reputation. Stalwartly, Diderot completed the project himself, writing hundreds of articles and editing hundreds of others. In a final act of misfortune, the bookseller, in fear of the government, eliminated the passages he considered too dangerous, thus mitigating the uproar sparked by the encyclopedia, but also (in the mind of Diderot) defacing the masterpiece. Nevertheless, the publication of the work, even in mutilated form, marked an appreciation and treasuring of knowledge that was to characterize the Age of the Enlightenment.

Social Reform

The great academic production that characterized the Enlightenment was matched with striving for social reform. No description of the Enlightenment could be complete without discussion of one of the period's most ambitious reformers, Jean Antoine Nicolas Caritat, Marquis de Condorcet. After being appointed inspector general of the Monnaie de Paris in 1774, he defended human rights, particularly those of women and blacks. In fact, he was an abolitionist, active in the Society of the Friends of Blacks. He supported the ideals embodied by the United States and proposed projects of reform in France. In the realm of politics, he is famous for Condorcet's paradox, which describes one of the problems of democracy. This problem is that it is possible for a majority to prefer A over B, B over C, and C over A simultaneously.

The culmination of the Enlightenment was the French Revolution, in which Condorcet took a leading role. He championed many liberal causes and hoped the revolution would lead to a transformation and reconstruction of society. In 1791, he was elected as the Paris representative in the Legislative Assembly and then became secretary of the assembly. In this position he was able to advance enlightened ideas for a better France. These ideas included a state education system and a Bourbon Constitution for the new France. He also advocated women's suffrage in France.

Condorcet's defense of human rights could be seen by his opposition to the death penalty for King Louis XVI during the public vote at the convention. It is this that would lead to his own untimely death. As the parties advocating the king's execution gained power, Condorcet was branded a traitor and a warrant was put out for his arrest. Subsequently, he went into hiding and wrote *Esquisse d'un tableau historique des progrès de l'esprit humain* (*Sketch for a Historical Picture of Progress of the Human Mind)*. The text outlines the enlightened paradigm with regard to time and history. In it, the history of civilization is described as the progress of the sciences, intimately tied to the growth and proliferation of human rights and justice. Furthermore, like the work of many Enlightenment thinkers, it outlines an optimistic view for future society crafted upon scientific knowledge and rationalist principles.

In fact, Condorcet's conception of time was sufficiently rigorous that he outlined nine great stages of universal history. The first stage he defined as the time when hordes of hunters and fishers united in tribes. The second stage was that of pastoral peoples. The third stage included the development of agriculture up to the invention of the alphabet. The fourth stage he described as the progress of the human mind in Greece up to the division of the sciences. The fifth stage he then described as the progress of these sciences until their eventual decline, followed by a sixth period, roughly the Dark Ages in which intellectual life stagnated. The seventh stage he saw as the reawakening of science and the innovation of printing in Europe. The eighth stage he characterized as the time when science and philosophy diverge from the auspices of traditional religious and monarchical authority, and finally the ninth stage he saw as the time spanning from Descartes until the emergence of the French Republic.

Having described these nine stages, his tenth stage is what is most emblematic of characteristic Enlightenment thought. This was the future stage of equality and freedom, which would be achieved by means of scientific achievement leading to, and/or partnered with, social reform. In this stage Condorcet foresaw a holistic perfection of humankind in physical, intellectual, and moral aspects, resulting in the eradication of war, prejudice, superstition, and disease. In fact, his faith in the scientific perfectibility of medicine led him to believe that humans would become virtually immortal, saying that death would be due only to extraordinary accidents and that the time between birth and death would have no assignable value.

Also working for social reform was Claude Adrien Helvetius. He is among the privileged writers whose work, *De l'esprit* (*On the Mind*), was deemed so heretical by the church and state that it was burned. Like Condorcet, he was interested in advancing human rights and increasing the general welfare of France. He made a fortune quickly at a young age as farmer-general (a tax-collecting office), but when his wealth was sufficient, he retired and employed his capital in the relief of the poor, as well as the development of agriculture and industry. The controversy surrounding his book actually helped to popularize it, and it was quickly translated and disseminated throughout Europe. Historians have divided his book into separate discussions, all of which present well-known and agreed-upon Enlightenment principles. First, all human faculties may be reduced to physical sensation. Second, self-interest, inspired by the love of pleasure and fear of pain, is the motivating factor for all decisions and action. Any case in which this appears not to be so is only a case in which there is an unseen pleasure or pain motivating the actor. Consequently, there is no such thing as good and evil, as they are classically defined. Third, all intellects are equal, and subsequently all people are born of equal ability. Inequalities actually spring from the passions, which motivate people unequally to receive instruction. These ideas, put forth by Helvetius in his controversial work can thus be summed up as utilitarian and democratic, both of which were currents of thought that ran strongly through the Enlightenment.

Voltaire

While La Mettrie, Diderot, Condorcet, and Helvetius all made important contributions to the paradigm embodied by the Enlightenment, perhaps none of their contributions was as great as that made by Voltaire, who is thought by many scholars to singularly embody the Enlightenment better than any other thinker. His thought was crucial to the Enlightenment in France and throughout Europe. In Paris, the year 1694 CE, he was born François-Marie Arouet to a noble family from the Poitou province. Later, he took up the pen name Voltaire, which was a good idea, given the controversy his work stirred up. He defended civil liberties and human rights, insisting upon the importance of religious freedom and, in matters of state, the right to a fair trial. He stood for freedom of speech, as was evidenced by his frequent disregard for French censorship laws. He often criticized the Christian Church and the dogma it proliferated. Most generally, he worked for social reform. Voltaire's energy toward the reformation of France caused him to end up on the wrong side of those in power more than a few times. He was repeatedly imprisoned and exiled. During one such period he spent 11 months in the Bastille for writing satire about France's aristocracy.

Voltaire symbolized the Enlightenment not only because of his personal efforts to reform society but also because of the compendious nature of his work. His work was perhaps more varied than that of any other scholar during the Enlightenment. He wrote poetry as well as a number of plays that attacked the church, monarchy, or aristocracy. Furthermore, he wrote what may be considered ethnography. Voltaire spent 3 years in London and condensed his experiences into a work titled *Lettres philosophiques sur les Anglais* (*Philosophical Letters on the English*). In this work he was very critical of French society while extolling the virtues of constitutional monarchy and human rights that he experienced in England. As could be expected, the French aristocracy found his work distasteful to the point that copies of it were burned and he was forced to leave Paris.

His expulsion from Paris only led to a greater diversity in his work. He traveled to the Chateau de Cirey on the borders of Champagne, Alsace, and Lorraine. Here he performed many scientific experiments, including one to determine the properties of fire. He was particularly interested in Sir Isaac Newton, to whom he had been exposed during his exile in England. Voltaire was especially curious about optics and gravity. He was impressed by Newton's discovery that white light is comprised of every color in the spectrum, and he was inspired to perform several of his own experiments on the topic. Voltaire ended up writing a book on Newton's philosophies: *Éléments de la philosophie de Newton* (*Elements of Newton's Philosophy*).

Demonstrating the compendious nature of Voltaire's studies, he additionally examined history and, in the spirit of the Enlightenment, paid particular heed to concentrating on past people who had contributed to the growth and development of civilization. He wrote an essay titled *Essay Upon the Civil Wars in France* and a biographical essay on King Charles XII, in which he began to reject religion, expressing a fundamental tenet of the Enlightenment that human life is not destined to be controlled by any beings greater than humans, but by humans themselves. Voltaire continued to do work relevant to religion, analyzing the Bible, and philosophizing on metaphysics. He advocated separation of church and state, a staple of the Enlightenment, which lives on today, and went so far as to claim, "One hundred years from my day there will not be a Bible [on] the earth except one that is looked upon by an antiquarian curiosity seeker." This irreverence for tradition and grand vision of a very different future is characteristic of the paradigm.

This criticism of religion was a theme common in much of Voltaire's work. He personally identified himself as a deist, as did many other philosophers and scholars of the time. The deist believed in God and found it reasonable to do so by virtue of creation. Therefore, the deist felt that faith was not necessary. Deists felt that the beauty of creation suggested some sort of supreme designer. However, they denied the phenomenon of divine intervention. The deist envisioned a world that ran like clockwork, according to laws designed by the Creator but not subject to whimsical change by him. Thus, deists did not believe in any traditional book of authority, because God did not need to reveal himself through such a book when he revealed himself through the beauty and workings of nature.

Immanuel Kant

While Voltaire singularly embodies the Enlightenment better than does any other individual, the culmination and aspirations of the Enlightenment can be seen outside of France in the work of Immanuel Kant (1724–1804). Kant stated that the Enlightenment was humanity's exit from a self-incurred minority. By this Kant means that the Enlightenment is people's exit from the fear or lack of determination to employ their own intelligence. Hence, Kant said the motto of the time was, "Have the courage to use your own intelligence!" Kant proclaims that it is time for Europeans to stop letting others, such as the propagators of religion and monarchical rulers, to direct their thoughts and actions. Kant reasoned that it was essentially laziness that kept other Europeans from thinking and directing themselves, and Kant encouraged them to use their reason to be self-determining. This, Kant said, necessitated open inquiry and discussion in the public sphere. Exemplifying what he meant, Kant said that a military officer has a duty to obey the commands of his superior officers, but he also had a duty to the public to express it if he felt his superior officer had blundered, thereby submitting judgment to the public. Likewise, a good citizen pays his taxes but is obliged to publicly utter thoughts about the undesirability or injustice of a tax if it is so. Finally, a clergyman teaches the faith to his congregants, but has a duty to criticize errant beliefs or practices of the religion in his own writing. Thus, it can be seen that to Kant, Enlightenment meant, in addition to free use of individual reason, free presentation of reasonable thought in the public sphere.

Furthermore, in addition to the free use of reason by the people, Kant defines the Enlightenment as an age in which people are ensured the right to do this by protection from the government. Kant said that the monarch's only concern is to prevent one subject from hindering another by force, to work according to each subject's best ability to determine and to promote his salvation. Kant added that it detracts from the monarch's power if he interferes in the matters of his constituents, and subjects to governmental supervision the writings by which the monarch's subjects seek to clarify their ideas, especially those concerning religion. Thus, it can be seen that according to Kant, enlightenment also consists of a government that will allow citizens to use their reason freely, both privately and in public discourse.

Concluding Remarks

Since the Enlightenment, we have seen that reason and freedom are not the simple panacea that the thinkers of the Enlightenment envisioned. Two world wars and the failures of numerous democratic governments prove this to be true. In fact, tyrannical regimes have often existed in the name of freedom and have bent reason and logic to justify their own existence. Thus, interpretations of and responses to the Enlightenment have been varied. Counter-Enlightenment movements and particularly Romanticism as inspired by Jean-Jacques Rousseau followed the Enlightenment. Friedrich Nietzsche, in particular, questioned the values of the Enlightenment and criticized its lofty ideals.

Thus, the legacy of the Enlightenment is multifaceted. However, for the most part the Enlightenment is seen as a positive historical trend that forms the roots of modern democratic government and our modern appreciation of science and education. The underpinning axioms of democracy were postulated and put forth during the Enlightenment, and the importance of education was firmly advocated. This emphasis on education led to the growth and development of educational systems in Western society. Although society is still far from being perfect, most would argue that we have made steps toward better societies. Particularly we have moved away from totalitarian monarchical governmental systems toward republican and democratic ones in which the people have more power.

Moreover, the separation of church and state that we esteem in the U.S. today, along with the values of free inquiry, education, reason, and knowledge, all have their roots in the Enlightenment.

Finally, and quite pertinently, conceptions of process as progress remain with us today. Despite the tragedies that have befallen humanity since the Enlightenment, such as the two world wars, much of humanity still has an optimistic attitude about the future. The idea that science will resolve the problems humanity faces remains with us. In fact it is an implicit truth to many in the modern world that life continues to improve as scientific and governmental advances occur. It is this tacit approval of science and the notion of a continually bettering world that has its roots in those conceptions of time and history born in the Enlightenment.

Mark Koval

See also Farber, Marvin; Kant, Immanuel; Materialism; Nietzsche, Friedrich; Postmodernism; Values and Time

Further Readings

Birx, H. J. (1984). *Theories of evolution.* Springfield, IL: Charles C Thomas.

The Blackwell companion to the Enlightenment. (1992). Oxford, UK: Blackwell.

Cassirer, E. (1965). *The philosophy of the Enlightenment.* Boston: Beacon Press.

Darnton, R. (1979). *The business of enlightenment: A publishing history of the* Encyclopédie, *1775–1800.* Cambridge, MA: Belknap Press.

Dupré, L. K. (2004). *The Enlightenment and the intellectual foundations of modern culture.* New Haven, CT: Yale University Press.

Encyclopedia of the Enlightenment. (2003). New York: Oxford University Press.

Harris, R. W. (1966). *Absolutism and enlightenment, 1660–1789.* New York: Harper & Row.

Hulliung, M. (1994). *The autocritique of Enlightenment: Rousseau and the philosophes.* Cambridge, MA: Harvard University Press.

Melton, J. V. H. (2001). *The rise of the public in Enlightenment Europe.* Cambridge, UK: Cambridge University Press.

Munck, T. (2000). *The Enlightenment: A comparative social history, 1721–1794.* London: Arnold.

Roche, D. (1998). *France in the Enlightenment.* Cambridge, MA: Harvard University Press.

Entropy

Entropy is a measure of disorder. This innocuous-looking definition indicates neither that entropy is connected closely to time nor that the road to an adequate understanding of entropy might sometimes wind its way through an area full of wrong paths and dangerous traps. To show the connection between entropy and time, and to dispel confusion, this entry provides a short tour of the history of the concept of entropy.

The concept of entropy was introduced in thermodynamics, the physical science that studies energy and how it is transformed. In the first half of the 19th century, the technological issue that drove thermodynamics forward was the problem of how to optimize the efficiency of steam engines. Efficiency is the ratio of the net work produced by a cycle of movements in a steam engine to the heat supplied to the engine during such a cycle. The higher the efficiency of a steam engine, the better it converts the supplied heat into work. What steam engine is the most efficient? In 1824 the French engineer and officer Sadi Carnot solved this problem by inventing an ideal steam engine, now called the Carnot machine. Its workings are completely reversible: A cycle in a Carnot machine can be made to go backward by an infinitesimal change in it because all forces that cause the cycle are only infinitesimally removed from balance. Someone viewing a motion picture of the working machine cannot decide whether the picture is being shown forward or backward. So it is impossible for the observer to distinguish objectively between different directions of time in Carnot machine cycles.

This result clearly contradicts our everyday experience: We know that heat is transferred only from a body at a given temperature to a body at a lower temperature. The German physicist Rudolf Clausius generalized this best-confirmed observation and stated the second law of thermodynamics: A transfer of heat from a body at a given temperature to a body at a higher temperature never occurs spontaneously, that is, without any other change in the state of the bodies at the end of the process. If the second law were falsified, it would be possible to construct a Carnot machine that could use heat transferred from the body at lower temperature to the body at higher temperature for the production of work. The latter body would give up and take in the same amount of heat, so that it would be in the same state at the end of the cycle as it was at the beginning. If the temperature of the colder body were kept constant, we would have succeeded in constructing a machine that is, for all practical purposes, a *perpetuum mobile:* Simply by cooling down its environment, it could completely transform thermal energy, of which there exists a practically unlimited amount in the environment, into work.

In 1865, Clausius introduced the term *entropy* (from the Greek verb *entrepein*, "to turn") to denote a mathematical function of the state of a physical system like a Carnot machine or an irreversibly working steam engine. The difference in entropy between two states of such a system is the integral, taken over a transformation from the first to the second state, of the ratio of the net heat absorbed by the system from its environment to the temperature of the environment. If the transformation of a thermodynamically isolated system (i.e., a system that does not exchange heat with its environment) is reversible, the difference in entropy is equal to zero; if the transformation of such a system is irreversible, the difference in entropy is greater than zero. Clausius could thus rephrase the second law of thermodynamics: *In a thermodynamically isolated system, the entropy can never decrease with time.* In case of an irreversible transformation, an observer can decide whether some state has occurred earlier or later than another state in the history of a system. One just has to calculate the difference in entropy between these states. After an isolated system has reached its state of maximum entropy, an irreversible transformation of energy cannot occur in it anymore. Clausius applied this result to our universe as an isolated system in which entropy tends to a maximum, too, and he called its final state "heat death of the universe": a state in which the whole of nature will be in thermodynamic balance.

Ludwig Boltzmann, one of the most important physicists of the second half of the 19th century, redefined Clausius's concept of entropy in statistical terms. Without going into the mathematical technicalities, *statistical interpretation* means roughly that thermodynamic concepts (like that of temperature as degree of heat in a system) are explained from an atomistic point of view (e.g., temperature as measure of the average kinetic energy of atoms in a system). Entropy then becomes a function of the number of atomic microstates of a system that can realize its present thermodynamic macrostate. Whereas the description of the microstate of a system contains information about the states of all atoms of the system, a description of its macrostate contains just such information that characterizes its overall thermodynamic properties.

The statistical interpretation of entropy can be illustrated by means of a thought experiment. Imagine that you have a box containing 1 million tiny red marbles and 1 million tiny blue marbles in your hands.

- At the beginning of your experiment, the red marbles are separated perfectly from the blue ones: All red marbles are in the right half of the box, and all blue marbles are in the left half. If this macrostate of the box is not be altered, then only such changes in the position of a marble (and, thus, in the microstate of the box) are allowed that let all red marbles stay in the right half of the box and all blue marbles in its left half.
- Now you shake the box violently. The longer you do so, the more the red and blue marbles will be mixed. The probability that a marble chosen randomly from, for example, the right half of the box, is blue will approximate the probability that it is red, namely 50%; before the shaking, the probability was 100%. The macrostate of an equal distribution of blue and red marbles to the halves of the box can be realized by many more microstates than the first macrostate: Any marble in, again, the right half of the box may interchange its position not only with any other marble in this half but also with any marble of the same color from the left half. The more microstates can realize one and the same macrostate of the system, the more disordered the system is and the higher its entropy is.
- The probability that, by shaking the box anew, the first macrostate will reappear is negligibly low. You might have to shake longer than the heat death of the universe will allow you. If you again start your experiment with another macrostate, your shaking will almost certainly transform this initial macrostate once more into increasingly probable macrostates, that is, into

> macrostates that can be realized by more and more microstates. Yet it is not completely impossible that your shaking will result in a less probable macrostate. The thermodynamical reason for such a decrease of entropy is that the box is not isolated: It absorbs the energy of your shaking.

Since the turn of the 20th century, the statistical concept of entropy has been used in many sciences other than thermodynamics to quantify the degree of disorder of a system. The most important of these applications is Claude E. Shannon's theory of information, which laid the foundation of modern communication engineering.

The concept of entropy attracted much interest also beyond science. The foremost reason for this is that the second law of thermodynamics not only implies the existence of an objective direction of time in nature but also has a pessimistic consequence from the standpoint that history is a process of unlimited progress. In the long run, the heat death of the universe sets an unsurpassable limit to the transformation of energy into work—even in a thermodynamically open system like the earth, which is currently fed with energy from the sun.

Thomas Pynchon's short story *Entropy* (1958–1959) is an intriguing literary document of the nonscientific reception of the entropy concept. Pynchon's narrative puts together, on a few pages, many of its facets: its thermodynamic sense, its statistical definition, its connection to information theory, its cultural interpretation as a natural boundary of human progress, and its psychologically disastrous misunderstanding by individuals who short-circuit their experiences with the general tendency of the universe toward heat death. Pynchon effectively contrasts a party that, in danger of ending in a state of total disorder, is prevented from reaching it by a constant energy input of the host, with the ordered everyday life of an isolated couple that has resigned itself to consider any event as a depressing symptom of the universe's growing entropy. Thermodynamics cannot tell us which ethics we should choose.

Stefan Artmann

See also Cosmogony; Information; Logical Depth; Maxwell's Demon; Time, Cosmic; Time, End of; Universe, Contracting or Expanding

Further Readings

Atkins, P. W. (1984). *The second law.* New York: Scientific American.

Balian, R. (2003). Entropy, a protean concept. In J. Dalibard, B. Duplantier, & V. Rivasseau (Eds.), *Poincaré seminar 2003* (pp. 119–144). Basel, Switzerland: Birkhäuser.

Van Ness, H. C. (1983). *Understanding thermodynamics.* New York: Dover.

EPISTEMOLOGY

The theory of knowledge emerges bearing several names: epistemology, gnoseology, noetics, or simply the theory of knowledge. Any attempt to precisely define these terms requires looking for equilibrium between two extremes. On the one hand, there is a danger of shifting to questions in infinite regression: How do we know that our knowledge is really correct, and how do we know that this precise knowledge is correct and not illusionary? On the other hand, we can be overwhelmed by bare historical description, because there are few themes like the problematic of knowledge that are interesting not only for all philosophers but also for many scientists, logicians, and mathematicians. We have no choice but to try to find a compromise solution and to rely above all on chosen intuitions that originate in our prephilosophical and prescientific behavior that need no theoretical justification. We trust these intuitions because they helped us to survive; we have nothing better to start with.

The different names for the theory of knowledge are often used as synonyms; in other cases, authors try to establish a certain differentiation in meaning. The term *gnoseology* usually accompanies an effort to describe the theory of knowledge as a set of questions and answers that define our cognitive dispositions, even before the beginning of the cognitive act itself. The terminology is moreover slightly complicated by the shifts of meaning and different application in main linguistic-cultural contexts.

Epistemology in Time Versus Time in Epistemology

The perspective of time can facilitate the classification of different approaches to the problematic of epistemology. An examination of the history of epistemology suggests a double sense: history of epistemology considered as a philosophical discipline and history of knowledge considered as our abilities to know ourselves and the surrounding world. This first approach can be called epistemology in time. The second line—time in epistemology—is dependent on the remarkable development of the natural sciences since the beginning of the 20th century, when many traditional philosophical notions—space, causality, determinism, movement, and time—appeared in the new context of modern physics. The category of time, in particular, is a frequent theme and subject of analyses and speculations. Time in epistemology is a prototypical problem of modern epistemology that exposes different approaches and a possible delimitation of the relation between philosophy and science.

The term *epistemology,* in use since the 19th century, has never been unequivocal. In Continental philosophy, epistemology—the study of knowledge—is often related to the philosophy of science, which focuses on scientific methods and the results of natural sciences especially. According to French philosophy, the term *epistemology* is often inappropriately identified with the theory of knowledge (gnoseology), considered as analysis and philosophical criticism of scientific knowledge. In their new thinking based on recent scientific discoveries, epistemologists try to describe the development of particular scientific disciplines from different points of view.

However, epistemology is not a theory of science. Epistemology does not deal with concrete problematics of particular scientific fields and their procedures; rather, it is concerned with questions that are *provoked* by these scientific procedures. When physicists search beyond their measured data—to discover something hidden, to explore to what extent their work is a conventional language game, or to wonder whether notions and concrete objects have something in common—they have left the field of natural science and have begun to deal with epistemological questions.

To move on to define the object and content of epistemology, various conceptions, according to linguistic-cultural spheres, must be distinguished.

The questions of epistemology are neither questions of science nor questions of traditional metaphysics. Metaphysical methods cannot be used to resolve the questions of epistemology, even if they may often touch on them thematically. That is why Pierre Duhem and Emile Meyerson try to distinguish metaphysics and science with its theory on the one hand and to find a common basis for both disciplines on the other hand. It follows that Duhem believes that logical order reflects the ontological order, whereas Meyerson is not content with simple description of phenomena and control over them but requires their explanation.

Logicians and mathematicians often deal with questions of intuition and abstraction, as well as the adequacy of their application in mathematical theory; many of them (e.g., Jean Cavaillès) find the central subject matter of their work in this field of epistemology.

The close connection between epistemology and science as such can be understood as a certain way to distinguish epistemology from the philosophy of science itself, which frequently deals as well with a larger problematic of scientific development and thus does not avoid economic, social, and institutional questions; it is often in touch with the sociology of science. In this perspective, epistemology is more "theoretical"—in contact with the theory of science, it approaches unanswered questions and doubts. At the same time, epistemology is more "practical" because it (much less often) enters directly into current problematics, as in the case of the question of determinism in connection to quantum mechanics.

Epistemologists rarely aim to create a general (the one and only) theory; rather, they look for variations by turning their attention to the past. The connection between epistemology and history of science thus results from the very basis of the problem and the logical process of its solution (see, e.g., the work of Pierre Duhem and Michel Serres). The close connection between history and epistemology gave birth to the new term *historical epistemology.*

Basic Issues

Epistemology can be characterized according to the basic issues it deals with, including the following:

1. *Crisis of the basis of science*—It does not matter which science, as long as it is natural or mathematical. For example, the crisis of formalism in logic, the crisis of mathematical essentials, and the crisis of basic physical principles are all events that provoke a continuous revival of the philosophy of science. The task is often undertaken by scientists active in particular scientific disciplines (e.g., Henri Poincaré, Meyerson).
2. *Mathematization of logic and attention to language* spurred philosophers to attempt to explain scientific assertions and to use formal analysis to verify or falsify those assertions (Poincaré).
3. *Specialization* of modern science leads also to the relative autonomy of *regional epistemologies,* that is, the study of the specificities of particular scientific disciplines (Gaston Bachelard).
4. The rapidity of development of science, especially in the past 2 centuries, is one of the main reasons for the emergence of historical epistemology, the study of the appearance of scientific theories and their successive changes (Duhem).
5. Epistemology also is influenced by efforts to obtain a better understanding of the *historical determination of changes in knowledge and scientific theories* and their individual and psychological sources (Jean Piaget, Michel Foucault).

In the European tradition as influenced by French philosophy, scientific *epistemology* is related especially to Gaston Bachelard and was developed consecutively by other French authors, such as Cavaillès, Georges Canguilhem, and Alexander Koyré. Scientific epistemologists typically connect the history of science to the epistemological problematic itself, but scientific epistemology should not be confused with the history of science.

Even though these features issue exclusively from the French domain, there is no "French epistemological school"; nevertheless, some French philosophers, including Bachelard, Canguilhem, and Foucault, have greatly influenced other European and American thinkers. Whereas Bachelard is interested in physics and chemistry, Canguilhem and Foucault concentrate more on biology or, more precisely, on the history of biological science. Foucault's research surpasses narrow specialization in many ways, whereas Canguilhem is profoundly interested in the same field of biology. As a specialist, Canguilhem offers a rather different perspective of the epistemological problematic; he provides a detailed view of specific scientific disciplines and, in this sense, approaches Bachelard. They both differ from the encyclopedic Foucault, who ventures into the fields of linguistics, economy, history, and biology.

Despite all differences, Dominique Lecourt finds some common traits—and not marginal ones—in the work of the Bachelard, Canguilhem, and Foucault. He starts with a comparison between French epistemology on the one hand and its equivalent in American and Russian philosophy on the other. Lecourt overlooks personal relations between the French philosopher-epistemologists (Bachelard was Canguilhem's teacher and Canguilhem was Foucault's teacher); nevertheless, he uncovers some relevant connections, for example, a common philosophical conception based on "nonpositivism," that is, an attitude that is in opposition to efforts to build "a science about science" or a technocratic variation of science organizing scientific work. Lecourt names John Desmond Bernal and Kernov among the proponents of "science about science"; he also mentions logical neopositivists (e.g., Hans Reichenbach), who talk about "the century of science" and seek to provide science about science and scientific criticism of philosophy at the same time.

Another approach to the theory of knowledge—again, called epistemology—derives from philosophers such as Bertrand Russell, Ludwig Wittgenstein, Rudolf Carnap, and Hans Reichenbach. It is mainly Anglophone philosophers who use the term *epistemology* to refer to a theory of basic themes in the theory of knowledge. These themes can be defined by general questions: What is knowledge: cognitive process, or fact? (This question focuses on trust, justification, truth, and their limits—the so-called Gettier problem.) What is the basis of justification, and what are its structure, sources, and limitations? (This question focuses attention on the principles and sources of knowledge and basic ways to work with them.) What are the basic cognitive attitudes? (Human knowledge can be extended in the form of principal attitudes in cognitive process, such as skepticism in various forms, cognitive optimism, relativism, etc.) What are the contributions of subject and object to the formation of knowledge, and what are the roles of empirical and rational (inductive and deductive) processes?

Epistemology, as a theory of knowledge in the broad sense, is the study of knowledge itself. This banal statement harbors considerable problems and many questions. Principally, the conception becomes gradually traditional; if not absolutely on the decline, it is certainly expanded by new themes. From a purely theoretical, often rather speculative level, it transforms into the methodological, empirical, or even "engineering" level. These changes are caused by the influence of the development of information technologies that necessarily demand a profound elaboration of formal cognitive processes, up to the level of research in artificial intelligence. From this perspective, the theory of knowledge is not considered only as a theory "for itself," that is, without the traditional impact on an object, because this object can stand for many scientific disciplines, under the influence of their rapid development; it is more often a discussion of aims. Many of these objectives are embraced by cognitive sciences that successfully develop contacts with special (often empirical) sciences, alternatively with or without engineering ambitions.

Traditional Approaches

Traditional approaches to the theory of knowledge follow at least three lines.

1. Epistemology is a theory of knowledge, in the sense of research on basic cognitive assumptions. What is the basis of our trust in the possibility of knowledge? Where do possible doubts about relevancy of obtained knowledge originate? Is there a historical model of knowledge? Does it make any sense to talk not only about knowledge as conceptual but also, in a larger sense, about the ways and methods of information exchange, that is, to take interest also in the animal world and even the nonorganic one? How long can we hold these (in most cases a priori) thoughts and resist the need to argue against the special sciences (e.g., biology and physics)? Are there any limits of knowledge? If we are willing to consider and seek them, should we turn to the external world to look for the laws of nature and physical connections that would determine these limits? Or should we turn to more subjective areas and take an interest in the possibilities of psychological, physiological, and historical determination?

The transitory state between a general epistemological problematic and its overlap with specific knowledge can be observed in the analysis of cognitive methods. The first rough division into empirical and theoretical, general, and special methods is a textbook case; any subtler distinction cannot stand without overlap to particular scientific disciplines. Analysis of simulation and modeling is mostly a study of concrete physical or mathematical models from selected domains: the atomic model, the universe model, models of *n*-dimensional spaces. Analysis of experiment is also intentional because real, physical experiments are genuine cases of empirical science. Theoreticians of thought experiments, who enjoy essentially a larger sphere of activity and avoid the aforementioned tendency, use numerous concrete illustrations. In view of the fact that the question of method is considered as a problem of theory of knowledge, epistemology can then participate in concrete scientific disciplines, but also—in the case of scientific experiment and methods related to modern technologies that open classic questions of mind (e.g., the question of artificial intelligence)—a shift from cognitive sciences to particular engineering procedures can be observed.

2. Beyond the limits of specialized knowledge is modern (regional) epistemology, often focused on one selected discipline of contemporary natural science, characterized by considerable empirical orientation. Narrowly focused epistemologies dealing with concrete problems (e.g., epistemology of theory of relativity, epistemology of evolution biology, etc.) are not exceptional. Another transgression of limits, this time toward practical application, or at least toward concrete considerations of possible applications (data collection and information exchange in expert systems, particular models of artificial intelligence, agents and robots, etc.), is a way toward the engineering approach to knowledge mentioned earlier.

3. Definition of the limits (albeit often imprecise) between an engineering approach and cognitive

sciences is not easy. Cognitive scientists provide their conclusions in the form of possible experiments in various shapes (from purely thought form up to completely realistic) or even directly in a concrete application.

Recognition of the content common to epistemology and cognitive sciences might be extended to other related disciplines—for instance, epistemological questions form part of the large field of thematic content of another specialized discipline: the philosophy of mind. Within the scope of philosophy of mind, attention is focused on problems related to identification of mental states, differences in the perspectives of first person and third person, and especially to the traditional problem of other minds.

The Philosophy of Science

This survey of possible approaches to the problematic of knowledge is certainly not exhaustive. A broadly conceived problem could embrace also a domain known as the philosophy of science. The theory of science usually defines critical analysis of the basis of scientific thought and proper scientific theories. However, if these bases are considered in the broad sense, they include also prescientific, philosophical, or metaphysical assumptions of science, which does not exclude possible overlap to the field defined earlier as gnoseology—namely, epistemology as a theory of a priori knowledge. Just as the philosophy of science cannot escape the history of science, it also approaches closely the content of particular scientific theories and overlaps the field of epistemology. Philosophy that shares with science itself some common characteristics—it is rational, constructive, it seeks veracity—cannot be an objective external perspective in all aspects. Besides, it is obvious that none of the mentioned approaches, not even the philosophy of science, can provide a universal methodology of science and scientific thought, even if such attempts can be found in the history of philosophy and science. Today, this ambition is consigned to the archives of unsuccessful ideas; nonetheless, its place has been quickly replaced by another effort, more poetically called dreaming—that is, dreaming about a final theory (Steven Weinberg) that would be the definitive theory. Dreams about the ultimate theory (theory of everything; unifying theory) were born in the field of physics as an effort to unify physical interactions. Nevertheless, some physicists would not protest against enthronement of this theory as the true Theory of Everything, to fulfill the ambitions of strict reductionism.

In conclusion, the traditional problem of the very possibility of knowledge studied by epistemologists has been divided into two lines. On the one hand, there are abstract, purely philosophical, analytical considerations of the essence of knowledge, the possibility of knowledge, and its foundation, justification, veracity with overlap to problems of language, role of subject (internal and external in knowledge), senses, and reason. On the other hand, there is discussion about physical, physiological, biological, and psychological limits, and it is predominantly particular disciplines that deal with the nature of these limits. Epistemologists (or philosophers in general) can express the pretheoretical basis of particular disciplines and touch on methodological problems. Even if epistemology cannot offer anything factual (in the sense of empirical fact), it is not without competencies. With respect to the factual aspect, epistemologists can ask questions of science, questions considered by philosophers of the first line of epistemology, that concern basic assumptions about the elaboration of scientific theories.

Josef Krob

See also Aristotle; Experiments, Thought; Information; Kant, Immanuel; Russell, Bertrand; Time, Teaching

Further Readings

Armstrong, D. M. (1973). *Belief, truth, and knowledge.* Cambridge, UK: Cambridge University Press.

BonJour, L. (2002). *Epistemology. Classic problems and contemporary responses.* Lanham, MD: Rowman & Littlefield.

Chisholm, R. (1989). *Theory of knowledge* (3rd ed.). Englewood Cliffs, NJ: Prentice Hall.

Dretske, F. (1981). *Knowledge and flow of information.* Oxford, UK: Blackwell.

Greco, J., & Sosa, E. (Eds.). (1999). *The Blackwell guide to epistemology.* Oxford, UK: Blackwell.

Thagard, P. (1996). *Introduction to cognitive science* (2nd ed.). Cambridge: MIT Press.

Equinoxes

An equinox is the actual point in time at which the sun crosses the celestial equator. The celestial equator is simply the projection of the earth's equator into space. An equinox is a particular point of time, not a full day as is commonly thought.

The word *equinox* is a translation of the Latin words *aequi,* meaning "equal" and *nox,* meaning "night." The equinox is commonly considered to be the day on which the day and night are equal in length on all parts of the earth, save for the poles. The poles will have either 24 hours of light or 24 hours of darkness. The word equinox, however, is a misnomer. Day and night are not equal on the day of an equinox, with daylight exceeding darkness by as many as 16 minutes. The days on which equal day and night occur are called *equiluxes* and usually occur either a few days before or after the date of the actual equinoxes.

Twice yearly, the sun crosses the celestial equator, the vernal and autumnal equinoxes. The vernal equinox, also called the spring equinox or the first point of Aries, occurs on or about March 20. The autumnal equinox, also called the fall equinox or the first point of Libra, occurs on or about September 22. The vernal equinox passes the equator from south to north, while the autumnal equinox indicates the sun is crossing the equator from north to south. The dates of each equinox are not fixed, however, because it takes the earth 365.25 days to orbit the sun. Although this is remedied, for the most part, by the addition of 1 day every 4 years, during the leap year, it does not allow a fixed date for the equinoxes to occur. As for the equinox, the sun crosses the equator at a particular point in time, which will occur approximately 6 hours later the following year, or 1 full day every 4 years.

Despite the occurrence of the equinoxes across the earth, both equinoxes are named in relation to the northern hemisphere. So, whereas the vernal equinox in the northern hemisphere indicates the beginning of longer days and the beginning of spring, it indicates shorter days and the start of fall in the southern hemisphere.

The equinoxes hold great meaning across cultures. Many celebrations and holidays are marked by each. Perhaps the best known is the calculation of the Christian holiday, Easter. Easter occurs on the first Sunday after the first full moon on or after the vernal equinox. Whereas Easter's date of occurrence varies greatly from year to year, the date of March 20 or March 21 is used as the date on which the spring equinox occurs, whether true or not.

Many calendars, including the Iranian calendar, utilize the vernal equinox as the start of the year. In Japan, both the vernal and autumnal equinoxes are national holidays—days to visit family graves and hold reunions. The autumnal equinox indicates the beginning of the harvest in many cultures and is celebrated as such in the United Kingdom.

Whether celebrated on a grand scale or simply observed in passing, equinoxes remain a natural, consistent indicator of seasons and an accurate measure of the passing of time.

Amy L. Strauss

See also Earth, Revolution of; Eclipses; Leap Years; Seasons, Change of; Solstice

Further Readings

Dickinson, T. (1987). *Exploring the night sky: The equinox astronomy guide for beginners.* Buffalo, NY: Firefly Books.

Staal, J. (1988). *The new patterns in the sky: Myths and legends of the stars.* Granville, OH: McDonald & Woodward.

Eriugena, Johannes Scotus (c. 810–c. 877)

Johannes Scotus Eriugena means "John the Scot born in Ireland" ("Scots" referred to the Irish in the early medieval period). Scotus Eriugena was one of the Peregrini—traveling Celtic scholars who established monasteries throughout Europe. Little is known of Eriugena's personal life; it is believed that he received his early training in one of the monastic schools in Ireland, possibly Clonmacnoise, or northern Britain that were established by an Irish monk, Saint Columba, after which some believe him to have studied in Greece. Others believe that he acquired his Greek training in Ireland, as scholars of Greek in the previous century often were assumed on the

Continent to be Irish. Although Eriugena preferred the teachings of the Greek theologians, he also respected the Latin works of Saint Augustine of Hippo. He is renowned as a theologian, poet (much of whose work was dedicated to his royal patron), philosopher, and translator of texts. He is considered by many to be the greatest mind of his era.

Eriugena arrived in France by 847, where, by 853, he served at the court of Charles II (the Bald; grandson of Charlemagne), as the translator of theological works. Eriugena served as rector of the University of Paris. He also may have spent time as head of the Irish scholastic community at Laon, France. There is no evidence of his having traveled to the Middle East or having settled in Malmesbury, England, as some sources claim. Among the works of Eriugena, possibly his greatest translation was the work of the early 6th-century mystic Pseudo-Dionysius the Areopagite from Greek into Latin. This work had a profound effect on European religious thought for some time. Others of his works, however, specifically his backing of the concept of free will and Neoplatonic denial of the existence of evil, earned Eriugena condemnation by church councils in 849 and 857.

Eriugena's six-volume *The Division of Nature* (*De Divisione Naturae*), written between 865 and 870, combined Greek and Latin scholarship to examine how God is revealed to thinking beings in terms of their own capacities to comprehend him through his three personalities. The pantheistic (some might say animistic) views in this book caused it to be prohibited by the Vatican in 1685.

It was in this work that Eriugena took on the concept of time and space as it related to the nature of the divine. Reality is created by and streams out from God, the Primordial Cause, who is the Center, through the Word, in which all things are eternal, through the levels of logic, and into the world of number (where the Word takes the form of angels); at this stage there is only the appearance of reality. It then enters time through Creation and exists in space, where the ideas become divided and subject to corruption and decay; they become material and the source of illness, discontent, and sin. Thus what we material beings see as matter, including ourselves, actually is thought to have originated ultimately from God. It is out of the eternal essence of God that all things are created. We are the ultimate completion of God's thought process. In our return to him through our redemption by our use of reason, we complete a divine cycle that was interrupted by original sin. It is in our return to God that we achieve timeless immortality with him, for, although God is in time (as it is part of him), he is not bound by it. God is eternal.

Michael J. Simonton

See also Augustine of Hippo, Saint; Eternity; God and Time; God as Creator; Idealism; Immortality, Personal; Materialism; Sin, Original; Time, Sacred

Further Readings

Brady, C. (2000). *The encyclopedia of Ireland.* New York: Oxford University Press.

Power, P. (2001). *Timetables of Irish history: An illustrated chronological chart of the history of Ireland from 6000 B.C. to present times.* London: Worth Press.

Scot, John the (Johannes Scotus Eriugena). (1976). *Periphyseon: On the division of nature* (M. L. Uhlfelder, Trans.). Indianapolis, IN: Bobbs-Merrill.

Reese, W. L. (1996). *Dictionary of philosophy and religion: Eastern and Western thought.* Amherst, NY: Humanity Books.

Erosion

The surface of the earth is continually being worn away by natural geologic processes. The displacement of this weathered material is called erosion. Agents such as water, wind, ice, and gravity work to level the land surfaces of the earth across vast expanses of geologic time. The shapes of continents constantly change as waves and tides cut into old land, while rivers deposit silt and build new land. Erosion eventually wears away mountains, but movements of the crust and volcanic activity raise new ones. Although erosion is generally a slow and gradual process that occurs over thousands or millions of years, human activity greatly increases the rate of erosion on fertile land. Farming, mining, and industrial development are all ultimately destructive processes.

Types of Erosion

There are two major categories of erosion: geologic erosion and soil erosion. Geologic erosion is initiated by the weathering of rock. Weathering can be caused by natural physical or chemical means. Heat from the sun may expand the uppermost layer of rock, causing cracking on the surface. Wind and rain then carry the particles away, completing the erosion process. In damp climates, minerals in the rock can react chemically with rainwater, causing the rock to gradually dissolve or decompose. Cold climates will cause water that has seeped into crevasses to freeze and expand, splitting rock at the surface. Roots of nearby plants may also grow into cracks and cause further breaking. Water is a very powerful erosional agent. Running water in streams and rivers not only wears away or dissolves rock but also can carry stones that cause further abrasion along the banks. Glaciers pick up and carry away all loose surface material. When the ice melts, only bare rock remains. Ocean currents and waves erode coastlines, sometimes carving into cliffs and other times depositing sandy beaches.

Soil erosion on uninhabited, untouched land is balanced by soil formation. Soil is protected by natural vegetation. Trees, shrubs, and grasses serve as windbreaks and protect the soil from the force of the rain. Roots hold soil in place. Unfortunately, many human activities involve removing the vegetation from the land. Agriculture, logging, construction, mining, and heavy animal grazing all greatly increase the rates of erosion. Some historians believe that soil erosion is partially responsible for population shifts and the collapse of some civilizations throughout history. Ruins of cities with agricultural artifacts have been found in arid deserts, demonstrating that farming was widespread in these areas in the distant past.

Rates of Erosion

Over geologic time, approximately the past 500 million years, there has been about 60 feet of erosion each million years. Currently, in areas of the United States being eroded by human agricultural activity, erosion is occurring at a calculated 1,500 feet per million years. The rate is even higher in other parts of the world. Soil formation varies, but it takes about 10,000 years for 1 foot of topsoil to form. Today, approximately 40% of the world's agricultural land is seriously degraded, The resulting in lower productivity and poorer crop quality. Virtually all arable land is in use.

Slowing Erosion Rates

Erosion is recognized as a serious problem. Judicious farming practices can greatly reduce erosion rates. Less disruptive tilling methods are being developed. Leaving plant debris in fields after harvest protects the soil and provides shelter for the creatures that assist in soil formation. Strips of land planted with trees and shrubs are left between fields to form windbreaks. Perennial crops that leave root systems in the soil over the winter also hold the soil in place. Contour plowing and terracing the land also help limit erosion. Urban developers can plan green space and replant vegetation after the construction process is completed.

A certain amount of erosion is both natural and healthy for an ecosystem. However, the huge population growth experienced in the past few centuries has put a great deal of stress on the surface of our planet. The availability of rich soil will be critical if we expect to feed future generations. There is unnecessary soil loss happening on every continent right now. Soil conservation programs can substantially reduce the loss of this basic, yet critical, resource. With careful planning, erosion can be minimized and the earth will remain a productive place for the generations to come.

Jill M. Church

See also Ecology; Geology; Glaciers; Sedimentation

Further Readings

Cattermole, P. J. (2000). *Building planet Earth: Five billion years of earth history.* Cambridge, UK: Cambridge University Press.

McNeill, J. R., & Winwarter, V. (2006). *Soils and societies: Perspectives from environmental history.* Isle of Harris, UK: White Horse Press.

Montgomery, D. R. (2007). *Dirt: The erosion of civilizations.* Berkeley: University of California Press.

Skinner, B. J., & Porter, S. C. (2004). *Dynamic Earth: An introduction to physical geology.* Hoboken, NJ: Wiley.

Eschatology

Eschatology refers to a set of beliefs about the last things or the end-times. Derived from the Greek words *eschatos* ("last") and *logos* ("word"), a Latin form of the word (*eschatologia*) was first used by Abraham Calovius in the 1600s. The word appeared in German in the early 1800s and in English in 1845. Since then, it has been considered an important (and usually the last) component of Christian theology, but it can be applied more generally to any view concerning future events.

Eschatology is divided into two subject areas. *Individual eschatology* focuses on the fate of the person after death. *Cosmic eschatology* focuses on future events related to the end of the world. People who adhere to religions based on a linear view of history generally believe that certain events will precede the end of history and that a new, eternal age will replace the current, temporary age. Such would be the views of those who follow Zoroastrianism, Judaism, Christianity, and Islam. The new age is described in these religions either as the restoration of the world to its previous state of perfection or as the replacement of the world by a better, more glorious one.

Religions based on a cyclical view of history—such as Taoism, Confucianism, and Shintōism—generally do not teach any kind of cosmic eschatology. Asian religions such as Hinduism and Buddhism, however, teach that certain events will happen in the future to usher in the next cycle of history. Chinese Buddhists, for example, view current history as a period of decline at the end of which a messianic figure called Maitreya will establish a new age of bliss and salvation.

In the ancient Near East, eschatological schemes often depicted the arrival of an eternal political order ruled by an ideal king. In some versions, history is divided into four successive kingdoms followed by the fifth and final one. A shift away from this kind of this-worldly eschatology occurred in Zoroastrianism, whose proponents viewed history as a cosmic struggle between the forces of light led by Ahura Mazda (or Ormuzd) and the forces of darkness led by Angra Mainyu (or Ahriman). The end will come with the victory of light, the resurrection of the dead, judgment of individuals, and destruction of evil.

Historical Background

Earlier conceptions of eschatology in the Hebrew Bible were this-worldly in orientation. They envisioned Yahweh's deliverance and judgment as occurring within history to end poverty and injustice. Beginning in the 8th century BCE, the prophetic writings depict Yahweh as coming to Earth on the "Day of Yahweh" to subdue the enemies of Israel and establish his reign with Jerusalem as the center of the world. After the Babylonian exile, writings such as Isaiah 60–66 and the Book of Daniel began to present an otherworldly, apocalyptic eschatology in which a new heaven and new earth would replace the current world. These biblical depictions of the future often adapted the imagery of the ancient Near Eastern myth of combat between God and the chaos-monster.

Apocalyptic literature, which flourished from 200 BCE to 200 CE among Jews and Christians, recorded autobiographical narratives of visionary experiences during which the seer received insight into either the structure of the cosmos or the events of the end-times. The futuristic apocalypses envisioned a future intervention of God into the flow of history to inaugurate a new, more glorious age. Some apocalypses depicted the future in earthly terms, others described it as more transcendental than worldly, and others combined the two. The Dead Sea Scrolls also reveal the central role that eschatology played in the belief system of the Jews who lived at Qumran.

Greek writers such as Hesiod and Plato described history as the cycle of one epoch or kingdom replacing another. The Stoics envisioned the periodic purification of the cosmos in a future conflagration. Other thinkers such as Cicero and Philo posited that the world may be eternal.

During the Intertestamental period, Jewish writings associated the Day of the Lord with the coming of the Messiah and the resurrection of the dead. The Day of the Lord would be preceded by a period of intense suffering, often referred to as "the messianic woes." During the 1st century CE, Jewish writings referred to "this age" as dominated by sin and death and "the age to come" as the period of bliss inaugurated when the Messiah (or God) would come to earth.

Modern Theology and Scholarship

Since the late 1800s, New Testament scholars have debated the role of this Jewish eschatology in the teachings of Jesus and Paul. Theologians such as Albrecht Ritschl and Adolf von Harnack ignored the eschatological teachings of Jesus and focused instead on his moral teachings. In opposition, Johannes Weiss interpreted Jesus as teaching that the kingdom of God was a cataclysmic event of the near future in which God would intervene in history. Albert Schweitzer, building on the work of Weiss, also stressed Jesus's expectation of the imminent coming of the kingdom. Jesus surrendered himself to death so that history might end and God's kingdom would come. However, the end did not come as he expected, and he died as a failed prophet. Early Christians struggled with the fact that Jesus did not return and establish the kingdom. Paul responded to this "delay of the Parousia" by developing his concept of "Christ mysticism." The elect have entered into the resurrection mode of existence in the here and now and enjoy bodily union with Christ. Schweitzer's view is called "consistent" or "thoroughgoing" eschatology.

Throughout the 20th century, theologians struggled with Schweitzer's interpretations of Jesus and Paul. Scholars such as Karl Barth and Rudolf Bultmann accepted the centrality of eschatology in the teachings of Jesus and Paul but denied its continuing validity for contemporary Christians. For Barth, eschatology did not focus so much on a time beyond this one as on the eternal, uncontrollable action of God from above to below. Bultmann attempted to "demythologize" the eschatology of the New Testament by reinterpreting the apocalyptic imagery in existentialist terms as a radical call to authentic existence in the present. This project was continued in the "new hermeneutics" of his students Ernst Fuchs and Gerhard Ebeling. However, another of his students, Ernst Käsemann, stressed the central role of future eschatology in the teachings of Jesus and Paul.

C. H. Dodd (following Rudolf Otto) took an approach that differed from the approaches of Barth and Bultmann. He emphasized the "realized eschatology" of Jesus and Paul: The kingdom of God arrived in the ministry, death, and resurrection of Jesus and is now present and available. The coming of Christ will not be a future event in history but occurs beyond space and time whenever people believe that the Lord is near. His student John A. T. Robinson denied that Jesus expected an immediate and supernatural return from heaven after his death.

Oscar Cullmann developed the view known as "inaugurated" or "proleptic" eschatology, a mediating position between Bultmann and Dodd. Both Jesus and Paul adopted the Jewish dualistic framework of history, but they held the paradoxical view that the age to come has already broken into the present. The kingdom of God is both present and future. This view has also been developed by Joachim Jeremias, Werner Georg Kümmel, George Eldon Ladd, and Anthony Hoekema, and it has become the dominant view of New Testament theology, especially among evangelical Christians. In this view, the "already" and the "not yet" of the kingdom of God are held in tension. The followers of Jesus believed that the promises and predictions of the Hebrew Bible concerning the messianic age and the kingdom of God were fulfilled in Jesus and that his death and resurrection resulted in the turning of the ages. The age to come has broken into the present age so that Christians now live in "the last days" (Acts 2:17; Heb 1:2). Christians have tasted "the powers of the age to come" (Heb 6:5) and are those "on whom the ends of the ages have come" (1 Cor 10:11).

These interpreters argue that the references to the future consummation of the kingdom cannot simply be dismissed as the invention of the church. The New Testament writers awaited the consummation on "the last day" or "the day of the Lord Jesus Christ" when Jesus would return, raise the dead, judge all people, and replace this corrupted world with a new heaven and new earth (1 Thes 4:13–18; 1 Cor 15). Christians now live in the overlapping of the ages and await the culmination of the victory that Jesus won on the cross.

More recently, Marcus J. Borg and John Dominic Crossan have argued that eschatology was not central to the teaching of Jesus. In their view, Jesus was not an apocalyptic prophet but a Cynic sage whose teaching focused on proverbial wisdom. In contrast to this growing trend, other scholars, such as E. P. Sanders, John P. Meier, and Dale C. Allison, Jr., have argued that Jesus was an eschatological prophet who looked forward to the restoration of the Twelve Tribes of Israel. The debate over the role of eschatology in Jesus's mission and ministry continues to dominate research into the historical Jesus.

In systematic theology, the centrality and futurity of eschatology have been promoted by Pierre Teilhard de Chardin, Jürgen Moltmann, Wolfhart Pannenberg, and liberation theologians. For Teilhard, evolution will lead toward greater human progress until Christ descends in his Parousia and permeates the whole cosmos. In opposition to Bultmann, Moltmann emphasized that hope for the future was central to faith in the God of the Bible. The resurrection of Jesus offered the promise of a better future for the world that cannot be reduced to a timeless, historical encounter between God and the individual. Pannenberg stressed that the full meaning of history as God's history will be revealed only at the end. The resurrection of Jesus anticipates the future end of the world but also allows the power of the future to work in the present. Liberation theologians proposed that a better future can be actualized through political struggle for justice and equality in the here and now.

Christian theology eventually developed four different systems of eschatology, each of which contains numerous variations. The focus of their differences is Revelation 20:1–10, which contains the only reference to the 1,000-year reign of Christ in the New Testament. The earliest view is known as "historic premillennialism" or "chiliasm." This view was held by many church fathers, including Papias, Irenaeus, Justin Martyr, Tertullian, Victorinus, and Lactantius. According to this schema, the Antichrist will persecute the church during 3 1/2 years of tribulation. Christ will return, raise the dead saints in new bodies, and transform the living saints into their eternal bodies. Christ will judge the nations, imprison Satan in the abyss, and reign on Earth with his saints for 1,000 years (the millennium). Then Satan will be released to draw the nations into one last rebellion. Christ will throw him into the lake of fire, raise all people from the dead, and carry out the last judgment, which will determine the eternal fate of all individuals. The unredeemed will be thrown into the lake of fire, or Gehenna, and the redeemed will enjoy eternity in a renewed heaven and earth. Throughout the history of Christianity, millenarian ideas have been promulgated by numerous theologians and Christian sects, including Montanism, Joachim of Fiore, Thomas Müntzer, Seventh-Day Adventists, and Jehovah's Witnesses. "Historic premillennialism" is still defended by some evangelical Christian theologians such as George Eldon Ladd, George Beasley-Murray, Robert Mounce, Robert Gundry, and Grant R. Osborne.

Several factors led to the decline of chiliasm: (a) its association with Montanism, an early heretical movement; (b) the diminishing expectation of Jesus's imminent return ("the delay of the Parousia"); (c) the cessation of official persecutions of the church; and (d) the influence of allegorical interpreters such as Origen, Ambrose, Eusebius, Tyconius, Jerome, and Saint Augustine of Hippo. These theologians interpreted the 1,000-year reign as a spiritual reign of Christ through his church in the present age. Although they retained belief in a literal Antichrist, their teachings eventually resulted in the system of "amillennialism," which traditionally has denied a literal tribulation period, Antichrist, and millennium. The Council of Ephesus in 431 CE condemned as superstition the belief in a literal, 1,000-year reign of Christ on Earth. Amillennialism became the official doctrine of Roman Catholicism and is accepted by most mainline Protestant denominations.

In the 1700s, the system of "postmillennialism" was developed by Daniel Whitby and others and was held by Jonathan Edwards and Alexander Campbell. According to this view, the eventual acceptance of the gospel by all the nations will usher in a golden age of prosperity and peace. After the 1,000 years of bliss, Christ will return to raise the dead, carry out the last judgment, and usher in the eternal age. This view resonated with the optimistic views of progress promoted by the Enlightenment and Darwinism, but the tragedies of World War I caused it to fall into disfavor. Most postmillennialists adopted amillennialism, but some Presbyterian theologians have continued to promote it.

"Dispensational premillennialism" originated among the Irvingites and Plymouth Brethren in Great Britain in 1830 and was disseminated to the United States through the efforts of J. N. Darby. The *Scofield Reference Bible* popularized this view among fundamentalist Christians, and popular writings in America since the 1970s have increased its acceptance among evangelicals and Pentecostals. This view differs from historic premillennialism by teaching that Christ will come secretly before the 7-year tribulation to "rapture" living Christians from the earth. This view also places more emphasis on God's future plans for Israelites, who are still his chosen people. Because this system incorporates numerous passages from the Old Testament as well as the New Testament, it offers the most complicated and detailed of the four systems of eschatology.

Islamic and Secular Eschatology

Islam also offers various versions of eschatology. The central theme of Muhammad's eschatology was "the hour," the Day of Judgment and final catastrophe. After resurrecting both body and soul, Allah will reward individuals who acted justly by assigning them to paradise (Janna) and will punish other individuals by assigning them to hell (Jahannam). Near the last hour, Gog and Magog will devastate the earth, assault heaven, and be destroyed by Allah. In later versions, Gog and Magog will be led by the Antichrist (al-Dajjal). Some versions, especially among Shiʿites, also teach that a messianic imam called al-Mahdi (the "guided one") will return to establish a just society on Earth. The Antichrist, al-Dajjal, will usurp his reign until he is destroyed by ʿIsa (Jesus) or by al-Mahdi. Then will come the final judgment.

Secular versions of eschatology have also been proposed. Charles Darwin viewed natural selection as an ineluctable progress toward perfection. Karl Marx envisioned the future overthrow of the ruling capitalist class by the proletariat, resulting in a utopian, classless, and nonreligious society. Ernst Bloch argued that hope for a better future is a universal characteristic not only of humanity but of the whole universe. In contrast to the Christian view of eschatology, these secular versions propose a better future that is not dependent on the action of God. They criticize Christian eschatology for encouraging political passivity by denying the possibility of a better future within this age brought about by human efforts.

Gregory L. Linton

See also Afterlife; Apocalypse; Bible and Time; Christianity; Ecclesiastes, Book of; End-Time, Beliefs in; Evil and Time; History, End of; Islam; Judaism; Last Judgment; Parousia; Revelation, Book of; Religions and Time; Satan and Time; Teilhard de Chardin, Pierre; Teleology; Time, End of

Further Readings

Cohn, N. (2001). *Cosmos, chaos and the world to come: The ancient roots of apocalyptic faith* (2nd ed.). New Haven, CT: Yale University Press.

Hayes, Z. J. (1990). *Visions of a future: A study of Christian eschatology.* Collegeville, MN: Liturgical Press.

Hoekema, A. A. (1979). *The Bible and the future.* Grand Rapids, MI: Eerdmans.

McGinn, B. J., Collins, J. J., & Stein, S. J. (Eds.). (2003). *The Continuum history of apocalypticism.* New York: Continuum.

Polkinghorne, J. C. (2002). *The God of hope and the end of the world.* New Haven, CT: Yale University Press.

Schwarz, H. (2000). *Eschatology.* Grand Rapids, MI: Eerdmans.

Eternal Recurrence

The engaging concept of the eternal recurrence may be traced back to cosmic speculations in ancient Greece and early thought in the philosophies of India. This idea focuses on time, maintaining that it is essentially cyclical (rather than linear) in nature. Over the centuries, some serious thinkers have held that this finite universe has been, and will be, returning in exactly the same way; thus for them, reality is an infinite series of identical universes. This assumption that our universe is forever a repeating circle of objects, events, and relationships has far-reaching consequences for science, philosophy, and theology. This intriguing concept of time has appeared in major works of world literature, and it is also referred to in modern lyrics and major films.

In antiquity, the eternal return may be found in the thoughts of the Pythagoreans and the Stoics, as well as in Hindu and, later, Buddhist speculations on time. Among the Presocratic philosophers, Heraclitus developed a version of the eternal recurrence. He taught that the flux of reality is endless, but within it everything returns forever in an infinite series of finite cycles: Night and day follow each other, as do the lunar phases and the four seasons of the year. Likewise, life and death are followed by rebirth. On the cosmic scale, the whole universe returns periodically. Heraclitus's dynamic view of the world greatly influenced several process thinkers who came later, especially German philosopher Friedrich Nietzsche in the 19th century.

If true, then the idea of an eternal recurrence of the same raises profound questions concerning metaphysics and ethics; for example, if our universe is strictly determined, then can there be human freedom in the world? This idea also challenges the concepts of identity, causality, and creativity. Even though it is an extreme point of view, the eternal recurrence remains a unique frame of reference for making value judgments.

In recent philosophy, Friedrich Nietzsche (1844–1900) grounded his own worldview in the eternal recurrence of the same, thereby reviving this perspective in serious thought. In fact, it is his central idea. This concept came to him as a result of a fortuitous summer visit to Switzerland. In early August of 1881, while staying in Sils-Maria of the Upper Engadine, Nietzsche took a walk through the wooded Swiss Alps and along the lake of Silvaplana. The philosopher tells us that, while walking alone in deep thought not far from Surlei, he unexpectedly came upon a huge pyramidal rock in his path. Suddenly, in a flash of intuition "6000 feet beyond man and time" (as he put it), the restless thinker experienced a new vision of reality far superior (so he thought) to those views that had been presented by all other philosophers. Nietzsche's instant grasp of the colossal idea of the eternal recurrence made him delirious with joy, as he claimed that this concept would justify his own iconoclastic interpretation of ultimate reality, a worldview that he had been developing over the previous years.

Nietzsche had undertaken a rigorous reevaluation of all values, with alarming results. His scathing criticisms of Western civilization (especially Christianity) concluded that those basic ideas and entrenched beliefs that underpin the modern sociocultural milieu are actually false and have therefore been responsible for reducing human beings to a pitiful mediocrity. Claiming that "God is dead!" but overcoming nihilism, Nietzsche now desired to give to humankind a new philosophy that focused on the value of affirming life in general, and he gave priority to those superior individuals who are capable of impressive creativity.

Concerning time, Nietzsche had embraced the Darwinian theory of evolution with its sweeping framework of time. Evolution awoke the philosopher from his dogmatic slumber, giving to him a scientific foundation for his dynamic worldview. Nietzsche now saw this universe as a pervasive driving force or the will to the power responsible for the creative evolution of all life; he saw our own species as a temporal link between the fossil apes of the remote past and the overbeings to emerge in the distant future. But, must there exist only this one evolving universe? Why not an endless series of cosmic evolutions, each cycle absolutely identical to all the others? Christianity taught a unique and unrepeatable history of this world from the Divine Creation to the Last Judgment. In sharp contrast, however, the eternal return is far more than just a single linear history of this world or a general periodicity of different worlds. For Nietzsche, time has no preestablished final state or predetermined end goal. Furthermore, in the ongoing circularity of this universe, each successive cosmic cycle is absolutely identical in all general and specific details. Each cycle will be trillions of years in duration. This philosopher hoped that advances in the natural sciences would offer sufficient empirical evidence to, one day, demonstrate the truth of the eternal return of cosmic reality.

Nietzsche attempted to give rational arguments to convince other thinkers that the eternal recurrence of the same is a viable interpretation of our dynamic universe. He made three crucial assumptions: Space is finite, but time is eternal, and the cosmos consists of a finite number of atomic units. Therefore, the number of objects and events that can exist in this universe is also finite, and the resultant sequence of things will occur in a finite series. Nietzsche concluded that if time is eternal, then the same cosmic sequence of things would repeat itself (no matter how long it would take). As such, the identical galaxies would return with their same stars, comets, planets, and moons (each object playing out its same history). Every snowflake, drop of water, blade of grass, and grain of sand that has ever existed will reappear in an identical series of events throughout all time. The earth will return, undergoing the same evolutionary sequence of organisms, with fossil apes giving rise to our species and human beings preceding the emergence of superior overbeings to come. In the distant future, the wise overbeings will joyfully accept the cosmic truth of the eternal recurrence, which guarantees for them that they will exist forever.

In fact, Nietzsche thought that this identical universe would return an infinite number of times! Thus, for him, the eternal recurrence of the same was the quintessential interpretation of this universe; one is reminded of the oscillating model for this universe in modern cosmology. Concerning human conduct, the eternal recurrence offers this existential imperative: One ought to choose to act only in such a way that every choice is a decision made forever. This duty to eternity follows from the cyclicality of reality and gives infinite value to each choice. But there is no recollection of any past cosmic cycle, and, because each cycle is identical, it is always as if a person is free to decide among the actions that may be taken. However, if the eternal return is true, then each and every choice has been determined for all time, and, consequently, there is no free will (freedom is an illusion).

If true, then the eternal recurrence gives meaning and purpose to all existence. Nothing, not even the human animal, will pass out of existence forever. Everything has returned, and everything will return over and over again, including Friedrich Nietzsche (who would, in Nietzsche's view, live to formulate his idea of the eternal return an infinite number of times). If it is better to exist than not to exist, Nietzsche argued, then it is better to return to live one's identical life over and over throughout all time than to never exist again. As such, the eternal recurrence offers to human beings a natural substitute for personal immortality outside of religious beliefs and theological assumptions.

Actually, one may see the eternal recurrence of the same as a philosophical replacement for the personal God of the Judeo-Christian-Islamic religious tradition. The cyclical universe itself is the eternal, necessary, and sufficient Being that gives endless existence to everything in material reality. No doubt, Nietzsche found enormous comfort in this comprehensive idea, because it offered him a form of personal immortality without the need for postulating a spiritual soul within his naturalistic standpoint. Nevertheless, it remains puzzling that he had devoted so little space to explicating his idea of eternal return in his writings. Nietzsche had planned to author a book exclusively on this concept, but his intention was never realized. Even so, the highly controversial idea of eternal recurrence is both unverifiable and unfalsifiable. Therefore, it remains only a metaphysical speculation, although a very powerful one.

H. James Birx

See also Cosmology, Cyclic; Eliade, Mircea; Experiments, Thought; Heraclitus; Nietzsche, Friedrich; Nietzsche and Heraclitus; Time, Cyclical

Further Readings

Eliade, M. (2005). *The myth of the eternal return: Cosmos and history.* Princeton, NJ: Princeton University Press. (Original work published 1949)

Hatab, L. J. (2005). *Nietzsche's life sentence: Coming to terms with eternal recurrence.* New York: Routledge.

Kitt, T. F. (2007). *Eternal recurrence: A step out of time.* Twickenham, UK: Athena Press.

Löwith, K. (1997). *Nietzsche's philosophy of the eternal recurrence of the same.* Berkeley: University of California Press.

Stambaugh, J. (1972). *Nietzsche's thought of eternal return.* Baltimore, MD: Johns Hopkins University Press.

Eternity

The idea of eternity has two meanings: eternity as timelessness and eternity as everlastingness. In Western intellectual history, both meanings have been principally connected with discussions of God, especially regarding God's relation to time. Ever since Saint Augustine of Hippo (354–430 CE) and Ancius Boethius (c. 480–c. 524 CE), the view that God is timeless has became the dominant one. However, those who stress God's immanence and activity within human history have at times preferred divine everlastingness, especially in more recent times. The debate has been sharpened by the use of John M. E. McTaggart's distinction between A-series and B-series accounts of temporal sequence. The idea of a timeless "eternity" has resurfaced recently in experiential claims by many New Age proponents.

The word *eternal* comes from the Latin *aeturnus,* which means everlastingness. Philosophical discussions lead, however, to the two meanings already mentioned: One of these equates eternity with atemporality; the other equates it with sempiternity or everlastingness.

Classical Discussions

Perhaps one of the oldest discussions of a timeless eternity goes back to Parmenides of Elea (5th century BCE) and surrounds his notion of the One, though scholars disagree about this. Clearly, however, in Plato's *Timaeus* (37E6–38A6) there is a contrast between eternal and timeless forms and the world of change and becoming (with time being at least the measure of change). Time is famously termed by Plato "the moving image of eternity." Eternity here is a "movingless" realm. Aristotle, in contrast, more modestly claims that the existence of necessary things (like a God) only requires that such necessary things be unbounded by time—but only in the sense that they cannot age (*Physics* 221b30). Aristotle could be viewed as being an early proponent of eternity as everlastingness. Later, Philo Judaeus (20 BCE–50 CE) ascribes, possibly as the first Jewish philosopher, timelessness to the Jewish God. Plotinus (204–270 CE) goes further in identifying timeless eternity and life. *Nous* (or soul) for Plotinus is eternal and beyond time, enjoying duration without succession.

Subsequent ancient discussion of eternity in Western philosophy and theology has centered on the manner of God's existence. Book XI of the *Confessions* of Augustine and Book V of *The Consolation of Philosophy* by Boethius are the most famous ancient sources.

Boethius distinguishes between timeless eternity, which only God enjoys, and the temporal everlastingness of the world itself. God's existence, however, being that of a living being could not be like the timeless existence of lifeless abstract objects like numbers or ideas. For Boethius, God has life, yet its life is all "at once," or simultaneous. This atemporal simultaneity helps resolve the puzzle of how God's foreknowledge of all events is compatible with humans' real free will. (If God knows my choices in advance, then how can I really have the power to avoid making those choices?) For Boethius this is not a problem, because God does not know anything "in advance" but knows what happens atemporally.

The puzzle that leads Augustine to agree with the atemporal view of eternity is this: How can God precede all times in order for God to create all times? After all, the notion of precedence is itself a temporal notion. Augustine concludes that only by being outside of time can God "precede" all times. God's type of eternity is "always in the present." This divine present, of course, is not a moment in time or of time. There is no temporal sequence in God's manner of existence. God transcends time. Unlike his creation, God is changeless and exists necessarily. Augustine shares this view with Plato, that is, the assumption that change is a mark of imperfection. God's perfection, therefore, rules out its being subject to change and thus to time. If God were temporal, then God could in principle change, and perhaps the changing of a perfect nature could only lead God away from perfection. God must exist as a finished and perfect unity. Unlike material objects, God cannot be spread out in time (or in space). God must exist all at once.

Anselm of Canterbury (c. 1033–1109), Moses Maimonides (1131–1204), and Saint Thomas Aquinas (1225–1274) propose similar views. For Aquinas and for John Duns Scotus (c. 1266–1308), God's timeless eternity is a correlate of divine simplicity, which is incapable of being defined or fully grasped by a creature.

Modern Philosophical Debates

Modern debates between eternalist and temporalist approaches to understanding God's eternity—and of God's relation to our time—have benefited from a distinction put forth by J. M. E. McTaggart (1866–1925). This is the distinction between an A-series view of time (where the temporal series is viewed from within and uses terms like *tomorrow, now, then, past,* and *future*) and a B-series view of time (where the temporal series is viewed indifferently as a series of moments or events placed as *earlier than, later than,* or *simultaneous with* other moments or events).

Some current thinkers, such as Paul Helm and Katherin Rogers, argue that for God, who exists timelessly, the temporal order is a B series. All times are equally present to God's mind. According to this view, God is in no temporal relation to this B series.

Other defenders of divine timelessness, such as Eleonore Stump, Norman Kretzmann, and Brian Leftow, insisted that God's eternity has some of the features of extension or duration, which they claim are not temporal but which critics have found objectionable.

Temporalist opponents, such as Anthony Kenny and Richard Swinburne, have argued that eternalism is incoherent. If God exists all at once, then God exists simultaneously with all the events that occur in the universe. They argue that since an event now and an event 2,000 years ago are each simultaneous with God, the two events must then be simultaneous with each other. But the latter is absurd. Thus, God's simultaneity with every temporal event must be impossible.

This argument is still the subject of debate, as it is not clear that God could not be "simultaneous" to separate temporal events in such a way that the two temporal events would not be forced to be simultaneous with each other.

Paul Tillich (1886–1965), in his book *The Eternal Now,* claims that a timeless and divine eternal now is required for our sense of temporal present now. For, looked at from the outside, time as a succession of moments does not exhibit any present or any "now," but only a chain of moments sequentially arranged. Yet we experience a now. The experience of a present now, Tillich claims, is made possible only by the breaking through of a timeless eternal present (of God and of our essential divine self) in the time sequence.

Common Analogies

A much repeated metaphor meant to shed light on the paradoxical relation between a divine eternal now and our successive time is the image of God as an immovable point at the center of a circle, a center point equally distant from every point on the circumference. The circumference represents the moving, successive, spread-out nature of time. Such a circumference would have to be imagined as infinitely long and as not necessarily returning to close upon itself. Also, in this image the distance between God, as center point, and each point on the circumference would have to be imagined as nonexistent—to establish the immediacy of God's presence in every moment of time.

A second analogy often used to convey the paradoxical relation between a divine eternal now and our successive time appeals to the possibility of a hidden macro dimension within which time is embedded. Imagine how a third spatial dimension would appear to a Flatlander (an inhabitant of two-dimensional space). A three-dimensional line perpendicular to a Flatland plane would have to be conceived as a stack of points piled on each other and yet each *in some sense* occupying *the same* Flatland place. Imagine how motion along this perpendicular line (as the motion of a missile or point going straight up) would have to be conceived by Flatlanders. Ordinarily for Flatlanders all motion is horizontal motion. Thus, they would have to speak of perpendicular motion as of a kind a spatial dynamism that is not really spatial. This could, by analogy, shed light on the paradox of nontemporal *yet dynamic* events. Just as the motion of a missile moving in a direction perpendicular to Flatland would be incomprehensible to Flatlanders, yet quite real, so too an atemporal fifth-dimensional divine observation of temporal events might be *dynamic* in a way that is incomprehensible to four-dimensional beings like us. Whether this spatial analogy can in fact shed light on temporal paradoxes has, of course, been disputed. A second question that has been raised is whether this extradimensional analogy points to a timeless God or to a hypertemporal god.

These debates between eternalists and temporalists are complicated by the new physicist notion of relativized spacetime—which denies that there is an objective temporal sequence of temporal events (i.e., which events happen before and which ones happen after depend on an observer's spatiotemporal standpoint).

Temporalists have also objected that eternalism relies on a false view of time, the B-series view—time must inherently be experienced from within. Whether this is true, however, is controversial.

Temporalists have further objected that eternalism would make God a "lifeless" being. Any personal living God, who is affected by the suffering of its creatures and who affects changes in this world, must be a temporal God. Of course, whether a God must be personal in this fashion is subject to dispute. In addition, whether a timeless God would be automatically unable to engage "timelessly" in such interactions is itself not completely obvious, particularly if there could be either nontemporal dynamisms or forms of hypertime totally foreign to our form of time. The appeal that is often made here—particularly by mystics—is that God's nature transcends, at least in part, our intellectual, linguistic, and imaginative powers.

Finally, philosophers like Swinburne find divine temporalism attractive because it is most compatible with the libertarian free will of creatures (and perhaps also of God itself). For the perfect omniscience of a timeless God might make alternative choices by agents impossible. However, a temporalist God might also be in the position of knowing human choices *in advance*—thereby possibly making alternative possibilities in human choices an illusion. Moreover, Boethius's type of defense of eternalism (that a timeless God does not know anything "in advance," hence its timeless knowledge might be in some sense simultaneous and thus harmless with respect to agents' free will) may remain still substantially sound.

It is worth adding that in Eastern thought, eternalists have dominated the characterization of the Ultimate Source. Among such eternalists, the account of Brahman by the Hindu Vedanta philosopher and theologian Shri Adi Sankara is one of the most influential. He characterized the ultimate Brahman—following, he claimed, older Upanishadic sources—as pure timeless awareness and bliss. Here too there have been criticisms that any pure divine awareness of all things, including awareness of the changing world of Maya or our apparent universe, would seem to require some internal structure and dynamism. The latter might be incompatible with timelessness.

Recent Accounts or "Experiences" of Timeless Eternity

There has been a recent resurgence of nonphilosophical and nontheological experience-based claims regarding some form of timeless eternity. These accounts derive partly from the New Age movement since the 1950s—a dispersed movement characterized by eclectic nontraditional mysticism-based spirituality. Similar claims derive also from the now widespread phenomena of near-death experiences.

The former movement includes a number of alleged spirit-channelers reporting on rather Eastern-like pantheistic claims to the effect that God is in everything and that by turning inwardly we can access God's and our own (and more real) timeless nature. This viewpoint advises that beneath our ordinary temporal realm there is another and more basic one, often characterized as a divine eternal now. The metaphysics underlying this claim seems to be that the ultimately timeless Divine Reality opts to manifest itself as the temporal and spatial multitude of things we call the universe (and perhaps as many other universes as well). Such metaphysics appear to have roots in ancient Indian thought. The popular "Seth" books by Jane Roberts may constitute the most sophisticated and serious example of this New Age account of reality.

There is, in addition, an extensive recent literature regarding the *experience* of some form of timelessness during alleged near-death experiences (experiences one has during certain traumas and sometimes in hospitals through moments while one is mistakenly declared clinically dead). During parts of such experiences—while reviewing one's whole life "instantaneously," or while engaging in some form of "instantaneous" thought-travel—many people claim that their sense of time slows down drastically, or stops altogether, while their awareness of countless events continues. Some claim that this represents the experience of an eternal now, and they often attribute this eternal now to a feature of the postlife divine environment.

Carlo Filice

See also Anselm of Canterbury; Aquinas, Saint Thomas; Aristotle; Augustine of Hippo, Saint; Boethius, Anicius; Bruno, Giordano; Duns Scotus, John; Eternal Recurrence; God and Time; McTaggart, John M. E.; Nietzsche, Friedrich; Plato; Sankara, Shri Adi; Tillich, Paul; Time and Universes

Further Readings

Anselm. (1998). The Monologion (S. Harrison, Trans.). In B. Davies & G. R. Evans (Eds.), *Anselm of Canterbury, The major works.* Oxford, UK: Oxford University Press.

Augustine. (1991). *The confessions* (H. Chadwick, Trans.). Oxford, UK: Oxford University Press.

Boethius. (1969). *The consolation of philosophy* (V. E. Watts, Trans.). London: Penguin.

Craig, W. (2001). *Time and eternity: Exploring God's relationship to time.* Wheaton, IL: Crossway Books.

Helm, P. (1988). *Eternal God.* Oxford, UK: Clarendon Press.
Leftow, B. (1991). *Time and eternity.* Ithaca, NY: Cornell University Press.
McTaggart, J. M. E. (1908). The unreality of time. *Mind: A Quarterly Review of Psychology and Philosophy,* pp. 456–473.
Pike, N. (1970). *God and timelessness.* London: Routledge.
Roberts, J., & Butts, R. F. (1994). *Seth speaks: The eternal validity of the soul.* San Rafael, CA: Amber-Allen.
Sorabji, R. (1984). *Time, creation and the continuum: Theories in antiquity and the Early Middle Ages.* London: Duckworth.
Stump, E., & Kretzmann, N. (1981). Eternity. *Journal of Philosophy.*
Swinburne, R. (1994). *The Christian God.* Oxford, UK: Clarendon Press.

ETHICS

Our time on earth has an exceptional value. It is valuable because with the death of one human being a whole world dies. In other words, the unique perspective of a person disappears with his or her death. This is one of the reasons why murder is considered such a horrible crime: It destroys "a whole world." An important task of every ethics consists in establishing a framework preventing us from killing or harming each other.

The term *ethics* was first coined by the philosopher and physician Aristotle (384–322 BCE) in his book *Ethika Nikomacheia* (a book on ethics for his son Nikomachos). *Ethics* has its roots in the noun *ethos,* which means "custom." Aristotle understood it as the rational study of customs, which as a practical science does not have the methodological exactness of, for example, mathematical science, but is nevertheless guided by principles. Today the term *ethics* is used in a manifold way. In everyday language, it is often used synonymously with moral behavior; that is, people are called ethical if they behave morally. In philosophy, ethics is synonymous with moral philosophy and deals with questions regarding how we can justify norms, distinguish good and evil, or develop consistent ethical theories. For some philosophers of the analytic tradition, ethics can only be metaethics, meaning that it is able to analyze ethical terms and principles but is unable to provide universally valid ethical norms. Others reduce ethics to a hermeneutic description of ethical attitudes, using it to interpret how it influences the world in which we live. For theologians of the Christian tradition, ethics is synonymous with moral theology, thereby reflecting the moral precepts of the Bible and Christian communities.

This entry begins with the fundamental question of whether or not there is free will and, subsequently, if moral obligation is possible. Next it explores why the concepts of time and space have a significant role in ethical theories by giving a short historical overview of ethical positions, which at the end focuses on the question that pits ethical relativism against ethical universalism.

The Question of Free Will

Neurobiological discoveries, in combination with modern genetics, have led some to the opinion that human beings are biological machines determined by their biological hardware. This is especially the case with human brains and genes, though outside influences play a role as well. In this case, there is no room for free will; the web of motivations that moves us to act is fixed. We simply do what we are predetermined to do. If ethics is supposed to develop moral norms that dictate what we ought to do, it now seems to be in contradiction with the assumption that we are determined. In other words, we need the ability to act in accordance or discordance with the "ought to" and, moreover, because we have free will and are not already determined. If there is no free will, the concept "ought to" becomes meaningless.

There are various solutions to this problem. Philosophers often suggest a version of free will in terms of modular brain functions that is compatible with determinism. Human beings are perceived as a complex, determined, neurophysiological system. Data are taken in, and alternatives are generated and ranked. Eventually an output initiates action, and this action is considered free, notes Simon Blackburn, if the following is valid: "The subject acted freely if she could have done otherwise in the right sense. This means that she would have done otherwise if she had chosen differently *and,* under the impact of other *true and available* thoughts or considerations, she *would* have chosen differently. True and available thoughts and considerations are those that represent her situation accurately, and are ones that she could reasonably be expected to have taken into account." Theologians tend to offer an incompatibilist version; that is, free will is not compatible with determinism. For strict Calvinists, for example, there is no free will. God predetermines what we do. The Roman Catholic Church explains freedom of the will by insisting that the human person can be reduced to a physiological, and therefore entirely material, reality. The moral self has a transcendent element, generally associated with the soul, and moral decisions reflect the complexity of that body–soul reality; that is, it cannot be a simply material determination. The question of how moral thoughts are evaluated, such that humans may or may not choose the "good" action, is answered by introducing the concepts of grace and sin and the mystery of evil.

A Short Overview of Ethics and the Importance of Time

Ethics can be either religious or philosophical. Some religious ethics require a belief that God reveals himself (Judaism, Christianity, and Islam), while others are more similar to secular ethics, for example, Buddhist ethics or Confucianism. Jewish and Christian ethics are based on the Ten Commandments: The first three commandments relate to the worship of God, that is, no graven images of him should be made and a day of worship should be set aside, whereas the other seven deal with relationships between human beings dictating that we should honor our parents (4) and refrain from killing other human beings (5), from breaking the vows of marriage (6), from stealing (7), from false testimony (8), from desiring the wife or husband of another (9), and from desiring the belongings of another (10). We follow these commandments when we love God, as well as when we love our neighbors as we love ourselves. The Five Pillars of Islam are (1) the declaration of faith, (2) praying five times a day, (3) almsgiving, (4) fasting during the month of Ramadan, and (5) making the pilgrimage to Mecca at least once in one's lifetime. All three monotheistic religions stress the importance of our time on earth and its relation to eternity. Whoever does not follow the commandments puts his or her eternal life and reward at risk and is faced with the threat of eternity in hell. For this reason, our time on earth is extraordinarily important.

In a similar sense, Buddhist ethics emphasizes the importance of our life on earth. Whoever does not follow the Eightfold Path, which can be considered a kind of virtue ethics, does not reach Nirvana. The elements of the Eightfold Path are the (1) right view, (2) right resolve, (3) right speech, (4) right action, (5) right livelihood, (6) right effort, (7) right mindfulness, and (8) right meditation. But instead of going to a hell, those who do not follow the Eightfold Path will be reincarnated into a life form that corresponds with the deeds in their former life. However, here we have to ask: When are the view, the resolve, and so forth, right? The answer is rightness exists when one follows the five principles: refraining from harming living creatures, from taking what has not been given, from sexual immorality, from speaking falsely, and from taking intoxicants. Confucianism also provides a number of practical principles for life here on earth instead of a focus on a future eternal life.

In Western philosophy, written ethical reflection in the philosophical sense begins with Plato (c. 428/427–348/347 BCE). Plato, Aristotle (384–322 BCE), and the Christian philosopher and theologian Saint Thomas Aquinas (1224–1274) believed that an objective, transcendent reality guarantees the good and the rightness of principles, norms, and corresponding actions. For Plato this is the idea of the Good; for Aristotle it is the unmoved mover, which is the first cause; and for Aquinas it is God as love, who reveals himself in history. Human beings touched by this reality will do good and avoid evil. Furthermore, this represents the fulfillment of human nature. Therefore, these ethical approaches are often called doctrines of natural law, even though they sometimes significantly differ in the concrete norms they establish. For example, Aristotle allows abortion, whereas Aquinas forbids abortion. The common bond, however, is the focus on virtues as good habits that foster a good life. Consequently, these ethical theories are sometimes called virtue theories. For Platonists, though especially for Neoplatonists and Aquinas, the good life does not end here on earth, but reaches fulfillment only in the presence of God.

A completely different class of ethical approaches is the class of contractarian theories. Religious wars destroyed people's trust that religion could bring peace and prosperity because all sides defended their actions by claiming to act in accordance with God's will. Hobbes (1588–1679), therefore, did not use a transcendent reality as the foundation for ethics. Instead, he developed a contract theory according to which the lives of all humans are guaranteed when they relinquish their freedom to an all-powerful sovereign. The sovereigns implement the contract, and they have all freedoms except one: They has to protect the lives and well-being of their subjects. Thereby, a contract, not the idea of "good" or a god, secures our lives and well-being. However, even today it remains unanswered how such a contract can be realized and implemented. A similar approach that focuses on a moral ideal rather than on securing life and well-being is called contractualism. John Rawls (1921–2002), the most famous contractualist, bases the contract on the moral ideal of justice as fairness. His main idea is as follows: On the basis of their common interests, people would rationally choose a democratic society based on the principles of freedom and justice as fairness (the option for the "least advantaged") if they did not know what their later position in society was to be. Contractarians and contractualists agree on the relevance of the life of every human being. Our lives are so important because death terminates every possibility of action here on earth for the respective person.

In contrast to Plato, Aristotle, and Aquinas, who focus on an objective good, and to contractarians and contractualists, Immanuel Kant (1724–1804) emphasizes the role of goodwill. The goodwill is realized by action guided by a fundamental commandment called the "categorical imperative," a principle of action that is a universal moral law. All rational beings endowed with freedom, regardless of their particular interests and social backgrounds, have to adopt this principle: "Act only according to that maxim [the determining motive of the will] whereby you can at the same time will that it should become a universal law" By using the term *universal law* Kant means that this principle does not allow for any exceptions like laws of nature do. Kant's ethics is called deontological (from the Greek to deon, meaning that which you have to do) because you have to follow this imperative for the sake of duty and not for any other reasons. The categorical imperative is not commanded from someone other than the agent—that is, it is not heteronomous (*heteros,* "the other"; *nomos,* "the law")—but rather it is a law that the practical reason of agents gives to them. Consequently, it is autonomous (*autos*, "self"). Thus, a fulfilled life is a life lived for the sake of duty. To a certain extent and in the tradition of Kant, the contemporary philosopher Jürgen Habermas has developed a discourse theory according to which norms are established by means of an ideal discourse situation. This is a situation free from the threat of violence, where every participant has an equal say in the process of establishing the necessary norms. As a result, all participants accept the norms they have agreed upon together. Like Kantian ethics, Habermas's discourse theory has no real relation to time and space. It is a universalist ethics beyond time and space.

Kant's and Habermas's ethics differ very much from all forms of consequentialism (Latin: *consequi,* "to follow"), which assess the rightness or wrongness of an action in terms of the goodness or utility of its consequences. Insofar as most religious ethics, though also the virtue ethics, assess the rightness or wrongness of actions in terms of goodness, that is, an eternal life, they can be called consequentialist. Nevertheless, these ethics are not utilitarian. Utilitarianism is a specific form of consequentialism. Though it has a long history dating back to Plato's time, its classical formula was coined by Jeremy Bentham (1748–1832): "by utility is meant that property in any object, whereby it tends to produce benefit, advantage, pleasure, good, or happiness (all this in the present case comes to the same thing) or . . . to prevent the happening of mischief, pain, evil, or unhappiness." The goal should be to maximize utility, which means the greatest happiness for the greatest number should result. Nowadays, there are a variety of utilitarian theories. However, most important is the difference between act utilitarians and rule utilitarians. For questions regarding applied ethics, Peter Singer's preference utilitarianism is of great interest. In contrast to utilitarians like John Stuart Mill (1806–1873), Singer emphasizes the importance of the preferences of humans as well as other animals.

Ethical Relativism Versus Ethical Universalism and the Importance of Time

Most ethical theories have to deal with an argument taken from social and cultural anthropology: Social and cultural anthropologists, up to the present day, have discovered huge differences among societies with respect to their moral evaluation of issues such as euthanasia, infanticide, sexuality, child support, the poor, the status of women, slave labor, and so on. The Greek historian Herodotus gives us one of the most famous examples. Darius, the king of Persia, once asked Greeks, who burned the bodies of their deceased relatives, how much he would have to pay them to eat the dead bodies of their family members. They refused to do it at any price. Then Darius offered a huge amount of money to some Indians, who, according to custom, ate the bodies of their parents, to burn their fathers' bodies. The Indians refused to do such a horrid act, which would have been in violation of their beliefs. Herodotus drew the obvious moral conclusion: Each nation considers its own customs as morally right and the customs of others as morally wrong.

Two very important questions arise from this conclusion: Does cultural relativism entail ethical relativism? Is morality only a matter of what is customary; that is, is it relative to a particular society? If this is so, then words such as *good* and *bad* just mean "acceptable in a certain society" or "unacceptable in a certain society." Even if there are common moral convictions across cultures, this does not mean that ethical relativism has been proven wrong. There was a time in which slavery was not questioned by any known society. Today we, of course, do not accept slavery as morally right. Although the nations involved in World War I were excited about going to war in 1914, we do not claim today that the war was morally "good."

From a logical point of view, ethical relativism cannot be proven wrong, but the examples of slavery and of World War I show that this ethical position is highly problematic: We do not accept slavery today because *our* society disapproves of slavery. We reject slavery because we are convinced that slavery was wrong and is wrong and will continue to be wrong. And we have good reasons to think so in order to defend human dignity and human rights, which through the experiences of the atrocities of the 20th century, have become the foundation of a common universal ethical bond among human beings. Alan Gewirth has developed a rational argument for an ethical universalism with respect to human dignity and human rights. His argument rationalizes the experience given in history and so given in time: I do (or intend to do) X voluntarily for a purpose that I have chosen. There are generic features of agency in a deep sense of the word *agency.* My having the generic features is good for my achieving the purpose I have chosen. I ought to pursue my having the generic features of agency. Other agents categorically ought not to interfere with my having the generic features *against my will* and ought to aid me in securing the generic features when I cannot do so through my own unaided efforts *if I so wish*. I have both negative and positive rights to claim that I have the generic features. If I have these rights, all agents have these generic rights, and I have to respect their rights. Whoever does not accept this reasoning contradicts him- or herself because then it is possible to interfere with his or her generic features against his or her will.

But even if this argument gives good reason for ethical universalism, it does not explain what exactly generic features are. Therefore, on the one hand, the various results of social, cultural, philosophical, and theological anthropologies do not necessarily lead to ethical relativism. On the other hand, they prevent us from quickly labeling a norm as universal, and they indirectly let us understand that we have our own lives to live, not just a kind of universal life.

Ethical universalism gives a framework for what we should do. This framework, however, cannot abolish the responsibility every human being has in living his or her true nature. Every human being as a being in time and as a being able to anticipate his or her death knows about the finitude of his or her time on earth. Ethics cannot substitute this individual responsibility of living the proper life. A human being may follow all commandments of a religious or secular ethics, but if he or she does not live his or her true nature, this life was not his or her proper life. So, it is the finitude of our time on earth that transforms every universal ethical approach into a personal way of life.

Nikolaus J. Knoepffler

See also Aquinas, Saint Thomas; Aristotle; Christianity; Herodotus; Kant, Immanuel; Morality; Plato; Values and Time

Further Readings

Blackburn, S. (1999). *Think. A compelling introduction to philosophy.* Oxford, UK: Oxford University Press.

Gewirth, A. (1978). *Reason and morality.* Chicago: University of Chicago Press.

Sterba, J. P. (Ed.). (1998). *Ethics: The big questions.* Oxford, UK: Blackwell.

Event, First

A contemporary cosmology of the universe is based on the theory of general relativity, which includes a creation event, a first event. Using the equations of general relativity, it is possible to trace the origin of the universe backward in time to an estimated beginning point, a first event. The big bang as a first event is viewed as the beginning of the universe and more specifically as the beginning of time. As a result of the big bang, the universe is continually expanding and changing because galaxies are moving away from each other at high speeds. In the big bang cosmology, time is finite and has a specific beginning point and a possible ending as the expansion that began with the big bang comes slowly to an end due to gravitational forces. A series of photos collected from the Keck and Hubble space telescopes show the universe in the various phases of expanding from the time before galaxies existed to newly formed galaxies tightly packed together and still colliding, to the current stage of development when there are few new star formations, and galaxy collisions are less frequent. It is believed that photos have captured the moment in cosmic history when the universe was only 300,000 years old. At that moment, light is thought to have separated from darkness, a description that some contemporary theologians believe fits the biblical account of Creation.

The big bang theory was proposed in 1946 by George Gamow, a Russian scientist, who identified the big bang as an exploding, primeval fireball that contained the entire physical universe, including the dimensions of time and space. In 1965, observations at the Bell Telephone Laboratories of a ubiquitous background radiation provided convincing evidence of the validity of the big bang theory. In 1992 the NASA (National Aeronautics and Space Administration) satellite Cosmic Background Explorer provided additional evidence that placed the beginning of the universe at about 15 billion years ago. In the 1970s the work of Stephen Hawking and Roger Penrose helped to prove that time is finite in a universe with an identifiable beginning event and possible predictable ending. Using mathematical calculations to establish the presence of mass in the universe and the general relativity theory of Einstein to show how mass can be expected to behave, Hawking and Penrose established that time is finite and must have started when the universe began. Hawking defines an event as something that happens at a particular point in space and at a particular time. For Hawking, time and space begin together in the big bang and therefore are never truly separate. He refers to space and time together as spacetime. Hawking's description of the big bang as the "singular boundary" for space and time is known as the singular boundary theorem. For some philosophers and theologians, the spacetime theorem lends itself to the argument for the existence of God because the concurrent beginning of the universe and time make it necessary to find a first cause. For many theologians, the first cause can only be a deity who transcends time and all other dimensions of the cosmos, including space, matter, and energy. While it is not necessary to narrowly define the first cause as the God of the Christian Bible, many philosophers and theists agree that it is not possible for something to come out of absolutely nothing; therefore, the universe must have a cause that existed before the big bang. The big bang theory of the universe requires a transcendent force that is separate from the universe to bring the universe into being. Without endorsing any theological beliefs, many physicists acknowledge the need for a universe with a beginning and a pre–big bang first cause or superior reasoning power. Some members of the scientific community continue to argue for a static or steady-state universe where time and space are still absolute and separate according to the calculations proposed by Isaac Newton. However, for some cosmologists, this universe may be cyclical and therefore does not require a beginning in time or a transcendent ultimate force.

Elaine M. Reeves

See also Big Bang Theory; Black Holes; Causality; Cosmogony; Cosmology, Inflationary; Einstein and Newton; Hawking, Stephen; Time, Arrow of; Time, Emergence of; Time, End of; Universes, Baby

Further Readings

Gribbin, J. (1999). *The birth of time: How we measured the age of the universe*. New Haven, CT: Yale University Press.

Hawking, S. H. (1988). *A brief history of time: From the big bang to black holes*. New York: Bantam Books.

Trinh, X. T. (1993). *The birth of the universe: The big bang and after.* New York: Abrams.

Evidence of Human Evolution, Interpreting

In the fossil human record, the most famous fossil discoveries have been those that provided evidence to either support a current theory, reject a previously supported theory, or that have created new theories about human history. The information that new discoveries provide comes more from the analysis and interpretation of the evidence than from its display in a museum and observation by the public. Although interpretations can vary based on the knowledge and opinions of an individual, they provide meaning for the object. The evidence holds the facts, and it is the interpretation of the evidence that exposes the facts. Over time, as new discoveries continue to fill in the fossil record of human existence, it is not the fossil skeletons and artifacts themselves but the interpretation of the evidence that allows for solution of the puzzle. A fossil, in and of itself, is nothing more than the preserved remains of an organism, but analyzing it and drawing a conclusion from this analysis reveal its true historical footprint. A large portion of our current knowledge is the result of this process of observation, then analysis, followed by interpretation, and finally assumption, deduction, hypothesis, and theory.

Generally, the more complete the specimen, the more information it reveals, but even small partial fossil remains can give an overwhelming amount of data about human history. A simple leg bone can help researchers date the characteristic ability of hominids to stand erect and walk upright on two legs. Even a fractured, partial skull bone can help prove if bipedal walking or the enlargement of the brain arose first in hominids. The morphology is what tells the story. But as interpretations are based on the perceptions and opinions of the individual investigator, they are not infallible. As a result, the theories created from these interpretations are always subject to change over time. As new evidence becomes available, the current theories are either rejected or confirmed; they evolve. It is not uncommon for several interpretations to exist that conflict with each other. Although the interpretation of evidence is not flawless, it is fundamental for the understanding of human evolution. As our only source of information about human evolution, every new piece of evidence is valuable and influential. This is especially true because only a small number of all the hominids that have ever lived on Earth became fossilized, and of those that were, only a fraction have been discovered. But as more evidence is found each year, we develop a better understanding of, and appreciation for, our human evolution.

Early Interpretations: Germany and Java

Even before the first fossil humans were discovered, many naturalists in the 19th century had already begun to recognize that the earth was much older than described in the Bible. Therefore, the length of existence of humans on Earth became open to interpretation, and the field of paleoanthropology was born. The first discovered human fossils were those of a Neanderthal in August 1856. Found in a limestone quarry in the

Neander Valley, the bones were brought to Johann Fuhlrott, who recognized them as both human and ancient. He gave the bones—consisting of a skullcap, two femora (thighbones), fragments of an upper and lower left arm, a partial pelvis, and several other small bones—to Hermann Schaaffhausen, an anatomy professor.Schaaffhausen's report described the anatomical features with great detail, and he concluded that they belonged to a strong, muscular individual. What most intrigued Schaaffhausen were the pronounced ridges above the eyes and the low, narrow forehead, which he said resembled the skulls of the large apes. From this, he concluded that "man coexisted with the animals found in the diluvium; and many a barbarous race may, before all historical time, have disappeared, together with animals of the ancient world, whilst the races whose organization is improved have continued the genus." His interpretation fit into the common idea of the time. Before Charles Darwin's publication of *On the Origin of Species* (1859), the dominant theory was one that proposed a variety of species had existed. This was a more fundamental approach, in which the thought was that all the species that exist today existed in the past, but some species have become extinct. So Neanderthals, Schaaffhausen concluded, were a "barbarous race" of humans that had coexisted with the ancient relatives of modern humans but had gone extinct sometime in the past. The human fossil record at that time was not seen as evidence for the idea of human evolution, only as evidence of human antiquity and diversity.

It took several years for the full scope of Darwin's idea of evolution as "descent with modification" to be realized. The leap to the thought that "species are the modified descendants of other species," as Darwin described, was a difficult one. Many did not want to accept an idea that proposed humans had descended from the same ancestors as the apes. Darwin's publication of *On the Origin of Species* laid the foundation for this change, but it was another decade until it emerged. In 1868 and 1871, Ernst Haeckel and Charles Darwin, respectively, published books that supported the idea that both apes and humans share a common ancestry. The first fossil evidence to support their ideas was not discovered until 1891 in East Java, Indonesia, by Eugene Dubois. The fossil remains, known as Java man, consisted of a skullcap, a femur, and several teeth. The femur was similar to that of a modern human femur, which meant that the animal had been bipedal. However, the skull showed apelike characteristics, most notably the pronounced ridges above the eyes. The size of the brain, 900 milliliters (ml) in volume, although considerably smaller than the brain of modern humans (which is around 1400 ml in volume), is much larger than those of the modern apes, around 400 ml. Therefore, because the brain was larger than that of modern apes, Dubois asserted that these remains were that of an ape-like man and not of a man-like ape. He named it *Pithecanthropus erectus,* meaning "upright apeman." Dubois claimed that it could be classified neither as human nor ape but was an intermediate between modern humans and the common ancestor of humans and apes. His evidence demonstrated that bipedality arose prior to the enlarged brain size; Darwin had proposed that a large brain preceded bipedality. Today this ancestor is classified as *Homo erectus,* and most anthropologists believe that the earlier ancestor of modern humans is the *Homo erectus* found in Africa, not in Asia.

Early Interpretations: South Africa and China

Another major discovery was that of the Taung skull in 1924. Found in a quarry in South Africa, the fossil consists of an almost complete face, a mandible with teeth, and an endocranial cast of the braincase. An endocranial cast is a cast of the cranial cavity showing the approximate shape and size of the brain. The fossil, among others, was given to Raymond Dart, an anatomist and anthropologist, who recognized it as the skull of a child of an unknown hominid species, intermediate between humans and apes. Dart named it *Australopithecus africanus,* meaning "southern ape of Africa." The brain was larger than that of an immature ape but not as large as that of a modern human child. This trend was also seen in the teeth, which were smaller and more human-like than those of the chimpanzee, which Dart's critics believed he had found. The skull also showed human-like characteristics such as a less robust mandible and a rounded forehead that lacked the pronounced eyebrow ridge. Dart was criticized at the time because most of the traits he described as human-like could be attributed to the fact that it was a juvenile and had not fully developed its facial features and secondary sexual characteristics. There was one feature, however, that his critics could not attribute to immaturity. What convinced Dart he had discovered a bipedal man-like ape was the position of the foramen magnum, the hole in the skull where the spinal cord attaches to the brain. It was positioned at the base of the skull, the same as in humans, not at the back of the skull, as in apes. This meant it had walked upright, on two legs. His interpretation was also criticized because, at the time, it was believed that the ancestors of humans would be found in Asia and not in Africa because of the discoveries of Java man and later Peking man in Asia. Also, because the earth was considered to be only around 65 million years old at the time, the Taung child would have appeared too late to be a human ancestor. Dart's interpretation of the Taung child as representing an extinct race of hominids that can be categorized between living apes and modern humans is important because it was the first major fossil human evidence from Africa. It confirmed Darwin's theory that human origins would be traced back to Africa and not Asia or Europe. As a result, more people began to search in Africa for human fossils. Today, hundreds of human fossils from Africa support Dart's original interpretation.

Dart's theory about human origins in Africa was meeting stiff opposition because some naturalists gave priority to the theory of Asian ancestry. This theory became even more dominant with the discovery known as Peking man. Since the discovery of *Pithecanthropus erectus* by Dubois in Java had become popular, the fossils of Peking man were more readily accepted. The first evidence was that of two fossil human teeth from Zhoukoudian near Beijing. In 1926, they were given to Davidson Black, an anatomy professor, who began excavating the same site the next year. Following the discovery of another tooth there, he created a new genus and species, *Sinanthropus pekinensis,* the "Chinese man of Peking." Many anthropologists did not accept his conclusion based solely on three teeth. It was not until 1929 that a braincase of *Sinanthropus* was found. Although it possessed a slightly larger brain and steeper forehead than the Java man, analysis showed that it was an early human very similar to that individual. From this, Black concluded that *Sinanthropus* was an intermediate form between *Pithecanthropus* and the Neanderthals. Today, it is classified as *Homo erectus*. While proving that *Pithecanthropus* was an early human form and not an ape form, it also gave some insight on the advancements made by *Sinanthropus*. Among the stone tools found at the site were animal bones that showed signs that they had been burned. Black interpreted this as evidence that *Sinanthropus* used fire; this contention is still debated. By 1937, 14 fragmented skulls, more than 100 teeth, and various other bone fragments had been found at the site. In 1941, unfortunately, the original fossils were lost, stolen, or destroyed while in transit to the United States for safekeeping during World War II, but not before casts of the fossils were made. The casts still exist today.

Later Interpretations: South Africa and Tanzania

Although the discovery of Peking man fostered the claim that Asia was the origin of human existence, Dart's discovery of the Taung child had already begun the shift in focus toward an African origin for human beings. One such supporter of Dart's interpretation of human evolution in Africa was Robert Broom. Convinced that Dart's theory of *Australopithecus* as an ape–human intermediate was correct, the Scottish physician stopped practicing medicine to take a position as an assistant in paleontology at the Transvaal Museum in Pretoria in 1934. During excavations at a limestone mine in Sterkfontein in 1936, Broom found an incomplete *Australopithecus* skull. He immediately presented the evidence as proof of the validity of Dart's interpretation. Broom's next discovery came at Kromdraai, across the valley from Sterkfontein, in 1938, when a young boy named Gert Terblanche found hominid fossils. The fossils were of a mandible and maxilla, with teeth. The thickness of the bones and the large molar teeth led Broom to classify the remains as *Paranthropus robustus*. At another nearby site, Swartkrans, additional fossils were found that further revealed the facial structure of these hominids. After observing the similarities between the fossils found at Kromdraai and Swartkrans and those of known

Australopithecus africanus (both are bipedal with brain capacities intermediate between modern humans and apes), Broom's *Paranthropus robustus* became referred to as *Australopithecus robustus*. It is now considered a facially robust species of australopithecine that went extinct about 1 million years ago. One of Brooms's most important discoveries was made in 1949 with the help of his assistant John Robinson at Swartkrans. The hominid fossils were much more human-like and eventually became classified in the genus *Homo*. The significance of this find at Swartkrans was that it demonstrated for the first time the apparent coexistence of two types of hominids. This coexistence of more than one lineage of hominid from the divergence of early australopithecines was later seen in East Africa as well.

The pioneering discoveries of the Leakey family in Olduvai Gorge, Tanzania, in East Africa, have become the cornerstone of our knowledge of the human lineage. Louis Leakey assumed that Olduvai Gorge held the secrets to human evolutionary history. Throughout the 1950s, he searched for hominid fossil remains with little success, finding only a few hominid teeth and the remains of large mammals. The fossil remains he believed had been killed and eaten by humans because of the various stone tools found in the same sites. As Louis Leakey maintained at the time that toolmaking was the distinguishing characteristic between humans and ape-like forms, he claimed that these sites were used by the earliest members of the genus *Homo*. But in 1959, Mary Leakey found, in a site known as FLK 1, the skull of a robust *Australopithecus*. Very similar to the skulls found by Broom in Swartkrans and Kromdraai, the skull, named Olduvai Hominid (OH) 5, had massive chewing molars, undersized canines and incisors, a small brain size (about 530 ml), and a large sagittal crest (the ridge of bone that runs along the midline of the skull as the attachment site for jaw muscles). This indicated great jaw strength. Although Louis Leakey had argued that modern humans did not have an australopithecine ancestry, the evidence contradicted his theory that toolmaking was a uniquely human (*Homo*) ability. To resolve this conflict, he classified the skull as an australopithecine but of a new genus and species, *Zinjanthropus boisei*. Nicknaming it the "Zinj skull," Leakey described it as a distinct form from the South African specimens found by Broom and Robinson. Not long afterward, Robinson challenged Leakey's evidence as insufficient for classifying his australopithecine in a new genus. Eventually renamed *Australopithecus boisei,* just as Robin-son's *Paranthropus robustus* was renamed *Australopithecus robustus,* both are now sometimes reclassified again as further evidence has been found to justify *Paranthropus* as a genus distinct from *Australopithecus*. There continues to be debate to this day whether this distinction should be made.

Another issue that existed was Louis Leakey's doubt that his *A. boisei* was the actual maker of the stone tools found in the similar strata. The size of its brain was quite small, and as a result of this evidence, he did not believe that it would have possessed the cognitive ability needed to create tools. The fashioning of stone tools required several complex levels of thought. It required knowledge of rocks to know which type is ideal. It required a capacity to understand physics, to know at what angle and with how much strength to strike the stones together. It also required an advanced ability to recall previous events, such as hunts, to know how to make the tools effective and efficient. These are all advanced, higher levels of cognitive thinking that Louis Leakey did not think an australopithecine brain was capable of accomplishing. His unwavering theory proved to be correct when in 1964 he, along with his own team members as well as Phillip Tobias and John Napier, described a specimen they thought was the creator of the stone tools. First discovered by Jonathan Leakey in 1960, the fossil remains consisted of an incomplete mandible with several teeth, various hand and wrist bones, and two parietal bones. From an examination of the mandible and teeth, the team determined that the hominid had possessed a less robust jaw, smaller and more rounded molars, and a facial structure much more similar to modern humans than any australopithecine. The parietal bones gave perhaps the most significant and most debated evidence. Tobias estimated that the bones from the juvenile skull would have given a brain capacity at maturity of 675 ml, much larger than any australopithecine. Between 1960 and 1964, additional similar hominid fossils were found, and by 1964 enough evidence existed, Leakey claimed, to classify the hominid remains as *Homo habilis* or "handy man."

Its increased brain capacity and reduced molar size convinced Leakey that *Homo habilis* was the toolmaker. The ability to use tools allowed for a more general diet. This is reflected in the reduced molar size, which had been specialized for plant consumption in the australopithecines. Many believe that *H. habilis* was a scavenger rather than strictly a plant eater. This may explain why *H. habilis,* which coexisted with *Australopithecus* for over a million years, was able to survive longer within the same environment. Its decreased specialization allowed this species to more easily adapt to global climate changes in the past.

Later Interpretations: Ethiopia and Tanzania

The next major fossil hominid discovery occurred in northeast Africa in 1974. Donald Johanson of the International Afar Research Expedition found almost 40% of the skeleton of "Lucy," perhaps the most famous fossil hominid. Discovered in Hadar, Ethiopia, Lucy was a young female adult hominid. As most fossil hominid discoveries until that point consisted of fragmented bones, individual teeth, or scattered, almost random remains and only occasionally a complete skull, the fact that Lucy was an almost complete skeleton, of a single individual, made her a celebrity overnight. The Lucy skeleton contains fragments of arm bones, ribs, vertebrae, a partial pelvis, one femur, partial lower leg bones, a fragmented skull, and a mandible complete with teeth. When no duplicate bones were found, Johanson concluded they were from a single individual, making Lucy an incredible discovery. After analyzing the remains, he recognized that Lucy had been bipedal and that, although her brain was relatively small, her whole body was proportionally small. She would have stood about 3 feet tall and had a brain size around only 400 ml. This brain size was well within the ape range. This was significant because Lucy was found to be about 3.2 million years old, over half a million years older than *A. africanus* and *A. boisei.* Lucy had a smaller, more ape-like brain than *A. africanus* and *A. boisei,* but she had a hominid-like postcranial skeleton that walked upright and bore many similarities to modern humans. As a result, she proved that bipedality had existed in human precursors far earlier than had been thought and, more importantly, that bipedality arose before an enlarged brain size. This officially disproved Darwin's theory that an enlarged brain size had predated bipedality.

The next task for Johanson was to classify Lucy. Together with Tim White, the two began to study and analyze fossils from Hadar and Laetoli that coincided with the same period in history, from about 3 million years ago and older. The Hadar fossils included Lucy and several other fossil hominids, such as the "First Family" found at a different site the year after Lucy. There, the remains of 13 individuals were discovered, including men, women, and juveniles. From the Laetoli site in Tanzania came the famous "Laetoli footprints," discovered by Mary Leakey, and also numerous hominid fossils that dated back to roughly the same time as those found at Hadar. With the Lucy skeleton providing the evidence that bipedality was possible over 3 million years ago in Hadar, Ethiopia, and the Laetoli footprints demonstrating that it definitely occurred in Tanzania 3.7 million years ago, the two pieces of the puzzle needed only to be brought together. White's casts of the Laetoli fossils were compared with Johanson's fossils from Hadar, and the two men created many influential and, as always, controversial theories. Their interpretation of the fossil evidence led them to conclude that the Hadar hominids represented neither apes nor any known hominid species. These hominids, along with the Laetoli specimens of the same age, represented a single hominid species that was yet unidentified. The unique characteristics of the species included full bipedality, arms longer (proportionally to their legs) than in modern humans, a small brain, sexual dimorphism, and dental anatomy somewhat intermediate between apes and humans (with some exclusive characteristics). Because no stone tools were recovered at any of the sites and their brain size was very small, Johanson and White recognized that these early hominids did not use stone tools. They classified these hominids as *Australopithecus afarensis,* the last common ancestor between humans and chimpanzees that existed from 3.9 million years ago until about 3 million years ago. One problem that this exposed was why, if stone tools were not used for another million years, did bipedality exist if the adaptation of bipedality was to free the hands for tool use?

Recent Interpretations

By the 1980s, Africa had become generally accepted as the birthplace of human origins because of the overwhelming amount of fossil hominid evidence that had been found there. The only dilemma was that, although the previous decades had brought forth an unprecedented amount of fossil evidence for the divergence between apes and early hominids, no link had been found in Africa between the primitive *Homo* species, such as *H. habilis,* and the later, more modern *Homo* species such as *H. neanderthalensis* and *H. sapiens*. The only evidence of this link that existed at that time was that of *Homo erectus*. Many held that Dubois' *H. erectus* from East Java, Indonesia, in Asia, was the missing link, but no specimen from that period, about 1.8 to 1 million years ago, had been found in Africa. That was until 1984, when a team led by Richard Leakey discovered a hominid skeleton even more complete than that of the Lucy skeleton. Discovered near the western shore of Lake Turkana in Kenya, it became known as the "Turkana boy." The skeleton was of a young male that Leakey and White determined had been about 12 years old when it died, although some speculate it could have been as young as 9 years old. The overall height of the individual was 5 feet 4 inches, which many estimate would have been about 6 feet at adulthood. The Turkana boy was the first evidence of an essentially fully human anatomy. Only slight skeletal variations exist between *Homo erectus* and *Homo sapiens*. These variations include a narrower pelvis in *H. erectus,* increasing its ability to run, longer arms than in modern humans, and an upwardly narrowing chest, similar to but not to the extent of Lucy. This shape of the chest put the shoulders of *H. erectus* in a position adapted more for tree-dwelling than balanced, bipedal walking. Its running ability suggested that it was a hunter, not a scavenger as many believed *H. habilis* had been. The brain capacity of the Turkana boy was about 880 ml and estimated to have been about 910 ml as an adult. Although the brain was only slightly smaller than in modern humans, the skull structure showed many ape-like characteristics, such as pronounced eyebrow ridges, the lack of a prominent chin, and a low forehead. Richard Leakey quickly classified the fossil hominid as *Homo erectus,* an African example of the species originally found in Asia by Dubois. He was convinced that the increased brain capacity, similar to a modern infant, was evidence of an ability to make tools, which were found in similar strata. The brain and vertebrae were, however, not large enough to convince Leakey that communication would have been possible to the extent that it is in modern humans today. Various discoveries in the following years led to a debate about whether the African *H. erectus* species should be classified as separate from the Asian species and renamed *H. ergaster.* This is still debated today, although most classify the African species with the Asian species, all as *H. erectus*. The overall significance of the Turkana boy was that it showed an early *Homo* species had indeed become fully human, anatomically, in Africa.

Since the 1980s, hominid fossils have been found in Africa, Asia, Europe, and America. With each new discovery, we learn more about our human history and our evolution. Every new piece of evidence holds the ability to alter what is thought to be true. Therefore every theory about human evolution can, and does, evolve. And theories will continue to evolve, just as humans and every other species on Earth continue to evolve. For example, a hominid discovery in Chad in 2001 of a *Sahelanthropus tchadensis* was dated to be about 7 million years old. Yet this hominid form had been bipedal, demonstrating an even greater antiquity for bipedality in hominids. Another discovery, reported in 2006, of *Homo erectus,* found in Dmanisi on the European continent, gave many new insights. These fossils from Dmanisi had brain capacities similar to *H. habilis* but were determined to be *H. erectus,* based on their cranial morphology. If this was a *H. erectus,* it meant that humans may have left Africa for Europe and Asia far earlier than many had theorized.

What is even more important than the idea that the theories of human evolution can evolve is the need to understand that these theories exist only because of the interpretations drawn from the evidence. The Lucy skeleton was an amazing discovery; to be able to show and display an almost complete skeleton of a human from millions of years ago is a great scientific achievement. But more importantly, the information gained from investigators' analysis of the remains has provided an immense amount of information about human history on Earth.

It is now considered a fact that the enlargement of the human brain developed after the ability to walk upright on two legs. This theory is universally accepted because fossil evidence exists where the leg morphology is similar to modern humans but the cranial capacity of the individual is vastly reduced. In Africa, two different hominid species were found at separate sites, several years apart, but because they were found in strata dated to the same era, it is known that more than one hominid species existed at the same time in the past. The amount of knowledge that now exists about human evolution simply through the analysis of some fossilized bones found in the ground is astonishing. Through interpretation of these fossilized bones and stone artifacts, a story emerges of struggle, defiance, adaptation, and triumph. In short, it is the story of human evolution over millions of years.

Michael F. Gengo

See also Anthropology; Darwin, Charles; Dating Techniques; Evolution, Organic; Fossil Record; Fossils, Interpretations of; Fossils and Artifacts; Haeckel, Ernst; Huxley, Thomas Henry; Laetoli Footprints; Olduvai Gorge

Further Readings

Aczel, A. (2007). *The Jesuit and the skull: Teilhard de Chardin, evolution, and the search for Peking man.* New York: Penguin.

Clark, W. E. L. (1955). *The fossil evidence for human evolution.* Chicago: University of Chicago Press.

Ember, C., Ember, M., & Peregrine P. (2007). *Physical anthropology and archaeology.* Englewood Cliffs, NJ: Prentice Hall.

Johanson, D., & Shreeve J. (1989). *Lucy's child: The discovery of a human ancestor.* New York: Early Man Publishing.

Poirier, F., & McKee J. (1999). *Understanding human evolution* (4th ed.). Englewood Cliffs, NJ: Prentice Hall.

Stringer, C., & Andrews P. (2005). *The complete world of human evolution.* New York: Thames & Hudson.

Tattersall, I. (1995). *The fossil trail: How we know what we think we know about human evolution.* New York: Oxford University Press.

Evil and Time

The notion of evil intersects with that of time in three main areas: with regard to the thesis of moral relativism, to the question of our moral responsibility for the future, and to the problem of metaphysical evil.

Moral Relativism

According to moral relativists, there are no universal moral values; rather, what is good or evil is relative to social environments, cultures, and the like. An important aspect of this view is that what is good or evil changes over time; morality is thus rather like the rules of a game. For example, the over in the game of cricket was originally four balls long, then was changed to five, and then to today's six; it would be absurd to say today that the result of a match in 1850 should not count because only four balls were played per over. Similarly, say relativists, slavery was not evil in ancient Athens because it was in accordance with the moral system of that time and place; in contrast, it is evil in the modern world because it offends against the moral systems now in place.

This analogy between morality and games is weak, however. In the case of games, there are two systems of values: the rules within each game and the moral system, which includes the notion and status of following those rules. The notion of cheating, for example, is the same in the 19th, 20th, and 21st centuries: It consists in deliberately breaking the rules, whatever they happen to be at the time, usually in order to gain an advantage. The rules may change across the centuries, and thus which actions constitute breaking the rules will be different at different times, but the view of cheating remains the same: It is wrong.

In the case of morality, however, relativists must avoid appealing to a similar two-level structure; if they do, they are distinguishing between a local morality that includes rules about slavery, and so on, and a universal morality that asserts the wrongness of breaking local moral rules. In the case of games, people are justified in expressing disapproval of a 19th-century cricket cheat who bowled six balls in an over, even though that would today be perfectly correct; moreover, if someone were to condemn as a cheat a 19th-century cricketer who bowled only four balls in an over, people should say that they were wrong to make such a judgment. Relativists, however, must not only deny that people are justified in condemning ancient slavery but also must avoid saying that it is wrong to condemn it; to do so would be to make a universal claim and hence would involve self-contradiction. Moreover, if relativists in one culture, such as that of the United Kingdom, say that their compatriots should not judge the behavior of citizens of another culture, such as that of Saudi Arabia, they must surely be committed to saying that people in Saudi Arabia should also not judge the behavior of people in the United Kingdom; they are therefore doing exactly what they said must not be done—imposing on the Saudis their own view of what should be done, their own relativist moral theory.

In an attempt to develop a more sophisticated form of relativism that avoids problems such as this, Bernard Williams has appealed to what he calls a "relativism of distance." He argues that the problem with "vulgar relativism" is that the conclusions it draws are not simply *within* morality but *about* morality; hence he develops an appraisal-relativism, which focuses on the conditions under which individuals can appraise their appraisals in terms of genuineness (using "genuine" in an absolute sense).

The core of this approach is the claim that talk of right and wrong with respect to moral outlook need apply only if a society is sufficiently close to one's own. Williams distinguishes between two types of confrontation with belief systems: real and notional. A real confrontation between a society and another belief system at a given time occurs when it would be possible for the society rationally to adopt the belief system without losing its hold on reality. The confrontation is merely notional if the society could not rationally adopt the belief system; it is too far from its view of the world. Making clear the difference between this and vulgar relativism, Williams stresses that it is not that one society *cannot* judge or interfere with another, but that it would lack any rational basis for doing so.

Put another way, a confrontation is notional between our own moral outlook and another, such as one in the past, in the sense that the other is not a real option for us. We are not in a position to make an assessment or appraisal, because the moral point of view from which such appraisals are made is no longer our moral point of view. The fact that we do not share or no longer hold that point of view makes it impossible for us to make or continue to make such assessments. We have lost or no longer share the concepts and the point of view from which we can make such assessments; we can still understand and learn about the culture, history, and social world of the other moral outlook or moral concepts, and see that in some sense these circumstances warrant or entail the truth of their moral judgments, without sharing their moral outlook or these judgments, in much the same way as a historian can understand and learn about a society or an outlook that he or she does not share. Thus, our own moral concepts, appraisals, and moral judgments get no purchase on the other outlook; we can assess its internal consistency, but we cannot claim that it is incorrect; we must simply leave it unjudged and unappraised.

Williams's approach is reminiscent of Thomas S. Kuhn's account of paradigms in the philosophy of science (and it is interesting to note that Kuhn denied that his was a relativist theory). Two scientific paradigms are incommensurable, for they make different assumptions; use different standards, definitions, and concepts; and use language in different ways. Rational comparison of paradigms is prevented by the fact that one must judge one paradigm from within another; there is no neutral or privileged viewpoint. As with Williams's sophisticated moral relativism, though, this makes no claim about the possibility of one paradigm actually being better (closer to the truth) than another; it merely claims that we can never be in a position to know this.

With respect to many questions, however, in particular with questions of justice, Williams admits that people find it difficult not to treat the confrontation between opposing sets of belief as *real* rather than notional. Also, John McDowell has pointed out that there is an urgent question about the coherence of the relativism of distance: If an outlook conflicts with one's own (a condition of the problem to which relativism is supposed to be a response), how can one coherently combine one's recognition of the conflict and standing by one's own outlook with a disclaimer of any interest in, or even possibility of, making some negative assessment of the other? The fact that going over to the other outlook is not a real option makes no obvious difference to this.

Responsibility for the Future

Is it possible for an action to be evil because of its consequences for future victims? There are various ways in which such a question arises; in one sense, after all, most if not all actions have consequences for future victims, because an action's effects are in the future by definition. The assassin's finger squeezes the trigger shortly before the bullet hits its target and perhaps days before the victim dies, by which time both assassin and victim are, in many ways, different people. The temporal aspect of such examples, however, seems to raise no real extra moral problems. We are here concerned with more straightforward cases in which the effect *significantly* postdates the cause, especially with cases in which the thing or person affected does not yet exist when the action is performed. For example, in the sociopolitical context many kinds of behavior have implications for future generations. Environmental ethicists are concerned with this issue, but the most direct example is raised in the field of political philosophy.

A dilemma is raised for believers in democracy by the existence of political parties whose platforms include the dismantling of the democratic system. If the people of a state vote for such a party, and thus choose to move to a dictatorship, tyranny, theocracy, or the like, what should the committed democrat think? On the one hand, the democratic will of the people has been made clear and should surely be honored, but on the other hand the result goes against the democrat's central principle. One way of resolving the dilemma is to point out that democracy involves the right of the citizens of a state to choose *their own* government, not that of other people. If, for example, one state invades and overthrows the government of its neighbor, it is no excuse to say that the invasion was the result of a democratic referendum or that it was carried out by a democratically elected government. If we are not entitled to take away our neighbors' freedom by invading them, why should we be entitled to take away that of our children or grandchildren by installing a dictatorship? That they are separated from us by time rather than by space surely makes no difference morally.

The main objection to such a position depends upon the view that the future, having not yet come to be, is not real. Future generations, therefore, do not exist, and we cannot have moral responsibilities toward what does not exist. In response, it can be argued that there is an important distinction to be drawn between individuals and classes: Whereas we can have no obligations to a nonexistent and therefore indeterminate individual, we can have obligations toward a class whose members are all in the future, for such a class *can* be determinate. For example, we know exactly which criteria will allow us to determine the members of the class of people born in the year 2027, even though we cannot yet identify any of them, but we have no independent criteria by which to pick out a particular member of that class, even in principle.

Such considerations also affect other moral questions concerning the role of time, such as abortion, contraception, and celibacy. To what extent is the future person who would (or might) have existed a genuine object of our moral concern? Can it be a moral object as an individual, or merely as a member of a class? For example, it might be argued that universal vegetarianism is not clearly desirable even from the point of view of our moral obligations to animals, as the suffering and deaths of the animals killed for food has to be set against the fact that millions of future sheep, cows, pigs, and so on, which would otherwise have been bred for the table, would no longer be needed and would thus lose their chance at any sort of existence. If a short life is better than no life, then it would seem that universal vegetarianism would deprive millions of future animals of their lives and that this would outweigh any good done.

This reasoning, however, makes the assumption that the members of the class of future animals are determinate individuals with moral status. It is true that future animals that would be killed for their flesh can be treated as such, for if we continue to breed animals for food, our actions will create individuals to which harm can be done. If, on the other hand, we decide to stop the breeding process, then no animals (determinate or otherwise) are created by our actions; an animal that is never born is not an animal at all; it does not (and never will) exist in order to suffer harm. The same reasoning is relevant, *mutatis mutandis,* in other areas of practical ethics, such as abortion and euthanasia.

Metaphysical Evil

The notion of metaphysical evil arises primarily in the context of theodicy and involves the fact and effects of contingency, that is, issues such as death and the shortness of life. In fact this usually involves talk of time when what are actually at issue are temporal processes—changes occurring within time. This sort of confusion is most obvious with regard to utterances such as "time is the great healer" or "*tempus edax rerum*" ("time the devourer of things"); strictly speaking, time has no causal powers, either of healing or of destroying, but what we really mean to refer to is the succession of causally related events occurring within time (note, however, that whether time is in fact something in itself rather than merely the relationship between events is one of the main questions dealt with in the metaphysics of time).

In pre–Islamic Arabic thought, time was viewed as the controller of human destinies (usually impersonal), setting the outcomes of our actions rather than the individual actions themselves, and in particular determining the time of our deaths. This role was taken over by God in Islam (though with deep disagreements concerning the degree to which God determines events, especially with regard to the human will).

Systems of thought such as those of Hinduism and Buddhism have responded to aspects of metaphysical evil by developing the notion of reincarnation (or, in Buddhism, rebirth). According to such accounts, it is true that the individual human life span is short and that there is great unfairness in the distribution of goods with which we are born, such as health, intelligence, social status, and so forth; this, however, is placed in the context of an existence that spans many lifetimes, either through the passing of a changeless *atman* from one incarnation to the next, as in Hinduism, or the causal chain of deaths and births, as in Buddhism.

For theologians such as Saint Augustine of Hippo, our existence in time is both symptom and condition of our imperfect nature; God is not in time but rather is eternal, creating time in his creation of the world. This view can be traced to influences on Augustine from the Manichaeism of his early life, before his conversion to Christianity. A similar approach can also be found in Zoroastrianism, though its account is particularly complex, involving two types of time: boundless time and the bounded time of the world as we know it. There was originally only boundless time, but Ahura Mazda created bounded time in order to constrain Ahriman, the evil one, and to enable his ultimate defeat. The notion that time is both a worldly imperfection and the means to the overcoming of that imperfection can be found in much of the later theology of the Abrahamic religions.

Peter King

See also Angels; Bible and Time; Devils (Demons); God and Time; Satan and Time; Sin, Original; Time, Sacred

Further Readings

Carus, P. (1991). *The history of the devil and the idea of evil: From the earliest time to the present.* Chicago: Open Court.

Gentry, K. L., Jr. (1999). *Perilous times: A study in eschatological evil.* Nacogdoches, TX: Covenant Media Press.

Shermer, M. (2004). *The science of good and evil: Why people cheat, gossip, care, share, and follow the golden rule.* New York: Henry Holt/Times Books.

Evolution, Chemical

Chemical evolution is the process of the synthesis of biochemically important molecules starting from simple molecular building blocks, such as water (H_2O), nitrogen (N_2), carbon dioxide (CO_2), and hydrogen sulfide (H_2S), under plausible primordial conditions that governed the prebiotic Earth. It describes a process of increasing complexity from simple inorganic compounds toward first simple organic compounds that in turn formed biochemically important structures for a first living system. First life may have started up as a final product of chemical evolution. This event is probably the result of a multitude of processes, most of them not very likely, that led to a proper arrangement and activation of complex molecular building blocks.

Chemical evolution on a timescale is preceded by the formation of elements in stars in consecutive nucleosynthetic processes and by the formation of first simple compounds in space at a later stage. Eventually, interstellar matter aggregated to form the solar system and the terrestrial planets, Earth, Mercury, Venus, and Mars, about 4.6 billion years ago.

Chemical evolution on Earth is a process that probably started later than about 3.8 billion years ago. It is difficult to date the single stages even roughly, as little geological and chemical record remains. During the following millions of years chemical evolution must have led to the origin of life on Earth, as the oldest- known fossil records stem from a period about 3.5 billion years ago.

Chemical evolution is a development that is strongly influenced by the environment of the terrestrial planet, such as composition of the atmosphere, types of radiation, and geology. Any development is determined by the laws of nature and statistics. Therefore, it should be possible to simulate basic chemical processes that occurred several billion years ago. A fundamental problem, however, is the lack of knowledge about the exact environment on planet Earth at that time. Because of the lack of knowledge, the possibility to plausibly reconstruct the process of chemical evolution is very limited.

Not only does the environment affect chemical evolution, but chemical evolution changes the environment. Molecules are formed and altered. There will be a kind of competition between molecules for nutrients. The rate of formation as well the rate of destruction is decisive for an enrichment of certain types of molecules.

Chemical evolutionary processes, in general, should not be limited to Earth but could also proceed on any terrestrial planet because principal chemical laws should be valid throughout the whole universe.

Origin of Elements

Until the beginning of the 19th century, there had been only little knowledge about the abundance and the origin of elements in the universe. The development of spectrochemical analysis in 1860 made it possible to identify elements by their wavelength characteristics of emitted light. By investigating the light of stars and other celestial bodies, for example, nebulae and dust clouds, optical spectroscopy proved the existence of the same chemical elements in the sun and throughout the universe. Hence, there is only one kind of chemistry in the universe.

In the 1950s, after scientists had discovered that hydrogen is the main constituent of the sun, a theory was developed that explained the formation of practically all elements in the core of stars. At extremely high temperatures of at least 10^7 K (kelvin) and extreme pressures, the elements—more precisely the nuclei of the elements—are built up in consecutive thermonuclear fusion processes starting from hydrogen. As a primary process, hydrogen is converted to helium (He) by the combination of four hydrogen nuclei, simple protons, into one helium nucleus. This process, which can take up to some 10 billion years, goes on until practically all hydrogen in the star is exhausted. In secondary processes and at even higher temperatures, He can be converted to heavier elements that in turn can be converted or combine in complex fusion or secondary processes to form all other elements. Uranium is the heaviest element being formed in stars.

Besides hydrogen and He, which amount to 99% of the elements in the universe, carbon, nitrogen, and oxygen are the next most abundant elements. Beyond these elements, abundance decreases somewhat irregularly with increasing atomic weight, with the exception of elements around iron. The relative abundance of elements in the universe is controlled by the rates of thermonuclear fusion and secondary processes of the nuclei in stars. It is probably decisive for further chemosynthetic processes how the relative abundance of elements is at an actual place of chemical evolution.

Once liberated from a star, the generated elements can readily condense and undergo reactions with each other at lower temperatures in space. Accumulation processes of this material will give rise to nebulae with dust and molecular clouds. Dust in the interstellar matter consists mainly of carbon and different oxides. From such a kind of nebular system that began to condense, our solar system started about 5 billion years ago. That means that practically all atoms that built up the solar system originated from former nucleosynthetic processes in other stars.

The Primitive Earth

Formation

About 4.6 billion years ago, the Sun and planets were formed within the protostar disc, which mainly consisted of gas and dust. At that time meteorites also were formed that still preserve some of the original material of the solar system. It is feasible to date meteoric material found on Earth by analyzing the content of specific radioisotopes, for example, potassium or uranium, that suffer radioactive decay. This gives an estimated age of the solar system, and hence the Earth, of about 4.6 billion years.

An immense heat and strong solar winds were emitted from the contracting protostar in the center of the dust disc. These radiations blew away all volatile substances like hydrogen (H_2), He, and N_2 from the inner zone, the terrestrial planet zone. Only dust grains and aggregates of nonvolatile, dense matter were left over in that region. Consecutive collisions and accumulation of these materials finally led to the inner protoplanets. In the case of the earth, accretion led to a metal core of mainly iron, which was surrounded by a mantle and a crust of moderately volatile compounds like oxides that also contained volatiles like H_2O (water). At the end of this accretion process, which took about 100 to 200 million years, the planet Earth presumably was covered by magma oceans due to an enormous release of energy from core formation and radioactive decay of instable isotopes. How and how long the cooling of the earth took place is still discussed.

Environmental Conditions

An accepted model of the primitive atmosphere does not exist because air records are missing and geological records are incomplete. Anyhow, it is decisive for the plausibility of any hypothesis regarding chemical evolution to know which components were the major and minor constituents of the primitive earth's atmosphere.

Because most gases from the original dust cloud were swept away by solar winds during the formation of Earth, there was no or only a thin atmosphere at the beginning. It is assumed that intense volcanic activity led to the degassing of occluded and chemically combined volatiles that formed a secondary atmosphere. Some components like methane (CH_4), N_2, H_2, and ammonia (NH_3) are liberated if meteoric material, assumed to be similar to the material of the primitive earth, is heated to about 1000 K. Hence, these gases could contribute to a primitive, reducing atmosphere. Such an atmosphere is indeed crucial for one major scientific theory about the origin of life, the so-called soup theory. Nevertheless, it is doubtful whether such an atmosphere could persist for a long time. Hydrogen could escape easily from the weak gravitational field of the earth, and NH_3 as well as CH_4 would have been rapidly destroyed by the intense solar ultraviolet radiation.

Today it is supposed that the outgassing from intense volcanic activities provided the compounds for a secondary, only weakly reducing atmosphere consisting of mainly steam and CO_2. These compounds are the major constituents of extant volcanic exhalations, too, and it is reasonable to assume a similar composition for the extant ones as for those on the primitive Earth. Besides, there was no oxygen (O_2) present in the atmosphere at that time, as could be concluded by the abundance of reducing ferrous ions in geological material. Recent studies hint at a higher proportion of H_2 in the primitive atmosphere.

One has to regard possible energy sources for the formation and conversion of first organic molecules as one prerequisite for chemical evolution. On the primitive Earth that was already cooled down, the three main sources of energy were solar irradiation, electric discharges, and energy from geochemical reactions, beside minor contributions from radioactivity, volcanoes, and shock waves as a result of impacts. Solar radiation provided the main source of energy, although the relevant wavelength range for organic synthesis, the ultraviolet (UV) radiation, contributes only a small fraction to the total irradiation. Many simple gaseous molecules like CO_2, carbon monoxide (CO), H_2O, and CH_4 absorb UV radiation only below 190 nanometers, and very simple organic molecules can be generated as well as destroyed by that short-wave UV radiation.

Electric discharges are an efficient source of energy for the production of biomolecules from gas molecules, but it is doubtful whether this source contributed remarkably to the generation of organic substances. Energy and catalytic activation could also be provided by geochemical reactions that could have led to the selective generation and further modification of organic compounds from simple inorganic precursors.

Any just-formed organic compound was immediately endangered by decomposition due to UV radiation or other secondary processes. Only molecules that found a sheltered place or could react to form more resistant molecules could persist for some time.

The Primitive Soup

How life could develop on Earth has been the subject of religious and philosophical discussions for centuries. The first approach to explaining the generation of organic matter scientifically and a proposal for how first life originated on Earth were done independently by Alexander Oparin and J. B. S. Haldane in the 1920s.

Their hypothesis was based on the assumption that Earth's primitive atmosphere had reducing properties and consisted mainly of CH_4, NH_3, H_2, and H_2O. The atmosphere was exposed to various energy sources, for example, lightning, volcanic heat, and solar radiation, leading to the formation of organic compounds. These compounds accumulated in the primitive oceans to form a "hot dilute soup." Because the compounds would remain there for long periods of time, first life would ultimately develop in a spontaneous process of organization.

Today, the primitive soup theory is seriously questioned although it is still strongly propagated. The primitive atmosphere assumed to be reducing, according to the theory, was evidently rather neutral, lacking significant amounts of CH_4 and NH_3. Moreover, these compounds would have suffered rapid decay by photolysis. Furthermore, most organic molecules would not persist for a long time in the postulated primitive soup but would be destroyed quickly so that high concentrations of organic compounds are not likely. Additionally, a spontaneous linkage of many building blocks (monomers) to polymers that exist in extant life cannot happen as easily as proposed, for energetic reasons. Thus, the origin of a living system based on biopolymers is not plausibly explained.

Precursors to Organic Evolution

Since 1953, laboratory scientists **have** attempted to produce all biologically relevant compounds, such as amino acids, nucleobases, and sugars, under prebiotic conditions, thus mimicking the environmental conditions of the primeval Earth. These investigations were motivated by the assumption that the same kinds of biochemical substances as extant ones were the basis for the development of first life.

In 1953, Stanley Miller and his supervisor Harold Urey set up an experiment designed to simulate the atmospheric conditions of the primeval Earth. It was intended to produce possible precursors of chemical evolution. A flask was filled with H_2O and the reducing gases NH_3, CH_4, and H_2. After closing, the flask was heated and exposed to electric discharge for 1 week. The obtained reddish solution proved to be rich in some sort of tar as well as simple amino acids (a total of about 1%) and some small reactive intermediates like hydrogen cyanide (HCN) and formic acid. The energy input into the experiment is comparable to that of about 50 million years ago on the primitive Earth. Experiments using another input of energy like heat and solar radiation generated yields of products that were consistent with the Miller–Urey experiment. Further experiments that simulated the interaction of the primitive atmosphere's gases with lava flows at temperatures of up to 900°C also showed a complex variety of organic molecules. All these experiments support the idea of chemical evolution in a way that the interplay of gaseous carbon, N_2, H_2O, and H_2 and an energy input leads first to the synthesis of reactive intermediates that in turn generate biologically related molecules. Some of the formed intermediates were used in further prebiotic experiments. In such experiments, usually rather high starting concentrations lead to the formation of the nucleobases, from HCN, and mixtures of sugars, synthesized from formaldehyde.

Many critical remarks were addressed to these results. First, experiments in which a mixture of N_2, CO_2, and some H_2O was exposed to electric discharges and heat did not yield amino acids, although such atmospheric conditions seem more realistic today. Besides, peptides (proteins)—as crucial compounds in extant life—could never be built up selectively from amino acids under prebiotic conditions. It is in general not very likely that larger molecules form spontaneously from building blocks in solution. Even if they do form, the sequence will be random and not specific; that is, no two identical copies will occur in billions of possible polymers. Moreover, many of the produced compounds are reactive, especially the nucleobases and sugars, and therefore not stable for many years under prebiotic conditions. Hence, higher concentrations and stability for a longer time as required for organization processes need more complicated constructions for a plausible primeval enrichment.

To summarize, the experiments provide a possible explanation for the formation of building blocks for extant biopolymers. Further organic evolution pathways leading to the specific buildup of biopolymers are highly uncertain and exhibit several principal problems that still need to be solved by scientists.

Theories Involving Minerals

Vital Clays

One major question in the field of chemical evolution is how a replicating system, a system that could generate and transfer information, could have evolved. The modern genetic machinery is much too complicated and was probably preceded by other systems.

Graham Cairns-Smith proposes that clay minerals were the first species that were able to reproduce. Clay minerals, being ubiquitous on the primitive Earth, are composed of many parallel layers that are stacked on each other. Information could be generated by stacking defects during crystallization that produced many identical layers until further modification, that is, occurrence of further mutation. Separation of the layers could spread new forms. Various types of surfaces formed and showed different catalytic activity for organic synthesis. Gradually, more and more complex organic substances were built up that finally started a more sophisticated replicating system replacing the clay replication system in a process termed *genetic takeover.*

Apart from a few controversial experimental investigations that show a conservation of layer structures on crystal growth, there is not much experimental evidence for the hypothesis. However, experimental investigations show the ability of clay minerals to attach organic molecules and to act as catalysts in organic syntheses.

Iron–Sulfur World Theory

Günther Wächtershäuser introduced an alternative hypothesis that suggests a process of chemical evolution in the environment of hydrothermal systems. A geochemical reaction plays the central role, namely, the reaction of the mineral iron sulfide FeS with the gas H_2S that provides the energy (reducing power) for the conversion of inorganic building blocks like CO_2 and N_2 to simple organic molecules. This reaction is driven by the formation of the mineral pyrite, commonly known as fool's gold. Any generated organic material becomes electrostatic when attached to and accumulated at the surface of pyrite. Further reactions at the surface could lead to the development of a surface reaction system and finally a true chemoautotrophic surface metabolism.

Proponents of this hypothesis rejected the idea that a situation like the primitive soup that led to a first heterotrophic organism ever existed on the primitive Earth. Instead, the first organism is supposed to have originated from the postulated surface metabolism.

The hypothesis gains attention because of the importance of iron–sulfur clusters in extant enzymes that convert simple molecules to complex molecules, for example, N_2, H_2, and CO, which also existed on the primitive Earth. Furthermore, one can find a rich fauna around hydrothermal vents (black smokers) at the bottom of the sea where hot fluxes rich in metal ions and sulfur species mix with cold sea H_2O. Similar places presumably existed on the primeval Earth, too. Today, they host several *Archaebacteria,* some of the most ancient living species on Earth, which feed on chemical reactions. Hence, these bacteria may be successors of first living species in that habitat.

First experimental studies did prove the reducing power of the proposed energy source, for example, showing the reduction of N_2 to NH_3. Critics remark that a direct reduction of CO_2 could not be observed in several studies. Moreover, it seems to be very difficult to verify experimentally whether the postulated complex metabolism would operate and how a replicating living system could finally emerge.

Precursors to Chemical Evolution on Earth

Comets, asteroids, and meteorites have always been deliverers of extraterrestrial material to Earth. Especially the primitive Earth was exposed to heavy bombardments, the last intense one 3.8 to 4 billion years ago. These impacts provided large amounts of H_2O and carbon-containing substances probably available for the process of chemical evolution.

Asteroids and their collision fragments, meteorites, stem from the asteroid belt that is situated between the orbits of the planets Mars and Jupiter. Meteorites contain ancient material from the time of the formation of the solar system that resembles the material of the accreting Earth. Beside stony-iron and iron meteorites as two main groups, there are carbonaceous meteorites representing about 3% of the meteoric material on Earth. The carbonaceous meteorites contain substantial amounts of carbon, including small fractions of simple organic molecules such as hydrocarbons, fatty acids, and amino acids. Meteorites of Martian material that were flung into space during impact events on Mars have also been found on Earth.

Comets originate from the outer solar system. Hence, they are rich in volatiles like water ice and simple carbon-containing substances that gathered together with dust grains around 4.6 billion years ago. They contain the oldest, mainly unchanged material within the solar system. It is assumed that comets carried large amounts of H_2O as well as some organic material to the primitive Earth, as simple amino acids could be detected in experimental studies simulating the behavior of comet-like material in space.

Although the impact of larger bodies led rather to a net loss of H_2O and destruction of organic material, certain amounts of organic molecules still arrived on the primitive Earth carried by smaller bodies. It remains uncertain to which extent the extraterrestrial material contributed to the chemical evolution on the primitive Earth.

There are supporters of the idea that germs of life were brought to the primitive Earth by comets or other carriers. This hypothesis lacks evidence, and it just shifts the location but does not provide a plausible explanation for how chemical evolutionary processes proceeded.

Is Chemical Evolution the Pathway to Life?

It is crucial to first determine the driving forces of chemical evolutionary processes. The main parameters are energy and kinetics, which determine whether and how fast reactions can proceed. If there are several parallel reactions that can occur, there will be, under thermodynamic equilibrium conditions, a statistical distribution of the possible products at the end, depending on the relative energy of the products. Thus, it may take time until energetically only less-favored products reach a significant quantity to establish new reaction pathways. Furthermore, any energetically less-favored product tends to convert to another, more stable product. Thus, rather simple and low–molecular-weight compounds (monomers) that are energetically favored will be the main products of reactions under thermodynamic equilibrium conditions.

For the formation of more complex systems, statistically not favored conditions or nonequilibrium conditions are required that favor rather complex and high–molecular-weight compounds (polymers). The latter case is only attainable if a continual energy source is present that can sustain such a nonequilibrium system. High–molecular-weight compounds can form from a complex reaction system either by a series of chance events with almost zero probability or by sequential processes driven by a suitable energy input that keeps the system away from thermodynamic equilibrium. Such nonequilibrium conditions may be essential for the generation of more complex compounds in a reaction system directed by catalytically active substances.

Even if for some reason high–molecular-weight compounds form that contain some kind of inheritable information, there will be still many other factors that have to occur simultaneously to start up a living system. Due to the complexity of life and its emergent property, it is difficult to imagine a process that will inevitably lead to life. The process of chemical evolution toward the origin of life, because it is partly due to nonequilibrium conditions, can be better described as a contingent process. This means that more or less probable processes like pre-organization have to be interpreted as embedded in other independent, external processes whose probability of occurring cannot easily be estimated. So the origin of life as a result of chemical evolution is neither exclusively directed by chance (consequently, unique) nor completely deterministically explainable and inevitable.

Any molecular process cannot be purposive in the sense of ultimately producing life, because molecules are not dead or alive and therefore do not show the complex characteristics of living systems. Likewise there is no indication that natural laws possess a preference that favors the production of chemicals important for biochemistry and ultimately will lead to life.

Is Chemical Evolution a Repetitive Process?

Chemical evolution is a process driven by one or multiple energy sources. A conversion of available inorganic precursors to organic molecules is followed by further steps that produce more complex molecules until, finally, biochemical compounds start up life. Such a development cannot proceed in the presence of O_2, it being harmful to organic molecules. Thus, sites that were exposed to the atmosphere could provide a possible environment only until about 2 billion years ago when the O_2 content in the atmosphere significantly increased. Despite the deterioration of the atmospheric conditions, there probably existed niches devoid of O_2 where chemical evolution still could take place.

A more serious problem was the heavy impact of asteroids or comets on the primitive Earth during the so-called late heavy bombardment around 3.8 billion years ago. At that time, Earth was regularly, in periods of every 10 to 100 million years, sterilized by heavy impacts whose violence could lead to the evaporation of the oceanic water and the melting of the earth's crust down to 1 kilometer. One can imagine that all life having arisen between two such impacts suffered complete extinction, and a new development had to start from the beginning. The picture of production–extinction cycles may describe aptly the situation at that time. As long as the basic environmental conditions of the primitive Earth did not change dramatically for a long time, chemical evolution could repeatedly take place. It is possible that different kinds of biochemical systems developed and disappeared during that rough period and that the last one was chosen by chance as the basis for further evolution.

In addition, such differently distinctive biochemical systems may also have developed simultaneously or successively in different environments as the result of similar chemical evolutionary processes. Nevertheless, ultimately all but one became extinct due to competition or accidents, because all extant life is based on a common biochemistry.

Chemical Evolution in Extraterrestrial Places

In the 16th century, philosopher Giordano Bruno, at the expense of his life, claimed that many inhabited worlds existed. He might have been right, as a simple count of the number of stars in the universe yields an enormous number. Many stars probably have a planetary system, so that there should be a huge number of planets similar to Earth. Taking into account that the same physicochemical laws and principles are valid throughout the whole universe and with the same elements present, chemical evolutionary processes should be possible at many sites in the universe. Even if extraterrestrial biochemical systems different from the terrestrial ones developed, the crucial bioelements carbon, oxygen, nitrogen, and sulfur, as well as H_2O, would have been required to start a chemical evolution.

At this point, one has to distinguish between (a) places of prebiotic synthesis of organic material in general, like dust clouds, meteorites, and comets; and (b) places of prebiotic synthesis that can lead to chemical evolution, such as planets or moons.

Interstellar clouds of dust contain a large variety of simple and reactive organic molecules, such as HCN and formaldehyde. Little is known about the mechanisms that alter the organic precursors, and there is no indication that more complex or even polymeric molecules can form. Nevertheless, the organic compounds in the dust grains will contribute to planetary material if solar systems arise from dust clouds.

Meteorites and comets contain larger and more complex organic molecules than was once thought by scientists. Remains of living systems, however, have not been found in that ancient material, and it is uncertain whether cosmic conditions allow life to arise there.

Terrestrial planets and moons, on the other hand, may have an atmosphere and some liquid solvent at the surface; in other words, there is a true environment for chemical evolutionary processes. Even if extraterrestrial bodies are similar to Earth, chemical evolution may have led to a different outcome. Because extrasolar sites are difficult to access, two prominent examples in our solar system, the planet Mars and Saturn's largest moon Titan, are briefly discussed.

Mars had a planetary history similar to that of Earth. About 3.8 billion years ago, an atmosphere of CO_2 probably caused a greenhouse effect that generated mild conditions with liquid H_2O at the surface. This short period was finished by bombardment from space, leading to the loss of the atmosphere and thus the end of the greenhouse effect. The dropping of temperatures on Mars caused water to freeze, being covered by rock gradually; solid CO_2 was deposited in the polar regions. It is assumed that geothermal processes releasing frozen water and CO_2 from the ground as well as instabilities in the orbit around the sun could have led to repeated short warmer periods. Today, Mars's surface is very cold and exposed to intense UV radiation so that no life is expected to be found there. It is rather probable that some chemical evolutionary process proceeded during the short warm period in Martian history 3.8 billion years ago and that the chemical record of that time exists deep in the rocks.

Saturn's moon Titan has a thick N_2 atmosphere with some proportions of CH_4, a reducing atmosphere as postulated by the "primitive soup" theory. There is evidence for continents covered with frozen water that are surrounded by oceans of liquid hydrocarbons. The visit of the Huygens probe on Titan indicated the occurrence of complex chemical processes at the surface as well as in the atmosphere. However, at temperatures of about −180°C organic reactions will proceed at a very slow rate. Because H_2O is solid, only a completely different pathway of chemical evolution using hydrocarbons, such as methane as solvent, could lead to some sort of biochemistry.

Verification Problems of Theories on Chemical Evolution

Any theory that proposes an explanation for chemical evolutionary processes is confined to an incomplete description. This is due, among other reasons, to our fragmentary knowledge of the primitive Earth, its atmosphere, and its detailed geological features, as almost no geological record from that time is conserved. Hence, it is impossible to imagine all possible sites where relevant chemical processes could proceed. Therefore, some local particularities that might have been decisive cannot be taken into consideration.

Nevertheless, this is not absolutely necessary as scientists are searching for plausible environments of chemical evolution. The exact place and the order of the pivotal processes of chemical evolution are and always will be out of the reach of scientific knowledge. Plausible environments are characterized by several features, such as availability of energy, input of molecular building blocks, and possible sites for accumulation and further modification of the generated molecules. Besides, every theory has to focus on a few central aspects of chemical interaction, simplifying other features of the environment, because it is not possible to include all potentially important characteristics within one theory. Thus, every theory may include some crucial features of the then-process.

One basic objection to any hypothesis is that it is not known how first life developed and how it was constituted. Most hypotheses assume a similar but much simpler constitution than extant life, and there are only a few hypotheses that propose first living systems on a completely different basis.

Limitations of Simulated Chemical Evolution

An experiment can only be as good as the hypothesis on which it is based. Experiments cannot take all environmental features into consideration, but some environmental conditions, over a certain period of time, might facilitate a complex process like chemical evolution. A high complexity in the interplay of the contributing factors to chemical evolution would hint at a singular process. If that process was singular, however, then a theoretical interpretation and an experimental repetition would be almost impossible.

Other challenges of experimental simulations are time and the rate of investigated reactions determined by kinetics. Chemical evolution might have required a time span of some 10 million years; thus, slow reactions also could have influenced the process. Such slow reactions proceeding over a period of, for example, 1,000 years may lead to a slow accumulation of certain reaction products that were important for chemical evolution. In the laboratory, such reactions have to be sped up by changing the reaction conditions to be able to detect some products at all. Different or more drastic reaction conditions may generate secondary reactions that change the primary result. Therefore, the outcome of simulation experiments has to be interpreted carefully.

Furthermore, experimenters may encounter other time problems when investigating buildup processes of various monomers, for example, amino acids to peptides. Statistics show that a huge number of possible sequences in a peptide results from the combination of few different amino acids. Hence, it will take many runs to find a desired peptide with a certain sequence.

Finally, it will be always uncertain whether experimental results show one feasible pathway of chemical evolution or the actual process of chemical evolution having proceeded on Earth.

Recent Chemical Evolution on Earth

Hypotheses about recent biogenesis existed until the mid-19th century. Then, Louis Pasteur showed that life is not spontaneously generated in rotten organic material, concluding that all life is generated from other life.

All living species known on Earth are based on the same basic principles. Thus, if there are still places where chemical evolution evolves into living systems, they will be somehow remote. Otherwise they would have already been detected. Because bacteria have been discovered in secluded areas as deep as several kilometers in the rock, such places or recesses at the bottom of the sea may be promising candidates. Energy could be provided by radioactivity or geochemical reactions there. However, it remains uncertain how such processes can be identified, considering that organic material is permanently produced and altered by natural processes and living species.

In general it is unlikely that processes similar to those that led to first life on Earth still occur, because the environmental conditions (e.g., the composition of the atmosphere) have changed much since then. This is due to chemical evolutionary processes that continually change the environment. Besides, there always will be interaction between living species as competitors for energy and nutrients.

Can Simulated Chemical Evolution Create Life?

Laboratory experiments can generate the basic constituents of modern life in chemical evolution simulations. Furthermore, the simulation of basic processes in living systems like replication, in the case of separate ribonucleic acid (RNA) strands and their replication enzyme, and metabolic reactions can be performed in the laboratory.

Nevertheless, these experiments are still remote from the creation of an interaction of the separate and complex replicable and metabolic machinery. These two running systems show a complex interplay so that the mixing of all necessary proteins and the genetic apparatus from dead bacteria in a nutrient-rich environment would probably not start new life easily. It is not sufficient to put all relevant molecules together to start life, as illustrated by the analogy that a heap of bricks is still far away from being a house. At present, the only possibility of simulating life-like systems is by computer modeling.

One can still imagine that simple living systems may arise unexpectedly and with uncommon characteristics in laboratory experiments. Such systems are difficult to predict because they may differ remarkably from known systems. It is uncertain whether such emerging living systems would form at all and whether they would be recognized as life.

Could Chemical Evolution Occur Again on Earth?

Because there is still disagreement about how chemical evolution, leading to life, once proceeded and how unlikely this process is, it is rather difficult to predict the future. Starting from restrictions on possible present chemical evolution, future processes also will be limited to niches in remote areas. These restrictions seem even more plausible as an extinction of life may be caused or accompanied by some sort of environmental catastrophe that deteriorates the atmospheric situation. Future chemical evolution, if possible, would probably have to choose different pathways due to other environmental conditions.

Theodor Alpermann and Wolfgang Weigand

See also Chemistry; DNA; Evolution, Organic; Geologic Timescale; Life, Origin of

Further Readings

Davis, P. (1998). *The fifth miracle.* London: Penguin.

Dörr, M., Alpermann, T., & Weigand, W. (2007). The FeS/H2S system as a possible primordial source of redox energy. *Origins of Life and Evolution of Biospheres, 37,* 329–333.

Folsome, C. E. (1979). *The origin of life.* San Francisco: Freeman.

Mason, S. F. (1991). *Chemical evolution.* Oxford, UK: Oxford University Press.

Miller, S. L., & Orgel, L. E. (1974). *The origins of life on the earth.* Englewood Cliffs, NJ: Prentice Hall.

Shapiro, R. (1988). *Origins.* London: Penguin.

Evolution, Cosmic

Cosmic evolution can be defined, in the simplest terms, as the scientific study of change as it has occurred since the beginning of this universe. The age of the universe is now estimated to be approximately 14 billion years. The concept of the arrow of time has been employed to record the major changes that have resulted in the universe's increasing complexity. Cosmic evolution focuses on the interconnectedness of all parts of the universe. This orientation can be noted at least as early as the 16th century in the writings of Nicolaus Copernicus and Galileo Galilei. The idea of the centrality of planet Earth was abandoned only in the past several hundred years. The movement toward more critical thinking about humans and the universe was a prominent element of the Renaissance.

Julian Huxley, a 20th-century British biologist, is associated with a scientific approach to the study of cosmic evolution. Pierre Teilhard de Chardin, a 20th-century French geopaleontologist and Jesuit priest, emphasized the religious aspects of cosmic evolution. Mainstream scientists have generally taken an objective orientation, claiming that it is crucial to continually gather and test data to further our general understanding of the order and nature of this universe. Implicit in these attempts is an implication that humans, however important and advanced at present, should not be considered as unique or as the center of the universe. The study of cosmic evolution is becoming increasingly interdisciplinary in that it includes scholars in astronomy, physics, chemistry, geology, biology, and anthropology. Recently, physicist Eric Chaisson has written extensively on the seven major stages of cosmic evolution: particulate, galactic, stellar, planetary, chemical, biological, and cultural.

The *particle epoch* refers to the first few minutes after the big bang that scientists generally agree created our universe. The big bang itself probably took only a few seconds and could be described as the beginning of the arrow of time, or of time itself. At that point, the intense energy kept matter from forming even elementary particles. The weakening and cooling of energy initially resulted in the production of hydrogen, the lightest and most common element in our universe. Research on the *galactic epoch* represents special challenges to scientists. Though galaxies have been observed throughout the universe, there are still questions about exactly how they were formed. It is generally concluded that most were formed during the universe's first billion years, and that conditions conducive to their formation are no longer present. The conditions that first produced stars during the *stellar epoch* still exist at the present time. Astronomers have observed new stars being formed in the Milky Way. For stars to form, stellar gas must combine with large amounts of matter. The sun is an example of a star with medium mass that has lasted around 5 billion years and is expected to last at least that long into the future.

The *planetary epoch* is generally assumed to have developed as the result of the stellar epoch, since planets appear to form as the result of the explosion of stars with a large mass. At the time that the sun was forming, around 5 billion years ago, other planets appear to have been formed by the fragmentation of a large ball of gas and dust. Earth is an example of a planet closer to the sun, which accounts for its smaller size and rocky surface. Under the original harsh conditions, it seems likely that life did not yet exist. Earth is also held to be approximately 4.6 billion years old. During the *chemical epoch* the available energy resulted in the growing complexity of simple chemicals that would eventually make life itself possible. Perhaps 4 billion years ago, the *biological epoch* began with the formation of the earliest and simplest forms of life. Fossil records have indicated that a particularly diverse set of new life forms appeared during the Cambrian period, about 550 million years ago. Compared to other forms of life and complex organisms, humans have existed for only a few million years, with more advanced humans appearing only about 150,000 years ago.

The *cultural epoch,* the seventh and final stage, includes the present day. The most rapid period of advancement of civilization took place within the last 10,000 years, including the rise of technology, the development of symbolic language as articulate speech, and even the desire and ability to measure time itself more accurately. This fertile period represents just 1% of human history. As humans evolved, an actual increase in brain size occurred. Those changes increased their capacity to acquire and store information and to pass it on to others, as well as to have the curiosity and ability to tackle a topic as complex as cosmic evolution.

Chaisson emphasizes the importance of energy in the evolutionary process. Though the amount of energy in the universe is fixed according to the conservation principle, cosmic expansion has resulted in an ever-increasing energy flow per mass over the past 10 billion years. Galaxies, stars, planets, and various life forms can be described as open systems. They are able to exchange energy and matter with their surroundings. The increased energy that results may explain the growing complexity of the universe and the increased order of its various structures. In this sense, a kind of natural selection occurs when a specific system survives because it has been able to process energy at the most efficient level. Chaisson describes the arrow of time as linear and not reversible, with the sequence of the various epochs that occur being more important than identifying how much time actually passed during each epoch. It can be useful to imagine the arrow of time as flexible and able to be modified as scientists gather more data. Fortunately, modern scientists have the advantage of increasingly sophisticated technological resources for finding new data. An important example is the Hubble Space Telescope, a major tool used in the 2007 Cosmic Evolutionary Survey (COSMOS) at the California Institute of Technology. The survey revealed that this universe consists of only 4% ordinary matter. The remainder, not directly observable, consists of 22% dark matter and 74% dark energy.

Cosmic evolution can be described as a historical study as well as a scientific discipline. Scientists strive to avoid being judgmental in their observations, and the interdisciplinary nature of the field can only increase the scope of what scientists and other scholars may discover. In addition to satisfying humankind's natural curiosity, the study of cosmic evolution is an important way of linking the past with the present and speculating on the future. What we learn could also allow us to monitor our impact on evolution in the most constructive way possible.

Betty A. Gard

See also Copernicus, Nicolaus; Cosmogony; Cosmology, Inflationary; Galilei, Galileo; Hawking, Stephen; Time, Emergence of; Universe, Closed or Open; Universe, Contracting or Expanding; Universe, Evolving; Universes, Baby

Further Readings

Chaisson, E. J. (2001). *Cosmic evolution: The rise of complexity in nature.* Cambridge, MA: Harvard University Press.

Chaisson, E. J. (2006). *Epic of evolution: Seven ages of the cosmos.* New York: Columbia University Press.

Tyson, N. deG., & Goldsmith, D. (2004). *Origins: Fourteen billion years of cosmic evolution.* New York: Norton.

Evolution, Cultural

The process of cultural evolution is a phenomenon the strict and clear definition of which can hardly be found in contemporary anthropology and philosophy. In most branches of humanitarian knowledge, concepts of cultural and social evolution are viewed within the framework of the entire theory of evolution of human society, which inevitably implies an evolutionary approach to human culture as well. At the same time, the history of cultural evolution conceptualization in anthropological thought proves that the idea of evolving social structures and functions, as well as material culture, throughout a vast period of time has been in this disciple since the middle of the 19th century.

Concepts of Cultural Evolution: The Evolutionist Paradigm

Ideas about the evolution of human culture were formulated for the first time at the end of the 19th century as a logical application of evolutionism to a peculiar branch of cognitive philosophy that was based in turn on an idea of development (mostly progressive in its character) of human beings and human culture over time.

Early ideas about cultural evolution as the essence of human history were expressed by Edward Burnett Tylor in 1865 in his *Researches Into the Early History of Mankind,* in which basic postulates of further understanding of this phenomenon in ethnology, cultural, and social anthropology were expressed. According to Tylor, in all parts of the world, human culture gradually evolves from its savage stage through barbarism toward civilization; cultural differences among different peoples can be explained by the fact that these groups represent different stages of cultural evolution and have no racial or any other implication. Cultural achievements (innovations) could be invented by the cultural group itself or inherited from previous generations; alternatively, they could be also adopted from neighbors.

In a series of subsequent scientific works (*Primitive Culture,* 1871; *Anthropology,* 1881) Tylor improved his understanding of cultural evolution as an immanent process of gradual development that is identical with cultural progress and inevitably means steady perfection of certain cultural phenomena over time. Notwithstanding differences with the so-called degeneration theory of Joseph de Maistre, widely popular at that time, Tylor did not totally exclude the possibility of regressive changes in human culture caused by historical and natural catastrophes.

Based on his own original definition of the historical and social essence of culture taken as a general anthropological concept, Tylor provided numerous examples of so-called evolutionary rows, in frames of which particular genres of cultural phenomena and artifacts were arranged in certain sequences, beginning with their simplest form up to contemporary highly developed versions. The "doctrine of survivals," or living cultural fossils (archaic cultural elements preserved from one stage of cultural evolution into the next), was another instrument applied by Tylor to prove that changes of culture through time were progressive and gradual.

An original understanding of cultural evolution as a cyclic process was proposed by another early evolutionist, Adolf Bastian. He interpreted the history of humankind as a continuous round of events that were altered only when new challenges ("irritants") provoked a new turn in the evolutionary process. The more isolated a group is in its life cycle, the more unalterable its culture is, thus providing few chances for evolution. According to Bastian, the deeper the connection certain collectives have with their geographic habitat, the weaker the evolutionary prospects are for their culture.

It should be stressed, nevertheless, that most early evolutionists, such as Lewis Henry Morgan, Herbert Spencer, James G. Frazer, and others, tended to emphasize a stage approach to the interpretation of cultural evolution, stressing universality: Insofar as basic principles of cultural evolution are common for all of humankind, similar stages of cultural evolution yield similar results and outcomes. This thesis was regarded as a substantial background for the creation of global historical periodization of human cultural development and social changes.

Continuity of cultural changes was considered by early evolutionists as one of the basic principles of cultural evolution, and in their understanding these changes were mostly quantitative and did not imply qualitative transformation of the subject under study. Thus, no attempts to explain the history of culture and its components' origin could be traced in the works of these early evolutionists.

Cultural Anthropology Between World Wars I and II

Formation of national schools in ethnography and cultural and social anthropology at the turn of the 20th century brought new insight into the application of cultural evolution in native culture studies and caused broad diversification in the understanding of the essence of cultural changes in time, not limited to evolutionary methodology.

At this time, cultural history occupied the attention of the anthropologist Franz Boas, who effectively dismantled the idea of orthogenic evolution with respect to human society, stressing at the same time that globalization and generalization in terms of cultural essences carries the risk of veiling the real cultural diversity of the world. He believed that every culture has its own history that is unique and precious. Thus, the development of culture should not be labeled as progressive, cyclic, or regressive as was done by early evolutionists. According to Boas, cultural changes reflect the peculiarities of the inner social development of a group as well as external social and environmental impacts, which cause an elaboration of peculiar modes of life or human behavior.

His followers, representatives of the historical school of cultural anthropology, were far from understanding the history of a culture as an evolutionary process progressive in its inner essence. They tended to explain the dynamics of culture in time mostly by processes of cultural diffusion, which imply broad intercultural interaction. Similar cultural phenomena could be caused by principally different challenges and have different origins.

Further studies in the field of cultural changes in time are connected with the name of Melville Herskovits, who argued that morphological differences between humans, geographic position of a group, and mode of production could not be regarded as the basic determinants of certain cultural origins and changes over time. According to his views, which became the theoretical background of cultural relativism, every culture is equally valuable and important, representing a unique cultural focus that is highly distinctive and often cannot be compared with cultural focuses of other cultures. Denying ethnocentricity in any form, cultural relativists regard the history of humankind as a set of independently developing cultures, each of which is at the same time stable and variable; this cultural variability is the basic source of global culture dynamics in time.

Neoevolutionary Interpretation

The constructive critique of early evolutionists' linear understanding of cultural evolution by most ethnological and anthropological schools of the first half of the 20th century provoked a fundamental revision of the theoretical background of evolutionists' theory of cultural dynamics and gave rise to the peculiar ideology known as neoevolutionism.

Within this framework, evolution is viewed as forward movement stimulated by an indefinite set of reasons, motives, and challenges. Their detection is the focus of most of representatives of this theoretic branch of cultural anthropology. Diversity in understanding of the cultural essence of evolution and the peculiarities of its realization within certain human groups is perhaps the most striking feature of the neoevolutionist understanding of cultural evolution. Interpreting culture as a set of interdependently and pluralistically evolving systems is typical of neoevolutionists. The question of the universality of stages in the historical evolution of culture is another subject of sharp theoretic discussion among neoevolutionists, along with the idea of multilinear forms of cultural evolution.

One of the most widely known versions of neoevolutionistic interpretation of cultural changes through time is represented in series of monographs by Leslie A. White (*Science of Culture,* 1949; *Evolution of Culture,* 1959). According to White, cultural evolution is a unified process of development in which one form is growing through another in chronological consequence; every form of culture in this context is shaped by a combination of different elements of culture. He believed the basic reason for cultural evolution was the improvement of human adaptation to the world, and he suggested that the degree of success of this adaptation could be measured rather precisely.

White believed that energy is the basic source and driving force of any process, cultural evolution included. Energetic richness of a culture is the main criterion of its maturity, and cultural progress could be measured by quantity of energy per capita used annually by its transmitters. In this way, progressive forms of cultural evolution implying improvement of human adaptation were associated with a growth in power consumption.

Julian Steward, another famous representative of neoevolutionism, also tended to link cultural evolution with human adaptation. In his *Theory of Culture Change: The Methodology of Multilinear Evolution* (1955), Steward proposed an original interpretation of culture as a peculiar system of evolution determined by the necessity to adapt to particular geographic environments. Taking into account the variability of geographic situations and the plurality of its changes through time, cultural evolution inevitably displays itself as a multicircuit process resulting in a plurality of cultural phenomena and forms. The origin of the latter he proposed to explain by correlation among peculiarities of natural environment, technological parameters of certain societies, and specific features of its activity (functioning).

Adhering to a pluralistic version of cultural evolution, Steward believed that different cultures could develop in fundamentally different ways, and this difference depends on the plurality of their adaptation to natural environment: Peculiar landscapes elicit an elaboration of peculiar adaptive forms and elements of culture. He put into scientific circulation the notion of "cultural ecology," which describes the process of human cultural adaptation and the interaction between culture and the natural environment. Cultural adaptation was understood by him as a permanent and perpetual process, inasmuch as no known cultures have failed to adapt perfectly to their niche.

On the basis of his original understanding of the role of natural environment in cultural evolution, Steward detected the phenomenon of "parallel evolution," which implied that cultures of human collectives living in similar geographic situations and characterized by similar technology evolve similarly, even if they are located far from each other and have no direct or mediated contact.

It is worth mentioning, nevertheless, that Steward was rather far from simplistic explanations of all elements of culture and their changes through time by ecological adaptation. In his works environmental impact on cultural evolution is viewed dualistically: The geographic situation stimulates the elaboration of certain forms of culture and, at the same time, restricts realization of some innovations. He was a proponent of the pluralistic approach to the conceptualization of the role of environment in cultural evolution, suggesting that at the early stages of cultural evolution, human culture mostly was prone to environmental impact, while the cultural compass of societies with highly developed technology is considerably wider.

In contemporary cultural anthropology, neoevolutionistic ideas concerning plurality and multicircuitry of cultural evolution have been developed by Marvin Harris. In his *Cultural Materialism* (1980), he argues that cultural evolution results from, and is stimulated by, satisfaction of human needs with the help of technologies that show strict correlation with peculiarities of environment at certain periods of time and imply optimal forms of exploitation of available resources using minimal expenditures of labor and energy.

Recent tendencies in the study of cultural evolution are connected with a symbolist approach to culture as a global phenomenon. One such version is represented by Charles Lumsden and Edward Wilson, who identified the central importance in cultural evolution of a process they call *reification,* for which the enabling device is symbolization. The central place in this process is occupied by language as the basic means of symbolization, whose origin and changes over time are integral parts of the subject field of cultural anthropologists, linguists, historians, as well as geneticists who are studying gene flows and reconstructing, on this basis, cultural contacts and further cultural changes. Recently, Richard Dawkins introduced the notion of a *meme*—a replicator of cultural information analogous to the gene. On this basis a wide variety of computational approaches to cultural evolution have been elaborated, most popular among which are Liane Gabora's MAV (meme and variations) model, David Ackley's concept of distributed Lamarckian evolution, Lee Spector and Sean Luke's idea of cognition evolvability, and others.

Olena V. Smyntyna

See also Evolution, Social; Harris, Marvin; Language, Evolution of; Spencer, Herbert; Tylor, Edward Burnett; White, Leslie A.

Further Readings

Ackley, D., & Littman, M. L. (1994). A case for distributed Lamarckian evolution. In C. G. Langton (Ed.), *Artificial life III: Proceedings of the Workshop on Artificial Life held June 1992, Santa Fe, New Mexico*. Reading, MA: Addison-Wesley.

Boyd, R., & Richerson, P. J. (1985). *Culture and the evolutionary process*. Chicago: University of Chicago Press.

Gabora, L. (1997). The origin and evolution of culture and creativity. *Journal of Memetics—Evolutionary Models of Information Transmission, 1*.

Lumsden, C., & Wilson, E. O. (1981). *Genes, mind, and culture*. Cambridge, MA: Harvard University Press.

Steward J. H. (1955). *Theory of culture change: The methodology of multilinear evolution*. Urbana, IL: Urbana University Press.

Tylor, E. B. (1958). *The origin of culture*. New York: Harper. (Original work published 1865)

White, L. (1959). *The evolution of culture: The development of civilization to the fall of Rome*. New York: McGraw-Hill.

Evolution, Issues in

There is no shortage of issues in evolution. Some are highly contentious, others are benign. Evolution, by its very nature, is prone to controversy because it is largely a science of inference about a historical process, a process that takes place over time and space. Evolution involves unique events that can never be revisited in their entirety and can only be reconstructed through evidence associated with those events. In this way, reconstructing evolution is methodologically no different from a process of detective work that attempts to reconstruct a crime scene or any other event that has occurred only once. Because evolution is a historical process, its expression over time provides the focus for many of the uncertainties and questions in the science of evolution. These challenges may be relatively ephemeral as they are recognized and solved, or they may persist over longer periods before being solved or reformulated, or they may even emerge again under new scrutiny or with the discovery of new evidence. In evolutionary research, time is of the essence; it must always be addressed. This entry illustrates some of the issues in evolution that focus on, or are derivative of, evolution in time.

RNA or DNA?

A central dilemma for understanding the genetic origin of life is the identification of a stable, self-replicating genetic molecule that simultaneously carries the information necessary for copying itself and for catalyzing that replication process. Modern life relies on two complexly interrelated molecules for this process: DNA (deoxyribonucleic acid), as a carrier of information, and proteins, which perform chemical reactions. Proteins are involved in the formation and maintenance of DNA, and yet DNA is required for the protein formation instructions. This dual function raises the question of which process came first. One possibility is that a self-replicating peptide or other protein molecule evolved first, and DNA became possible as a result. The problem with this model is that it requires a random assembly of amino acids to form chainlike polymers rather than irregular clusters. A simultaneous evolution of proteins and DNA would require two improbable events. The evolution of a sequence of elements that replicates and also provides the template of replication represents another possibility, suggested by the role of RNA (ribonucleic acid) in living organisms.

The single-stranded nucleic acid molecule known as RNA can function both as a carrier of information and as a catalyst promoting the self-replication. RNA also includes genes that accelerate biochemical reactions. RNA has the potential to make and maintain DNA as well as proteins. This RNA theory suggests that life may have first begun as an "RNA world" of organisms that preceded the evolution of DNA life. The RNA world theory suggests there was a time when RNA rather than DNA was the primary mechanism of storing genetic information, but when replication of genetic material already followed the same rules as modern DNA by matching the amino acid adenine with uracil (equivalent of the DNA thymine) and cytosine with guanine. This ancient, ancestral RNA is theorized to have played the same catalytic roles as modern protein enzymes where the first genetic life-form was simply a self-replicating strand of RNA that may have been enclosed within a protective lipid membrane while modern metabolic processes, with an efficient replication process, emerged later.

If life and genetics are synonymous, the evolution of life through an RNA world may represent the beginnings of modern life. The possible antiquity of RNA implied by the RNA world model is emphasized in biochemical studies showing that RNA molecules play key structural roles in the formation of a variety of essential coenzymes that mediate manufacture of lipids and other biological molecules. RNA also includes genes that change shape when binding to specific cell molecules and regulates cell chemistry by turning genes on and off. There is widespread agreement that RNA represents a critical step in the origin of life, but after decades of chemical experiments, the emergence of a fully functional RNA world from earlier prebiotic chemical solution remains problematic.

The RNA theory provides no insight as to how life first made the transition from a prebiotic solution of biological molecules to those of DNA and cellular life. There may have been a critical transition stage, such as a metabolic system, that was followed by a genetic molecule that was structurally simpler and chemically more stable than RNA. Metabolism initially uses relatively simple molecules (carbon-oxygen-hydrogen and possibly sulfur), whereas RNA function relies on exact sequences of chemically complex nucleotides involving a carbon-oxygen-hydrogen-nitrogen-phosphorus system. Biologists are generally confident that there was a transition from an RNA world to the current DNA-protein genetic system, but how the prebiotic molecular world evolved the linkage between individual nucleotides comprising an RNA strand remains unsolved.

Viruses as Life

Viruses cross the boundaries that are used to define the concept of life. In general, evolutionary biologists may not give due consideration to the role and contribution that viruses have made to the origin and evolution of life. This oversight may be due, in great part, to a widely held view that viruses do not represent living entities and do not, therefore, represent significant elements or contributors to the tree of life. But viruses can be killed, can become extinct, and adhere to general rules of evolutionary biology, including the process of natural selection. And they do have a large impact on the survival and evolution of their hosts.

The determination of viruses as living or nonliving entities represents a persistent question since viruses were first identified. As in all other biological systems, viruses store, copy, and express information. In some respects they conform to qualities of organisms that are accepted as having a living state, but in other respects they do not. There is widespread agreement that life is bounded by birth and death for organisms that live with a degree of biochemical autonomy and have the metabolic ability to produce the molecules and energy necessary to maintain life. Viruses, on the other hand, lack biochemical autonomy because they lack the means to produce their own proteins and consequently rely totally on their symbiotic molecular parasitism of other living organisms. Because viruses are parasitic to support essentially all the biomolecular requirements, they may be viewed as nonliving parasites of living metabolic systems. In this context they can be described as metabolically active containers lacking the genetic potential to propagate without "borrowing" life from other living organisms. Viruses may be no more than environmental or chemical toxins that kill off some hosts.

The question of whether viruses are alive may be no more informative than the question of whether a gene or protein is alive. Individual subcellular constituents such as mitochondria, DNA, RNA, genes, enzymes, and cellular membranes all represent levels of chemical complexity equivalent to those of many viruses, and yet they are generally considered not to be living in the same way as cells or organisms are living. Unlike cellular organisms, some viruses can bring themselves back to an active or "living" state and some viruses can replicate in "dead" host cells such as those without nuclei. Where an individual cell is infected by more than one dead virus, the virus can become reactivated when the multiple viral genomes complement the damage and reassemble the "living" virus. This is the only known biological entity to have this capability.

A widely held view on the origin of cellular life is that it first evolved in oceans and that it was preceded by a period of evolution involving precellular, chemical-replicating forms. These chemical entities were able to use themselves as a template for synthesis using existing molecules in the surrounding environment. Given the fact that all cellular life uses nucleic acid molecules as genetic information and relies on protein-based catalysis, the ancestral replicating systems may also be assumed to rely on nucleic acids or related molecules as information storage and biotic synthesis. As the main storage molecule of genetic information in living organisms, DNA is a comparatively chemically inert and stable molecule that cannot perform the catalytic process required for replication. In contrast, RNA is known to function as both genetic storage and as a catalyst of RNA, and autocatalytic RNA may have been the principal molecule used as both information storage and catalysis in the prebiotic world. RNA can break the molecular bonds of RNA, although it is comparatively inefficient in constructing new RNA molecules. If more efficient replicating systems did not exist in the prebiotic world, then this inefficient RNA-based process may have represented a viable system of replication. With the subsequent emergence of protein catalysis and faster replication processes, the prebiotic RNA replicators would have became extinct, with the possible exception of RNA viruses as the sole living descendents of the prebiotic world.

Viruses are obligate intracellular parasites. They cannot replicate outside cellular environments. This current condition may be seen to preclude the existence of viruses before the evolution of cellular life. If, however, viruses are recognized as molecular genetic parasites, they may be capable of parasitizing any replicating systems, including other viruses, and any prebiotic molecular systems. Any genetic replicators, including noncellular prebiotic replicators, would be susceptible to parasitic replicators or viruses, as are viruses parasitized by other viruses. These parasites of parasites could be anticipated to have also existed in the prebiotic world.

No fossil record of viruses has been discovered, so there is no external reference to calibrate the origin of various virus lineages. As prebiotic life forms, viruses would have to precede the first record of prokaryote cellular life (bacteria), about 4 billion years ago, and the cyanobacteria (blue-green algae), about 2.6 billion years ago. Each of these groups has distinct and characteristic viruses, but they also share the presence of tailed viruses and this may be the result of this group of viruses evolving prior to their divergence. The earliest eukaryotes (unicellular algae) appear in the fossil record between 2.2 and 1.8 billion years ago, followed by relative evolutionary stasis until the Cambrian explosion with the appearance of numerous skeletal organisms. The evolution of these forms also is likely correlated with the emergence of many types of viruses.

Viruses appear to have numerous evolutionary origins as indicated by the different specific genome replication processes of individual virus families, suggesting each virus family derived from a different ancestor. Other viral groups are so large and diverse that available sequence data currently do not support the view that even they evolved from a single common ancestor.

It is now widely thought that viral lineages are old, and they originated independently of the replication system in their hosts, and there are several independent origins for viruses.

Origin of Complex Life

There is no objective demarcation between "complex" and "simple" life, but a major organizational difference separates unicellular and noncellular organisms from multicellular organisms (Metazoa) where specialized cell functions are present. Metazoan cells are interpreted as descendants of unicellular organisms that may also have a composite origin involving the combination of noncellular organisms resulting in the metazoan cell with a central membrane-bounded nucleus surrounded by cytoplasm with specialized organelles. The combination or incorporation of precellular organisms would explain the occurrence of nonnucleic DNA in organelles such as mitochondria and chloroplasts.

In the context of relative complexity, the combination of cells results in new features not present in unicellular organisms, such as extracellular matrix providing support for the cells and including gelatinous matrices infused with fibers such as collagen and other macromolecules. Metazoan cells comprising tissues are also connected to each other by molecules that form attachments and also permit intercellular communication. Most tissues comprise sheets of cells that are usually interconnected and have apical and basal regions and are usually attached to a basal layer of extracellular matrix. Connective tissues are also embedded in extracellular matrix, but they are not as closely associated. Another major tissue category is nervous tissue, which forms the main integrating and coordinating system of the body and is present in almost all free living metazoans.

The Metazoa comprise a range of contrasting body structures that appear abruptly in the fossil record and lack intermediates. The Metazoa appear to be monophyletic (share a most recent common ancestor not shared by nonmetazoan life), but the arrangement of major lineages (phyla) is variable even though many researchers use the same information. In morphological studies, the Cnidaria (jellyfish and their relatives) are often represented as one of the earliest of living metazoan phyla. Even the Chordata, which mostly comprise the vertebrate groups (fish, amphibians, reptiles, birds, and mammals), are often treated as having originated near the beginning of metazoan life and are often linked with the invertebrate Echinodermata (starfishes). Molecular phylogenies have yielded some different results, some suggesting that cnidarians evolved independently of the remaining bilaterally organized metazoans.

Two main evolutionary issues concern when metazoan life evolved and in what sequence. The branching order of lineages may be theorized through phylogenetic analysis that predicts their evolutionary relationships. This order may be compared with their order of appearance in the fossil record, and where the two sources of evidence coincide, the sequence may be viewed as an accurate representation of metazoan evolutionary history. This approach is challenged by the uncertainties of fossilization, and soft-bodied organisms, particularly those that are unicellular, are rarely preserved as fossils. The definition and dating of the earliest geological formations in relation to the fossil record may also be problematic. The earliest rocks dating from about 600 million years ago (mya) comprise the Neoproterozoic era until the beginning of the Cambrian period about 543 mya. Metazoan fossils earlier than about 565 mya are limited to embryos, body fossils, and traces of metazoan activity and include the sponges as the only living metazoan phyla represented, although Cnidaria (jellyfish) are thought likely present because they represent a basal or primitive lineage. Later Neoproterozoic fossils include small, shelled fossils. The first appearance of recognizable trace fossils (formed by disturbance of sediments by the activities of an organism) formed by a series of straight to curving segments mark the beginning of the Cambrian about 530 mya. The Cambrian fossil record includes the first appearance of 11 of the modern phyla, including mollusks, arthropods, starfish, and chordates. From the end of the Cambrian (490 mya) to the beginning of the Mesozoic (248 mya) only four additional metazoan phyla first appear, whereas most of the remaining phyla either have a post-Mesozoic (65 mya) fossil record or lack a fossil record altogether (14 soft-bodied phyla).

Cambrian Explosion of Life

Fossils may raise as many problems as solutions for scientists who track the temporal origin and sequence of life in the fossil record. Fossils are informative in the sense that they provide empirical evidence for the existence of an organism at a particular place and time. But they are less informative about the evolutionary identity and the relationship of that past organism to modern life. This problem occurs at all levels, from identifying a species relationship for recent fossils (e.g., whether Neanderthals are a separate species or a variation within modern humans), to their placement at a higher taxonomic level such as a genus, family, order, class, or phylum. These problems may be compounded by the lack of preservation in fossils, particularly the general absence of information on soft-tissue organization. Even features that do fossilize may be only partially preserved.

Fossils also yield ambiguous information about the timing of evolutionary events. The oldest fossils represent forms that can be identified only at a high level of classification, that they represent, for example, a bacterium, a single-celled organism, an animal, or a plant (and even then, the identification may be uncertain). The oldest recognizable fossil for any particular group of organisms also cannot provide any temporal information other than the minimal age of fossilization of that group.

How much the origin of a group may precede the fossil record cannot be directly gleaned from the fossil itself. Given this limitation, the fossil record is presumed to give a reasonable indication of historical sequence as more derived groups (e.g., mammals) appear in the fossil record later than those that are more generalized (e.g., fish or invertebrates). When larger groups representing many species are absent from the fossil record, there may be greater confidence that they are either rare at that time or had not yet evolved. There may be a relatively high level of confidence in correlating fossil appearance with the timing of evolutionary origin when skeletonized organisms are involved, but in the absence of skeletons the lack of fossilization may represent the relative rarity of conditions for fossilization of soft tissues rather than an actual absence. In dealing with the origin and first appearance of skeletal life, this is a major constraint on scientists' efforts to identify the temporal origin of skeletonized organisms.

The problem of correlating the first fossil appearance with evolutionary origin is exemplified by the various multicellular phyla that first make their appearance in the fossil record during the Cambrian period that began about 543 mya and lasted until 490 mya. The earliest Cambrian fossils indicate an increase in biological diversification and body size compared with Precambrian organisms. The earliest fossils are traces of movement or occupation of sediments by organisms and mineralized skeletons that increase in diversity during the first 15 million years of the early Cambrian. The traces are also larger and more diverse than Precambrian traces and include branching burrows and larger vertical burrows. Major locations recording diversification of Cambrian life include the Chengjiang fauna from Yunnan, China (Middle Cambrian), and the Burgess Shale formation, British Colombia, Canada (Middle Cambrian).

Precambrian fossils that may be recognized as members of living metazoan phyla are limited to sponges, although the soft-bodied Cnidaria (jellyfish) are presumed to be present. In the Early Cambrian, about 530 mya, fossil members of modern phyla that first appear include single- and double-shelled mollusks (snails and shellfish), echinoderms (starfish), annelids (worms), Cnidaria (jellyfish), chordates (precursor to vertebrates), a diverse array of arthropods (bodies with external, jointed skeletons), many of which cannot be assigned to living arthropod classes, and forms that may represent primitive fish. It is the arthropod groups that show the most striking diversification of body structures, including many that are distinct from later arthropod groups, and others that look like members of the phylum Onychophora, a living group that may represent a transitional stage between soft-bodied annelids and the externally skeletonized arthropods.

Because these fossils appear over a geologically short period of time, their pattern of fossilization is characterized as the "Cambrian explosion." The appearance of these fossils would represent a comparatively rapid explosion of evolutionary diversification if the fossil record accurately represents their evolutionary origin. Because most of the diversity corresponds to organisms that have evolved durable, mineralized skeletons, their fossil appearance may be an artifact of fossil perseveration, representing an increase in the durability of skeletal structures rather than their first appearance. Evidence that may suggest the fossil record corresponds to a rapid diversification during the Early and Middle Cambrian is found in groups that appear to have required durable skeletons to function so their evolutionary origins may be no earlier than the origin of their durable skeletons. The large increase in trace fossil abundance and variety also began only shortly before the fossil explosion and may suggest that many of these groups may have first evolved around the time of their fossil appearance. There is also the possibility that the ancestral forms of the Cambrian phyla were present in the Precambrian, but rarely preserved, if at all. As with any fossil record, the absence of earlier fossils does not preclude an earlier origin, which may be corroborated only through later fossil discoveries.

Origin of Sex

Sex involves the coming together of complementary cells, where the biological attraction is strong enough to recombine genes, with the result that the new organisms are genetically different from their parent cells. Understanding the evolutionary and temporal origins of sexual reproduction is linked to understanding the origin and evolutionary relationships of organisms that may be classified into five main reproductive groups. Two groups are entirely or principally unicellular. The bacteria are single-celled organisms that lack nuclei. These organisms reproduce through binary fission, although bacteria may also incorporate genes from other bacteria or absorb genes that have been released into the surrounding water from dead bacteria. The protocists comprise cells with a nucleus (including algae, slime molds, and ciliates) that also often reproduce through binary fission, but also sometimes exhibit cellular fusion. Most protocists are single celled, but some form colonies of cells that adhere together.

The multicellular groups comprise the fungi, which reproduce through the production of spores, the plants that reproduce from both spores and the cellular unions that produce embryos, and the animals that develop from the union of egg and sperm. It is in plants and animals where sexual reproduction requires cellular fusion followed by the division of a fertilized egg that forms the embryo. This process requires an alternating halving and doubling of DNA in each generation and a correlated parental mortality.

The origin of multicellular organisms from unicellular ancestors appears to involve not only the adherence and intercommunication of individual cells but also novel combinations of unicellular organisms. Both animals and plants include organelles that have their own DNA (mitochondria in animals, chloroplasts in plants). Some comparative studies have resulted in the proposition that protocists first evolved through the integration of bacteria, and this process of symbiosis may also have significant implications for the origins of metazoan sex. Each generation of animals reverts to what is effectively a single-celled protocist-like stage, and the mammalian fertilized egg may resemble the ancestral protocists that evolved the first doubled chromosome complement. But instead of remaining a single-celled organism, the cells of this ancestor stayed together and formed an embryo with differentiated tissues and organs.

The origin of sex in plants and animals would appear to be contemporaneous with the evolution of multicellular organisms that develop from an embryo. The reproductive links may be indicated in some protocists where asexual and sexual reproduction is present along with multicellular organization. Seaweeds comprise single algal cells that remain together, but they are not plants in the sense that they do not develop from an embryo. In some algal colonies any one cell may break away and start another colony, whereas others (e.g., *Volvox*) form small colonies within themselves that are later released when the gelatin holding the parent colony together dissolves. Some *Volvox* colonies will produce cells that function as ova and others that function as sperm that swim to and fertilize the ova. The fertilized ova forms a zygote within which meiosis will take place, and each resulting cell will begin a new colony.

The presence of sex within protocists suggests that sex may be as old as the protocists in general. There is no direct way of dating this origin. The earliest metazoans may extend back as far as 600 mya whereas the first protocist evolution may have taken place at any time earlier when life was first possible on the planet, perhaps 3.8 billion years ago. Even with such uncertainties, sex would seem to have a history as old as that of cellular life, and sexual reproduction through the formation of embryos may even have preceded the evolution of the multicellular organisms that comprise the plants and animals that dominate life's diversity in the present.

Punctuated Equilibrium?

A long-standing question is whether the rate of evolution is constant over time or whether it is variable with periods of rapid evolution and other periods when little or no evolution takes place (stasis). The concept of punctuated equilibrium represents a proposal in favor of evolution alternating between sometimes long periods of stasis punctuated by periods of rapid evolution during speciation. Punctuated equilibrium was popularized in the English-speaking world by Niles Eldredge of the American Museum of Natural History and Stephen Jay Gould of Harvard University. They introduced the concept of punctuated equilibrium in response to an incongruity between the fossil record and the popular version of evolution as a gradual process of evolutionary change over time.

Eldredge and Gould observed that Charles Darwin emphasized a process of gradual evolution, but this theory was incongruent with the expectation that this gradual evolution would be observable by the prevalence of transitional forms between very similar stages in the fossil record. In reality, although a series of transitions in succeeding geological layers over time could sometimes be observed, in most cases there were gaps between the older and younger fossils. The lack of transitional forms was attributed by Darwin to the incomplete nature of the fossil record; transitional forms were missing because they were often not preserved. In this way, the fossil record was misleading about the process of evolution over time by giving the impression that evolution was a continually interrupted or punctuated process.

Not all evolutionists supported the theory of gradual evolution, and some proposed major evolutionary changes whereby new species or forms appeared without any identifiable intermediate form. These "saltationists" included Richard Goldschmidt, who proposed that species could give birth to entirely different forms that were anatomically different from their parents. As this process was not observed in the laboratory, it raised many questions about how such a novel form could survive and reproduce, and Goldschmidt's theory did not gain wide popularity among evolutionists.

Some fossil gaps may be apparent rather than real, where speciation occurred through dispersal to another locality where a new species evolved, and this did not overlap the related species until a later date when it would also fossilize in the same location and give the appearance of a gap. But that theoretical possibility notwithstanding, Eldredge and Gould argued that between the gaps in the fossil record were relatively long periods where a species persisted and that the problem with the fossil record was less that there were gaps than that there were these periods of stasis suggesting that evolution was not a gradual process.

As well as a description of the fossil record, punctuated equilibrium was also proposed as an evolutionary mechanism, based on conventional speciation theory and the notion of adaptive change through natural selection, which explained the origin of reproductively isolated communities over time. They argued that most anatomical change, whether or not it was adaptive, does not occur throughout the bulk of a species' history but during rare events when reproductively isolated species bud off from parental species. Most species do not have a continuous distribution but comprise geographically isolated populations, and given physical isolation of relatively small populations on the edge of a species range, it was possible to get adaptive divergence taking place. This divergence was rapid over geological time although it was not ecologically instantaneous and may involve tens of thousands of years and may mostly involve small evolutionary changes.

As a pattern, punctuated equilibrium described the apparent stasis of species evolution interrupted by speciation taking place over relatively short time intervals. As a mechanism, punctuated equilibrium represents a theorized mechanism based on natural selection of isolated populations affected by changes in the environment. This mechanism may be problematic for many situations where related species are vicariant (replace each other in geographic space) and each occupies a relatively broad geographic distribution, which may suggest speciation involves multiple populations. New developments in developmental and molecular biology also suggest the possibility that the "sudden origin" of new species or morphological structure may take place without necessarily requiring natural selection as the driving force. This is particularly significant for the origin of species over broad geographic areas that span many different local environments and populations that may be broader than the effect of natural selection at the local level.

Continuum

Evolution, by its very nature, is a theory about continuity. But in the present, life is full of discontinuities between those individual organisms that are involved in a close biological (usually reproductive) relationship and those that are not. The sense of discontinuity is also seen in the fossil record, where distinct species or other groups appear or disappear without apparent intermediate forms. The appearance of discontinuity is often seen as more of a problem for evolution than that of continuity and results in various theoretical solutions, ranging from that of punctuated equilibrium to proposed molecular and developmental transitions of entire organ or tissue systems rather than always through incremental and gradual evolution by many small steps.

Biological continuity may be seen in those individuals grouped into units called species. Most species are sufficiently distinct as to be almost self-evident, but limited cases involving various levels of hybridization and different modes of reproduction have led evolutionists to propose universal criteria for recognizing and distinguishing species. In most cases these attempts have focused on the creation of definitions that are true regardless of time and space. These definitions act as essential qualities or essences by which a species may be recognized and often center on reproductive relationships involving criteria such as a reproductive isolation (and its converse, mate recognition) with many, many scientific arguments about whether a species is a "true" species or not. All criteria of this kind are independent of a particular place and time and measure the status of a species solely on whether or not it conforms to the definition. In this approach, species are being defined according to an essential attribute (such as reproductive isolation) or essence.

The problem with essence as the attribute of a species is that essences do not evolve over time or space, but species do. Ancestral species diverge and become descendant species. For evolution to take place, species cannot exist as the expression of an essence because the essence precludes evolution. Recognition of this problem led to the formulation of species as historical entities or individuals that share a unique common history. At any one time and place, the biological limits of a species may be diagnosed with respect to those features of the organism and environment that are seen to identify the species boundaries. Such species diagnoses are valid in reference only to the specified place and time and do not, therefore, require a species to refer to an inner essence. In practice, species may be characterized by one or more particular features, including morphology or reproductive biology, but there is no absolute demarcation required to recognize these qualities independently of a particular spatial and temporal context.

As historical individuals, species may show evolutionary discontinuities where the biological features are spatially and temporally distinct and continuity where they are not. Evolutionary continuity may be seen over time as descendant species merge at their origin with the ancestor or over space where species may show local continuity in biology or reproduction (e.g., breeding between adjacent populations) or discontinuity where more distant populations are spatially isolated so they never interbreed or are unable to produce viable offspring when brought into contact. Here discontinuity is a function of an overall biological continuity that separates out over time and space. In this context a species, like all other units of biological classification, represents a link in the chain of divergence and differentiation rather than a point of separation and isolation.

Extinctions

The history of evolution is the record of speciation and extinction, from the first appearance of life through to the present. The process of evolution is a complicating factor in understanding extinction. When speciation takes place, there is a transformation of the ancestor into descendants, and this transformation may be regarded as a form of extinction even though the lineage continues to exist. Species may also hybridize, causing the "extinction" of the original forms, at least with respect to their original spatial and temporal characteristics.

Extinction may be fast or slow, and its causes local or regional, and climatic or extraterrestrial in origin. The fact of extinction is not at issue, but the causes and extent of extinction are. Even in the present when the planet is faced with one of the most severe extinction rates over a geologically instantaneous moment of time, there is controversy over what, if anything, can be done about the global destruction of habitat and even climate through human modification and destruction of the environment.

Past extinctions on a similar scale have been referred to as "mass extinctions," when species diversity dropped dramatically and globally. Causes of such extinctions have been attributed to major planetary changes related to the balance of global temperature, the influence of massive regional volcanic eruptions, and climate altered through plate tectonics. Only over the more recent decades has greater attention been given to the extinction role of extraterrestrial objects such as asteroids and comets even though it has long been recognized that the earth has a history of many major meteorite impacts.

Periodic major extinctions became apparent to late–19th-century geologists, who delineated geological layers that could represent particular units of geological time. The sequential arrangement of these layers according to their relative age resulted in the formulation of a geologic timescale. The early geologists relied on fossils to correlate the geographically separate geological layers representing the same temporal units. Through their different fossil compositions, major geological layers could be recognized. The different fossil communities were at first attributed to the separate and sequential creations of life.

Evolutionary paleontologists later came to recognize that the contrasting fossil biotas in the major geological layers resulted from evolution and diversification following major extinctions of previously dominant forms. Several major episodes of global declines in species diversity have been identified over the last 550 million years of the earth's 4.6-billion-year history, beginning with a mass extinction inferred from geological evidence of a catastrophic climatic change to the most recent change characterized by the extinction of dinosaurs as the earth's dominant life form.

Extinction of dinosaurs at the end of the Cretaceous at 65 mya is widely attributed to the impact by a comet that caused a 30-fold increase in iridium deposits at the Cretaceous-Tertiary boundary. A major impact crater that also formed at this time in the Yucatán Peninsula of Mexico is widely believed to be involved with, or solely responsible for, the mass extinction of members of the dinosaur clade except the birds, and perhaps 79% of terrestrial plants and 47% of the marine genera, including most marine reptiles. The extinctions are attributed to the effect of the immediate impact as well as atmospheric dust, acid rain, and the elimination of sunlight sufficient for photosynthesis. The extent and persistence of these effects is, however, uncertain, as some studies suggest the dust may have been rapidly reduced through rainfall, and the correlation of many modern plant and animal distributions with Mesozoic tectonics suggests the widespread survival of many lineages, possibly including some modern bird and mammal groups that then diversified in the Tertiary.

The nature and causes of earlier mass extinctions becomes more difficult to assess. The end of the Triassic at 199 mya is marked by the extinction of 53% of marine genera and 22% of marine families, and 12% of vertebrate families. It is after this extinction that dinosaurs became dominant on the land. The causes of this extinction remain unknown, but possibilities include rapid sea level rise and volcanic eruptions. Only 50 million years earlier was the largest recorded extinction, at the close of the Permian at 250 mya, reducing 57% of all families and perhaps 96% of all species in the sea. On the land there was a 77% reduction of tetrapod families (amphibians and reptiles). Among the marine extinctions, the tropical groups or members of the reef-building community were particularly affected. These relatively large estimates are problematic because there is a lack of complete terrestrial fossil layers from that time and errors in taxonomic classification as well as false extinctions where taxa disappear from the fossil record at the end of the Permian only to turn up again later in the Triassic. The extinctions coincide with the massive Siberian volcanic flood basalts, some degree of low oxygen and other changes in ocean chemistry, and a sudden spike in global temperatures. Explanations encompass a variety of terrestrial factors as well as the possibility of an extraterrestrial source.

In the late Devonian, at 376 mya, 57% of marine genera and 22% of marine families disappeared, including the trilobites. At the end of the Ordovician Period, at 439 mya, the second largest mass extinction induced the disappearance of the trilobite-dominated communities of the Cambrian. There was little life on land at this time, with the earliest fossil evidence of plants in the form of spores from the uppermost Ordovician. The extinction may have occurred through an alternation of cooling and warming over a short period of time, which eliminated 60% of marine genera and 26% of marine families. In the early Cambrian, at 512 mya, the elimination of about 50% of all marine species and geological evidence of sea-level glaciers near the equator at in the Precambrian at 600 to 700 mya have led to the Snowball Earth hypothesis, according to which the entire earth was ice-covered until terminated when carbon dioxide accumulation reversed the cooling. This event is inferred to have resulted in a major extinction of existing organisms, although this impact cannot be measured through the fossil record.

Human Origins

The origin of humans begins at the time when the human lineage separated from the common ancestor shared with the nearest living great ape relative. It is at or after this point of separation that the human lineage (hominids) evolved a new skeletal structure that made bipedalism obligate and freed the forelimbs from necessarily assisting with terrestrial locomotion. In contrast, the nearest great ape relative is descended from a lineage that did not evolve these features even though it too is derived from the same common ancestor as humans.

The hominid fossil record currently extends back about 6 million years with fossils that are mostly assigned to the genus *Homo,* which includes humans (*Homo sapiens*) and the australopiths (*Australopithecus* and *Paranthropus*). There are also four other genera that have been proposed as hominids although the evidence for their being hominids is far more ambiguous as they comprise limited fragments and bipedalism extrapolated from indirect evidence (*Ardipithecus, Sahelanthropus, Kenyanthropus*) or partial direct evidence (*Orrorin*).

The initial separation between humans and the nearest living great ape species was initially thought to have occurred much earlier, as another fossil thought to also be a hominid or close hominid relative dated to about 13 mya. This fossil, known as *Ramapithecus,* was represented by an apelike jaw with humanlike dentition. The fossil was fragmented at the midline of the palate, so the shape of the jaw was not known, but reconstructions suggested it was more like the squat, parabolic shape of humans than the U shape of apes. Paleontologists regarded *Ramapithecus* as a definitive hominid or at the very least a close hominid relative that showed the human lineage first diverged from the common great ape ancestor at least by this time.

An apparently contradictory perspective developed in the 1960s, as biologists started comparing protein molecules, and later, as they focused on DNA molecules. These studies at first pointed to African apes as being most closely related to humans, and subsequently this arrangement was replaced by a closer relationship between humans and chimpanzees because they showed the least amount of molecular differences in their DNA (although the contrast between humans and gorillas and orangutans was also very small). Molecular systematists argued that differences in molecular similarity could also indicate the relative age of divergence between related groups. Where members of a group were equally different from another external group, their divergence was seen to occur at a steady, clock-like rate and this clock-like divergence could be used as a measure of evolutionary time. All that was needed was a calibration point to match divergence with absolute time, so that molecular ages could be given for those species lacking an adequate fossil record. By including species with an accepted fossil record, it was theoretically possible to date the divergence between humans and their nearest living great ape relative.

It is now almost universally accepted as a scientific fact that humans and chimpanzees diverged from a unique common ancestor and that even though chimpanzees are structurally more like gorillas, the latter resemblance is misleading. The oldest fossil members of the human lineage (hominids) date back to about 6 mya, but neither chimpanzees nor gorillas have a recognized fossil history beyond some very recent records. The molecular clock appeared to provide a solution, and calibrated molecular clocks predicted divergence dates of 5 to 8 mya for humans and chimpanzees. This was a much more recent date for hominid origins than suggested by the *Ramapithecus* fossil, but a later discovery of another fossil in the *Sivapithecus* group appeared to provide a solution. *Sivapithecus* was recognized as representing the same group as *Ramapithecus,* and because *Sivapithecus* was the older name, it took priority for naming this combined group that included the former *Ramapithecus.* As more complete fossils of *Sivapithecus* were found, it was apparent that these fossils were distinctly orangutan-like. This similarity was believed to preclude these fossils, including the original *Ramapithecus,* from representing a fossil hominid or even a close hominid relative because orangutans were not believed to be more closely related to humans than were the African apes. The alternative possibility, that orangutans were more closely related to humans than African apes, was not considered. Humans were now promoted as not only having diverged very recently from a common great ape ancestor with chimpanzees, but also having evolved a radically different biology resulting in very little, if anything, that was structurally unique to humans and chimpanzees.

The absence of uniquely shared structures between humans and chimpanzees remained an evolutionary anomaly because the theory of evolutionary classification established over the past several decades is based on the principle that sister groups (those that share a unique common ancestor) also share one or more unique features inherited from that unique common ancestor. In the absence of any other theory of relationship, the lack of unique features shared by humans and chimpanzees could be disregarded, but in the early 1980s evidence for the existence of many features unique to humans and orangutans began to accumulate, and these structural characteristics support a closer relationship between humans and orangutans than humans and chimpanzees. As many as 40 unique features have been identified, and at least 30 are strongly documented comparative studies. If orangutans are more closely related to humans than are African apes, then so too are fossil orangutans relatives such as *Sivapithecus,* which is now dated to about 13 mya. This fossil record may suggest that the divergence of hominids from the nearest living great ape (the orangutan) occurred earlier than the time that the molecular clock theory predicts.

The structural evidence for the orangutan relationship with humans sharply contradicts the widely accepted theory that similarity of DNA molecules necessarily precludes any other pattern of relationship derived from nonmolecular evidence. Unlike the molecular evidence, which does not correspond to any comparable structural similarity between humans and chimpanzees, the orangutan evidence is congruent with the fact that the earliest accepted hominid fossils not only look more like orangutans than African apes, they also include several features that are otherwise unique to orangutans and their close fossil relatives.

The contradiction between the molecular and structural (anatomical, reproductive, physiological, behavioral) evidence for human origins represents one of the most controversial and profound challenges of modern biology. At the very least, the orangutan evidence raises critical questions over the validity of commonly accepted assumptions about molecular similarity and evolutionary relationships, and whether molecular clocks can necessarily identify maximum divergence ages. And yet the orangutan theory of human origin has become one of the least recognized and debated issues in evolutionary biology today. There is an almost total silence on the subject within the scientific community. Such silence fails to apply the scientific method, according to which anomalous results demand further research and investigation. As long as this challenge to mediocrity remains unchallenged, the credibility of evolution as a science suffers. Here time is definitively of the essence.

Teleology

Teleology is a temporal concept of causality by which a current structure or process originates in order to serve a future purpose or goal. In this concept it is the future that determines the past and the present. Teleology was the predominant mode of reasoning to explain the natural world dating from the time of Aristotle, who saw life as showing a trend toward perfection, and even after Darwin, who provided a mechanistic view of biology in his book *On the Origin of Species.* The theory of evolution was supposed to end teleology as an explanation of origin in terms of meeting a future goal or purpose because evolution was seen to be an interaction between random mutation and the process of natural selection favoring differential survival of those individuals with variations that resulted in increased reproductive fitness. In Darwin's theory the mechanism of evolution was seen not as a process having a demonstrable relationship to the future but rather as a consequence of past events and current relationships between the organism and the environment. This outlook does not preclude a philosophical or religious perspective that treats evolution as a teleological process, but such perspectives are not derived from scientific observations that are not informative about whether or not evolution, or the universe, has a purpose.

Evolutionary explanations based on teleological language continue to abound in modern biology in publications ranging from professional research to popular media. This teleological language explains the origin of a particular structure, behavior, or other adaptation as having occurred "in order to" serve its current function—where *function* refers to the contribution a structure gives to the survival of an organism or a species. This function cannot empirically exist without the structure that makes the function possible, and yet the origin of the structure is attributed to that future function. In this context, evolutionary theory uses teleology to explain the origin of biological structure (whether anatomical, physiological, or behavioral) as meeting the requirements of future functions that confer increased survival on the species.

The prominent American Darwinian evolutionist Ernst Mayr claimed that there is now complete consensus among biologists that teleological statements do not imply any conflict with physical or chemical actuality, and the problem of teleology is reduced to the distinction between which teleological statements are legitimate and which are not. It may be argued that teleological language may not require a teleological meaning if it does not endorse unverifiable theological or metaphysical doctrines, attribute physical and chemical properties to biology that are not also applicable to inanimate objects, accept future goals as the cause of current events, or apply human qualities such as intent, purpose, planning, or deliberation to organic structures. Because biological systems behave as if they were teleological (e.g., the maintenance of homeostasis by physiological processes of the cell), teleological language may be unavoidable. It may also be argued that evolutionary biologists are irreducibly involved with teleology because they are in the practice of trying to understand the world with reference to the future when addressing the evolutionary significance of biological structures in terms of their functions.

The principal teleological expression in modern evolutionary biology is the explanation of a structure in terms of its function. This expression is usually in the form of a structure evolving in order to serve or achieve a particular function. For example, feathers evolved as an adaptation for flight. But when it became evident that feathers preceded flight, feathers were understood as an adaptation for some other preexisting function that was later co-opted into a new function. This resulted in evolutionists trying to guess whether an adaptation existed for the existing function or an imagined preexisting function, or whether there is ever any function in the original appearance of the structure or during its subsequent evolution. Evolutionary history becomes a field of imagination where any manner of functions may be invented and somehow explain the origin of the structure, even though such temporal and goal-directed explanations say nothing about the nature of the structure itself.

In preevolutionary biology, natural theology provided a supernatural explanation for teleology. Darwin's argument for natural selection suggested that evolution was a mechanical or physical process that is not organized to meet future goals or purposes. Many early evolutionists, however, continued to view evolution as a teleological process such as the *scala naturae* or "chain of being" where a steady advance was seen to occur through a supernatural force or internal drive toward perfection. This teleological philosophy was also applied to non-Darwinian alternatives to natural selection such as *orthogenesis,* a term used in 1893 by the German evolutionist William Hacke, who recognized that there were evolutionary sequences in complexity in which reversals either did not occur or were rare. As an example, a penguin may become a marine animal, but it remains a bird and does not become a fish. Hacke argued that if any kind of variation could occur, such reversals should be frequent due to those variations being advantageous as some stage. That this was not the case suggested that evolutionary changes may take place that did not owe their origin to environmental selection.

The orthogenetic theory recognized that evolutionary changes were limited to those that were made possible by existing biological structures. This view was supported by a minority of early evolutionary biologists, and it was most explicitly developed and supported as an alternative to Darwinism in the panbiogeographic synthesis of Léon Croizat. In the absence of a biological mechanism for explaining how new mutations may not be random, orthogenesis was characterized by Darwinian evolutionists as mystical and teleological. The teleological restriction for orthogenesis was also seen to be evident in examples from the fossil record that were supposed to demonstrate a linear direction to evolution, with the reduction of toes in horses from the ancestral five to the current single toe as the classic example. This linear concept was contrasted to phylogenetic evidence that evolution was not linear but rather involved a process of diversification or branching. Falsification of linear evolution was consequently a falsification of orthogenesis. This rejection mistakenly conflated two distinct concepts: that of linear evolution and that of orthogenesis. In his original formulation of orthogenesis, Hacke cited the reduction of horse toes from five to one as an illustration of a biologically driven trend, but he did not confine the process to that of a linear or purposeful evolution. Whether or not the historical sequence of horse evolution was "linear" or a branching "bush," there was a reduction of toes that took place over space and time resulting in the single-toed horse of today. Croizat resolved the apparent contradiction between diversification through speciation and the apparent linear sequence implied by orthogenetic sequences by proposing a vicariant form-making model by which characters are heterogeneously distributed over a widespread ancestral range and these geographic variations provide spatially different starting points for subsequent differentiation and speciation. In recent decades new molecular genetic discoveries have also drawn attention to patterns of "concerted evolution" and biological mechanisms of molecular drive, such as biased gene conversion, that result in evolutionary novelty without requiring improved reproductive fitness as a necessary result.

It may be argued that resorting to teleological explanations for the origin of structures in terms of their future function obfuscates the evolutionary process by avoiding the need for causal explanation and a deeper understanding of biological structure. For example, the teleological explanation for the evolution of the leaf as an adaptation for photosynthesis, or the evolution of a feather as an adaptation to flight or insulation, provides no information about the evolutionary origin and structure of the organs themselves. Adaptive, teleological explanations contain no greater information content than purely teleological creationist explanations.

As an empirical science, evolutionary theory can only be neutral about whether or not there is an underlying teleology in the universe and its evolution. Such possibilities are broached from theological or philosophical perspectives but not from science. Teleology remains the most troubling presence of nonscientific thought in modern evolutionary biology that obscures any distinction between a supposedly empirical science of evolution and teleological theories of existence such as intelligent design.

John R. Grehan

See also Dinosaurs; DNA; Evidence of Human Evolution, Interpreting; Evolution, Organic; Extinction and Evolution; Extinctions, Mass; Fossils, Living; Hominid-Pongid Split; Life, Origin of; Piltdown Man Hoax; Saltationism and Gradualism; Teleology

Further Readings

Craw, R. C., Grehan, J. R., & Heads, M. J. (1999). *Panbiogeography: Tracking the history of life.* New York: Oxford University Press.

Croizat, L. (1964). *Space, time, form: The biological synthesis.* Caracas, Venezuela: Author.

Donovan, S. K. (1989). *Mass extinctions: Processes and evidence.* New York: Columbia University Press.

Eldredge, N. (1985). *Time frames: The rethinking of Darwinian evolution and the theory of punctuated equilibria.* New York: Simon & Schuster.

Erwin, D. H. (2006). *Extinction: How life on earth nearly ended 250 million years ago.* Princeton, NJ: Princeton University Press.

Hazen, R. M. (2005). *Genesis: The scientific quest for life's origin.* Washington, DC: Joseph Henry Press.

Margulis, L. (1998). *Symbiotic planet: A new look at evolution.* New York: Basic Books.

Mayr, E. (1988). *Toward a new philosophy of biology.* Cambridge, MA: Harvard University Press/Belknap Press.

Schopf, J. W., & Klein, C. (1992). *The proterozoic biosphere.* Cambridge, UK: Cambridge University Press.

Schwartz, J. H. (1999). *Sudden origins: Fossils, genes, and the emergence of species.* New York: Wiley.

Schwartz, J. H. (2005). *The red ape: Orangutans and human origins.* New York: Basic Books.

Schwartz, J. H., & Tattersall I. (2005). Craniodental morphology of *Australopithecus, Paranthropus,* and *Orrorin.* In J. H. Schwartz & I. Tattersall (Eds.), *The human fossil record* (Vol. 3). New York: Wiley-Liss.

Tattersall, I., & Schwartz, J. H. (2000). *Extinct humans.* Boulder, CO: Westview.

Valentine, J. W. (2004). *On the origin of phyla.* Chicago: University of Chicago Press.

Villarreal, L. P. (2005). *Viruses and the evolution of life.* Washington, DC: ASM Press.

Evolution, Organic

The notion of Darwinian evolution of forms and entities, according to which all organic species descend from a common ancestor through various processes, among which natural selection is the most crucial, forms the framework of current biological investigations. Although biology has undergone deep transformations and conceptual shifts since 1859, the initial formulation of this modern idea of evolution is due to Charles Darwin's *On the Origin of Species.* Darwin promoted a new interpretation of major biological concepts (e.g., adaptation or function) and raised new problems for researchers. The notion of biological evolution entails important consequences regarding the idea of time, especially concerning the time of biological processes and forms, as well as the use of temporal processes in biological explanations.

The first section of this entry sketches the historical context of the rise of evolutionism. The second section explains the major concepts of biological evolution, according to the contemporary version of Darwinism. The third section then focuses on some major controversies that recurrently appeared in the history of evolutionary biology, concerning the process and the pattern of evolution.

History of the Idea of Organic Evolution

The idea of an evolution of species traces back far prior to Darwin. However, Darwin is credited as the father of modern evolutionism because he argued not only for a pattern of descent between species—the *tree of life*—but for a process likely to explain this pattern—*natural selection.* Among prior tenets of what was called transformism, some 18th-century writers (e.g., Jean-Baptiste René Robinet, Benoit de Maillet, and Jean-Baptiste de Lamarck) held versions of evolutionism that explained evolution, yet through rather implausible mechanisms.

Several problems met by naturalists were reasonably stimulating biologists to conceive of a general evolution of species. First of all, whereas big differences among species are obvious, it is not so clear sometimes whether two individuals are of distinct species or of distinct varieties of one species. Therefore lots of classes held to be distinct species, hence distinctively created by God, might turn out to be varieties of one single species. A mechanism would then account for the differences among them. Carolus Linnaeus, author of the most general system of classifying species and proponent of the idea that species were distinctively created by God (fixism), yet faced in this way the problem of hybrids. His contemporary and rival George Buffon defined a concept of species in terms of the ability to interbreed and have fertile offspring, a concept that fared better than a purely morphological concept of species like that of Linnaeus but that was not generally applicable. Moreover, as Immanuel Kant famously explained in the *Critique of Judgment,* naturalists until the 19th century noticed more and more frequently that the types of various species are often quite similar to one another, as if, for example, all the vertebrates were variations on a same theme—what Johann Wolfgang von Goethe called "original type." Étienne Geoffroy Saint-Hilaire in 1820 claimed that whereas the two major orders, vertebrates and arthropods (such as crustaceans), seem absolutely separate (an idea held by his rival Cuvier), they were actually variants of a same type, the arthropod living inside its spine and the vertebrate outside of it. Therefore, several thinkers, particularly from the school of *Naturphilosophie* in 19th-century Germany, conceived of a general evolution of species from the simplest to the most complex forms—though often a logical evolution of forms rather than a historical process—as an explanation of this pattern of similarity.

Religion has obviously been an obstacle to the acceptance of evolution. The Church claimed officially that the earth was only 6,000 years old, which makes a process of transformation of species inconceivable, because at the scale of human civilization no one had witnessed any such change. But this difficulty, which was still precluding Buffon from accepting explicitly the evolution of species (even if he would accept the transformation of varieties) slowly vanished during the 19th century, because, among other reasons, of the discoveries of fossils of unknown animals and of the advancement of geological theories of Earth. Charles Lyell, who was Darwin's friend, wrote *Principles of Geology* (1830–1833), which claimed that Earth could have been shaped several million years ago.

For those reasons, a general audience became more familiar with the ideas of evolution. Just before Darwin, Robert Chambers wrote *Vestiges of the Creation,* a widely read book that sketched a picture of the evolution of organic forms without providing a scientific theory to support it. At the time, philosophers such as Herbert Spencer elaborated general theories of evolution, which in general relied on a formal scheme of complexification. Before him, Lamarckism, the most accomplished transformist theory before Darwin, appealed to two forces: complexification (which explains why, in the same genus, simple forms are likely to give rise to more complex forms) and adaptation to circumstances through inheritance of acquired characters (the latter is generally the version people think of when they refer to Lamarckism).

Evolution by natural selection is one example of simultaneous discovery in the history of science: Darwin, after a long journey on the HMS *Beagle,* came to this idea through reflections on the geographical distribution of species, on morphology, and on domestication, while at the same time naturalist Alfred Wallace had the same idea. This anecdote indicates that in the 1850s the time was ripe for evolutionary theories. Darwin and Wallace presented their results in 1858 in a joint meeting that anticipated the publication of *On the Origin of Species,* which Darwin wrote over several years and published in 1859, before revising it extensively in five successive editions. The book is "one very long argument," and whereas most chapters use arguments from various fields such as embryology, morphology, biogeography, or paleontology to support the idea of evolution by natural selection, several other chapters are devoted to a rebuttal of objections that Darwin foresaw, such as the lack of intermediary forms in the fossil record, complex organs like eyes, and the evolution of instincts.

In general, however, many biologists were convinced by Darwin's demonstration of an evolution of species. The general audience was more reluctant because of religious reasons. However, the fate of Darwinism is more concerned with the reactions to the process hypothesized by Darwin to account for evolution, that is, natural selection. Darwin was indeed pluralist regarding the processes generating evolution; for example, he accepted Lamarckian inheritance of acquired characteristics. The major question then was the relative impact of those several processes on evolution, and this is perhaps the main issue that biologists who followed Darwin have had to address.

What we call Darwinism might have been born when German biologist August Weissmann, working on heredity, conceived of a separation between somatic cells and germinal cells, that is, the characteristics of an individual (and likely to change) and the characteristics that the individual inherited from his or her parents and passed to his or her offspring. This prevents any inheritance of acquired characters and leaves natural selection as the most plausible general mechanism of evolution.

The history of Darwinism in the 20th century means first the modern synthesis, followed by neo-Darwinism in the 1930s. Briefly stated, natural selection, according to Darwin, sorts individuals that vary and have various offspring. The process of selection will occur no matter how the variation is caused, so Darwin's theory was neutral regarding an explanation of hereditary variation (i.e., why all offspring of a couple of zebras are alike, as zebras, and different, as differing to some extent from their parents). But in the 1900s, Mendelian genetics came into play. At first sight, genetics and Darwinism seem at odds, because Darwin was talking of evolution through selection of small differences, whereas genetics treats combinations of discrete characteristics, which seems nongradual. Hence, a controversy opposed Darwinians and Mendelians until the 1920s. Then, Ronald Fisher, Sewall Wright, and J. B. S. Haldane showed that by devising probabilistic models of the evolution of genetic frequencies in populations (a field called population genetics), far from opposing Darwinism, Mendelian heredity is an explanation of heritable variation that makes natural selection necessary and powerful. Mutation of genes and recombination during meiosis and fecundation (in the case of sexual reproduction) provide the variation upon which selection operates. This synthesis between Mendelism and Darwinism is the origin of today's biology. Later, such synthesis was extended to systematics (with Ernst Mayr) and paleontology (with George Simpson). However, the preeminence of population genetics in the modern account of the processes of evolution entailed that evolution is now conceived of as the "change of gene frequencies in a population," whereas the first Darwinians were thinking more loosely, in terms of change of organic forms.

Concepts in Darwinian Evolution

The Concept of Natural Selection

Darwin thought of natural selection as the result of the "struggle for life": Because resources generally are rare in an environment and because the rate of increase of a population generally exceeds the availability of resources (an idea that he famously took from Thomas Malthus's *Essay on the Principle of Population,* 1798), it follows that only the individuals who are better equipped to obtain resources will survive and reproduce, being then likely to pass those abilities to their offspring. The frequency of those traits supporting those abilities increases, and this continued process explains a general change in the species, which finally leads to a novel species (some individuals being so different from the initial ones, or so distant, that they could no longer interbreed with them). More concretely, this competition (mostly between members of the same species) consists in procuring food, escaping predators, and finding sexual partners.

A more abstract formulation of natural selection, less tied to this biological case, can be given. Following Richard Lewontin, any population of individuals satisfying three conditions will undergo natural selection: Those individuals vary regarding some traits (*variation*); they have offspring that vary from them and from one another, in a way that the variation between offspring and the mean of the population positively correlates with the variation between their parents and the mean of the population (*heritability*); and those properties according to which they vary are relevant to the expectation of their having some number of offspring. (If several organisms replicate and vary, but the properties transmitted have no consequences upon their probability of reproduction, there will be no selection at all.) This third property can be called *fitness*. Whereas still intuitive for Darwin when he talked about "survival of the fittest" (following Spencer, and wanting to reject any intentional connotation of the word *selection*), *fitness* is now a technical term that means both survival and expectancy of offspring. Defining the fitness of a trait implies assuming that this trait somehow correlates with the offspring expectancy (Fig. 1).

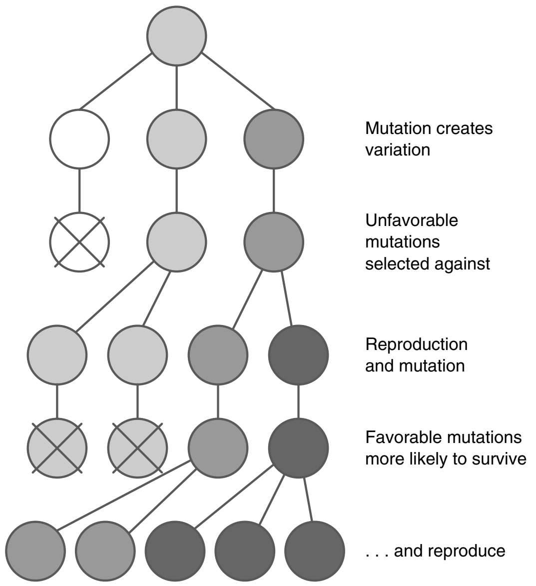


Figure 1 Diagram of a selection process in neo-Darwinism

What the selected individuals really are is not relevant in this formulation. Hence there logically can be selection of organisms, which was what Darwin thought, but also of groups, of species, and, at a lower level, of genes. One of the most debated questions in the philosophy of biology, indeed, is the "units of selection" controversy, namely, the question of what, among those kinds of things, are the ones by which selection takes place. In *Adaptation and Natural Selection* (1966), George Williams argued that selection apparently acting on groups—for example, altruistic behaviors that seem to increase the well-being of the group while threatening the organisms that achieve them—can in fact be explained in terms of selection acting on individuals (organisms or genes). Kin selection, according to William Hamilton, is a selection acting on one gene carried by several individuals: Selection will retain an organism that acts against its "interests" if the consequences can favor one of its kin. On this basis, Richard Dawkins has argued that natural selection indeed acts upon genes rather than organisms. Genes do "replicate"—they are "replicators," in Dawkins's language—but the rate at which genes successfully replicate depends upon the interactions among organisms in terms of reproduction. Philosopher David Hull suggested another formulation of selection: Natural selection is the process according to which replicators differentially reproduce due to the interactions of entities named interactors (in the usual case of biology, it is the organisms). This formulation suggests that natural selection can occur among various objects to the extent that they replicate; for example, Dawkins writes of cultural selection, because cultural entities also seem to replicate.

Explaining Through Natural Selection

The *diversity* of species (in time and in space; e.g., why there are kangaroos in Australia but not in South America) and the *adaptation* of organisms to their environments are explained through Darwinian evolution. First, the taxonomy of species receives a historical interpretation. The only diagram in *On the Origin of Species* (Fig. 2) represents a pattern of branching between species, or genera, or any biological taxa. All the taxonomic relations (being part of the same genus, etc.) were reinterpreted by Darwin in terms of history: The closer two species are in a morphological taxonomy, the closer they are in the temporal sequence of evolution.

The traditional explanation for adaptation referred to the Divine Will or a Providence that would account for the fit between organisms and their environment—for example, the beak of certain species of finches that fits to the depth of the holes within which they chase insects. The Darwinian explanation of adaptation is natural selection: Such a process obviously led to the fit of the beaks with the holes, and in the same time, to the divergence of the Galapagos finches into several species, all being specialized in one kind of hole and characterized by one length of beak. This Darwinian example illustrates how natural selection accounts for both diversification and adaptation of species.

Natural selection provides also a way to escape the suspicion of teleology that constantly assaulted biology. Modern natural sciences exclude explanations in terms of intentions or goals, because by

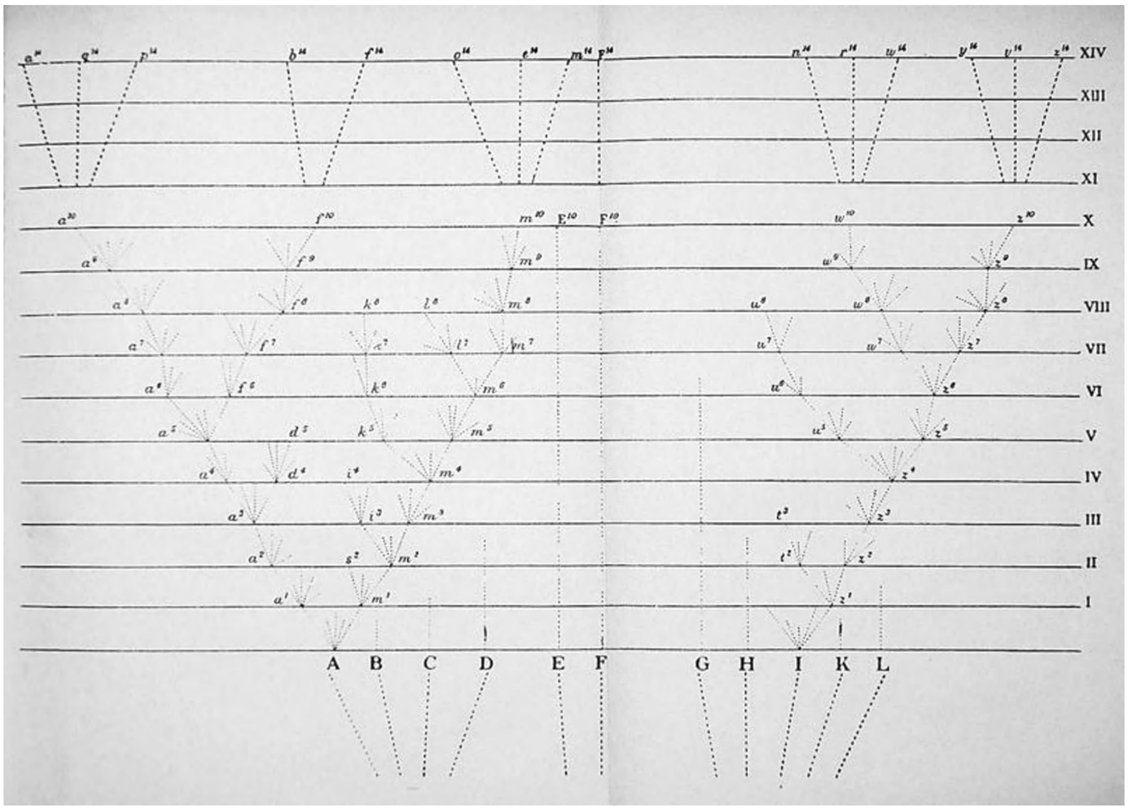


Figure 2 Darwin's diagram of branching evolution

principle nature has no desires. However, talking of *functions* of organic parts means that those parts are here *in order to* do such and such: Such a proposition seems teleological. Although not really embarrassing for biologists, this problem puzzled philosophers of science—especially when funding science for research on concepts in theology was no longer admitted. Kant devoted half of the *Critique of Judgment* to the problem of legitimizing teleological judgments in life sciences without appealing to a Creator. Yet in the Darwinian framework, functional statements do not object to naturalism: philosophers Larry Wright and Ruth Millikan suggested interpreting "the function of X is Z" as "X has been selected because it was doing Z," which does not appeal to any transcendent intention. Natural selection might legitimate the functional talk traditional in biology.

Proximate and Ultimate Causes

The emergence of evolutionism entailed a whole transformation of biology. During the rise of molecular biology, after James Watson and Francis Crick's discovery in 1953 of DNA as the substance of genes, Mayr reflected upon the synthesis to which he contributed. He argued that causal explanations in biology can take two forms: proximate and ultimate. Proximate causes are the processes and events that cause a feature in the life of organisms; for example, the "genetic program" of a certain bird accounts for its migrating behavior, and the physiology of its muscles accounts for the way it flies. Molecular biology, physiology, biochemistry, and embryology unveil proximate causes and constitute what is called functional biology. Evolutionary biology aims at accounting for why the organism is likely to be the way it is; it searches for the evolutionary history that led to the genetic program embodied by the migrating bird. Those ultimate causes extend far prior to the existence of the organisms or species considered. Paleontology, behavioral ecology, ecology, systematics, and population genetics constitute the main disciplines of this evolutionary biology. Mayr added that whereas proximate causes amount to explanations of the same kind as those usually found in physics and chemistry, ultimate causes require another kind of explanation, as they rely mostly on natural selection and have to integrate knowledge of history as a background condition. This of course makes evolutionary biology the core of biology, upon which relies the specificity of biology regarding other natural sciences. This implies that biology has an irreducible historical dimension, contrasting with natural sciences that search for unhistorical laws or correlations, striving only for what philosophers, following Ernst Nagel, call "nomothetic explanations." Moreover, most of the conditions of evolution are themselves products of evolution (e.g., the process of fair meiosis assumed by all the Mendelian rules). The science of organic evolution therefore required that scientific explanation consist also in depicting contingent temporal processes.

Form and Function

In 1916, historian Edward Stuart Russell published *Form and Function,* in which the history of biology is depicted as a fight between two general approaches to living phenomena: a focus on *function* versus a focus on *form*. Those features—forms and functions—are obviously both proper and exclusive to living beings (brute matter does not display transmitted forms). Russell saw the famous debate that opposed Cuvier and Geoffroy Saint-Hilaire at the natural history museum in Paris in 1830 as one major episode in this long-standing debate. Geoffroy, arguing in favor of one general type of organisms realized in all orders, was a tenet of form biology, whereas Cuvier was interested primarily in functions and proposed the principle of "conditions of existence," according to which all functions in an organism must be feasible and compatible. For this reason, because one could not change one function without altering the whole and then making the organism unable to fulfill the principle of conditions of existence, Cuvier opposed Lamarck's gradual transformism. On the other hand, for Geoffroy the general types are fine-tuned only by local adaptations, but their main morphological rules are something universal in the living realm, hence not connected to specificities of the various environments within which various species came to life: For this reason, adaptation cannot account for those rules. The spine, for example, pervasive across all order of organisms, exemplifies such a formal feature.

In *On the Origin of Species,* Darwin considers this debate from the viewpoint of evolution by natural selection. He admits that there are two general principles of biology: conditions of existence (Cuvier) and unity of types (Geoffroy Saint-Hilaire). He inquires into their connection, namely, whether functions of organisms, shaped by natural selection, are the main factors accounting for the various features of the species or whether some general formal features, independent of the successive environments of organisms but historically transmitted, are the major constraints on the history of life. He answers that the principle of the conditions of existence redounds to natural selection, whereas unity of type specifies the stable persistence of organic forms. However, because those inherited forms are themselves constituted through evolution by natural selection, those types in the end rely on the action of natural selection and the unity of type gets subsumed under the conditions of existence principle. This means that Darwinian biology subordinates form biology to function biology.

Major Long-Standing Issues in Evolutionary Biology

Issues Relevant to the Process of Evolution

Even if selection is acknowledged as one of the main causes of evolution—Lamarckian evolution being excluded—other mechanisms have been conceived of by biologists. One classical formulation of the question of evolution in population genetics is analogous to mechanics, as argued by philosopher Elliott Sober in his 1984 work *The Nature of Selection*. Considering some varying traits in a population, geneticists first write the equations that would rule the change of gene frequencies in a pure Mendelian case with no selection, no mutation, and no migration—this is called the Hardy–Weinberg equilibrium. Then they compare it to the actual case. Any deviation from the expected equilibrium frequencies should have a cause, possibly natural selection. Yet, Sewall Wright in the 1930s showed that in small populations, a sampling error occurs that can lead to the fixation of some genes independently of their selective value. This “random drift” would disappear in infinite populations, but because real populations are always bounded, random drift surely matters in the actual evolution of gene frequencies.

Thus apportioning the causes of evolution, especially selection and drift, is a constant problem faced by population geneticists. Several important controversies in the course of evolutionary biology revolved around such issues. At the origin of the modern evolutionary synthesis, Ronald Fisher argued against Wright about the role of drift. If drift is important, as claimed Wright, then the mean fitness of populations is not always maximized, whereas Fisher opposed a mathematical formula he proved, the “fundamental theorem of natural selection,” meaning that the mean fitness necessarily increases until genetic variance is exhausted. Deciding this point implies an empirical knowledge of the size of natural populations. Later, the question involved an investigation of the reasons of genetic variability—polymorphisms—in populations. Biologists such as Theodosius Dobzhanski and Hermann Müller, among others, forged theories to account for this maintenance. Later, Motoo Kimura vindicated the so-called neutralist theory of evolution, claiming that most evolution at the level of nucleotides (the molecules composing the DNA) is neutral, due to drift, because most of the mutations of nucleotides are selectively neither advantageous nor deleterious. Although theoretically important, this theory does not truly oppose Darwinism because it is concerned only with the molecular level and leaves intact the idea that the evolution of genes themselves and of phenotypes is due to selection. However, the neutralist theory emphasized that evolution is a constant process occurring at many levels and according to various mechanisms.

It is often difficult to consider the evolution of one population of one species, because the ecological fates of several species are tied—each one defining selective pressure for the others. Cases of parasitism and of mutualism (e.g., between figs and wasps, ants and plants, humans and intestinal bacteria) belong to a general study of co-evolution, which accounts for innumerable features of the organic world.

Other important controversies arise when we turn our gaze from microevolution, which concerns rather short timescales and relatively unmodified environments, to macroevolution, or evolution at a higher level, concerning, for example, the appearance of new classes of organisms. It has been debated since the founding fathers of the modern synthesis whether macroevolution is microevolution at a larger scale or whether it requires novel principles. Simpson and Mayr defended the former position, because they thought that an appeal to novel principles (e.g., macromutations) would threaten Darwinism. Biologists such as Stephen Jay Gould, Niles Eldredge, Elisabeth Vrba, and Sean Rice consider natural selection of species, in which case the properties selected (e.g., the geographic range of a species; the genetic variability) are properties of the species itself, unlike the mechanisms accounting for microevolution, all of which have to do with traits of individuals.

But the main challenges concerning this question of macroevolution came recently from the evolutionary theory of development, or Evo-Devo. In microevolution, natural selection shaping adaptations for some functions is plausibly the main cause of evolution. This exemplifies the Darwinian bias in favor of function biology. However, in *The Changing Role of the Embryo in Evolutionary Biology* (2005), Ron Amundson argues that the adherents of form biology constantly opposed this Darwinian demonstration of the supremacy of function biology. Their challenge gets more consistent because they invoked some novel style of laws of forms that scientific investigation has been pinpointing for 3 decades. Briefly said, neo-Darwinians thought that mutation (and recombination) forms the material for natural selection. They separated two ideas traditionally joined: inheritance (i.e., transmission of characters from parents to offspring) and development (i.e., the ontogenetic process of an individual). Selection acts on traits, no matter the process through which the individual came to display those traits, so development seemed relatively external to evolution. Yet, some developmental theorists emphasized that development can both constrain and provide variations by changing the rhythm or order of the process, as Gould summarized in his classic 1977 work *Ontogeny and Phylogeny.* Evo-Devo researchers contend that the changes relevant to macroevolution, for example, key innovations like the wings of insects, or the thermoregulation system of mammals, involve the effect of developmental constraints and are not understandable solely as effects of natural selection acting on punctual mutations in the DNA. (But for them evolutionary theory is therefore more concerned with explaining across-taxa features, like the vertebrate limb, rather than change within taxa and thus adaptations.) This debate is obviously related to the set of problems posed by the understanding of the phylogenetic pattern in general.

Issues Relevant to the Pattern of Evolution

The tree of life raises three types of questions, all crucial to current evolutionary biology: the shape of evolution, its orientation, and finally its origins.

Gradualism and Discontinuities

For Darwin, evolution of the species was a gradual branching process. Neo-Darwinism emphasized gradualism, as variation would rely on small mutations. For this reason, neo-Darwinists have constantly been puzzled by discontinuous evolution, for example, key innovations. In the 1970s, paleontologists such as Gould and Eldredge challenged the general gradual view of phylogeny, arguing that changes in evolution display a discontinuous pattern: a fast (at the geological timescale) burst of novelty and a very long period of stasis, with only minor modifications possibly due to adaptation to local conditions. This theory of punctuated equilibria, albeit neutral regarding the mechanisms of evolution, fits with theories from Evo-Devo (held by Gould), which contrast very big changes relying on transformations in developmental processes with minor changes due to selection on point mutations. This issue rests mostly on the interpretation of the fossil record: Darwin claimed that its lack of transitional forms was due to geological reasons, whereas adherents of punctuated equilibria claim that the record is, as such, quite reliable and constitutes evidence for the stasis–burst schema of macroevolution. In this case, macroevolution would not be easily reducible to mechanisms of microevolution, and neo-Darwinism in general—since its core is population genetics—would have to be qualified. The emergence of the most general plans of organization (e.g., the one taking place in the Cambrian and explaining most of the extant phyla) is not accountable solely on the basis of micro-evolutionary principles.

In 1995, John Maynard Smith and Eors Szathmary initiated a theory of the major evolutionary transitions. Those are the fundamental events in evolution, through which the forms of inheritance and replication changed. Replicating macromolecules, single cells, multicellular organisms, social organisms, and organisms with language are the steps of this evolution. Each time, natural selection both contributes to the transition and becomes changed through it, because new selectable entities arise. In this perspective, evolution by natural selection is not absolutely tied to genes or life, and extends from molecule to talking beings. Such a globalized theory casts a new light on the problems of discontinuity in the mere history of life. Cooperation between entities (e.g., genes in chromosomes or insects in colonies) is a pervasive pattern of explanation of those transitions and requires understanding how natural selection could favor cooperative behaviors while selfish defection would be at first sight selected for.

Direction

A common view of evolution sees it as oriented toward greater perfection and achievement. Yet this is precluded by the very logic of Darwinism, for which natural selection optimizes populations regarding their environments—hence, two organisms of two different species, belonging to different environments, cannot be compared or considered as stages of a continuous improvement. At the same time, it is difficult not to notice in a given branch of the tree of life (e.g., the vertebrates or the mollusks) trends of increasing complexity: diversification of functions, finessing of detecting devices, increase of some quantities related to the size of genes, and so forth. Darwin was ambiguous regarding this issue: Although he opposed the notion of absolute perfection, he was led by common intuitions about progress in evolution. The major conceptual issue, however, is still to figure out a concept of complexity likely to capture those contrasted intuitions. Biologist Dan McShea has shown in recent papers that a "complexity" thought in pure formal terms (diversity of parts with no functional considerations) makes visible some phylogenic trends in increasing complexity. This notion is yet far from the intuitive one, and it seems, then, that no theory could decipher in the history of life this constant progress culminating in human species.

Origin

Evolution by natural selection commits one to say, like Darwin, that all forms of life came from one single organism (a position that irritated the defenders of religious orthodoxy). The fact that all species share elements of the same genetic code provides more evidence of this single evolutionary history. From a Darwinian viewpoint, the issue is the genesis of an entity satisfying the conditions of natural selection. This problem involves both chemists and paleontologists—people seeking traces of what happened and people conceiving processes that could have happened. Within evolutionism, questions of origin are crucial: origin of sexual reproduction (why humans pass on only 50% of their genes to the next generation, whereas organisms that reproduce asexually pass on 100%), origin of mind and of culture. Whereas no theory is completely satisfying, natural selection clearly plays a fundamental role in those events.

Philippe Huneman

See also *Archaeopteryx;* Coelacanths; Darwin, Charles; Dinosaurs; DNA; Evolution, Cultural; Extinction; Extinction and Evolution; Extinctions, Mass; Fossil Record; Fossils, Interpretations of; Fossils, Living; Ginkgo Trees; Haeckel, Ernst; Huxley, Thomas Henry; Life, Origin of; Paleontology; Progress; Saltationism and Gradualism; Trilobites

Further Readings

Arthur, W. (1997). *The origin of animal body plans: A study in evolutionary developmental biology.* Cambridge, UK: Cambridge University Press.

Brandon, R. (1996). *Adaptation and environment.* Cambridge: MIT Press.

Dawkins, R. (1982). *The extended phenotype.* Oxford, UK: Oxford University Press.

Eldredge, N. (1985). *Unfinished synthesis: Biological hierarchies and modern evolutionary thought.* Oxford, UK: Oxford University Press.

Gayon, J. (1998). *Darwinism's struggle for survival.* Cambridge, UK: Cambridge University Press.

Gould, S. J. (1980). *The panda's thumb.* London: Penguin.

Hodges, J., & Radick, G. (Eds.). (2003). *The Cambridge companion to Darwin.* Cambridge, UK: Cambridge University Press.

Kimura, M. (1983). *The neutral theory of molecular evolution.* Cambridge, UK: Cambridge University Press.

Lewontin, R. (1974). *The genetic bases of evolutionary change.* New York: Columbia University Press.

Maynard Smith, J., & Szathmary, E. (1995). *The major transitions in evolution.* Oxford, UK: Oxford University Press.
Mayr, E. (1961). Cause and effect in biology. *Science, 134,* 1501–1506.
Mayr, E., & Provine, W. (1980). *The evolutionary synthesis. Perspectives on the unification of biology.* Cambridge, MA: Harvard University Press.
Michod, R., & Levin, B. (Eds.). (1987). *The evolution of sex. An examination of current ideas.* Sunderland, MA: Sinauer Press.
Michod, R. (1999). *Darwinian dynamics.* Oxford, UK: Oxford University Press.
Odlin-Smee, J., Laland, K., & Feldman, M. (2003). *Niche-construction: The neglected process in evolution.* Princeton, NJ: Princeton University Press.
Richards, R. (1992). *The meaning of evolution.* Chicago: University of Chicago Press.
Sloan, P. (2005). Evolution. *Stanford encyclopedia of philosophy.* Retrieved August 18, 2008, from http://plato.stanford.edu/entries/evolution
Sober, E. (1984). *The nature of selection.* Cambridge: MIT Press.
Williams, G. C. (1992). *Natural selection: Domains, levels and challenges.* Oxford, UK: Oxford University Press.

Evolution, Social

Social evolution is regarded as a particular form of general evolutionary process that occurred in communities of the genus *Homo* (or, more narrowly, in communities of anatomically modern humans). It implies changes over time of different forms of relationships among human beings (individuals and their group) that are inwardly connected and interdependent and have given rise to new social forms and connections.

Chronologically, the concept of social evolution applies to the process of origin and change in social organizations and social complexity, which is associated with structural changes in human society. It is difficult, however, to distinguish properly the social form of evolution from political, cultural, and other forms of nonbiological evolutionary processes, just as it is practically impossible to distinguish between social evolution and social development.

Social Evolution in 19th- and Early 20th-Century Anthropological Thought

Early ideas about social evolution were expressed in the works of ancient Greek philosophers such as Democritus and Aristotle; such ideas were disseminated more widely in the early medieval period on the basis of Saint Augustine of Hippo's Christian concept of sacral history. The Enlightenment brought new insight into social evolution, with multidimensional analyses of social changes framed in terms of the natural evolution of the world. In such a context, social evolution was identified with progress, which was understood as the gradual perfection of society, realized on the basis of humankind's spiritual emancipation. In the modern era, social evolution has been interpreted by Georg Wilhelm Friedrich Hegel, Karl Marx, and followers as a process determined by its primordial essence. The closest analogy to such an understanding of society's changes in time may be found in the life of a plant, which grows from a particular seed. Sometimes it takes a final form implying the preexistence of a certain final stage of evolution (as in different forms of utopias). Nevertheless, in terms of a teleological understanding of social evolution, the problem of the origin of new forms of social life remained unattended.

The tendency to conceptualize human history in a framework of gradual development that implies improvement of an already existing substance or the origin of new ones has occupied the attention of scientists and the public since the 1870s when Charles Darwin's *On the Origin of Species* was published. The concept of social evolution as directional and irreversible linear change became an integral part of the scientific discussions of that time, and it is not surprising that in seeking to explain its driving forces, anthropologists refer to mechanisms in biology.

The earliest application of evolutionary ideas to the study of human society, and the origin of the organic school in sociology, is traditionally ascribed to the work of Herbert Spencer, who managed to synthesize the embryology of Karl Ernst Ritter von Baer, the geological theories of Charles Lyell, the physical law of conservation of energy, and the ideas of Charles Darwin. According to Spencer, social evolution is a permanent redistribution of elements in their movements toward integration and disintegration, thereby creating some kind of equilibrium. Social dynamics was understood by Spencer as the progressive transition of a society from homogeneity to heterogeneity, or its differentiation. He distinguished four evolutionary types of human society (simple, compound, doubly compound, and trebly compound), which could range from politically nondifferentiated (egalitarian) primitive societies to complex civilizations. Survival of the most adapted industrial societies based on positive knowledge he considered the basic law of social development. Spencer's views created a background for social Darwinism, an ideological trend in social thought, widespread at the turn of the 20th century, that advocated for a reform of human social development according to laws of biological evolution. Competition, natural selection, the struggle for existence, and survival of the most adaptive individuals were recognized by social Darwinists as the basic determinants of social life.

Nevertheless, most early evolutionists did not share the view that different stereotypes of social behavior reflect different stages of historical development, and in frames of their peculiar field of study tried to illustrate social progress with the help of pertinent cultural phenomena. McLennan, Maine, Robertson Smith, and others studying common law, marriage, and kinship systems helped to promote the Stadialist hypothesis about social development by stages. In their understanding, these stages are universal, and the diversity of social institutions is the outcome of specific contingencies in the life history of certain groups.

For the first time, such ideas were shaped into strict schemes of human history periodization by Lewis Henry Morgan in his *Ancient Society* (1877). According to Morgan, human history could be subdivided into two global phases: The first one—*societas*—was characterized by social organization based on kinship, fraternity, and tribes and demonstrates egalitarianism, whereas the second—*civitas*—was represented by political organization based on different attitudes of humans to territory and property and was characterized by social and economic inequalities.

A different approach to social evolution was elaborated at the end of 19th century by Karl Marx and Friedrich Engels, whose basic point was the concept of the evolution of modes of production, understood as a concatenation of productive forces (often identified with technology) and relations that are practiced in the course of production (in most aspects determined by the ownership of productive forces). Against this background they distinguished four stages of societal development: primitive, slavery, feudal, and capitalist (*German Ideology,* 1847). Later, Engels, in his *Origin of Family, Private Property, and the State* (1884), based on detailed studies of Morgan's *Ancient Society,* worked out in detail the periodization of human history and interrogated the final period of prehistory (later called the "war democracy stage") when private property, classes, and the state arose. He demonstrated that the origin of the state, characterized by such traits as authorities estranged from the wider public, the taxation system, and so on, is the result of society's internal subdivision into classes.

Under the influence of Marx and Engels, the "stadialistic" scheme of social evolution, based on economic determinism, became widespread in Soviet academic life. During the period 1929 to 1934 on the basis of Engels's work, a general understanding of historical process as the dialectic replacement of one form of economy by another, more progressive one resulted in the elaboration of a five-component scheme of social and economic structures (Marx's four plus communism, grounded by Vladimir Ilich Lenin), which was proclaimed the only officially approved explanation of social evolution.

A gradual decrease in the popularity and reliability of evolutionism as the universal foundation of cognitive and interpretative methodology, and a tendency after World War II to replace it by functional and structural analysis and by historical, geographic, psychological, and sociological comparativistics, have led to a partial revision and shaping of neo-evolutionism as a self-sufficient methodological approach. Its proponents (V. Gordon Childe, Leslie A. White, Julian Steward, Marshal Sahlins, and others) had serious doubts about the possibility of global unilinear progress in culture and technology, arguing for plurality of historical process and its driving forces.

Stages of Social Evolution: Neo-Evolutionistic Approach

The stadial scheme *band—tribe—chiefdom—state,* outlined in brief by Marshal Sahlins in

1960, worked out in detail by Elman Service in 1962–1971, and further elaborated by Joseph Marino, is in a sense a restitution of the unilinear evolutionary scheme. In proposed consequence every stage could be described by a set of social, economic, and political parameters that demonstrate correlations with a certain chronological span. At the same time, Service implied that new social and political forms are strictly functional ones, and their evolution fits new needs of evolving communities. In such a context, social complexity could be viewed as an adaptive response to challenges to human survival. In contrast to Steward's and Service's adaptationist understanding of social evolution, proponents of the so-called political approach to detection of the driving forces of leadership shaping argue that central power results from expanding domination and necessity to control rather than the management of the economy for the benefit of an elite. This view is connected with the further development of Marxist ideas and is reflected in the particular view of social complexity formation elaborated by Robert Carneiro.

Band societies, or the family level of social organization, traditionally exemplified by leaderless egalitarian communities of prehistoric and contemporary hunter-gatherers, represent the simplest level of social complexity. The only principle of community leader choice is his or her personal qualities and abilities (primitive form of so-called meritocracy principle); in the case of nonsufficient management, administration, or both, the leader could be replaced immediately. Recent studies indicate that the gender attribution of the leader is not a decisive factor in leader choice and function delineation. At the same time, some hunter-gatherers (e.g., Australian aborigines) practice a form of nonegalitarian community with a tendency to concentrate power in a close group of elders who are organized hierarchically.

Tribal (or segmentary) society stage, or "local group" form of social complexity, usually is ascribed to the community with signs of so-called prestigious economy, which implies the presence of surplus product based on hunter-gatherers as well as productive economy. These social structures are characterized mainly by high territoriality and fragmentariness insofar as their main units—villages—tend to be self-sufficient economically but at the same time tending toward political, social, and ritual agglomeration.

Chiefdom and its conceptualization is one of the most widely discussed issues in contemporary social and political anthropology. Usually it is defined as a social organism consisting of group of villages (communities) organized hierarchically and subordinated to the central, biggest among them, where the chief (ruler) is living. The functions of the chief include organization of the economy, including procurement and redistribution; regulation of judicial and mediatory processes; and supervision of the social unit's religious and cultural life. In exercising power the chief could rely on rudimentary bodies represented in all territorial segments of the chiefdom. According to R. Carneiro, chiefdom structure is the first experience of political hierarchy introduced into local communities' networks and entailing loss of autonomy. At the same time, the endogamous elite of society had no monopoly over the application of force in the case of weakening of their control over the group. Usually the supreme power is sacralized or even theocratized, and chiefdom as a whole is characterized by common ideology and rituals. A. Johnson and T. Earle distinguish between simple chiefdoms, which include perhaps a thousand people with modest social differentiation, and complex chiefdoms, which engage tens of thousands of hierarchically organized people. The earliest signs of chiefdoms in Europe usually are traced back to the transition from Neolithic to Eneolithic period (about 5000 BCE) when primitive forms of town (protected settlements) spring up alongside ordinary settlements; origin of megalithic constructions, stratified burials, separation of special ceremonial places usually are connected with that time. During the Bronze Age these phenomena gradually became common for the whole ecumene.

The *state* phase of social complexity formation is characterized by internal differentiation by class, tightly connected with the origin of private property and exploitation; by high centralization maintained with the help of military, religious, and bureaucratic administration; and by the origin of ethnicity. Among other important traits of the state, record keeping, highly developed transportation and communication means, and the use of written language for civil and criminal law codification are usually mentioned. The most recent trend in the conceptualization of state origins is connected with the distinction of the so-called early state phase, characterized by nonstable relations and transferable status of classes, and by an ill-defined position of administration owing to a nonfixed legislation system, which is in the process of transition from common law to codified written form. Traditionally the earliest states are found in the Near Eastern zone (famous cities of Mesopotamia) and Ancient Egypt. Attribution of the ancient Greek *polis* to that phase remains disputable.

This stadial scheme, in spite of its imposing restrictions on the cultural and economic variability of human societies in time and space, had by the mid-20th century contributed greatly to the systematization of an impressive database collected by archaeologists and ethnographers. In the late 1980s it was brought into correspondence with a new database by A. Johnson and T. Earle and, since that time, has remained one of the most widespread in Western and former Soviet Union anthropology schemes dealing with issues of the origins of social complexity. Currently it is competing well in distinguishing among egalitarian, rank, and stratified society as the main evolutionary stages of social complexity evolution in prehistory, proposed in 1967 by M. H. Fried and based on the dynamics of social inequality.

Multilinear Social Evolution: Contemporary Theories and Hypotheses

Traditionally, the origin of the multilineal version of cultural evolution is associated with Steward, who in the context of rapid development of neoevolutionism in the mid-20th century had proposed the concept of *multilinear evolution,* with special emphasis on plurality of social development (*Theory of Culture Change,* 1955). An important cornerstone in this context also was proposed by Sahlins and his distinction between general and specific evolution (1960), which opened wider perspectives for a pluralistic interpretation of the global history of humankind and human culture.

Nevertheless, the roots of multilineal understanding of social evolution could be traced back to 1857–1861, when Marx distinguished three social and economic forms preceding capitalism—Asian, Antique, German—each of which could be interpreted as independent versions of the transition to state organization. Later, Engels (1878) suggested two forms of state origin (Eastern and Antique). Engels understood pluralistically not only lines of evolution but also the background of the process itself. Engels's "enigma" is widely discussed in the context of neo-Marxism, along with the well-known private property–based class theory of state origin, explained in detail in *Origin of Family, State and Private Property* (1884). In other works (e.g., *Anti-Dühring,* 1876–1877), Engels used a functional version of the explanation of state formation consonant with that of Marx.

These multilineal ideas, maintained since the very beginning by representatives of so-called intellectual Marxism (e.g., K. Vittfogel, N. Plekhanov), were later creatively developed by representatives of Soviet science and Western neoevolutionism. In this context, Soviet science emphasis was shifted toward detection of differences between "eastern" (or state property–based) and "western" (or private property–based) lines of social development (Yu. Pavlenko, G. Kiselev, K. Morrison, A. Southall).

Some researchers interpret Asian and Antique lines of state formation as dead-end versions of social development, with the Antique going no farther than a slave-owning system; only the German line managed to give birth to a feudal economy and, later, the capitalist society of the modern era. The final third of 20th century brought to light a "Slavonic" line of state formation and further social development connected with impetuous administration and bureaucracy development and a "nomadic" version of social, political, and cultural evolution characterized not only by unique forms of economy and livelihood but also by a relatively high level of aggression.

In the 1970s, a shift toward environmentalism in anthropological thought brought into researchers' view the ecological situation, which could stimulate or impede social transformations. This idea, based mainly on Steward's assumption about the adaptive abilities of economic systems, was later developed in a series of models that included such variables as climatic risk and resource base diversity. Certain fundamental ideas were proposed by Marvin Harris (1977, 1979), who believed that social evolution is provoked by an inherent human tendency to suffer eventual depletions in living standards that, in their turn, result from population pressure and environmental degradation.

The subject of social evolution remained a focus during the entire 20th century. In contrast to most of the aforementioned theories of social evolution, Max Weber suggested that the subject could not be identified with society itself—rather, it is a mere abstraction, arising from individuals who are evolving in the context of a certain value system. His idea has become a background for the elaboration of typological, psychological, and culturally anthropological approaches to social evolution conceptualized through interaction of cultural and social systems, in which individual motivation is conditioned by values (patterns) of particular cultures, and each social system determines the realization of motives. In this context the principal source of social evolution could be found in world models elaborated by human beings; such world models determine ways in which individuals realize their interests in the course of social evolution, trying to find problem solutions (i.e., world rescue) through the introduction of innovations in all spheres of human life, sometimes creating new problems and threats.

Olena V. Smyntyna

See also Darwin, Charles; Engels, Friedrich; Evolution, Cultural; Harris, Marvin; Hegel, Georg Wilhelm Friedrich; Language, Evolution of; Lenin, Vladimir Ilich; Marx, Karl; Morgan, Lewis Henry; Spencer, Herbert; Tylor, Edward Burnett; White, Leslie A.

Further Readings

Earle, T. (2005). Political domination and social evolution. In T. Ingold (Ed.), *Companion encyclopedia of anthropology* (pp. 940–961). London: Routledge.

Flannery, K. V., & Coe, M. D. (1968). Social and economic systems in formative Mesoamerica. In L. Binford (Ed.), *New perspectives in archaeology* (pp. 267–286). Chicago: Aldine.

Fried, M. H. (1967). *The evolution of political society: An essay of political economy.* New York: Random House.

Glassmann, R. (1986). *Democracy and despotism in primitive societies: A neo-Weberian approach to political theory.* New York: Associated Faculty Press.

Johnson, A., & Earle, T. (1987). *The evolution of human societies: From foraging group to agrarian state.* Stanford CA: Stanford University Press.

Lenski, G. F. (1966). *Power and privilege: A theory of social stratification.* New York: McGraw-Hill.

Mann, M. (1986). *Sources of social power: Vol. 1. A history of power from the beginning to A.D. 1760.* Cambridge, UK: Cambridge University Press.

Sahlins, V. (1960). Evolution: Specific and general. In M. D. Sahlins & R. E. Service (Eds.), *Evolution and culture* (pp. 298–308). Ann Arbor: University of Michigan Press.

Sanders, W., & Webster, D. (1978). Unilinealism, multilinealism and the evolution of complex societies. In C. L. Redman, et al. (Eds.), *Social archaeology: Beyond subsistence and dating* (pp. 249–302). New York: Academic Press.

Sanderson, S. K. (1990). *Social evolutionism: A critical history.* Oxford, UK: Blackwell.

Wiltshire, D. (1978). *Social and political thought of Herbert Spencer.* Oxford, UK: Oxford University Press.

Existentialism

Defining existentialism as a philosophy is notoriously difficult, primarily because it embraces several philosophical positions, many of which conflict. Yet, existentialism can be generally defined as a reaction against traditional philosophy's emphasis on the abstract, the objective, and the rational; instead it emphasizes the dynamic, the subjective, and the personal. Emphasizing personal involvement, engagement, choice, and commitment, existentialism is concerned with the existential, feeling, thinking individual who makes decisions and acts from a particular life situation rather than from a universal position determined by reason, history, or time. Existentialists advocate choosing an *authentic* life: a life not attained through social norms and everyday expectations but rather through the individual's own choice, engagement, and self-creation. Consequently, abstractions and generalizations are avoided on the basis that each individual should choose and create his or her own nature. This radical freedom, checked only by death, which defines the limits of existence, and personal responsibility leads to the feelings of despair, boredom, and alienation popularly associated with existentialism. Thus at its core, existentialism is the study of problems of existence and questions of being. Questions of time—how the individual exists within the present and relates to the past and future—are central to many existentialist philosophers' questioning of being.

As an intellectual, literary, and cultural movement of the late 19th and early 20th centuries, existentialism is largely identified with the French intellectual Jean-Paul Sartre. The major intellectual precursors of the movement are varied but are found primarily in the work of 19th-century Danish religious thinker Søren Aabye Kierkegaard, German philosopher Friedrich Nietzsche, and Russian novelist Fyodor M. Dostoyevsky. A few major philosophers identified as existentialists include Martin Heidegger, Karl Jaspers, Martin Buber, Maurice Merleau-Ponty, Gabriel Marcel, and Miguel de Unamuno y Jugo. However, many, most notably Albert Camus and Martin Heidegger, rejected the label, in part to avoid generalization and group classification. As a cultural and literary movement, existentialism flourished in Europe in the 1940s and 1950s, largely under the directive of Jean-Paul Sartre, Simone de Beauvoir, and Albert Camus.

Heidegger and Sartre

Concerning issues of time, two of the most important existentialist writers are Heidegger and Sartre. Yet, their differing conceptions of the power of the moment and its relation to time, as well as of individual freedom and choice, led them to differing theories of time. In *Being and Time* (1927), one of the most influential existential works published before World War II, Heidegger proposed a new conception of our relation to time and history. For Heidegger, existence is always historical. Rather than view time as a sequence of moments, he argued that human existence must be understood from three units of existential time: past, present, and future. Existential time is a unified structure in which the future recalls the past and gives meaning to the present. Existence, then, is more than just being present in a series of temporal moments; it is the orientation of oneself within the unity of a history. He further argued that while choice belongs to a moment, it is not limited to the moment. Thus, to lead an authentic life, the individual must understand choice within a historical framework. For Heidegger, human choice is always within the context of the past, present, and future, and therefore within the context of meanings and agendas that did not originate with the individual and so cannot be eliminated. The freedom to make choices, then, does not allow individuals the ability to escape their historical contexts. Rather, the freedom of choice allows humans the opportunity to create responses that have the potential to generate unexpected possibilities within their given context.

Whereas Heidegger argued that existence is historical and that individual freedom and choice are informed and checked by a historical context, Sartre argued a strikingly different position on being and history that was originally formulated in one of his best-known philosophical works, *Being and Nothingness* (1943). Sartre viewed history as the foundational situation in which the individual makes choices and the process of self-making occurs. His understanding of the individual's position in time is largely informed by his theories on meaning, freedom, and choice. For Sartre, the individual's only source of meaning is freedom—more specifically, freedom of choice. All things and beings, including humans, acquire meaning through human projection. Because that projection is totally free and not conditioned by the past, individuals are defined only by how they choose to define themselves. This open freedom allows individuals to completely control the meaning in their lives and thus to control the meaning of the past, present, and future. Individuals, then, are solely responsible for the future. Sartre argued that individuals fear this open freedom and responsibility and cling to rigid self- and social definitions. He demanded that human individuals recognize this freedom and act decisively in an otherwise inherently meaningless world.

Together Heidegger and Sartre raise questions about how the future is linked to the past and how the present is constructed. Both recognize that the past does not simply continue unguided, and both argue that the influence of the past is propelled by human freedom and choice. For Sartre, freedom of choice provides humans the agency to control the meaning of the past. For Heidegger, freedom of choice provides humans the agency to overcome the past. In addition, both reject the idea that rational analysis of the past can guide future values. For Heidegger, human choice is always contained within a framework of meanings and contexts that can be creatively reformed and manipulated to generate new possibilities. For Sartre, human choice is always separated from the past through a moment of indeterminate freedom: The individual is always granted the freedom to choose what past to propel, and in doing so, to shape the present and the future anew.

Nietzsche

Whereas Heidegger and Sartre dealt with conventional views of time divided into past, present, and future, other existentialist writers—namely, their precursor Friedrich Nietzsche—adopted a cyclical view of time. Throughout his writing, though most notably in *The Gay Science: With a Prelude in Rhymes and an Appendix of Songs* (1882) and *Thus Spake Zarathustra* (published in four parts between 1883 and 1892), Nietzsche advocated a revival of the ancient concept of time as "eternal recurrence," wherein time repeats itself cyclically and one's life is lived over and over again. The cyclical nature of time bestows the individual with an enormous responsibility, and the way that one lives life becomes crucial. Nietzsche's conception of time placed significant importance on questions of being and existence, as well as the significance of the choices one makes in life. Nietzsche's premise is most notably dealt with by the 20th-century writer Milan Kundera in his novel *The Unbearable Lightness of Being* (1984).

Conclusion

At the core of existentialism's questioning of being is the questioning of time: What will humans choose to become? How much freedom and choice do humans have in relation to the past, to the present, and to the future? For most existentialists, freedom of choice and the ability to make authentic choices allow humans agency in carrying on the past, negotiating the present, and directing the future.

Amanda Kuhnel

See also Dostoevsky, Fyodor M.; Heidegger, Martin; Humanism; Kierkegaard, Søren Aabye; Merleau-Ponty, Maurice; Nietzsche, Friedrich; Unamuno y Jugo, Miguel de

Further Readings

Heidegger, M. (1996). *Being and time* (J. Stambaugh, Trans.). Albany: State University of New York Press. (Original work published 1927)

Kundera, M. (1999). *The unbearable lightness of being.* New York: Harper.

Nietzsche, F. (1974). *The gay science: With a prelude in rhymes and an appendix of songs* (W. Kaufman, Trans.). New York: Random House. (Original work published 1887)

Sartre, J.-P. (1956). *Being and nothingness* (H. Barnes, Trans.). New York: Philosophical Library.

Experiments, Thought

Because we are not always able to carry out physical experiments to learn more about our world, scientists, philosophers, and others use thought experiments. This type of experiment is a way to use the imagination to investigate puzzles and new theories. Anyone can conduct thought experiments. All that is needed is to conceive of some problem or question, imagine in your mind how it might be tested or resolved, develop in your mind a method to do this, and rationalize what the results might be and how these results would affect the real world.

By no means are all thought experiments confined to scientific areas. They are used in philosophical arguments, in discussions about ethics and morals, and in other areas. Sometimes they are used to disprove preexisting theories and sometimes to advance new theories.

Thought experiments are nothing new—they were carried out by thinkers more than 2,000 years ago. A very early experiment, known as "Lucretius' Spear," is described in his poem *De Rerum Naturam* ("On the Nature of Things"). Lucretius used the technique in thinking about the nature of space. He described what might happen if one could carry a heavy spear to the edge of the universe and then hurl it forward. Only two results seem possible: Either the spear would keep going, in which case obviously there was something beyond the edge, or the spear would be stopped at the boundary. If there were indeed a boundary, then what was outside the boundary? In either result, space must be infinite.

Other Greek philosophers, such as Ptolemy, Plato, Socrates, and Aristotle, all used what we now call thought experiments. Some of the most important were created during the Renaissance, when thinkers such as Galileo Galilei, René Descartes, and Isaac Newton used them to develop principles still important today.

Newton, in his Newton's Bucket experiment, argued for the existence of absolute space and absolute motion. In other words, he attempted to show that space and motion are not dependent on anything else. If all matter in the universe were removed, space and motion would still exist because they do not depend on anything outside of themselves.

Newton's Bucket described an imaginary experiment in which a bucket is filled partway with water and then suspended by a rope from an overhead rafter. The bucket is then turned around and around until the rope is tightly wound. At this point, the water is perfectly level. However, when the bucket is released, it begins to spin. As it spins faster, just as water stirred in a cup gradually begins to rise around the edges and sink in the center, so too would the water in the bucket act.

At the beginning, while the water was level but the bucket had just begun spinning, there was a relative relationship between the water and the bucket. As the speed increases, even though the bucket and water are moving at the same speed, the level of the water changes. Newton felt this proved that the level of the water did not depend on the motion of the bucket; therefore space and motion were not in a relative relationship. Later thinking about space, time, and motion brought this idea into question.

A thought experiment by Albert Einstein dealt in a way with the questions of absolute motion or rest. Einstein described a magnet and a spiral wire. We know that a magnet next to a wire can create an electrical current. He imagined what would happen if the magnet were at absolute rest (assuming there is such a thing). The wire, because of its proximity, would develop an electric current. If the wire is stationary and the magnet moves, there would still be a current induced in the wire. Finally, if both were moving relative to each other, the induced current still would be created. These and other Einstein thought experiments all fed into his special theory of relativity, the first principle of which is that the speed of light is the same for all observers no matter what their position is in relation to the origin of the light source.

Anticipating concepts of relativity by more than 400 years was Giordano Bruno (1548–1600). In several thought experiments Bruno expounded relativistic concepts. For example, in the Argument of the Third Dialogue of his *De l'infinito universo et mondi* (*On the Infinite Universe and Worlds*), Bruno noted that looking down from a mountain on a sea on a bright night, we would see the whole sea illuminated. However, afloat on the sea at the same time, we would just see a small bright area near us.

Closely allied to these mental experiments are counterfactuals, which are used in many subject areas as well as in speculative fiction, sometimes called alternative history. Counterfactuals spring from taking a significant event in history and imagining what the world might be like had the event not happened. What if the Great Wall of China had never been built? Would the constant barbarian invasions have prevented developments in China that later influenced the West? In the United States, what if the South had won the Civil War?

Historiographers may use thought experiments to explore the development of various schools of political thought, such as Marxism. Social and public policy questions can draw on these techniques to try to shed light on moral and ethical questions such as abortion. A moral philosopher named Judith Jarvis Thompson set up the "Famous Violinist Problem." This experiment describes a situation where an individual is kidnapped. This individual's internal organs are linked to a world-famous violinist whose organs have failed and will die unless saved by this operation. By staying on this support for 9 months, the violinist will recover and survive. If disconnected before 9 months, the violinist will die and all the great performances that might have been will never take place. Do the perpetrators have a moral right to take such an action?

Today few scientists deny the usefulness of thought experiments. In fields such as philosophy, ethics, and linguistics, some thinkers raise questions about the validity of this way of thinking. These objections range from concerns about their impracticality, overreliance on intuition, divorcement from reality, to the tendency toward oversimplification of complex issues. However, when looking at the long list of scientific advances spurred by these experiments, it is difficult to deny their importance.

Charles Anderson

See also Aristotle; Aristotle and Plato; Bruno, Giordano; Darwin, Charles; Descartes, René; Einstein, Albert; Galilei, Galileo; Gosse, Philip Henry; Histories, Alternative; Lucretius; Newton, Isaac; Nicholas of Cusa (Cusanus)

Further Readings

Cohen, M. (2005). *Wittgenstein's beetle and other classic thought experiments.* Malden, MA: Blackwell.

Isaacson, W. (2007). *Einstein: His life and universe.* New York: Simon & Schuster.

Sorensen, R. (1992). *Thought experiments.* New York: Oxford University Press.

Extinction

The process of evolution allows for extinction in that the survival of the fittest tends to assist in population growth and diversity but extinguishes the weak. By extension or analogy, extinctions related to the evolutionary process affect not only plants and animals but culture as well, and all that it entails. In 1846, Justus Liebig observed that the success of a population or community is dependent upon an intricate complex of environmental conditions and that any condition that approaches or exceeds the limit of tolerance for the organism or population in question may be said to be a controlling factor. By exceeding the limits of tolerance, extinction can occur with innovations, inventions, communications, ethnicities, languages, economies, and civilizations. The Stanley Steamer became extinct when the internal combustion engine gained in popularity early in the 20th century. What ever became of the 13-key Marchant calculator so popular with statisticians in the 1950s? For that matter, how many communicate in Latin anymore? There were societal things that now no longer exist, or are no longer active, or have gone out of use, or have become ineffective: The incandescent lightbulb, so ubiquitous today, may become extinct in the 21st century as more energy-efficient alternatives become available to a world increasingly concerned with dwindling energy supplies.

During the past couple of billion years, life has evolved from simple one-celled creatures, such as the amoeba, into complicated complex multicellular life forms or living environments. Along the way, several mass extinction events have occurred. One of the two largest mass extinctions was caused by the breakup of Pangea at the end of the Paleozoic era, known as the Great Dying, when about 90% of all marine species and 75% of all land animals became extinct. The other was at the end of the Mesozoic era, when massive igneous eruptions and the impact of a great meteor created a highly toxic planetary environment, resulting in the extinction of about 75% of all marine species and, on land, the total extinction of the dinosaurs. The limit of tolerance was definitely exceeded in both cases.

In the past 500 million years there have been at least five or six major extinction events, and about the same number of smaller ones. A variety of conditions, including igneous (volcanic) eruptions and meteorites, have contributed to these extinction events. Toxic gases entering the atmosphere from extensive igneous eruptions, resulting in acid rain and acid deposition, have the ability to kill plant and animal species. This has occurred historically and is also taking place at the present time. Then, too, global cooling and global warming have resulted in extinctions by merely exceeding the limit of tolerance through significant increases or decreases in temperature. Along with the associated temperature change is the change in the amount of available moisture. Climatic stress is a very real thing as large areas exceed tolerance levels for the more sensitive species.

We will learn more about global cooling after the present global warming period ends; that is, if we are in another interglacial stage, as many scientists believe. With regard to global warming it is likely that emissions of methane gas (CH_4) in the sea floor, soils, and melting ice caps contribute to "greenhouse" gases in greater amounts than carbon dioxide. A large release of methane is often related to surface igneous activities, which are related to convection currents in the mantle, which in turn are related to plate tectonics. Such large emission of methane in the past may again take place in the future.

Extinction events, large and small, are continually being studied, particularly since the more recent glacial ice began retreating. These events tend to coincide with humankind exploring the land in areas where the ice was retreating, as well as other areas of the world. It is known that certain species of horses, camels, sloths, elephants, glyptodonts, peccary, antelope, and bison disappeared together over 8,000 years ago. The extinction of the mammoth occurred about 11,000 years ago. Certain birds also became extinct about the same time. And stratigraphic evidence, including volcanic ash, suggests that extinction of many species of tortoises occurred about 70,000 years ago, showing that climatic change and volcanic eruptions are both involved. Many archaeological sites show that extinction events closely followed the arrival of humankind. Very simply, civilization tends to shrink the range needed for other species: The Colorado squawfish, Carolina parakeet, California condor, Everglade kite, Eskimo curlew, and Labrador duck, among others, have become extinct in the past 200 years. These are not new observations about the diminishing wilderness and decimation of natural areas. Research continues as currently endangered species and the extent of their ranges are at the mercy of humankind.

A comparison of extinctions in the natural setting with those in the cultural domain is rendered difficult by the tendency to think in terms of human time rather than geologic time. Natural extinction events take thousands of years or even longer, while cultural extinctions occur in rapid succession with each technological innovation or societal upheaval. At the present time, as scientists continue to search for answers to the questions surrounding biological extinction, the paradigm of cultural extinctions may yield information useful in understanding and responding to these phenomena.

Richard A. Stephenson

See also *Archaeopteryx;* Coelacanths; Dinosaurs; Extinction and Evolution; Extinctions, Mass; Fossil Record; Fossils, Interpretations of; Ginkgo Trees; K-T Boundary; La Brea Tar Pits; Trilobites

Further Readings

Chernicoff, S., & Whitney, D. (2007). *Geology* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Merritts, D., De Wet, A., & Menking, K. (1998). *Environmental geology.* New York: Freeman.

Wright, H. E., Jr., & Frey, D. G. (Eds.). (1965). *The quaternary of the United States.* Princeton, NJ: Princeton University Press.

Extinction and Evolution

Charles Darwin (1809–1882) assumed that species have gone extinct in a steady and progressive way through the history of life; that is, over time. The diversity of life is reflected in the large number of present-day species, but a much larger number has existed over time, owing to the fact that extinction is the ultimate fate of all species; 99% of all species that have ever lived on Earth are estimated to have become extinct since life originated, about 3.5 billion years ago. A species' duration on Earth is very short on the geologic timescale; normally, a species becomes extinct within 10 million years after its origin. Thus, it is now widely accepted that species become extinct, but this fact was not known 200 years ago. It was previously thought that species were fixed in form, until Jean-Baptiste de Lamarck established that species change over time into new species. However, Lamarck assumed that lineages of species continue indefinitely without branching, so they did not go extinct.

Georges Cuvier (1769–1832) is accredited as the first to establish the extinction of species. He studied the fossils from large terrestrial mammals that had never been observed alive and realized that such fossils must not be overlooked. He considered that each species had had a different origin, and then it stayed stable in its form. Successive catastrophic events then drove these species extinct.

The principle of uniformitarianism, developed by the geologist Charles Lyell in his *Principles of Geology* (1830–1833), was essential for Darwin. It is simply that the basic physical processes involved in the present-day structure of the Earth are assumed to have been the same everywhere and at all times. In the pivotal work *On the Origin of Species* (1859), Darwin considered that the modern variety of species was the result over time of the process of descent with modification. Thus, the successive species are linked to each other by a branching genealogy, the tree of life. This tree-like evolution, where species disappear gradually rather than as a result of catastrophic events, allows for extinction. Darwin assumed that due to competition with other species, the causes of the extinction of species were mostly biological. However, there were a series of peak times when extinction rates appeared to be exceptionally high, now called mass extinctions, but Darwin attributed them to gaps in the fossil record rather than real catastrophic events. Today, the absolute dating of rocks by radioisotope methods has ruled that possibility out. Thus, Darwin held that extinction is coupled with the process of natural selection and is, therefore, a main element of organic evolution.

The Fossil Record: Evidence for Extinction

The fossil record is the main source of information on the history of life and it provides strong evidence for evolution and, therefore, for extinction. However, the fossil record is neither complete nor perfect. It contains merely a small part of all the species that have ever existed and not in a representative way. The proportion of species known from the fossil record is about 0.02%; in other words, about 250,000 fossil species. The fossil record is biased in favor of mineralized hard-skeleton invertebrate species, long life span species, and geographically and ecologically widespread distributed species. Foraminifera, single-celled eukaryote marine microorganisms, are one of the best groups to evidence organic evolution, as they show a widespread and almost continuous record with intermediate forms between species. But even with the best-recorded species, the exact time of extinction of a species is impossible to determine. The last appearance of a species in the fossil record usually happens before the time of extinction as a consequence of the lack of completeness in the fossil record. The misinterpretation of the fossil record may lead to what is called pseudo-extinctions. It means that a species (or higher taxon) apparently becomes extinct but it reappears in younger rocks. It may be due to taxonomic artifacts or to the incompleteness of the fossil record.

The divergence of species is usually based on physical expressed characteristics, that is, morphological and behavioral characteristics, but the latter are generally not observed in fossil species. Thus, two species that recently evolved from a common species may blur into each other, as would be expected in an evolutionary process. Furthermore, the extreme forms of an evolving lineage may seem sufficiently different that they are identified as different species, even more if due to the incompleteness of the fossil record when there are only few specimens recorded from the extremes so the evolving lineage cannot be detected. A second kind of pseudo-extinction due to taxonomic artifacts can occur in situations involving higher taxa above the species level. A paraphyletic group (an artificial group of taxa comprising a common ancestor but not all of its descendants) could become extinct although some descendants of that group continue to exist. For instance, the birds are descendants of one dinosaur group, which became extinct, but birds survived that extinction.

The so-called Lazarus effect is a kind of pseudo-extinction due to the incompleteness of the fossil record. A Lazarus species is one that disappears temporarily from the fossil record, but it can be inferred to have existed during that time by its reappearance in younger rock strata. However, its disappearance would be a pseudo-extinction if its later occurrence is overlooked. A mass extinction can seem artificially more abrupt, gradual, or stepped than it actually was because of the Signor-Lipps effect. Sampling gaps in the fossil record, through an interval of time before a mass extinction, may lead to the scattering of the last occurrence of taxa prior to their actual extinction.

The fossil record has been used to estimate the change of the diversity of life and therefore of the extinction rate through the history of life, compiling the time distributions of taxa in the fossil record. In the 19th century, the geologist John Philips, after plotting diversity against time, was able to recognize the great faunal transitions that mark the boundary between the Paleozoic, Mesozoic, and Cenozoic eras, that is, the major extinction events now called the end-Permian and Cretaceous-Tertiary (K-T) mass extinctions. But the most widely used compilation is that developed by Jack Sepkoski and published in a series of papers beginning in 1981. Three main conclusions are inferred from it: The average extinction rate seems to decrease from the Cambrian period (about 500 million years ago) to the present; there are five time periods of particularly high extinction rate, which have become known as the Big Five mass extinctions; and a periodic pattern of peaks in extinction rate occurs every 26.2 million years.

Extinction Over Time: Background Extinctions and Mass Extinctions

Extinctions have occurred throughout the history of life as a consequence of the branching structure of evolution. These extinctions are called *background extinctions*. The decline of the average extinction rate from the Cambrian period to the present is a controversial subject, because it may be an artifact caused by the way the extinction rate is measured. Diversity in the Cambrian is known to be lower than in the Mesozoic and Cenozoic eras. Consequently, for a given extinction rate, fewer taxa needed to go extinct. As a result of the branching structure of evolution, the numbers of species per genus and per family (higher taxa) have increased over time. Thus, fewer genera and families will go extinct through time for a given number of species going extinct. But the decrease in extinction rate may be real. Taxa may have become more resistant to extinction, perhaps suggesting progressive adaptive advances. Species may have initially occupied central niches (the position of a species within its environment and community, i.e., the habitats it occupies and the resources it consumes) that are subject to more intense competition than are marginal niches. Thus, a higher turnover of occupying species occurs. Over time, more marginal niches are occupied where the species may last longer and, consequently, have lower extinction rates.

The five major mass extinctions occurred at or near the ends of the Ordovician, Devonian, Permian, Triassic, and Cretaceous periods. The Permian mass extinction is the biggest in the history of life, with about 95% of the species going extinct. In the K-T mass extinction, where dinosaurs and ammonites (coiled-chambered shell cephalopods similar to the pearly nautilus) were driven finally extinct, at least half (and perhaps 75%) of species suffered extinction. Even though it is clear that the extinction rate was extremely high through mass extinctions, it is not clear whether mass extinctions are truly different from background extinctions. Thus, mass extinctions could just be the intensification of background extinctions, fully random or selective. In the last case, the most plausible idea, they would follow different rules than would background extinctions, which are responsible for the extinction of the vast majority of species.

It has been estimated that there was a periodic pattern of peaks in extinction rate every 26.2 million years during the Mesozoic and Cenozoic eras. However, not all predicted peaks coincide with known extinction events in the fossil record, and there was a lack of those peaks in the Paleozoic. Recently, another periodic pattern has been calculated every 27 million years, which clearly matches with the 26.2-million-year periodicity.

Extinction Selectivity

The combination of Darwin's theory of evolution by natural selection and Mendel's genetic theories constitute the modern synthesis, or neo-Darwinism. Species usually have excess fecundity so they generate many more offspring than can survive. This implies a competition within every species to survive, as the genes in the population of offspring are a random sample of the genes present in the parental population. The better-adapted forms to the environmental conditions, and thus the variants that improve survival or reproductive success, will increase in frequency and, eventually, a new species will be originated. Darwin considered that competition between species is the main cause for extinction, and thus all extinctions are selective. It is obvious that extinction does not affect all species in the same way, but more factors than only competition between species are implied. Species with large body size, ecological specialism traits, low reproductive rate, and slow growth are more likely to suffer extinction. Species with large body size are usually characterized by small populations and low reproductive rates; that is, they are rare. Species with broad geographic ranges are much less prone to extinction than species with smaller ranges, but not when extinction is so severe as during mass extinctions. In this case, survival depends on the geographic distribution of the entire group but not of the individual species. Tropical taxa usually suffer much more extinction than high-latitude taxa, but there is also no difference during mass extinctions. Species-rich taxa have lower extinction rates. Not all taxonomic groups show the same mean duration of their species, so those with shorter duration have higher extinction rates.

Taxonomic selectivity is not common, but occasionally it is prominent. Such is the case of the extinction of the trilobites (arthropods gone extinct at the Permian mass extinction), dinosaurs, and ammonites at the Mesozoic mass extinction. This evidence—that taxonomic selectivity may operate at higher levels than the species level—makes it possible that diverse higher taxa have become extinct. Therefore, mass extinctions can drive taxa extinct not because they are poorly adapted to normal environmental conditions, but because they happen to lack adaptations to the new conditions or characteristics, such as lacking extensive geographic ranges that favor survival during the extinction. These contrasts in selectivity between mass extinctions and background extinctions evidence the evolutionary importance of mass extinctions. Even though they account for less than 5% of the total number of species that have become extinct through the history of life, they can drive to extinction well-adapted and successful taxa. This makes sense in terms of evolution, as natural selection cannot ensure that its taxa will survive sudden abrupt environmental shifts. The species selection pattern can even shed light onto the nature of the mass extinction event.

Understanding the causes of the mass extinctions has become an important and controversial issue since the proposal of a giant meteorite impact as the main or triggering cause for the K-T boundary mass extinction. Other common abiotic causes of major extinctions are climate change, volcanism, sea-level changes, anoxia (low-oxygen conditions), and shifting continental position. However, the evolutionary consequences of mass extinctions are probably more important than the events themselves.

Evolutionary Consequences of Mass Extinctions

The evolutionary process following mass extinctions is a key to the postextinction role of the diversity of life as new evolutionary opportunities are created by the demise of dominant groups. After the dinosaurs became extinct at the K-T mass extinction, the mammals radiated rapidly and occupied the ecological space vacated by dinosaurs. Mass extinctions triggered the diversification of survivors, not only in terms of numbers of species but also in terms of morphological or ecological variety. However, the fossil record shows that not all survivors radiate after mass extinctions, and therefore survival alone does not guarantee evolutionary success. The diversity of survivor groups can follow different ways over time after a mass extinction. Some groups accelerate diversification following the extinction event, as is the case with mammals after the K-T mass extinction. Others groups suffer a delay just after the extinction event. Some of them rapidly recover and continued their diversification, but others never really recover from the mass extinction. The latter usually disappear several million years after the mass extinction, although some of them manage to survive until the present day, and they are often called living fossils (e.g., the pearly nautilus). Immediately after the mass extinction event, severe environmental conditions persist, and they can even prompt more extinctions and delays in species recovery. Mass extinctions, which are especially severe among rare and restricted distributed groups, tend to homogenize the postextinction fauna. Low-diversity assemblages dominated by generalist species characterize these intervals. Generalist species are often small in size, and under normal conditions they are rare, with very few populations. Even though mass extinctions have provided major evolutionary opportunities, they did not trigger such a big diversification of life as the one at the beginning of the Paleozoic era, the Cambrian explosion, when most of the major groups of animals appeared for the first time, as evidenced in the fossil record.

The recovery process after a mass extinction can show considerable variety all over the world. Furthermore, recovery processes are different for each mass extinction as different taxa and different ecological, climatic, and oceanographic settings are involved. Thus, the speed of recovery may differ between mass extinctions, but the fossil record shows that it always takes a long time to recover, as much as 10 million years.

Today, the extraordinary proliferation of just one species, our own, is triggering what is considered to be the sixth mass extinction. It may be viewed as not natural, but the fossil record provides strong evidence for mass extinctions throughout the history of life. Moreover, the fossil record provides evidence of recovery after all of them. Apparently, we should not be worried about a sixth mass extinction of all life on Earth due to the misguided actions of our own species. However, the fossil record also shows us that the evolutionary recovery of biodiversity is extremely slow compared to a human lifetime and a long time compared to the total life span of our species so far. Impoverishment is the legacy of extinction on human timescales, but extinction also creates new evolutionary opportunities. Even so, survivors of mass extinction are not always the best adapted, just the luckiest. Of course, not all survivors are going to be successful in terms of ongoing evolution.

Silvia Ortiz

See also Dinosaurs; Extinction; Extinction and Evolution; Extinctions, Mass; K-T Boundary

Further Readings

Jablonski, D. (2001). Lessons from the past: Evolutionary impacts of mass extinctions. *Proceedings of the National Academy of Sciences USA, 98,* 5393–5398.

Raup, D. M. (1995). The role of extinction in evolution. In W. M. Fitch & F. J. Ayala (Eds.), *Tempo and mode in evolution: Genetics and paleontology 50 years after Simpson.* Washington, DC: National Academies of Sciences.

Ridley, M. (2004). *Evolution* (3rd ed.). Oxford, UK: Blackwell Science.

Taylor, P. D. (Ed.). (2004). *Extinctions in the history of life.* Cambridge, UK: Cambridge University Press.

Extinctions, Mass

Unlike an extinction, which affects a single species, a mass extinction is the large-scale elimination of multiple species caused by catastrophic global events. There have been five mass extinctions in geological time. It is believed that a sixth mass extinction is currently in progress, the first since the advent of humankind.

Ordovician Mass Extinction

The first mass extinction took place at the end of the Ordovician time period 438 million years ago (mya). Life forms in the Ordovician period were restricted to the seas, and the Ordovician mass extinction is one of the most devastating extinctions in geological history, with more than one quarter of Earth's marine species being eliminated. Numerous species of the trilobites and brachiopods were eliminated, while graptolites and conodonts were also seriously affected. Over 100 marine invertebrate families were destroyed in the mass extinction. Scientists attribute the cause of the mass extinction at the end of the Ordovician to glaciations and the consequent drop in sea levels. As a result of the drop in sea levels, there becomes a shortage of inhabitable space on the continental shelves. Along with this shortage, the sea temperature dropped as a result of glaciations, also affecting life forms.

Devonian Mass Extinction

During the late Devonian period, a second mass extinction swept the earth around 360 mya. The reefs faced near elimination, as did several other marine animals. Creatures affected included brachiopods, trilobites, and conodonts, as well as the placoderm armored fish. Land records for this time are less clear, and it is possible there was a major extinction among land flora.

Permian Mass Extinction

The Permian mass extinction is the largest mass extinction in geological history. This extinction ended the Permian period, 250 mya, and marked the transition between the Paleozoic and Mesozoic eras. The effect of the mass extinction reached across both land and sea, wiping out over 90% of all species on Earth. Over one half of the marine species perished, including the rugose and tabulate corals, fusulinids, and several echinoderms. Brachiopods also suffered, ending their dominance in population. There was also a regionally vital extinction among plant life. The last of the trilobites were eliminated during the Permian mass extinction. Over one half of the vertebrate families were lost. The exact cause of the mass extinction is debated, with speculative causes including major volcanic eruptions, glaciations, and changes in sea level. Some scientists attribute the mass extinction to the collision of the Gondwana and Laurasia land masses to create the land form Pangea. Another theory includes a massive comet or asteroid impacting Earth, which would have also contributed to the mass extinction.

Triassic Mass Extinction

The Triassic mass extinction happened 50 million years after the previous mass extinction, about 200 mya. By this time, a number of land and marine life forms had repopulated the earth, and reptiles had evolved into crocodile-like animals and a few mammal-like reptiles. Most of these animals were destroyed in the mass extinction, including conodonts, and others, such as the calcareous sponges and shelled ammonites, were nearly wiped out. The cause of this mass extinction is believed to be the result of a combination of catastrophes happening over the span of 100,000 years or less. These events include an estimated 4-mile-wide meteor impacting Earth near Quebec, creating a 70-mile-wide crater; eruptions of lava flow underneath the Amazon river valley; and a dramatic change in climate. Together these events were sufficient enough to create a mass extinction, allowing the dinosaurs to emerge.

Cretaceous Mass Extinction

The best-known mass extinction took place 65 mya, ending the reign of dinosaurs and the Cretaceous period. This mass extinction marks the elimination of the calcite-shelled phytoplankton, coccolithophorids. Also eliminated in this extinction were the ammonites, belemnite cephalopods, and the primitive bivalves. Among the land-roaming animals, dinosaurs were wiped out in the Cretaceous mass extinction, allowing mammals to dominate Earth in the Cenozoic era. It is believed that a combination of catastrophic events is to be attributed to the cause of the Cretaceous mass extinction. The most drastic event was the impact of a 6-mile-wide asteroid colliding with Earth near the Yucatan Peninsula. This event created widespread forest fires, giant tidal waves, and massive amounts of poisonous gases in the atmosphere. There were months of darkness due to the large quantities of Earth and asteroid debris in the atmosphere, blocking out the sunlight. Numerous species of plants died and herbivorous animals starved. Over half of the species on Earth perished.

Causes of Mass Extinctions

The causes of the various mass extinctions are debated, including theories of volcanic eruptions, meteor impacts, sea-level changes, and climate changes. Mass extinctions do not happen overnight but rather over a period of thousands of years. Major volcanic eruptions create deadly gases in the atmosphere, resulting in a number of side effects. There is a regional warming due to the sulfur dioxide released into the atmosphere, as well as global warming from the carbon dioxide. These global temperature changes can affect a number of flora and fauna if, like coral, they are delicate in response to temperature change. Throughout prehistory, a dominant species of a period was not overthrown by another species but rather by a mass extinction. This allowed other species to evolve and become the next dominant group. Mammals existed during dinosaur domination; however, it was not until a mass extinction eliminating all nonavian dinosaurs that mammals evolved further and became the dominant life form. Mass extinctions were also fairly selective in which species were affected. An example is during periods of global warming or glaciations, species that survived within limited latitudinal distances were more strongly affected because of their inability to adapt to thermal changes. Other species living in a wider latitudinal range were more likely to tolerate the thermal change.

Future Mass Extinctions

Although a number of species have become extinct, there has not been a mass extinction since the dawn of humankind. Of the 1.7 million known species, only 5% of them have been catalogued, and there is an estimated 5 million to 50 million unknown species. It is estimated that 1 out of every 1 million species became extinct per year prior to human existence. It is estimated that today 1 out of every 1,000 species is becoming extinct. This rise in the rate of extinction is attributed in part to anthropogenic activities. This rate of extinction is rivaled only by the three most catastrophic mass extinctions, leading many scientists to believe we are heading toward, or are already in, a sixth mass extinction.

Mat T. Wilson

See also Catastrophism; Dinosaurs; Extinction; Extinction and Evolution; Fossil Record; Fossils, Interpretations of; Geologic Timescale; K-T Boundary; Paleontology; Trilobites

Further Readings

Broswimmer, F. J. (2002). *Ecocide: A short history of the mass extinction of species*. London: Pluto Press.

Hallam, T. (2004). *Catastrophes and lesser calamities*. Oxford, UK: Oxford University Press.

F

Farber, Marvin (1901–1980)

In the history of recent philosophy, Marvin Farber represents a bold thinker who dared to change his intellectual interests in light of continuing advances in the special sciences. Although he was at first drawn to the rigorous study of phenomenology with its focus on pure consciousness, Farber later became very critical of its subjective orientation and limiting methodology; he stressed that there is a crucial distinction between a claim about existence (ontology) and a method of inquiry (epistemology). Farber realized that phenomenology alone is unable to adequately answer important questions concerning ethics, epistemology, and metaphysics. It was Farber's serious acceptance of the fact of evolutionary time that resulted in his academic shift from idealism to materialism. The awesome cosmic perspective in astronomy and the disquieting implications of human evolution in anthropology convinced him that the sweeping temporal framework in modern science offered the only true interpretation of the fleeting place our species occupies in a dynamic universe.

Although Farber had studied phenomenology under Edmund Husserl (1859–1938), he found greater value in the diverse ideas of Giordano Bruno, Ludwig Feuerbach, and Friedrich Nietzsche. Bruno held that this universe is eternal, Feuerbach claimed that religious beliefs are the product of human psychology, and Nietzsche taught that "God is dead!" and therefore new values are needed to replace traditional superstitions. Farber incorporated these penetrating insights into his own critical investigations of the human situation. Furthermore, Farber's concern for human problems found inspiration in the social analyses of Karl Marx, Friedrich Engels, and Vladimir Lenin. Farber accepted the materialist stance and historical framework of these three social theorists and, with a keen sense of human compassion and critical optimism, he anticipated the emergence of increased enlightenment as our species embraces the ongoing findings of science and the indisputable power of reason.

Charles Darwin's theory of evolution had had an enormous influence on natural philosophy. It challenged the previously accepted age of this planet, fixity of species, and recent appearance of humans on the earth. The remarkable discoveries in geology, paleontology, anthropology, and biology (particularly genetics) throughout the 20th century yielded overwhelming empirical evidence to support the scientific fact of organic evolution. Farber stressed the independent existence of the evolving world from human consciousness. His own ideas went far beyond the myopic views of existentialists and even the pragmatic naturalism of John Dewey (1859–1952), whose philosophy retained a concept of God. Moreover, Farber advocated a pervasive naturalism that not only rejected all forms of spiritualism and supernaturalism, but also removed humankind from any special position in the flux of cosmic reality. Among the recent major philosophers, he stood almost alone as an unabashed atheist and uncompromising materialist.

Darwinian evolution contributed the fatal blow to any earth-bound and human-centered worldview. Marvin Farber acknowledged the quintessential value of having a sound comprehension of time in order to properly and accurately explain reality, whether it be cosmic history or human existence within it. His own naturalist attitude and refreshing vision, with its steadfast commitment to pervasive evolution, offered a sobering interpretation of our species grounded in an open inquiry that respected both scientific evidence and philosophical reflection.

H. James Birx

See also Bruno, Giordano; Darwin, Charles; Engels, Friedrich; Feuerbach, Ludwig; Haeckel, Ernst; Husserl, Edmund; Lenin, Vladimir Ilich; Marx, Karl; Materialism; Nietzsche, Friedrich

Further Readings

Farber, M. (1968). *Basic issues of philosophy: Experience, reality, and human values.* New York: Harper Torchbooks.

Farber, M. (1968). *Naturalism and subjectivism.* Albany: State University of New York Press.

Mathur, D. C. (1971). *Naturalistic philosophies of experience: Studies in James, Dewey and Farber against the background of Husserl's phenomenology.* St. Louis, MO: Warren H. Green.

Ryder, J. (Ed.). (1994). *American philosophic naturalism in the twentieth century.* Amherst, NY: Prometheus.

Fatalism

Fatalism is the belief that the future is fixed and that there is nothing we can do about it. It implies that our wills are causally inefficacious.

The Fates of Mythology

The belief in fatalism, like many others, has its roots in the quasi-religious mythologies of ancient peoples, many of which personified the notion of fate. Thus Greek mythology supposed that three Fates, daughters of the goddess of Necessity, had control of our lives from beginning to end and that it was therefore impossible for us to do anything contrary to what they had prescribed for us. We may think we are in control of our own destinies, but we are mistaken. Both Homer's *Odyssey* and Aeschylus's *Prometheus Unbound* depict mortals as puppets of the gods.

Fate and Predestination in Monotheistic Religions

Belief in the Fates has a correlate in each of the three main monotheistic religions: Judaism, Christianity, and Islam. In all three the concept of fate or destiny mutates into the theological doctrine of predestination—the doctrine that there is a Book of Life in which are written the names of those whom God has selected for salvation or damnation. As St. Paul took pains to point out, a person's ultimate future is already determined by the grace of God, not by anything we can do of ourselves.

This form of fatalism is often linked to the doctrine of God's foreknowledge. The God of theism is supposed to be omniscient (all-knowing) as well as omnipotent (all-powerful) and omnibenevolent (wholly good). By virtue of his omniscience, it has been argued, God knows our futures right down to the finest detail. Hence, it is concluded, we can't do anything other than he already knows we are going to do. The details of our daily lives, as well as our ultimate destiny, are already set (if not in stone, then in God's mind). Much theological debate has raged over which doctrine takes logical precedence: foreknowledge or predestination? Is God's foreknowledge of our futures a consequence of his having predetermined them? Or is it the other way around?

Such sayings as "Thy will be done"—whether the word "thy" is taken to refer to the Jewish Yahweh, the Christian God, or the Muslim Allah—incorporate the fatalistic suggestion that nothing can be done that is contrary to God's will. There's no use in struggling against it; one must simply submit.

Commonplace Sources of Fatalistic Belief

Belief in fatalism can have much humbler sources, as in such commonplace observations as "It wasn't in my stars," "It wasn't meant to be," "I guess his number was up," or "What will be will be." Persons mouthing such sayings may have some astrological, religious, or metaphysical doctrine in mind. But they need not. They may utter them without even pausing to ponder what, if anything, they mean. Thus can the inanities of ordinary language lend support to vague and unexamined philosophical doctrine.

Philosophical Sources of the Doctrine of Fatalism

Serious philosophers, too, can be led to flirt with fatalism by reflecting on matters of language and logic. Aristotle was a case in point. In *On Interpretation,* Aristotle puzzled over the application of logical principles to statements about the future. His example was, "There will be a sea-fight tomorrow." Clearly, he reasoned, this statement must—by his own Law of the Excluded Middle—be either true or false. Suppose it to be true. Then, it seems, there is nothing and no one that can bring it about that the sea battle will *not* occur. Otherwise the statement would not have been true. Suppose the statement to be false. Then, it seems, we can conclude that there is nothing and no one who can bring it about that the battle *will* occur. Otherwise the statement would not have been false. It seems, then, that logic itself dictates that the future, whatever it holds in prospect for us, is fixed and occurs of necessity. No one, on this analysis, can do anything to make the future be other than it is going to be.

Some thinkers have concluded that logic does indeed provide a sound basis for believing fatalism true. Others have thought to escape from fatalism by finding a path between the alternatives of statements being either true or false. Statements about the future, some have said, are neither determinately true nor determinately false. So-called three-valued logics have been devised accordingly. Still others have claimed that there is a fallacy involved. They have argued that from the truth of a statement about the future—that such and such an event will occur—all that follows is that it *will* indeed occur, not that it "must" occur. Likewise for the case where such a statement is false: All that follows is that the event *will not* occur, not that it "cannot" occur. There's no hint of fatalism in either case.

Determinism Distinguished From Fatalism

It is sometimes supposed that the doctrine of determinism—in the form of a belief in the causal interconnectedness of all events, from past to present and thence to the future—also has fatalistic implications. But surely this must be wrong. A determinist can well believe that just as our present actions are the effects of past events, so our present actions have their own effects and so can play a role in determining future events. That is to say, a causal determinist can consistently say that our wills are causally efficacious, at least some of the time. Since fatalism denies that our choices can have any effect on what the future is to be, a fatalist cannot consistently say this. Hence determinism does not imply fatalism.

Raymond Dynevor Bradley

See also Aristotle; Determinism; God and Time; Homer; Mythology; Predestination; Predeterminism

Further Readings

Bradley, R. D. (1967). Must the future be what it is going to be? In R. M. Gale (Ed.), *The philosophy of time.* New York: Anchor Books. (Reprinted from *Mind, 68,* 1959)

McKeon, R. (Ed.). (1941). On interpretation. In *The basic works of Aristotle.* New York: Random House.

Taylor, R. (1967). Fatalism. In R. M. Gale (Ed.), *The philosophy of time.* New York: Anchor Books. (Reprinted from *Philosophical Review, 7,* 1967)

Father Time

The intangible passage of time, challenged only in photographs, is an unstoppable entity with no clearly defined scientific beginning or end. As with grains of sand passing through an hourglass, there is nothing one can do to stop or freeze time itself in order to hold on to one specific moment. This leaves us with only memories. This concept of time, being such a powerful and unforgiving force, is commonly represented by the old and wise figure known as Father Time, which can be traced back to the early Romans and Greeks.

Before the ancient Greeks recognized the brothers Zeus, Poseidon, and Hades as rulers over the world, they worshiped their father Chronus (*Khronos*) (Latin root *Chronus* meaning time), the god of time. The Roman equivalent *Kronos* not only doubled as the Titan god, but also was seen as the god of agriculture (also giving him the name Saturn), often causing him to be portrayed with a scythe. There was also an annual midwinter weeklong harvest celebration called Saturnalia, held to honor, thank, and celebrate Saturn.

Father Time is traditionally depicted as an old, bearded figure, and as previously mentioned, always with a scythe at his side. To stress just how powerful he was, however, some ancient Romans depicted Kronos as the personification of Aion ("eternity"), a masculine and youthful god. Some murals show him against the sky holding a wheel inscribed with the signs of the zodiac. But for the Romans, the traditional portrayal with the scythe represents the sowing and tilling of the land each year, which brought about bountiful harvests. Like the Greeks, the Romans recognized Kronos's great importance as the god of time. In mythology, the ultimate flaw in any humans attempting to perform heroic feats was their mortality, giving the scythe a symbolic representation of how life is not only short, but also can be quickly and decisively ended at any point. This had been seen, and still is seen, as perhaps an inspiration to take the fulfillment of life's purposes with urgency.

The image of Father Time is culled from several sources, including the Holly King (a mythical figure), the Celtic god of the dying year, and Chronus, the Greek god of time.

Source: Archive Holdings Inc./Getty Images.

A similar equivalent character in contemporary society would be the Grim Reaper, as he is also always seen carrying a scythe, and like Kronos is much feared. But awareness of the figure Father Time is not completely removed from current society, and still carries the same messages; he is even mentioned and sung about in popular music. Father Time possibly has another connection to current popular society through his striking resemblance to the figure of Santa Claus. In the year 354 CE, Pope Liberius, originally Peter Valvomeres, declared that the observance of the birth of Christ would be on December 25. It is thought that perhaps this was done in hopes of drawing attention away from the pagan Saturnalia (in which there was also gift giving). Some movies and books portray Father Time as even having a connection with Christmas by stopping or slowing down time, allowing for Santa Claus to have time to travel all over the world in one night. Father Time is also sometimes recognized in popular culture soon after, in the recognition of the New Year. It is seen that with each passing year, at the striking of midnight, Father Time takes the old year and "passes on" the duties of time to the Baby New Year, who will in turn be transformed into Father Time during the months ahead.

Patrick J. Wojcieson

See also Cronus (Kronos); Elixir of Life; Grim Reaper; Hourglass; Shangri-La, Myth of; Youth, Fountain of

Further Readings

Barnes, T. D. (1992). *The capitulation of Liberius and Hilary of Poitiers.* Toronto, ON, Canada: Phoenix.

James, E. O. (1960). *The ancient gods.* New York: Capricorn.

Fertility Cycle

The creation of new life has always mystified and intrigued human beings. One source of this fascination

Starving peasants in 1846 clamor at the gates of a workhouse during the Irish potato famine. Famines have killed millions of people throughout the centuries.
Source: Getty Images.

is the cycle of fertility, which governs the existence of all living things. Indeed, the short period many species have to reproduce makes each fertile season extremely important. For people, finding ways to encourage fertility has been a goal for centuries. We now know that many factors affect human fertility, including age, nutrition, physical health, hormones, and genetics. Even with the advancement of medical technology in recent decades it is still difficult for some couples to conceive. It is easy to see why ancient societies would have put so much hope in magic and religion. Worship of gods and goddesses, festivals, and sacrifices have all been practiced in the hope of promoting life.

As vital to the survival of human civilization as the fertility of men and women is the fertility of crops. The time constraints of the reproductive cycle also impact agriculture. Because of the limits of seed growth, famines have killed millions of people throughout the centuries. Climate factors and disease also can destroy an entire season of crops. For example, the potato famine of Ireland in the 1840s not only killed many people but also caused mass emigration from that country. Ancient cultures learned quickly that the survival of the harvest was vital to the survival of the people.

Most cultures have had deities associated exclusively with the celebration of spring's growth and the fall's harvest. Before the advent of modern biological science, people could only guess at what helped to encourage life. The earliest farmers believed that their crops were inhabited by spirits that caused them to thrive or die. It was believed that the spirits were released when the plants were harvested. The harvesters began to perform rituals to thank the spirits for the crops that survived. This tradition continued and was practiced in most of the major civilizations throughout history.

In Egypt, Osiris was worshipped as the god of agriculture and was often depicted with a green face representing fertility. He was also the god of the dead, showing the Egyptian belief in the connectivity of life and the afterlife. The story of his death and resurrection was used as an analogy for the cycle of life. Every year the Nile flooded the plains and made the soil rich and fertile. During this time the Egyptian people had a festival celebrating the rebirth of Osiris and the opportunity for a new harvest to grow.

The Greek goddess Demeter was the patron of agriculture and fertility. She was believed to have taught humans how to tend the soil and raise crops. Thesmophoria was the festival held in her honor. It took place right before the harvest in hopes of achieving a bountiful return. These celebrations of life often included music, sports, and feasting. The goddess was known as Ceres in Roman times; her name translates to mean "grain mother." Some believe that the term *Mother Earth* was created to describe this goddess.

Native North Americans celebrate the Green Corn Festival when the harvest is ready to be gathered. During the first few days people cleanse themselves and their homes to prepare to welcome the new crop. The festival lasts for many days and includes dancing, sports, and feasting. It is thought that the American tradition of Thanksgiving comes from colonists attending this celebration.

Every species' primary goal is to thrive and reproduce. To accomplish this, human beings have created many rites and rituals. Pagan groups revered rabbits as symbols of fertility. Rabbits can produce several very large litters every year, and females are able to be impregnated with a second litter while still carrying a first. Early peoples were amazed and envious of rabbits' extraordinary ability to procreate. The tradition of the Easter Bunny originated among early Christians in the incorporation of pagan spring traditions into the celebration of Easter, which occurred at the same time of the year.

Typical ancient African fertility goddess, carved on wood, West Africa. The worship of gods and goddesses, festivals, and sacrifices has all been practiced in the hope of promoting life. The fertility of crops is as vital to the survival of human civilization as the fertility of men and women.

Source: Diane White Rosier/iStockphoto.

The Greek goddess Aphrodite, known among the Romans as Venus, was worshipped as the personification of love, beauty, and sexuality. Her festival was the Aphrodisiac and was celebrated throughout Greece in the spring. During this time people ate and drank certain items that they believed would increase fertility. The term *aphrodisiac* is still used today to describe foods with these qualities. Some people believe Aphrodite's connection with water is the reason that some seafood is considered as such. During the festival, orgies were encouraged and sexual intercourse with a priestess of the goddess was considered the highest form of worship. Hera was the goddess of marriage and motherhood and was also prayed to for help with fertility and reproduction. Her Roman counterpart was Juno.

In ancient Egypt, Min was the god of fertility and sexuality. He was worshipped as a god of the harvest but was primarily seen as bestowing sexual powers. Min is often depicted with an erect phallus. In Egypt, lettuce was believed to be an aphrodisiac and was eaten in the spring to promote reproduction. Bast, the goddess of fertility and childbirth, was represented as a woman with the head of a cat. In Egyptian society cats were believed to be divine and to have the power to give life. There were many festivals for Bast throughout the year. As with Aphrodite, some of the Egyptian fertility festivals included orgies.

In recent decades the human population has increased dramatically. Health care and food preservation technology have decreased infant mortality and increased life expectancy. Overpopulation has become more of a dilemma for the human species than the fear of extinction. Consequently, some people now use medicine and technology to shorten or even stop both male and female fertility cycles.

Jessica M. Masciello

See also Birthrates, Human; Egypt, Ancient; Life Cycle; Longevity; Mythology

Further Readings

Graves, R. (1955). *The Greek myths: Complete edition.* London: Penguin.

Wilkinson, R. H. (2003). *The complete gods and goddesses of Ancient Egypt.* London: Thames and Hudson.

FEUERBACH, LUDWIG (1804–1872)

Ludwig Feuerbach, German philosopher, was noted for his materialistic interpretation of God/ Christianity and humankind within a temporal framework. Although his philosophical and anthropological perspective was established before the theory of evolution (1859) by Charles Darwin (1809–1882), Feuerbach understood that the emergence of consciousness allowed humankind to integrate intelligence and emotion with the understanding of human mortality. Consequently, the concept of God, theology, and religiosity manifested itself in various ways in order to bring both ontological and teleological fulfillment to a personal finite existence. This materialistic and heretical explanation encompasses a range of metaphysical implications from religion to scientific and philosophical enlightenment. Feuerbach recognized that God, prayer, love, and the desire for immortality are deeply rooted in the psychology of the human species. Essentially, God and his attributes are humanity's projection of itself that is juxtaposed within the finitude of human existence and understanding. Scientific and philosophical knowledge has aided (and for Feuerbach must continue in the future to aid) humankind's understanding of itself within an evolving universe. Feuerbach's major works include *Thoughts on Death and Immortality* (1830), *The Essence of Christianity* (1841), and *Principles and Philosophy of the Future* (1843).

Experience, Identity, and the Infinite

Feuerbach presented a unique interpretation of time conditioned by human experience. The combination of emerging consciousness tempered with external experiences allows for a shift in the personal beliefs expressed within the historical context of individual and social integration. In these terms, personal and social identity become transformation events that alter perception, morality, and anthropomorphic qualities of deities. The changing qualities of deities, as with the concept of immortality, denote the distinction of these temporal shifts in thought. From the lost perspective on mortality of the ancient Greeks and Romans to the independent governing factors in individual immortality, the concept of God(s) becomes both a temporal and superficial essence. Ultimately, this essence is humanity's finite projection of the infinite that is, God. During this projection, humankind surrenders its inner being to a self-created nonexistent entity.

In Feuerbachian terms, the concept of time, when finite and infinite are juxtaposed, creates a sense of temporal eternity by which finitude is expressed in personal mortality. This awareness of death, a complete termination and dissolution of life and spirit, is a precondition of human life limited by human reason. The human spirit, which is equated with consciousness and reason, is limited within these parameters of a material existence. Although individual existence and individuality are temporal, human thought is considered by some to be beyond time; albeit solely dependent on the temporally finite material body. This in itself raises a perceived paradox. For Feuerbach, temporal experience (finite) and thought (finite yet infinite within finite consciousness) foster a sense of infinity that is in itself a finite spatiotemporal existence. Personal immortality becomes an illusion that is less illustrious than an infinite and personal God.

As Feuerbach pointed out, God and religion mirror human nature. The concept of God, a created and projected illusion subjected to shifts in definitions within time, is unique in human thought. God has become the archetype for the simultaneous existence of both the material/nonmaterial and finite/infinite. Consequently, the expressions of anthropomorphic qualities of God—life, emotion, infinite consciousness—and nature are steeped in mystical interpretations of the human quest for immortality. The greatest manifestation of this quest is seen in the basic and contradictory principles of Christianity. Concepts of the Trinity, Christology, and the Resurrection combine the supreme ideal—nonmaterial, infinite, loving, and omnipotent—with the antithetical states of human life, the limitations and frailties of human existence. When compared in this manner, sin becomes a self-imposed conceptual prison from which humankind seeks to free itself, via prayer, and reaffirm itself in value and unifying identity. However, rational and critical thought expose several contradictions within religious thought as presented by Feuerbach; among them God (essence), doctrine, and revelation being the greatest of all contradictions.

Feuerbach held that humans are unique in the animal world. Essentially, humans are held to be universal beings that reflect the totality of their being: unlimited and free. Artistic creativity, philosophical contemplation, and science are signs of this totality or unity. Differing from Aristotelian, Platonic, medieval, or modern philosophy/theology, the materialistic completeness or unity is regarded as the essence of being human. It signifies a metaphysical shift to a form of materialism that encompasses all known reality of human existence. Furthermore, Feuerbach understood the relevancy of scientific advancements—that is, creativity precedes science—and the role of philosophy in ultimately reclaiming humanity's loss and bringing about a completeness of being. This process begins with the task of what Feuerbach stated as the transforming and dissolving of theology into anthropology. Though Protestantism was considered as the beginning, Feuerbach would find today's humanism and advancements in science, especially in anthropology, biology, and psychology, as a progressive step in fulfilling this philosophical transformation. It is uncertain what direction this futuristic philosophy would take. However, the abstract notion and metaphysical implications of infinity and finitude will be redefined in the light of creative scientific advancements in biology (including physiology), physics, and technology; all of which will bring about a refined ontology and self-directed teleology. This signifies a continuous and dynamic process, as seen in Feuerbach's philosophical framework.

Feuerbach's Impact on Philosophy

The consequence of Feuerbach's thought on philosophy has been profound. Although materialism and naturalism were not new philosophical perspectives, Feuerbach did provide a new direction in the explanation of the human condition. His understanding of theology, particularly Aquinas and Hegel, combined with the spirit of the Enlightenment sought to free humankind from its perceived illusions of God and religion. This philosophical, albeit psychological, explanation forced a progressive reevaluation of the terms by which life and time are understood. Unlike Friedrich Nietzsche (1844–1900) in his proclaiming the death of God and the eternal recurrence, Feuerbach's humanization of God and religion becomes less nihilistic but retains discomforting thoughts about human finitude and mortality. Within the concept of time, human existence, both individual and as a species, is tenuous. In Feuerbach's view of reclaiming all parts of humanity, a complete unity of being can be attained and human fulfillment achieved. This is the essence in the finitude of humans in relation to the external world.

David Alexander Lukaszek

See also Farber, Marvin; Humanism; Infinity; Marx, Karl; Materialism; Nietzsche, Friedrich; Revelation, Book of; Wagner, Richard

Further Readings

Feuerbach, L. (1980). *Thoughts on death and immortality.* Berkeley: University of California Press. (Original work published 1830)

Feuerbach, L. (1986). *Principles of the philosophy of the future.* Cambridge, MA: Hackett. (Original work published 1843)

Feuerbach, L. (1989). *The essence of Christianity.* Amherst, NY: Prometheus. (Original work published 1841)

Fichte, Johann Gottlieb (1762–1814)

Johann Gottlieb Fichte was born on May 19, 1762, near Bischoffswerda in Saxony. He was a prolific writer, but space permits only a few of his works to be mentioned here. His ideas on time resolved largely into his notion of history.

Fichte studied at the prestigious University of Jena and then became a private tutor in Switzerland. Inspired by Kant's critical philosophy, Fichte published *Versuch einer Kritik aller Offenbarung* (*Attempt at a Critique of All Revealed Religion*) anonymously in 1792. Kant praised the work and made public that Fichte was its author. This made Fichte a formidable intellectual in the public mind, but the work's critical nature aroused suspicions of atheism. Fichte was greatly gifted in rhetoric, and he gained a wide reading audience in a series of publications. In 1793 he was offered a professorship at Jena at the suggestion of Johann Wolfgang von Goethe. He published a work in the same year designed to sway the German public to support the French Revolution. In the next year, *Grundlage der gesammten Wissenschaftslehre* (*Groundwork for* *the Entirety of Science*) appeared, which contained Fichte's attempt to turn Kantian metaphysics into a science deriving from a single principle. In their most exact form, Fichte's metaphysical ideas on time are found in the *Groundwork*. There followed *Das System der Sittenlehre* (*Science of Right*) in 1798, which showed the public that Fichte's scientific idealism would be a highly ethical, even moralistic and preachy, sort.

When he published *Über den Grund unseres Glaubens an eine göttliche Weltregierung* (*On the Grounds of Our Belief in a Divine World-Order*) in 1799, Ficthe ironically came into conflict with the University at Jena over charges of atheism. He had suggested in this work that the divine world-order requires human agency to become actualized. But the orthodox view was, of course, that the Divine Will of God cannot be thwarted by human free will, and the university officials supported orthodoxy. So Fichte moved on to Berlin.

There he published *Die Bestimmung des Menschen* (*The Vocation of Man*) in 1800. This highly popular work made his obscure scientific system accessible to the general reading public. Though *The Vocation of Man* was short on detail, the reader could discern the outlines of Fichte's notion of time. Strictly speaking, *secular time does not exist,* according to Fichte. Time as a metaphysical form and time as all of human history, have an essentially *sacred* nature. Time, independent of a Divine Will, simply cannot exist, because the internal form of intuition is a tool in the hands of the Creator; further, all historical events are manifestations of his will, for Fichte, but are achievable only if human beings freely choose sacred time. Man's free will creates the Divine world-order, in short, a notion that alarmed some readers. This insistence that *all time is sacred* sought to rescue history from empirical (English) science and from Spinozism. In this sense, Fichte's notion of history is more akin to Herder and Jacobi than Kant.

Fichte was awarded a professorship at Erlangen in 1805. In a series of lectures, Fichte argued against Schelling, among many others. While at Erlangen he also published *Reden an die Deutschen* (*Addresses to the German Nation,* 1800) to rally Germans after their defeat by Napoleon. In 1809 he became a professor at the University of Berlin. Fichte died on January 27, 1814.

Reputation as a Philosopher

Among his contemporaries, Fichte's reputation as a philosopher fluctuated wildly. In his *Lectures on the History of Philosophy,* Hegel judged that Fichte had completed and improved Kant's system. Fichte's one-time student Arthur Schopenhauer, on the contrary, considered Fichte to have been a charlatan capable of advanced rhetoric, but no more. The court of history, at least to date, has largely relegated Fichte to having been a minor idealist philosopher between Immanuel Kant and Georg Wilhelm Friedrich Hegel. And Fichte's status as an important figure in early German nationalism and the proto-Fascist economic system, and as an anti-Semite, has not aided his reputation. For recent scholars more interested in a philosophy of nature, Fichte has been overshadowed by his younger-yet-close friend Friedrich Wilhelm Joseph von Schelling.

Fichte on the Ego

Once Kant had introduced his "critical philosophy," thinkers began to question whether he had deduced the transcendental ideal structures of the "noumenal world," including time and space, correctly. Each post-Kantian philosopher reinterpreted and/or restructured the newly discovered noumenal world according to his own vision. For his part, Fichte reduced Kant's noumenal structures to the "transcendental ego," which he considered co-terminal with man and God, or more accurately, absolute ego is the identity of transcendental and empirical ego.

He began with the principle of identity, A = A, which would serve as a foundation for German idealism. Fichte played on the ambiguity between empirical ego and transcendental ego, and took the principle of ego (I = I), or the autonomous free self, to be the supreme principle upon which the rest of his idealist system would be based.

And yet the ego supported only his "science of knowledge." There is also faith in God, the transcendental ego, which in turn supports the empirical ego. God's existence is of the greatest certainty, and is the truth transmitting certainty to all other truths, argued Fichte in *The Vocation of Man.*

God has a Divine Plan, which has been produced through the transcendental ego and empirical ego.

Why this plan, and not another, was chosen by God, Fichte admitted was the great mystery of the world. Still, in Fichte's deeply religious worldview, the vocation of man is not only to know, but to have faith, too.

Fichte's Ideas on Time

As for time, Fichte accounted for it, like everything else, as a product of the self-positing I = I. The ego most certainly exists, he argued, in agreement with Descartes. In its second logical moment, however, the ego posits an object (a "non-ego") outside itself. "Inasmuch as I posit another in opposition to the ego, I posit myself as not posited." In other words, the ego structures objects that it then places outside itself, as if they were independent of the ego. The ego takes objects not as its own production but as part of an outside world. Yet all determinations of the object are ideal.

Time and space are examples of the division of ego and non-ego, which limit each other. Time limits space, and space limits time. The self views its own mental faculties operating in time but considers objects to exist outside, in space. In terms of identity,

I = Time, whereas Not-I (Object) = Space

In the third moment of his logical system, both ego and non-ego are partially negated to arrive back at the identity of ego with itself. For Fichte, this third moment is always moral and religious in nature. And so in this sort of spiritual insight, the limitations of one's own empirical ego are recognized, but also the limitations of the outer world constructed by the ego in the form of non-ego. The empirical ego, in its *partial negation,* comes to understand its own higher identity with the transcendental ego.

This means that the entirety of time has been produced from sensations and transcendental structures for a distinctly religious, moral purpose. (This notion that time is essentially a means toward a hidden divine end can be traced all the way back to Anaximander at the dawn of Western thought, but most directly from Herder.) Human beings are challenged by life not only to learn and know, but also to act—that is, to act morally. Only in this way does humankind bridge the subjective element of its existence with the objective world, which in the moral third moment is an ethical ideal outside one's self. Thus his idealism ended in a rather uncompromising piety.

Evaluation

From a Hegelian perspective, Fichte set out with the identity of subject and object, but then privileged the subjective as the absolute, after all. There was no final place for nature in his account; the ego produces all of time and space. For Hegel, Fichte came back again and again to only the empirical ego, and so was a subjective idealist. Even though Hegel considered Fichte's logic much clearer than Kant's method, history has judged otherwise. Much of Fichte's obscure argumentation met with criticism among his contemporaries.

To his great credit, though, Fichte's major contribution, again according to Hegel, was in his insistence that philosophy must become a scientific system following from a single principle.

Greg Whitlock

See also Goethe, Johann Wolfgang von; Hegel, Georg Wilhelm Friedrich; Herder, Johann Gottfried von; Hegel and Kant; Idealism; Kant, Immanuel; Schelling, Friedrich W. J. von; Schopenhauer, Arthur; Time, Sacred

Further Readings

Fichte, J. G. (1994). *Introductions to the Wissenschaftslehre and other writings, 1797–1800* (D. Breazeale, Ed. & Trans.). Indianapolis, IN: Hackett Co.

Fichte, J. G. (2005). *The science of knowing: J. G. Fichte's 1804 lectures on the Wissenschaftslehre* (W. E. Wright, Trans.). Albany: State University of New York Press.

FILM AND PHOTOGRAPHY

Film is traditionally understood to be the material medium that unites photography and cinematography. Photography and cinema are, together, distinguished from other media by sharing this material basis. In fact, the earliest photographers did not use film, but, rather, glass or polished metal plates, and a modern photographer or cinematographer is increasingly likely to use electronic means of recording rather than film. Nevertheless, film is the best starting point for appreciating both what these media have in common and what differentiates them. Specifically, they differ in respect of their representation of time: photography produces a still image of a moment frozen in time, whereas cinema employs film to produce a moving image that shows time passing. The representation of time, the technological control of time, and the viewer's experience of time are all features that have crucial importance for the application and the value of film media.

The term *photography* was established by John Herschel (1792–1871), in an 1839 presentation to the Royal Society in England. The Greek words *photos* (light) and *graphis* (paintbrush) or *graphê* (drawing) convey the idea of "drawing with light." Light from a scene is recorded on a photosensitive surface, such as chemically treated film or an electronic sensor. In the case of photography, the data are subsequently processed and printed to produce a still image. A photographic image, or photograph, is sometimes called an exposure because the photosensitive surface is exposed to light for a finite duration of time and records only the data available during that exposure time. In the case of cinema, a large number of individual exposures are projected sequentially onto a screen and, from the perspective of the viewer, the result is a moving image—known as a motion picture or movie. *Cinematography* is from *kinesis* (movement). The photographic image typically has just one relevant time constraint: the duration of the exposure time. The cinematic image has other relevant time constraints: in addition to the exposure time, the image is also a function of the speed of the cine-camera—the rate at which frames are exposed—and the projection speed—the rate at which frames are screened.

History of Photography and Cinema

A camera obscura (Latin: *camera*—room, *obscura*—dark) is a darkened room in which light from an outside scene is channeled through a narrow aperture, by lenses and mirrors, to form an image on a screen. However, the resulting image is not a photograph; instead, the image we view inside a camera obscura moves in real time on the screen and leaves no permanent record. Artists can produce a hand-traced outline from the image, and light-sensitive surfaces can react to produce a temporary image; but these are not photographs. A photograph occurs when an image produced by exposure to light is fixed and made to persist over time. The process can be entirely chemical or mechanical, so it can occur without human involvement. This led the first practitioners to claim that photography was the "spontaneous" or "automatic" reproduction of nature by itself, and some argued that photography was a discovery rather than an invention. The term *camera* is now used for any mechanical apparatus that records data in this way. A camera typically has three key elements: lens, shutter, and photosensitive surface. The lens, along with an adjustable opening (the aperture), focuses light onto the photosensitive surface. The shutter mechanism opens and shuts to control the duration of the exposure to light.

The Heliograph

In 1826, Joseph Nicéphore Niépce (1765–1833) succeeded in producing a fixed image from a camera obscura by a process he called Heliography (sun-writing). His image of the view from an attic window achieved important status as the first photograph precisely because it is an enduring image created entirely by an exposure of light on a photosensitive surface. Niépce is not considered the sole originator of photography as history recognizes technical contributions from numerous people working independently and simultaneously. As many as 24 individuals have some claim to have invented photography. Two early contributions to the photographic process deserve special note: the daguerreotype and the calotype.

The Daguerreotype

Niépce's 1826 heliograph, *View From a Window at Gras,* required an exposure time of some 8 hours. With the aim of creating a faster exposure time, he shared details of his process with Louis-Jacques-Mandé Daguerre (1787–1851), who took over the project after Niépce's death and gave his name to the resulting process. A daguerreotype began as a sheet of copper, plated with silver and highly polished. The plate was treated with iodine fumes to give it a light-sensitive surface of silver iodine. The first daguerreotype images had an exposure time of 4 or 5 minutes, and the photographic image became visible when the latent image was first treated with mercury fumes, then fixed with a solution of table salt (sodium chloride). The process results in a "direct positive" print, which is extremely delicate and each image is unique. *Still Life (Interior of a Cabinet of Curiosities),* 1837, is thought to be the oldest surviving example. In 1839 the process was made public to the world by the French Academy of Science.

The Calotype, or Talbotype

In England, William Henry Fox Talbot (1800–1877) developed a process he called "photogenic drawing." Unlike the daguerreotype, which produced a single inverted image, Talbot's process involved the creation of a negative on chemically sensitized paper, from which multiple positive prints could be made. He called this image a calotype—from *kalos* (beauty); an example of a calotype negative survives from 1835, titled *Lattice Window Taken With the Camera Obscura.* Calotypes could be multiply reproduced, but, hindered by long exposure times and problems arising from paper texture, the positive prints were usually indistinct. Daguerreotypes offered a superior quality image, with exceptionally sharp detail. For many years the daguerreotype was more popular among the public, particularly for portraiture. However, in 1851 the collodian wet-plate process replaced Talbot's paper negatives with glass plates and speeded up the exposure time. Ultimately, Talbot's negative–positive process proved to be the prototype for the future of commercial and popular photography.

The Stereograph

Throughout the 19th and early 20th centuries, the stereograph, from *stereos* ("solid") and *skopein* ("to look through"), was one of the most popular forms of photography. A stereograph is created by recording two images of a scene, simultaneously, but from slightly different locations. The two prints were placed side by side in a special viewer, one to be viewed by the left eye and one by the right eye. Viewing a stereograph in this way generates an illusion of three-dimensional space. Such was the demand for this format that a stereoscopic camera was produced. Equipped with two lenses, this camera was specifically designed to take two photographs at the same time. This format has subsequently entirely disappeared, not least because the stillness of the scene fails to entertain modern eyes more accustomed to moving images.

The Kinetoscope and Cinématograph

Even prior to the invention of photography, various devices had been designed to produce a moving image from static pictures. A moving picture is, really, an illusion of movement, created when one image is replaced by another in such a short period of time that the human eye registers the change as though it is the movement of an object. This phenomenon is known as "the persistence of vision." Many of the earliest devices used a rotating cylinder to generate a rapid succession of images. The viewer looked at a fixed point through a series of narrow slits in the rotating drum and saw an apparently moving image. These devices were merely entertaining parlor toys, whereas the invention of cinema in the late 19th century owed its origins to a breakthrough from the world of photography.

Two basic elements are essential for cinema: First, we need an apparatus that records a series of images in sequential time order; second, we need an apparatus that screens the series of images in sequential time order. There are numerous different ways to satisfy one or the other of these requirements, but the invention of celluloid photographic film in the late 1880s provided a straightforward way to satisfy both at once. The advent of film caused the birth of cinema, so it is understandable that the term *film* is used, both as a noun and in verb form ("to film"), as an abbreviation for cinema, but not for photography even though film has been the material medium of both. Roll film provided not just a means of recording a sequence of exposures, but, crucially, also a means of controlling the time sequence when screening the images. The innovations leading up to this point show why film provided the breakthrough that led to the cinematic revolution.

The pioneers of photography investigated two approaches for recording a series of time-ordered images: one solution is to have multiple cameras, each making a single exposure at timed intervals; another solution is to have a single camera making multiple exposures one after another. In the 1870s, Eadweard Muybridge (1830–1904) produced a time-ordered sequence of a running horse using a row of 12 cameras. The shutter of each camera was triggered by cotton threads as the horse ran past. In 1874 scientists were able to use a "revolver camera" to record the transit of the planet Venus across the sun. This camera gun, devised for the purpose by César Jules Janssen (1824–1907), made 48 individual exposures around a circular daguerreotype plate.

Inspired by these ideas, Étienne Jules Marey (1830–1904) developed a process he called chronophotography (time photography) in the early 1880s. Marey used a spinning disk in front of an ordinary camera lens. The disk had slots at regular intervals so that a moving subject appeared at a different position every time an open slot permitted an exposure. The result showed the movement of the subject as a series of overlapping images on a single photographic plate. Eventually, Marey designed a camera to produce a series of multiple exposures that did not overlap. To achieve this he required the light-sensitive surface to move for each new exposure, so the medium needed to be flexible and robust. Glass and metal places were unsuitable, but, when celluloid photographic film became available in 1889, Marey was able to produce a short "film" showing the movement of the human hand. A contemporary inventor, Louis Le Prince (1841–1890), patented a 16-lens motion-capture camera in 1886, but this was unsatisfactory as it recorded images from slightly different angles. By 1888 Le Prince had developed a single-lens camera-projector and used this to record exposures at 12 frames per second on paper-based Eastman Kodak film. Fragments of his first motion picture, *Roundhay Garden Scene,* have survived, and Le Prince is one of several figures who are credited with the invention of cinema.

Thomas Edison (1847–1931) invented the kinetoscope in 1894. This was known also as the peep show because images were screened inside a box and viewed by one person at a time. The kinetoscope screened a 50-foot length of celluloid film at 48 exposure frames per second, and the entire show lasted only 13 seconds. In 1895 the Lumière brothers, Auguste (1862–1954) and Louis (1864–1948), unveiled their Cinématograph, which used a film projector to screen films to a group audience. The majority of early films were studies of human or animal movement and, although cinema would very quickly expand into creative and unconventional treatments of the time sequence, the first film audiences were fascinated simply by viewing the moving image of an ordinary event occurring in real time.

Technology and the Control of Time

Photography and cinema are highly dependent on technical apparatus and therefore particularly sensitive to technological progress. Whenever practitioners have reached the limits of existing equipment, they have urgently invented new camera apparatuses and devised innovative means of production. In this way the creative impetus has driven technological progress, but new technical advances have also produced surprising applications. A survey of the most significant technological advances points to one primary technical challenge: the control of time. The production of a photograph has three stages: preparation time, exposure time, and processing time. Technological progress has dramatically altered the time and resources needed for each of these stages.

Film and Film Speed

Early photographers were forced to spend hours working with raw materials to prepare wet-plates. The laborious preparation time for each photograph removed any prospect of spontaneity; plus the size and amount of equipment required was an encumbrance to the photographer. Photography required wealth, leisure time, technical skill, and some degree of physical strength. A pre-prepared dry-plate process was developed in the 1880s, and in 1889 George Eastman (1854–1932) launched the first celluloid roll film. These technical advances dramatically reduced the burden of preparation time and expensive equipment, but also generated an important further advantage: faster film speeds. Film "speed" is a measure of the threshold sensitivity of the film surface. The current international measurement of film speed is the ISO scale. A representative section of the scale (from slow to fast) is: ISO 100, ISO 200, ISO 400, ISO 800. With greater sensitivity, a film is quicker to respond to the available light. Hence as film speed is increased, exposure times can be decreased. Long exposure times require a camera to be securely mounted, but short exposures make it possible to use handheld cameras. Thus by the time the first drop-in film cartridge was marketed in 1963, cameras were cheap, quick, simple to use, and easily portable, making spontaneous photography available in any location and at any moment.

Automation: Shutter, Exposure, and Flash

Exposure times can be reduced by faster film speed, but also by increasing the level of available light. From the 1860s, photographers created additional light by burning highly explosive magnesium flash powder. Flash technology became less dangerous with the invention of the flashbulb in the 1920s, but photographers still needed to activate shutter and flash separately. In the mid-1930s the mechanisms for flash and shutter were made to synchronize, thus providing far greater control over the timing of the photograph. By the 1950s this became a standard feature on popular cameras.

The first cameras were limited by manual exposure times. A photographer removed the lens cap to start the exposure and replaced the cap to finish. The introduction of mechanized shutters provided much greater precision and control and made it possible to work with exposure times far faster than human action allows. By the end of the 19th century, shutter speeds as high as 1/5000th of a second were possible. When combined with roll film, faster shutter speeds also increased the number of separate exposures that could be taken during a given period of time. The fastest modern SLR (single lens reflex) cameras can make 10 exposures per second.

Even with these mechanical aids, photography still required human expertise for judging the optimum exposure time. However, in 1938, Kodak manufactured a camera equipped with a sensor to calculate the exposure time. Combined with the other technical advances, it was marketed as the world's first fully automated camera.

Developing and Printing

Wet-plate photography necessitated that photographs were processed only a short time after the chemicals had been exposed to light, otherwise the image would not be preserved. This made it extremely difficult for a photographer to freely choose the time to take a photograph, a constraint that is evident in the subject matters favored in the 19th century. For example, photojournalism during the American Civil War was limited to images of the battlefield before or after the action took place. Even when dry-plate and film technology made it possible to process photographs after a reasonable delay, photographers were forced to spend long hours in the darkroom to develop film and enlarge prints from the negatives.

In the 1880s, Eastman marketed the first commercial developing and printing service, which gave the public an alternative to this time-consuming occupation. Kodak publicized the service with a now legendary slogan: "You press the button, we do the rest." With the advent of a developing and printing service, photography enthusiasts were free to pursue their hobby in two alternative directions. Many welcomed the convenience of the commercial service, but others saw processing as an integral part of generating their desired final image. This included techniques such as dodging and burning, where light projected through the negative enlarger is selectively blocked, to compensate for areas of overexposure or underexposure in the negative. In the 20th century, photography clubs became enormously popular and provided ample evidence that photographers across the social spectrum were prepared to invest the time required to master the darkroom arts.

The introduction of color film revealed the extent of this trend. Setting aside earlier experimental versions, the first color film was introduced for movie cameras in 1935, followed by a version for still cameras in 1936. The procedures required for developing color film and producing color prints were disproportionately laborious, even for the enthusiast, and the results were typically less successful than commercial prints. Hence, although color photography became increasingly common for the commercial mass market, enthusiasts in photography clubs preferred to print from black and white film, at least until the advent of digital photography in the late 20th century.

Whether processed by a commercial company or in the darkroom at a photography club, there was still a considerable time lag between making an exposure and viewing the printed image. To satisfy demand for instantaneous results, the first "instant" camera was produced by the Polaroid Corporation in 1948. Invented by Edwin Land (1909–1991), the automated process was able to deliver a sepia-colored print within one minute. The mechanism spreads chemicals over the surface of the film and each chemical reacts according to a time delay, so that each layer of the film is processed in the right order. By 1963 the Polaroid camera was able to produce "instant" prints in color.

Digital cameras do not require a chemical developing process, and an electronic image can be viewed immediately on the camera's own LCD (liquid crystal display) screen. The speed with which a photograph can be viewed is highly important because the power of film media does not lie just in its ability to record events, but also in the possibilities for disseminating images widely and quickly. A daguerreotype image could be disseminated only if it was first translated into an engraving, so rapid publication, such as for newspapers, was out of the question. In the present day, it is commonplace for a mobile phone to contain a digital camera, so photographs and video clips can easily be sent around the world within seconds.

Cinematography

The earliest cine-cameras were cranked by hand, so the speed at which exposures were recorded could be uneven. Most early movies were recorded at between 16 and 23 frames per second. However, nitrate-based film was highly flammable and liable to catch fire if projected at low speeds. Movies were therefore often projected at speeds higher than 18 frames per second, and this produced the appearance of accelerated, unnatural action in the moving image. This is because the perceived speed of an event, from the perspective of a viewer, is calculated by dividing the projection speed by the camera speed. At present, when a moving picture is screened at a cinema theater, images are invariably projected at a rate of 24 frames per second. Hence, when old movies are screened, the images appear to move at an absurdly fast pace. In some cases this phenomenon was deliberately exploited to comic effect by cinematographers.

Even when the standard projection speed of 24 frames per second is maintained, from the perspective of the audience, events can be made to occur faster or slower than the real-time event. The phenomena of high-speed photography and time-lapse photography both exploit the principle that the time-span of the recording can differ from the time-span of the screening. A cine-camera typically exposes film at a rate of 24 frames per second. Each frame is exposed to light for half the time and blocked by the shutter for half the time (i.e., each frame has an exposure time of 1/48 of a second). Time-lapse photography makes exposures at an extremely slow rate—this is sometimes called undercranking. If a camera records a 4-hour event by taking an exposure every minute and the exposures are screened at 24 frames per second, then the 4-hour event will be speeded up and appear to last only 10 seconds.

High-speed photography is known as overcranking because it requires the cine-camera to record exposures faster than 24 frames per second. When the exposures are screened at 24 frames per second, the event will appear to take place in slow motion.

The earliest cine-cameras recorded only the data of light from the scene, so until the 1920s, the results were moving pictures without sound: silent movies. In a significant departure from still photography, cinematographers sought to find a way to record sound—and their main problem became how to make the sound synchronize with the visual action. Again, film provided an elegant technical solution: Sound was recorded onto a magnetic strip along the edge of the photographic film. This ensured that an actor's voice would be heard to speak at the same time as his lips were seen to move. In fact, in 1929, the projection speed standard of 24 frames per second was established precisely because this was the optimal speed for the kind of film used for "talking movies" (talkies).

The Digital Future

Many interesting and important questions about photographic technology have arisen since the rapid emergence of digital photography. Digital cameras were designed by NASA in the 1960s for use in satellite photography. In 1981 Sony demonstrated the first consumer digital camera, and since 2003 digital cameras have outsold film cameras.

In a digital camera, light is captured by an electronic photosensitive surface and the data are digitized into binary code. One significant difference is that the wavelength of light is "interpreted" by the camera software, rather than registered as chemical changes in the surface of the film. In early digital cameras this process created an inconvenient time lag between triggering the shutter and recording the data; however, advances in microprocessor technology have subsequently solved this problem.

Digital photography does not, strictly speaking, involve a negative, so it might appear to have ended the dominant tradition of the negative–positive process. In fact, the digital file that stores data performs a function similar to the latent image on a negative because the binary data it contains needs to be accessed and processed in order to produce a visible "print." Postprocessing of an image, using computer software, has replaced the traditional darkroom work of dodging and burning, and has made possible many other manipulations, so it is still possible to spend many hours on an image before the final version is printed or screened.

It is increasingly common for digital photographs to be viewed and stored only on computers, rather than printed on photograph paper. Digital images are stored as binary data in computer files, hence in principle they can be copied, transferred, and saved for an indefinitely long period of time without degrading. However, archivists of digital photographs face the task of constantly updating the existing digital files, otherwise they could be lost as the retrieval technology becomes obsolete.

Unlike fully manual film cameras, digital photography requires electrical power, and a battery provides power for only a finite period of time. Modern photographers are thus subject to at least one time constraint that is different from, but reminiscent of, the problems that faced their predecessors.

Applications of Film and Photography

Film media are thought to hold a privileged epistemic position by virtue of having a guaranteed causal and temporal relation to reality. Each individual image has a causal relation to the light reflected or emitted by real objects in the world at an actual moment in time. Although a highly abstract image may not resemble any recognizable objects, nonetheless that image was caused by capturing the light from particular objects during a particular period of time. This essential characteristic shapes the applications and the value of photography and cinema.

Documentary

Much of the power of film media stems from their having a documentary function and, when viewed as a document of an event, it seems to matter greatly that a photograph or film was actually exposed at the time it appears to have been exposed. Periodically this feature has been emphasized and exploited, or subverted and resisted. There are two strong trends throughout the history of photography: one emphasizes the ideal of an unaltered image, produced without any retouching of the negative or print. The other embraces manipulation and postprocessing as an intrinsic aspect of a photographic image. Associated with the former we find the idea that a photograph stands in a special relation to the specific moment in time when the data were recorded. Nothing is subsequently allowed to add or take away data recorded at that moment. With the latter trend, we find the idea that a photographic image is not straightforwardly a record of a specific moment in time. Rather, it is the product of various processes and decisions that occur over an extended time and include the exposure as only one factor.

Although this debate persists, it is a fact that manipulation has been a feature of photography from the very beginning. The negative of a calotype could be retouched by scratching the surface before a print was made. In 1851, Edouard Baldus joined together parts from 10 negatives to produce a single print, the *Cloister of Saint Trophîme, Arles,* thus challenging the idea that a photograph necessarily represents a single exposure time.

There has long been a demand for additional evidence to verify when, in physical time, a photograph was taken. In 1914 the Kodak "autographic" camera enabled the photographer to write notes directly onto the undeveloped film while it was still in the camera. Later cameras automated the process of time and date stamping each image, and digital cameras record these data as part of the digital file. However, even a time-stamped image is not a guarantee of epistemic authenticity. It is possible for a photographer to reconstruct an event or reconfigure a scene in order to control the image. This, too, has been a feature of photography since its inception. The public did not object when Alexander Gardner (1831–1882) positioned a rifle next to a dead body for his 1863 Civil War photograph *Home of a Rebel Sharpshooter;* yet the 1945 World War II photograph *Marines Raising the American Flag on Iwo Jima* has been attacked following allegations that Joe Rosenthal (b. 1911) had merely photographed a repetition of the original event.

Despite these concerns, from photojournalism to the photo-finish image that gives a race result, we rely on photographs to stand as evidence that an event took place, or provide evidence about visual appearance at a particular time. This is true of formal contexts, such as law courts and passport photographs, and of informal contexts such as the holiday and wedding photographs in a family album. In both public and personal uses of photography, it seems that we use its documentary function on the one hand to highlight change and on the other hand to preserve against change.

Science

The first scientific applications of photography were reference book collections of scientific specimens. For this use photographs were treated simply as a superior substitute for hand drawings. Before long, however, scientists employed photography to make scientific observations that would not be possible by any other means. In particular, photography makes it possible to observe events that occur too fast for human perception and also to observe light from sources too faint for the human eye to detect. These applications require, respectively, very short and very long exposure times.

Muybridge's and Marey's studies of human and animal motion attracted scientific attention, and Muybridge's 1878 series, *The Horse in Motion,* conclusively proved that a galloping horse raises all its hooves off the ground at the same time. In these experiments exposure time was controlled by shutter speed, but to achieve motion-stop photography of much faster objects, electronic flash photography was essential. In 1851 Talbot created the first flash photograph, using the illumination from an electric spark in a dark room. The exposure time was 1/100,000 of a second—far quicker than any shutter action could produce. In 1931 Harold Edgerton (1903–1990) invented an instantly rechargeable flash mechanism he called the stroboscope and produced motion-stop photographs that fascinated the scientific world, including a bullet piercing a line of balloons and the coronet formed by a splashing drop of milk. Exposure times of a billionth of a second are possible, and the sound waves from bullets moving at 15,000 miles an hour have been "frozen" in a photographic image, making photography an instrument for scientific discovery.

As early as 1839 Daguerre produced a photograph of the moon, and astronomers soon understood that the exceptionally faint light from stellar objects could be recorded on film using extremely long exposures. Light that is too faint for the human eye to detect can accumulate over time on a photosensitive surface and eventually produce a strong image. Through photography, it is possible to observe areas of the universe that are invisible even with the most powerful telescopes—and, uncannily, to observe stars that ceased to exist millions of years ago.

Art

The enormous range of artistic movements in film and photography are too many and too varied to detail here, but it is significant that the supposed objectivity of photography, which made it so suitable for recording scientific observations, initially made it seem unsuitable as a basis for artistic work. Even now, despite the photographs exhibited in art galleries and a long tradition of art discourse, there are still figures who deny that it is possible for a photograph to be an artwork. More generally, it is recognized that, although a fully mechanical or automated photograph is possible, many photographs are valued artistically due to the creative contribution and thought processes of the photographer. Henri Cartier-Bresson (1908–2004) encapsulated this idea when he epitomized the composition of his photographs as "the decisive moment." Elsewhere, even stronger claims have been made to support the view that photographs can be an art form: the critic Susan Sontag (1933–2004) went as far as to claim that the passing of time gives aesthetic value to most photographs, however mundane.

The Viewer's Experience

The viewer of a photograph is able to control the amount of time spent viewing the photograph. The viewer of cinema has a significantly different experience. Photographs are, first and foremost, viewed privately. Multiple copies exist and individuals view individual copies in their own time. Cinema, first and foremost, involves a public viewing. The audience shares a period of time together and the duration of the viewing experience is dictated by the projection time of the movie.

Film media have a unique standing among visual media because they are considered to be such a close substitute for a visual experience that they seem more reliable than human memory, or even can be treated as surrogates for memory after time has passed. This along with an idea that every photograph is essentially a *memento mori*—a reminder of the inevitability of death—is condemned as a cliché by critics and psychologists, but it is undeniable that photography retains powerful associations with poignancy, nostalgia, and loss. The experience of viewing a photograph of one's own ancestor, long dead, is commonly felt to be disturbing and moving in a manner that is unlike viewing even the most realistic painting. A photograph, it has been argued, is "transparent" to the scene at the time it was taken; hence when we look at such a photograph, we are genuinely looking back in time.

In our digital, postfilm era, it is no longer strictly correct to characterize photography and cinema as film media. However, film remains an important feature of their shared history. And history shows that, thanks to film and photography, we have gained new and remarkable ways to experience time and we now have a relation to time and the world that would otherwise not be open to us.

Dawn M. Phillips

See also Clarke, Arthur C.; Perception; Photography, Time-Lapse

Further Readings

Barthes, R. (2001). *Camera lucida*. New York: New Library Press.

Clarke, G. (1997). *Oxford history of art: The photograph*. Oxford, UK: Oxford University Press.

Ford, C. (Ed.). (1989). *The Kodak museum: The story of popular photography.* North Pomfret, VT: Trafalgar Square Publishing.

Hoy, A. H. (2005). *The book of photography.* Washington, DC: National Geographic.

Marien, M. W. (2006) *Photography: A cultural history* (2nd ed.). London: Lawrence King Publishing.

Sontag, S. (1979). *On photography.* London: Penguin.

Szarkowski, J. (1966). *The photographer's eye*. London: Secker & Warburg.

FINITUDE

Finitude is the quality of being finite, or having an end. In this sense it can refer to a length of time, a quantity, or a physical space. It is the opposite of infinity.

Finitude in Mathematics

In mathematics, a set of numbers is a "finite set" if the number of elements can be counted and the total represented as a natural number (e.g., a positive integer). A finite set cannot be put into a one-to-one correspondence with a subset of itself (e.g., a set of the numbers 1 through 10 cannot be matched with a set of the numbers 2 through 8). This is contrasted with an infinite set (e.g., a set consisting of all multiples of 2, an infinite set, could be matched in a one-to-one correspondence with a subset consisting of all multiples of 10, since neither the set nor the subset come to an end).

A "finite decimal" refers to a number that comes to an end, such as 1.543. This is contrasted with a "repeating decimal," in which the same digits are repeated infinitely, represented in the format 2.714714714. . . .

Finite Resources

The second law of thermodynamics states that energy cannot be used indefinitely, and that available usable energy is a finite resource. In this sense, the word *finite* is often applied to the supply of the world's natural resources, as in "finite resources" (also called "nonrenewable resources"). Finite resources, such as oil, coal, and natural gas, are produced at a slower rate than they are consumed, and thus will eventually run out.

Finitude in Humans

The finitude of the human lifespan has been a source of many questions and arguments in theology and philosophy. Pascal, using the finitude of human life as an argument for theism, stated that without God, a person's life would be meaningless because he or she would eventually die. It has also been used as an argument for atheism, encouraging people to make the most of their time on Earth, rather than preparing for an afterlife. In his essays, Albert Camus raised many questions about the mortality, and therefore meaninglessness, of human existence, without arguing for or against any particular way of thinking.

Martin Heidegger wrote that when a human being accepts his or her eventual death is the point when the essence (a human's knowledge of his or her own existence) is brought into focus. This finitude gives human beings a drive to live a productive life and accomplish things before their time is up.

Finitude has also been used to refer to the limits of human knowledge and potential: Unlike the God of the Judeo-Christian tradition, who is infinite and omniscient, human beings cannot objectively know reality and truth. This is reflected in the bible verse I Corinthians 1:25, in which the apostle Paul writes, "God's foolishness is wiser than human wisdom."

Jaclyn McKewan

See also Eternity; Heidegger, Martin; Immortality, Personal; Infinity; Mortality; Nietzsche, Friedrich; Time, End of

Further Readings

George, T. D. (2007). *Tragedies of spirit: Tracing finitude in Hegel's phenomenology.* Albany: State University of New York Press.

White, C. J. (2005). *Time and death: Heidegger's analysis of finitude.* Burlington, VT: Ashgate Publishing.

Flashbacks

Flashbacks, also known as "intrusive recall," are traumatic memories, thoughts, and pictures from a past event that reoccur in the present when triggered by incoming sensory data. There are four categories of flashbacks: (1) nightmares or dreams; (2) dreams from which the person awakens but remains under the influence of the dream so as to be out of touch with reality; (3) waking flashbacks, in which the person may or may not lose touch with reality but also may have accompanying reactions and hallucinations; and (4) unconscious flashbacks, in which the person is unaware that he or she is reliving the traumatic event and there appears to be little or no connection between past event, present context, and flashback.

Flashbacks act like a video loop in the brain that replays the "recorded material" as if for the first time in its intensity. Flashbacks can take the pictorial form of the original events or present as reactions that accompanied the original traumas, with emotions such as dread, grief, horror, anger, or helplessness. Triggers of flashbacks are reminders of the trauma. They occur in the present tense and often are time-related dates and events, such as anniversaries of the trauma, holidays, and funerals; or an encounter with someone who was the source of abuse. Triggers also can be any stimulus that may have been present within the context of the original trauma, such as sounds that imitate the original sound of the ensuing trauma, or sights, smells, and tastes that were present at the time of trauma or that remind the person of the trauma. A flashback may psychologically paralyze the person and render him or her unable to carry on normal activities temporarily, or over the long term.

Sometimes, the trauma is literally "unspeakable." The brain's inability to respond cognitively and rationally to irrational events causes the brain to "short-circuit." The trauma is recorded within the brain as a whole, but cannot be accessed from the usual cognitive logical sources in the left hemisphere because it is so irrational. The event is nevertheless also recorded in pictorial form in the opposite hemisphere. Indelibly imprinted as images, the event is repeatedly reaccessed in the brain's attempt to assess and process the experience. In flashbacks the brain is revisiting the scene in order for understanding and healing to begin. In this respect the flashback can be thought of as a normal function in a dysfunctional or malfunctioning situation, to make logical sense of what is otherwise incommunicable. In some cases, the trauma is so great, or the time at which it happened so strategic, such as in youth, that the brain cannot accomplish the necessary restructuring of the event without adequate help. Flashbacks continue as a release of the internal horror the person feels.

Physiologically, trauma overwhelms the brain's ordinary responses to life and chemically changes the expressions the brain responds with. It stops the healthy normal interaction of right and left hemisphere so that the victim cannot access the helps needed to overcome the trauma. This process is an actual brain wound that causes a breakdown of functionality. Thus, a course of therapy that approaches trauma wounding from the right hemisphere of the brain, that is, intuitively and creatively, often sidesteps the chemically changed processing ability of the brain's left hemisphere by accessing a different set of communication methods. Often, therapeutic art-making literally can help "draw out" the trauma so it finally can be verbalized. Through this process and other integrative therapies, the hemispheres of the brain eventually may reconnect healthily as the memory-pictures are processed, and flashbacks cease.

Jacqueline O. Coffee

See also Consciousness; Déjà Vu; Healing; Medicine, History of; Memory; Spontaneity

Further Readings

Cohen, B. M., & Thayer, C. C. (1991). *Telling without talking*. New York: Norton.

Edwards, B. (1989). *Drawing on the right side of the brain*. Los Angeles, CA: Jeremy P. Tarcher.

Herman, J. (1997). *Trauma and recovery: The aftermath of violence—From domestic abuse to political terror*. New York: Perseus.

Smith, D. (1990). *Integrative therapy: A comprehensive approach to the methods and principles of counseling and psychotherapy*. Grand Rapids, MI: Baker Book House.

Wright, H. N. (2003). *The new guide to crisis and trauma counseling*. Ventura, CA: Regal.

Flaubert, Gustave (1821–1880)

Gustave Flaubert was a French novelist noted for his mastery of the realist style of writing and his pervasive irony. His most famous work was the novel *Madame Bovary* (1857), which describes the adulterous, discontented life of a provincial wife. The book's scandalous nature landed Flaubert in court on the charge of immorality, of which he was acquitted.

Flaubert influenced many other writers, including Joseph Conrad and the Italian novelist Giovanni Verga, who imitated his descriptive, realistic style. Flaubert is known to have agonized over the wording of every sentence he wrote. With this careful, meticulous approach, Flaubert developed a new school of writing known as realism, a style in which the author attempts to portray real-life scenarios as they are. The narrator does not judge the character, but leaves the reader to do so. Flaubert's novels often contained mediocre, even miserable characters. He strove to portray them as vividly as possible, with details that shocked French society at the time.

Though Flaubert came from a family of doctors, he harbored a strong contempt for bourgeois society, which is reflected in his work. He was highly critical of the vanity and pettiness that he considered prevalent in society. Flaubert is also known for his extreme nihilism, in that he saw human life and time as empty and meaningless.

Gustave Flaubert was born in Rouen, Normandy, the son of a successful surgeon. During the 1840s he briefly studied law in Paris but failed his second-year exams. In 1844 he suffered a nervous attack, which led him to reevaluate his life and pursue a career in writing. During that time he also had an intimate relationship with the writer Louise Colet. After leaving Paris in 1846, Flaubert settled in Croisset, near Rouen. In 1848 he visited Paris and witnessed the February Revolution there, which gave rise to the Second Republic.

Flaubert's most notable works include *Salammbo* (1862), a tale set in ancient Carthage, which he wrote following a visit there. He was awarded the Legion of Honor by Napoleon III shortly thereafter. He also wrote *A Sentimental Education* (1869), a story that deals with cynicism and doubt.

Flaubert wrote this book to critique the failures of bourgeois society.

In *The Temptation of Saint Anthony* Flaubert demonstrates his deep interest in time and religion. The book is written as a play in which the protagonist, Saint Anthony, resists a succession of temptations during one night of prayer in the Egyptian desert. The early medieval Christian hermit stands firm against the Devil's temptations, which come in various forms. Flaubert researched extensively for the book, reading 134 titles, in French and in Latin, on subject matter dealing with the ancient and medieval worlds. Flaubert worked on this book throughout his life, an attest to his perfectionist nature, and published a final version in 1874.

Some critics have classified Flaubert's work with the romantic movement for its concern with the decadence of Western culture over time. Indeed, Flaubert viewed contemporary French society as vain and self-indulgent. He resisted labels, however, placing greater emphasis on style. Later in life, Flaubert became increasingly reclusive and rarely left Croisset, though he maintained correspondence with friends, including George Sand and Emile Zola. Following years of declining health, Flaubert died of a cerebral hemorrhage in 1880, leaving his final novel, *Bouvard et Pecuchet,* unfinished.

James P. Bonanno

See also Alighieri, Dante; Joyce, James; Kafka, Franz; Mann, Thomas; Milton, John; Novels, Time in; Proust, Marcel; Woolf, Virginia

Further Readings

Lottman, H. (1989). *Flaubert: A biography.* Boston: Little, Brown.

Porter, L. M. (2001). *A Gustave Flaubert encyclopedia.* Westport, CT: Greenwood Press.

Wall, G. (2001). *Flaubert: A life.* London: Faber and Faber.

FORAMINIFERS

The foraminifers or foraminifera (forams for short) are a group of ameoboid single-celled protists belonging to the class Foraminifera, phylum Granuloreticulosa, and kingdom Cercozoa. Typically they are microscopic in size and studied by the paleontological branch called micropaleontology. They are also one of the main micropaleontological groups because they can be used to give accurate relative dates to rocks, among other utilities.

Characteristics

Modern foraminifers are primarily marine, although they can survive in brackish conditions, and a few species survive in fresh waters. They have two modes of life, planktic (marine floaters) or benthic (seafloor dwellers). About 275,000 living and fossil species have been recognized. The foraminifers are usually less than 1 millimeter in size, but some are much larger. The largest recorded specimens reached 19 centimeters. They are closely related to the Radiolaria, which also includes amoeboids with complex shells.

The foraminifers typically produce a shell, or *test,* some becoming quite elaborate in structure. The test can have either one or multiple chambers, with the multichambered forms being more frequent. Adjacent chambers are separated by septa. Most have calcareous tests, composed of calcium carbonate (calcite, aragonite), but others may have organic, agglutinated, or silica tests. The organic tests are composed of protinaceous mucopolysaccharide. The term *agglutinated* refers to tests formed from foreign particles (coccoliths, diatoms frustules, microfragments of mollusk and echinoderm, sponge spicules, quartz, mica, magnetite, or garnet), glued together with a variety of cements (organic, calcareous, or siliceous). The calcareous and siliceous tests are secreted. Calcareous tests may be again subdivided into three major types: microgranular (composed of equidimensional subspherical calcite crystals smaller than 5 microns), porcellaneous (composed of thin inner and outer veneers enclosing a thick middle layer of crystal laths), and hyaline (composed of lamellas of calcite crystals larger than 5 microns, which may be equidimensional or radiate).

The name *foraminifera* is derived from the foramen, the connecting hole trough the septa between each chamber. The living foraminifers have reticulating pseudopods (reticulopodes) used for locomotion, for anchoring, and in capturing food. The opening by which the pseudopods access the outside is called the aperture. A bidirectional cytoplasmic flow along these reticulopodes carries granules, which may consist of mitochondria, digestive vacuoles, vacuoles containing waste product, and even symbiotic dinoflagellates. For this reason, the pseudopods of foraminifera are also called *granoreticulopodes*. Foraminifers normally feed on diatoms, bacteria, and copepods. Many species have unicellular algae as endosymbionts, such as dinoflagellates, green algae, red algae, golden algae, and diatoms. Some foraminifers are kleptoplastic, retaining chloroplasts from ingested algae to conduct photosynthesis.

Uses in Science and Technology

The reason why foraminifers are so useful in micropaleontology is that their tests are easily fossilizable and very abundant in the fossil record. Because of their diversity, abundance, and complex morphology, fossil foraminiferal assemblages are useful not only in biostratigraphy and geochronology, but also in paleoenvironmental reconstruction, paleoclimatology, and paleoceanography. The oil industry relies heavily on foraminifers in finding potential oil deposits.

Classification

The traditional classification of foraminifera is based on the composition and morphology of their tests. The primary characters used in these classifications are mainly the following: wall composition and structure, chamber arrangement, the shape and position of the apertures, and surface ornamentation. At species level, other morphologic features are also used, such as the test shape, chamber shape, number of chambers, and so on. The commonly accepted classification of the foraminifera is based on that of the 1987 classification by Loeblich and Tappan, although molecular data and cladistic analysis suggest that this classification may vary substantially in the future. Foraminifers were initially considered to be an order in the class Rhizopoda, phylum Protozoa, of which 12 suborders were distinguished. Today, they are considered as class Foraminiferea, of which 14 orders are distinguished: Allogromiida, Astrorhizida, Lituolida, Trochamminida, Textulariida, Fusulinida, Spirillinida, Carterinida, Miliolida, Lagenida, Robertinida, Globigerinida, Buliminida, and Rotaliida.

The foraminifera have a geochronological range from the earliest Cambrian to the present day. Order Allogromiida (before suborder Allogromiina) includes foraminifers with organic tests, such as *Allogromia*. They are difficult to fossilize and do not have much paleontological interest, but include the ancestor from which evolved all the other groups of foraminifera. They are known from the Cambrian, although probably appeared in the Precambrian. Foraminifers with hard tests were scarce during the Cambrian, Ordovician, and Silurian.

Agglutinated forms were initially included in the suborder Textulariina, but they are now classified in several orders: Astrorhizida, Lituolida, Trochamminida, and Textulariida. They may be composed of randomly accumulated grains or grains selected on the basis of specific gravity, shape, or size. All species are benthic in mode of life. The textularinids first appeared in the Cambrian, 525 million years ago, evolving from organic allogromiinids. Earliest agglutinated species were single chambered; the multichambered varieties evolved 20 million years later. They flourished in the Cretaceous, culminating in the large conic or concave–convex tests of the orbitolinids, such as *Orbitolina, Palorbitolina,* or *Dictyoconus*. They are significant biostratigraphic markers of the Cretaceous in prereef sublitoral paleoenvironments.

The order Fusulinida (before suborder Fusulinina) includes microgranular calcitic forms. All species were benthic. They first appeared in the early Silurian, more than 430 million years ago (mya), probably evolving from some ancestral textularinids. The fusulinids began to be very abundant in the Devonian, culminating in the complex test forms of the Late Carboniferous and Permian times, such as *Fusulina, Schwagerina,* or *Triticites*. They are very important biostratigraphic markers of the Carboniferous and Permian in sublitoral paleoenvironments. They were extinguished in the Permian-Triassic boundary event.

The porcellaneous foraminifers are included in the order Miliolida (before suborder Miliolina). Their first appearance occurred in the latest Devonian or Early Carboniferous, 360 mya. They probably evolved from microgranular fusilinids, modifying the wall microstructure. Three major groups may be recognized: milioloids, soritoids, and alveolinoids, all of them benthic dwellers of sublitoral paleoenvironments. The first ones have the known milioline coiling (spiral coiling), rotating in such a manner that between the median planes of consecutive chambers various angles are produced, for example, 72° (*Quinqueloculina*), 120° (*Triloculina*), or 180° (*Pyrgo*). The soritoids, such as *Orbitolites* and *Sorites,* have cyclical arrangements (arrangement of cyclical chamberlets in one plane or in concentric layers). Finally, the alveolinoids include milioline or planispiral forms, such as *Lacazina* and *Alveolina.* The miliolids flourished in the Late Cretaceous and Eocene, periods for which they are important biostratigraphic markers. Although both groups were considered unrelated in the past, Miliolida today includes the suborder Silicoloculinina, foraminifers with siliceous tests and of scarce paleontological interest.

The most diversified group of foraminifers is the old suborder Rotaliina, today subdivided in two orders: Buliminida and Rotaliida. The rotalinids appeared in the Triassic, more than 249 mya, and diversified in the Jurassic. They are benthic, although some exhibit planktonic stages, and display hyaline tests. The morphology of rotalinids tests varies enormously. Some are small foraminifers (microforaminifera), with serial arrangement (chambers arranged in one [uniserial], two [biserial], or three [triserial] rows), such as *Bolivina, Turrilina,* or *Bulumina;* or with spiral coiling, such as *Discorbis, Nonion,* or *Cibicides.* Others are much larger (macroforaminifers), with orbitoid arrangement (annular series of equatorial chamberlets covered on both lateral surfaces by lateral chamberlets), such as *Orbitoides, Discocyclina,* and *Lepidocyclina;* or with planispiral coiling, such as *Nummulites, Assilina, Operculina,* and *Heterostegina.* The rotaliinid macroforaminifers had two radiations in the late Cretaceous and Eocene–Oligocene, periods in which they are very important biostratigraphic markers together with alveolinids.

The earliest foraminifers are all benthic, and the planktonic forms do not appear until the Middle Jurassic. These forms evolved from hyaline rotalinids that display a meroplanktonic mode of life (i.e., benthic with planktic stages). All planktic foraminifera are included in order Globigerinida (before suborder Globigerinina). The greenhouse conditions of the Cretaceous caused a major diversification of the globigerinids, appearing in large and complex forms such as *Globotruncana, Contusotruncana,* or *Racemiguembelina.* The Cretaceous/Tertiary mass extinction affected more than 90% of the latest Cretaceous planktic foraminifers; surviving scarce species consist mainly of *Guembelitria.* A rapid radiation of planktic foraminifers occurred during the Paleocene, with the appearance of planktic globigerinid and globorotalids. The best Cenozoic planktic foraminifera are *Globigerina, Orbulina,* and *Globorotalia,* but these genera appeared in the Late Paleogene and the Neogene. The planktic foraminifera are the most interesting biostratigraphic markers of the Cretaceous and Cenozoic in the pelagic environment.

Other foraminifer groups are less abundant and interesting, but worth mentioning. All of them are benthic and live to the present day. The order Lagenida included planispiral to uniserial foraminifers with radiate hyaline tests, such as *Nodosaria, Dentalina,* or *Lenticulina.* They appeared in the Late Silurian, evolving from extinct fusulinids or ancestral miliolids, and diversified in the Late Triassic and Jurassic. The order Spirillinida has a test constructed of an optically single crystal of calcite, appeared in the Late Triassic (evolving from extinct fusulinids), and include the old suborders Spirillinina and Involutinina (these latter have a two-chambered test composed of aragonite). The order Robertinida also has a test composed of aragonite and evolved in the Middle Triassic, probably from agglutinated texturalinids; they are the probable ancestor of benthic Rotaliina and planktic Globigerinina. The order Carterinida includes foraminifers that secrete spicules of calcite to form the test; they probably appeared in the Eocene, evolving from texturalinids.

Ignacio Arenillas

See also Chronostratigraphy; Evolution, Organic; Extinction and Evolution; Fossil Record; Fossils, Interpretations of; Geology; Paleontology

Further Readings

Loeblich, A. R., & Tappan, H. (1987). *Foraminiferal general and their classification.* New York: Van Nostrand Reinhold.

Forces, Four Fundamental

According to the standard model of elementary particle physics, all forces acting in nature can be traced back to four fundamental interactions. These are gravitation, the weak, the strong, and the electromagnetic force. Each one of these four forces has an individual coupling strength and distance dependence. Furthermore, they differ with respect to the properties of the elementary particles they act on. It was among the very first acts of nature to set up the fundamental forces. Within only 10^{-12} seconds after the beginning of space and time presumably unified one single force was successively split up into the four forces that are known today.

In the modern quantum field theory frame, the fundamental forces are described by the exchange of mediatorial particles, so called *gauge bosons*. The electromagnetic repulsion of two identically charged particles, for example, is mediated by interchanged photons in this theoretical framework.

The electromagnetic force acts between particles that carry electric charge. There are two types of electric charge: "positive" and "negative." Charges of identical signature repel one another, while those of different signature attract. The electromagnetic force is responsible for the structure of matter above the molecular level and dominates the physics of our macroscopic environment. It determines chemistry, that is, the physics of the electron sheath and its interactions with atoms and molecules. It causes the impenetrability of solid bodies and allows for action potentials that initiate and regulate muscular motion in the human body. The electromagnetic force between two charges declines with the square of their distance ($1/r^2$).

The strong interaction or force is acting in atomic nuclei consisting of more than one proton (which carries a positive electrical charge); the chargeless neutrons have to be stabilized against electromagnetic repulsion. This is the main task of the strong interaction, which acts around 100 times stronger than the electromagnetic force at very short distances. The strong force is also responsible for the inner coherence of the nucleons (protons and neutrons, the particles constituting atomic nuclei) as well as all particles that are composed of *quarks*. The strong force has an extremely short range (10^{-15} m) and is mediated by so-called *gluons*.

The weak interaction or force, like the strong force, has a very short special range of influence (10^{-18} m). It plays an essential role in radioactive decay and the complex fusion processes acting as energy sources within the stars. During the first minutes of the universe it was a major regulating factor in establishing the number density of neutrons, which again determines the cosmic abundance of hydrogen and helium. The weak force has a relative strength of 10^{-13} compared with the strong force. The mediator particles are the very massive bosons W+, W–, and Z0, first detected in 1983 at one of CERN's (European Organization for Nuclear Research's) particle accelerators.

Finally, gravitation, with a relative strength of 10^{-40}, is by far the weakest of the four fundamental interactions. It is nevertheless responsible for the orbits of the moon and the earth, the dynamics of the solar system, and the large-scale structure of the universe. This apparent contradiction—the weakest force dominating on the largest scales—can be explained by two facts: the first is that gravitation, like the electromagnetic force, has an infinite spatial range. Second, gravitational forces cannot be cancelled by an opposing force. Thus the effect of gravity can in fact spread over very large distances. Today it is the only fundamental interaction that does not have a theoretical description in quantum mechanics. Its mediator particle, the graviton, is therefore still hypothetical. According to Einstein's general theory of relativity, gravitation is understood as intrinsic to the curvature of spacetime.

Immediately after the big bang, at the beginning of time when the universe had a temperature of 10^{32} Kelvin, the fundamental forces are believed to have been perfectly unified into one force called *quantum gravity.* During only the first 10^{-12} seconds after the big bang, the individual interactions—first gravity, followed by the strong force and then the electromagnetic force—separated from a decreasing level of unification and then finally the weak interaction broke away, resulting in the four forces of nature known today.

Helmut Hetznecker

See also Big Bang Theory; Cosmogony; Cosmology, Inflationary; Einstein, Albert; Hawking, Stephen; Light, Speed of; Quantum Mechanics; Relativity, General Theory of; Universe, Origin of

Further Readings

Börner, G. (1993). *The early universe: Facts and fiction.* Berlin: Springer.

Greene, B. (2003). *The elegant universe.* New York: Norton.

Hawking, S. W. (2001). *A brief history of time.* New York: Bantam Books.

Fossil Fuels

Fossil fuels—coal, natural gas, and petroleum—provide an invaluable and still readily available source of energy. Application of these fuels is wide ranging, from heating homes to powering jet aircraft. The fuels are found beneath the earth's surface, and were formed from plant and animal remains dating back 300 million years. To obtain energy from this raw form, the fuels must be burned to release the chemical energy present within the resource.

Given the vast time necessary for biological remains to accumulate and create this sort of fuel, they are not practically renewable, as it would take millions of years to resupply the world's constantly depleting reserves. Most of these reserves can be found in the Middle East (e.g., Saudi Arabia, Iran, Iraq), and also in Canada and Russia. Because the fuels are so vital to present-day society, it has become necessary for able nations either to stake a physical claim in these parts of the world, or to engage in diplomatic and strategic alliances so as to ensure continued access to this necessary commodity.

Only recently has humankind begun to harness the power of fossil fuels to any appreciable extent. Although coal was used by ancient humans, there was no concerted search for it; instead, early humans stumbled upon it by chance. During the Industrial Revolution of the late 1700s, coal became the main source of energy, displacing wood charcoal. Currently, it is estimated that there are approximately 240 years of coal remaining if consumption rates remain the same as today.

The oil industry is less than 150 years old, yet based on present consumption rates there are only 42 years of proven reserves remaining worldwide. Drilling for oil originated in 1859 when the Pennsylvania Rock Oil Company became interested in drilling for natural oil so as to eliminate dependency on expensive whale oil used for heating and illumination. At present, the oil industry is the largest industry in the world, generating around $100 billion annually.

Unlike oil and coal, natural gas (in its original state) cannot be stored and transported in containers. Instead, it must be piped from producing fields directly to the end user. At present usage rates, there are approximately 60 years remaining of proven natural gas reserves. Of the three fossil fuels, gas is by far the cleanest burning, as it emits mostly water vapor and carbon dioxide (CO_2), although significantly less CO_2 than both coal and oil. It is CO_2 that is widely credited with trapping heat beneath the earth's ozone layer, thus leading to what is commonly referred to as global warming.

Ironic as it may seem, the existence of present-day civilization is heavily dependent on these products that are millions of years old. If fossil fuels were to disappear overnight, modernity would be crippled. As such, the current era must recognize that its progression has been possible only by a strong linkage to the ancient past through this invaluable source of energy. Given its apparently short-term viability, alternative means of energy—such as geothermal, nuclear, and solar—are aggressively being developed, eventually to provide for a gradual and, it is hoped, relatively calm switch as humanity weans itself from fossil fuels.

Daniel J. Michalek

See also Fossil Record; Geological Column; Geologic Timescale; Geology; Paleontology

Further Readings

Bartok, W., & Sarofim, A. F. (1991). *Fossil fuel combustion: A source book.* New York: Wiley.

Gore, A. (2006). *Earth in the balance: Ecology and the human spirit.* Emmaus, PA: Rodale.

Seidel, S. (1983). *Can we delay a greenhouse warming?* Washington, DC: Office of Policy Analysis, Strategic Studies Staff.

Fossil Record

The fossil record is the set of remains or traces of past organisms identified in fossiliferous rock formations and sedimentary strata (the stratigraphical record) from previous geologic ages to present. Both stratigraphical and fossil records constitute the geological record. The fossil record, or paleontological record, is a primary source of information for evaluating the history of life, including evolutionary processes and extinction events. Paleontologists have studied the fossils of many thousands of species that lived in the past. They have identified evolutionary successions through time, manifesting the morphological transitions from some species to others.

The fossil record confirms a basic prediction of evolutionary theory: *the past organisms were quite different from present ones*. Furthermore, the farther back in geological time we look, the simpler and more morphologically similar are the larger taxonomic groups that became fossilized, precisely what to expect if the hypothesis that all life on Earth originated from a universal common ancestor were true. Other features are observed in the fossil record that provide evidence for evolutionary theory: transitional fossils between ancient species and more modern ones, consistent hierarchy in homologies and analogies of past organisms, paleobiogeographic data that show that proposed descendants appeared in the same general area as their predecessors, and so on. Exceptional outcrops containing very well-preserved fossils of past fauna and flora, what is called a *Konservat-Lagerstätte,* have been found worldwide for the different geological time periods and epochs.

Archean Fossil Record

The oldest fossil traces are the stromatolites of 3,500 million years ago (Paleoarchean era, Archean eon). The stromatolites consist of attached, lithified growth structures, accretionary away from a point or limited surface of initiation. The result is a laminated rock built of layer upon layer of sediment and precipitants. The stromatolites are formed by the trapping, binding, and cementation of sedimentary grains by microorganisms, especially cyanobacteria. The first stromatolites were probably built by green sulfur-bacteria and purple bacteria, and they were not very abundant. However, the stromatolites became common during the Paleoproterozoic and Mesoproterozoic eras (early and middle Proterozoic eon, between 2,500 and 1,000 million years ago [mya]), due probably to the great proliferation of colonial cyanobacteria.

The first putative fossil bacteria were found in a stromatolitic formation from the Warrawoona Group (Western Australia) of 3,460 mya. They seem to belong to the domain Eubacteria, but microfossils of extremophilic domain Archaea have also been identified in the Archean eon. Archean life was surely limited to simple nonnucleated single-celled microorganisms, or prokaryotes (bacteria). There are no known eukaryotic fossils in Archean rocks, although they might have evolved then and simply not left any fossil. Cyanobacteria and oxygenic photosynthesis first evolved in the Mesoarchean era (3,200–2,800 mya), and were common during the Neoarchean era (2,800–2,500 mya). The combination of oxygen released by photosynthetic cyanobacteria and dissolved iron in oceans formed a distinctive Archean (and Proterozoic) type of rocks, called banded iron formations.

Proterozoic Fossil Record

Pre-Ediacaran Time

While it was involved in oxidizing the oceanic iron and precipitating banded iron oxides (magnetite), biogenic oxygen could not be accumulated in the atmosphere, which continued to be a reducing environment, containing less and less oxygen. This geological process ended in the Proterozoic eon. At that time, the progressive accumulation of oxygen in the atmosphere might have caused the extinction of numerous groups of anaerobic bacteria, what sometimes has been called the oxygen catastrophe of the Paleoproterozoic era (2,500–1,600 mya). It is considered that the atmosphere changed to oxygen-rich during the Orosirian period (2,050–1,800 mya), since the banded iron formations were abundant in the previous periods, mainly during the Siderian period (2,500–2,300 mya) but also during the Rhyacian period (2,300–2,050 mya).

A major event in the history of life occurred at the beginning of the Statherian period (1,800–1,600 mya): the evolution of the eukaryotic cell. Unlike prokaryotic cells, the genetic material of the eukaryotes is organized in a membrane-bound nucleus. Moreover, eukaryotic cells have a variety of internal membranes and structures, called organelles (mitochondria, chloroplasts, endoplasmic reticulum, Golgi apparatus, etc.), and an inner cytoskeleton that includes motile cytoplasmic projections (pseudopods, flagella, and cilia) and other structures (e.g., centrioles). The origin of the eukaryotic cell is disputed. It is believed in general that the nucleus and the internal membranes derived from the invagination of the plasm membrane (F. J. R. Taylor's autogenous model), whereas mitochondria, chloroplasts, centrioles, flagella, and cilia evolved from certain types of eubacteria that a group related to the archaeobacteria engulfed through endophagocytosis (Lynn Margulis's endosymbiotic model). Sphaeromorph microfossils (assigned to acritarchs) from the 1,800-million-year-old Changshoigou Formation (Jixian, north China) are interpreted as probably representative of first unicellular eukaryotic protists.

During the Mesoproterozoic era (1,600–1,000 mya) another major event in the history of life occurred: the evolution of sexual reproduction. It has been suggested that cannibalism by primitive protists (protogametes) in times of starvation could have led to a stalemate, with cells becoming fused (protofecundation) but eventually separating when the environmental conditions improved (protomeiosis). The cannibal fusion of cells during conditions of environmental stress was accompanied by the formation of cysts. Cysts are resistant structures, sometimes mineralized, that become preserved in the fossil record. The first fossil group with sexual reproduction is thought to be the acritarchs, known from at least 1,400 mya; that is, approximately at the boundary between the Calymmian and Ectasian periods. The acritarchs were single-celled organisms (protists) that included a wide range of different taxonomic groups. Some acritarchs might be cysts of unicellular algae that were ancestors of the dinoflagellate (a large group of flagellate protists). Microfossils attributed to clear dinoflagellate have been found in 1,100-million-year-old rocks (Stenian period, which lasted from 1,200 to 1,000 mya). Other acritarchs might be related to the prasinophycean green algae (probable unicellular ancestral stock from which descended all other green algae and later the plants). Clear microfossils of green algae or chlorophytes were identified in 1,000-million-year-old rocks.

Fossil evidence of eukaryotic red algae or rhodophyte (*Bangiomorpha*) has been identified in the transition between the Ectasian and Stenian periods (approximately 1,200 mya), in the Hunting Formation (Somerset Island, Canada). This is the earliest known complex multicellular organism. The development of sexual reproduction in unicellular protists might have precipitated the evolution of multicellular life. The multiplication of cells in the first multicellular organisms could occur in the interior of a resistant cyst after fecundation and before meiosis.

The eukaryotic cell, sexual reproduction, and multicellular eukaryotic organisms could have had an early evolution. Because the first organisms would not have had hard parts, the first unicellular and pluricellular eukaryotic organisms are probably not preserved in the Archean and Proterozoic fossil record. It is hypothesized that these three significant milestones in the history of life were developed very early. For example, the first eukaryotic cells could have appeared 2,700–2,100 mya, coinciding with the release of atmospheric oxygen; and sexual reproduction could have developed at least 1,800 mya, the age of the first possible acritarchs in China. Moreover, 1-meter-long fossil tubes called *Grypania* were identified in 2,000-million-year-old rocks of Lake Superior and have been attributed to unicellular eukaryotic algae, although also to giant bacteria.

The Neoproterozoic era (1,000–542 mya) covers one of the most interesting times in the history of life and the fossil record, such as the development of complex multicellular organisms and the appearance of animals or metazoans. Different lineages of eukaryotic protists also evolved during this era. The first radiation of acritarchs occurred during the Tonian period (1,000–850 mya). The first fossil record of ciliates and testate amoebae occurred more than 750 mya, that is, in the Cryogenian period (850–630 mya). This period is characterized by worldwide glacial deposits, suggesting that during this time Earth's climate suffered the most severe ice ages in its history (Sturtian and Marinoan glaciations). It has been hypothesized that planetary oceans were frozen over completely (the Snowball Earth hypothesis).

In spite of the fact that the acritarchs suffered a significant mass extinction event during the cold Cryogenian period, the development of multicellular animals may have been favored due to increased evolutionary pressures during the multiple icehouse–hothouse cycles of the Cryogenian period. Animals are generally accepted to have evolved from choanoflagellates, collared flagellate protozoa that have the same structure as certain sponge cells. Using nuclear-encoded protein sequences, geneticists and molecular biologists have suggested that the appearance of animals occurred as early as 1,200 mya (the Mesoproterozoic era). However, a conflict between these molecular models and the traditional perception of the fossil record makes some paleontologists wish to reconsider the molecular data. In spite of this criticism, the Proterozoic fossil record is supplying new, unexpectedly complex life forms probably related to multicellular metazoans: enigmatic bedding-plane impressions (*Horodyskia*) of colonial benthic eukaryotic organisms living 1,500 mya (Calymnian period from the Belt Supergroup of Montana); fossils of worm-like segmented organisms (*Parmia*) in 1,000-million-year-old Tonian deposits in Timan (Russia) and interpreted as a probable predecessor of the annelid worms; and macroscopic fossils of worm-like organisms (*Protoarenicola* and *Pararenicola*) discovered in 740-million-year-old Cryogenian deposits from Huainan (China) and related probably to annelids and pogonophorans.

Ediacaran Fossils

The end of the global glaciations of the Cryogenian period occurred 630 mya, and after it came one of the most interesting periods in the evolution of life: the Ediacaran period (635–542 mya), also called the Vendian period. This period is characterized by a group of ancient life forms called Ediacaran or Vendian biota. This fauna is older than the oldest shelled fossils of classical paleontology: the Cambrian faunas. Its first fossil record was found in the Ediacara Hills Konservat-Lagerstätte (South Australia). Dozens of outcrops with related fossils have been found since then, especially important being the deposits found in the White Sea (Russia), in southwestern Africa, in northwestern Canada, and in southeastern Newfoundland. Another significant Ediacaran Konservat-Lagerstätte deposit was found in the Doushantuo Formation (Guizhou, China). In addition to bacteria, protists, and algae fossils, the Ediacaran fossil record includes the oldest definitive multicellular animals. They are generally segmented or frond-like organisms, and many of them are difficult to interpret. Some have been redescribed as trace fossils, such as *Dickinsonia,* and often interpreted as ancestral arthropods; forms such as *Spriggina* can resemble trilobite traces. Ediacaran organisms include frond-like forms called *rangeomorphs;* they have disk-type morphologies with various ornamentations (e.g., *Charniodiscus* and *Charnia*). They could belong to cnidaria (related to modern sea pens) or be possible precursors of arthropods and mollusks. Various disk-like forms could be also related to anemones (e.g., *Mawsonites*) or sponges (e.g., *Palaeophragmodictya*). Nevertheless, many of the best-known Ediacaran creatures appear to have no obvious relationship to later metazoans, including organisms that resemble sessile bags, annulate disks, and air mattresses. An alternative interpretation is to consider that these extinct organisms belonged to a new separate kingdom (kingdom Vendobionta) that comprises nonmetazoan, coenocytic groups, or giant multinucleate eukaryotic unicellulars. These organisms disappeared across the Ediacaran-Cambrian boundary (approximately 542 mya), perhaps wiped out by a mass extinction event.

Phanerozoic Fossils

The Phanerozoic eon (545 million years–present) is a period of geologic time during which abundant hard-shelled animals lived. Its name derives from the Greek and means "visible life," referring to the abundant fossil record. Significant events in the history of life occurred during this eon: rapid radiation of a great number of animal phyla; emergence of terrestrial plants and animals; evolution of complex plants; and evolution of fishes, amphibians, reptiles, and mammals. All of these evolutionary events allowed the development of the modern faunas and floras, although this process was also sprinkled with multiple mass extinction events. Two of these extinction events (Permian-Triassic and Cretaceous-Paleogene events) mark the boundaries between the Phanerozoic eras: the Paleozoic (542–251 mya), Mesozoic (251–65 mya), and Cenozoic (65–0 mya) eras.

Paleozoic: From the Cambrian Explosion to the P-T Extinction Event

Cambrian

The Proterozoic-Phanerozoic boundary (or Neoproterozoic-Paleozoic boundary, or Ediacaran-Cambrian boundary) has been classically placed at the first appearance of trilobites and archeocyathids. These extinct life forms are complex compared with the preceding Ediacaran fauna. A large number of animal groups appeared nearly simultaneously at the beginning of the Cambrian period (542–488 mya), such as mollusks, brachiopods, bryozoans, arthropods, echinoderms, and even vertebrates. There is some fossil evidence that simple life (algae, fungi) may have invaded land in this moment, although plants and animals do not take to the land until the Silurian or Devonian. This rapid episode is known as the Cambrian explosion, and represents the most significant evolutionary radiation to happen in the history of life on Earth. The major groups or phyla of animals emerged suddenly, in most cases without evidence of precursors. The Early Cambrian metazoan radiation was also accompanied by a diversification of organic-walled protists, including prasinophyte and dasyclad green algae, benthic foraminifers, and acritarchs. Exceptional fossiliferous outcrops (Konservat-Lagerstätten) of the Cambrian have been found at Burgess Shale (British Columbia, Canada), Maotianshan Shales (Chegjiang, China), Sirius Passet (Greenland), Orsten and Alum Shale (Sweden), Murero (Spain), Emu Bay Shale (South Australia), Kaili Formation (Guizhou, China), and the House Range (Utah).

The most famous Cambrian fossils are the trilobites, a group of extinct marine arthropods that form the class Trilobita. Many thousands of trilobite species are known, and they serve as excellent Paleozoic index fossils because they evolved rapidly and present a good fossil record. Their ancestors seem to be morphologically similar to taxa like *Spriggina, Parvancorina,* and other trilobitomorphs of the Ediacaran. It is reasonable to assume that the trilobites share a common ancestor with other arthropods that lived prior to the Ediacaran-Cambrian boundary. The most primitive groups appeared during the Early Cambrian and belong to the orders Agnostida, Redlichiida, Corynexochida, Naraoidia, and Ptychopariida. Although the agnostids have the most primitive characteristics, the redlichid trilobites are the first true arthropods to appear in the fossil record. The earliest known trilobite is the redlichid genus *Fallotaspis.*

The trilobites could be related to the chelicerata (spiders, scorpions, and related forms), the Cambrian aglaspids being an intermediate group. Crustaceans also first evolved in the earlier Cambrian, as part of the great radiation of Cambrian coelomate animals. Although the crustaceans have hard exoskeletons reinforced with calcium carbonate, their fossil record is rarer than that of trilobites during the Cambrian.

Arthropods are thought to have branched from an ancestor of the segmented worms, probably prior to the Cambrian, and the onychophorans are a good example. The onychophorans (or velvet worms) are a phylum that today includes segmented terrestrial animals somewhat resembling both annelids and arthropods. Traditionally the annelids have been considered the closest relatives of arthropods and onychophorans, due to their common segmentation. Annelids are known at least as early as the Cambrian, and there is some evidence that they appeared during the late Neoproterozoic (*Cloudina* may be an early serpulid worm fossil of the Ediacaran). They comprise the segmented worms, and include the well-known earthworms, leeches, serpulids, and tube worms. However, the similarities between annelids and arthropods have been more recently considered convergent evolution. The arthropods may be more closely related to certain pseudocoelomates such as nematodes (roundworms) or priapulids (penis worms); further, the annelids are more closely related to mollusks, bryozoans, and brachiopods.

The brachiopods (lamp shells) are sessile, two-shelled, marine animals with an external morphology resembling bivalve mollusks. However, they have a lophophore (a ring of ciliated tentacles surrounding the mouth) similar to that of the bryozoans. Although possible brachiopods have been found in the Ediacaran period, the earliest unequivocal brachiopods in the fossil record occur in the Early Cambrian, appearing first as inarticulate forms (e.g., *Lingula*) followed soon by articulate forms (e.g., *Obollella*). Apart from perhaps the trilobites, brachiopods are one of the most important Paleozoic index fossils. Unlike bryozoans, they are solitary and never form colonies. Together with bryozoans (ectoproctans) and phoronids (horseshoe worms), brachiopods belong to the informal lophophorates and they almost certainly share a common ancestor.

The briozoans are small colonial animals that build skeletons of calcium carbonate, superficially similar to coral. They were initially subdivided in two subgroups, ectoproctans and entoproctans, based on their similar body plans (with lophohore) and mode of life. Nevertheless, the ectoproctans are coelomate (possessing a body cavity) and the entoproctans are acoelemate. Molecular studies do not support a phylogenetic relationship between the two groups. For this reason, the entoproctans are now considered a phylum of their own and related to mollusks and annelids, whereas the ectoproctans are considered synonymous with bryozoans and related to brachiopods and phoronids. The true bryozoans, the ectoproctans, perhaps evolved from a phoronid-like ancestor in the Cambrian, but their first fossil record occurs in the Ordovician period. The phoronids are worm-shaped creatures that secrete chitinous tubes in which to live, and some early Cambrian forms (e.g., *Iotuba*) have been attributed to them.

The earliest mollusk fossils belong to the univalved monoplacophorans. They are probably the ultimate common ancestor of all univalved and bivalved mollusks; they first appeared in the fossil record in the earliest Cambrian. By the Late Cambrian, most living classes of mollusks has been found in the fossil record, including Gastropoda (snails and slugs), Cephalopoda (nautilus, ammonites, squids, octopuses, cuttlefish), and Pelecypoda or Bivalvia (clams, scallops, mussels, cockles). All of them were initially marine. The first true gastropods appeared in the Middle Cambrian (e.g., *Protowenella*) and Late Cambrian (e.g., *Chippewaella* and *Sterpsodiscus*), although some Early Cambrian forms have been related to gastropods (e.g., *Scenella*). The cephalopods also developed during the Cambrian, with the plectronocerids (e.g., *Plectronoceras*) considered the basal group. A little-known but important Cambrian group of mollusks was the helcionellids, such as *Helicionella, Yochelcionella,* and *Latouchella*. They could have affinities with other primitive groups like poliplacophorans (chitons). The Lower Cambrian fossil *Tommotia,* which had squid-like tentacles and a snail-like foot, is considered to be a basal cephalopod.

Many Cambrian taxa do not seem to have any relationship to modern taxonomic categories. *Halkieria* could be an inarticulate brachiopod or at least a stem group, or even represent the procoelomate ancestors of all higher (coelomate body plan) animals, including brachiopods, annelids, and mollusks. The present aplacophorans (small, cylindrical, and worm-like mollusks) could be relics of the original Ediacaran or Cambrian procoelomate-molluskomorph radiation. *Wiwaxia* and *Odontogriphus* have been considered protomollusks, and related to Ediacaran *Kimberella,* which could have also mollusk-type radula. *Orthrozanclus,* a fossil recently discovered at the Burgess Shale Formation (Canada), could be the evolutionary link among mollusks, annelids, and brachiopods. The genera *Halkieria* and *Wiwaxia* have been placed tentatively in a group called Halwaxiida. Other poorly understood Cambrian taxa have been included in an informal Lobopodia family. These include such famous fossils as *Anomalocaris, Opabinia, Xenusion, Amiskwia, Odontogriphus,* and *Hallucigenia*. *Anomalocaris* seem to be closely related to the arthropods. It is included in the collective group named anomalocarids, which also includes *Laggania, Amplectobelua,* and probably *Opabinia*. Some of the lobopodia taxa, such as *Xenusion, Aysheaia,* or *Microdictyon,* are onychophore-like forms. The famous *Hallucigenia* was considered to belong to Lobopodia, but is now considered to be a true onychophoran. Finally, *Amiskwia* could be a chaetognath (arrow worm) or a nemertean (ribbon worm); its affinities are not clear.

Echinoderms also evolved in the Early Cambrian from deuterostome animals with bilateral symmetry, but later acquired their typical pentaradial symmetry. Their larvae are organized in a bilaterally symmetric fashion similar to embryonic chordates. An extinct class of bilateral forms, called helicoplacoidea, includes the earliest fossil echinoderms (*Helicoplacus*), found in the lowest Cambrian fossil record of the White Mountains (California). With scarce exceptions, all extant echinoderms fall into five well-defined classes: crinoidea (sea lilies), asteroidea (sea stars), ophiuroidea (brittle stars), echinoidea (sea urchins), and holothuroidea (sea cucumbers). All of them could have evolved from an extinct Cambrian echinoderm group called homalozoa (*Stylophora, Soluta, Cincta,* and

Ctenocystis), which have been connected to the chordates. *Arkarua,* a small disk-like taxa of the Ediacaran with fivefold symmetry, has been proposed as a possible precursor of the extinct Cambrian asteroidea (edriosteroidea). Echinoderms are a sister group of hemichordates and chordates.

Hemichordates are worm-shaped marine animals—deuterostomes like echinoderms and chordates—that also evolved in the Lower Cambrian. They include a significant fossil group named graptolites. The earliest graptolites are known from the Middle Cambrian, such as *Chaunograptus* of the Burgess Shale Formation (British Columbia, Canada) or *Chepalodiscus* of the Wheeler Shale Formation (Utah). The graptolites were colonial hemichordates, and their fossils resemble hieroglyphs. The graptolite colony, known as a rhabdosome, has numerous individuals (zooids) with theca distributed in a variable number of branches (stipes). Because many graptolites are good index fossils, they are used in Paleozoic biostratigraphic scales. The most primitive graptolites, the dendroids, had many stipes and were generally benthic. *Emmonaspis,* an enigmatic worm-like animal from the Lower Cambrian of Vermont, has been associated with graptolites and chordates.

Chordate origins are not fully understood, although Cambrian Burgess Shale outcrops have some small fossil taxa called *Piakia* with all the ancestral chordate characteristics. It is very similar to the most primitive living chordate, *Amphioxus.* The chordates are distinguished by a notochord, a semiflexible rod running along the length of the animal. This is replaced and surrounded by the vertebra or backbone in the vertebrates. There are three major groups of chordates: urochordata (tunicates), cephalochordata (lacenlets), and vertebrata. *Yunnanozoon,* a suspected chordate or hemichordate similar to the most primitive vertebrate *Haikouella,* was found at the Lower Cambrian Maotianshan shales of Chengjiang (Yunnan, China). *Haikouella* is surely a chordate related to the first agnathans vertebrate.

Vertebrates also started to evolve during the Cambrian explosion. They are chordates with backbone, vertebral or spinal columns, and include fish, amphibians, reptiles, birds, and mammals. Between the first clear vertebrates are fish-type forms like *Haikouichthys* and *Myllokunmingia,* which are probably primitive agnathans related closely to the lampreys. Agnatha are fish-like vertebrates characterized by the absence of jaws and paired fins, and they include such extant groups of jawless fish as lampreys (petromyzontids) and hagfish (myxinids).

Some paleontologists and molecular biologists question the apparent suddenness of the Cambrian radiations, suggesting it is a problem of discontinuity in the fossil record. The Cambrian explosion could represent simply a swift increase of animals with hard parts easily fossilizable. Several modern phyla, mainly those with small and soft bodies, have no fossil record in the Cambrian or any another period of the Phanerozoic. Therefore, the first appearance of those phyla could truly occur in the Proterozoic, but their first forms were made up of soft parts that did not fossilize.

Ordovician

The Ordovician period (488–444 mya) is characterized by shallow epicontinental seas rich in life, particularly trilobites and brachiopods. Corals flourished in the Ordovician, including rugose and tabulate forms. Mollusks became common during the Ordovician, especially bivalves, gastropods, crinoids, and nautiloids. Nautiloids are a group of shelled cephalopods that flourished during the Ordovician, although they evolved in the Late Cambrian (they are first known from the Fengshan Formation, China). Their shells may be straight, curved, or coiled. The straight-shelled nautiloids (e.g., *Orthoceras*) are common in Ordovician limestones from Scandinavian and Moroccan outcrops, and some of them reached large dimensions, as Endoceras (measuring up to 3.5 m in length) and Cameroceras (probably 11 m in length). Exceptional marine Late Ordovician Konservat-Lagerstätte were discovered in the Soom Shale (South Africa), which includes well-preserved fossils of sea scorpions (eurypterids), conodonts, orthocerid nautiloids, brachipods, trilobites, and chitinozoas. Graptolites also thrived during the Ordovician, evolving the first pelagic forms (graptoloids) at the beginning of this period. They are most commonly found in black shales (deepwater, dysoxic facies). Abereiddy Bay (Wales) is a well-known outcrop for Ordovician graptolite fossils. A significant fossil group of jawless fishes appeared in the Ordovician: the ostracoderms (shell-skinned). They were primitive agnathans covered in an armor of bony plates and usually less than 30 centimeters in length. An important evolutionary event that occurred during the Ordovician was the first appearance of terrestrial plants, evolving from green algae (charophyta). Fossil spores from terrestrial plants, probably from bryophites (mosses, hornworts, liverworts), have been found in uppermost Ordovician sediments. The symbiosis between the roots of land plants and fungus (mycorrhiza) occurred surely at the same time, and this mutualistic association is today essential for the growth of the land plants. The Ordovician finished with a series of extinction events (between 444 and 447 mya) that, taken together, comprise one of the five major mass extinction events. About 85% of all species became extinct, causing the disappearance of one third of all brachiopod and bryozoan families, as well as numerous groups of conodonts, trilobites, and graptolites. Much of the reef-building fauna was also decimated. The most commonly accepted theory is that these events were triggered by the onset of a glaciation, causing a progressive fall in sea level and a drastic change of the marine habitats. This ice age ended the long, stable greenhouse conditions typical of the Ordovician.

Silurian

The Silurian (443–416 mya) was a period characterized by high sea levels and warm shallow seas that provided a hospitable environment for marine life. Wenlock Series Konservat-Lagerstätte (UK) contains well-preserved fossils of worms, sponges, graptolites, chelicerates, and mollusks, as well as abundant radiolarians, a protist group that produced intricate siliceous microskeletons. The first appearance of coral reefs occurred in the Silurian, built by extinct rugose and tabulate corals. Trilobites, mollusks, brachiopods, and briozoans were very common and quite diverse. Besides the trilobites, other arthropods began to be diversified. Giant sea scorpions (*Eurypterus, Pterygotus*), some of them more than 2 meters in length, lived during the Silurian, and were formidable predators. Although they are not true scorpions, they are related to the arachnids. The arthropods colonized the terrestrial environment for the first time in the Late Silurian. Among them, the myriapods (millipedes) were surely the first terrestrial animals. The first appearance of terrestrial arachnids occurred in the Late Silurian, and the trigonotarbids (spider-like arachnids) are one of the oldest known land arthropods. Myriapod and arachnid cuticles have been found in Upper Silurian rocks in Shropshire (England). The first true fishes were the acanthodians (spiny sharks), which appeared in the Early Silurian. This extinct group had features transitional between the two main groups of extant fishes, the bony fish (osteichthians) and cartilaginous fish (chondrichthians). Placoderms, armored fishes, are also known from Upper Silurian rocks of China (e.g., *Wangolepis*). The first fossil record of vascular plants or tracheophytes (with specialized tissues for conducting water, minerals, and photosynthetic products) occurs in Silurian rocks, and it includes primitive vascular plants (rhyniophytes) like *Cooksonia* (early Silurian of the Northern Hemisphere). Most evolutionary rhyniophytes (as *Rhynia*) and primitive lycopods (as *Baragwanathia* from the Upper Silurian rocks of Australia) were other vascular plants that appeared in this period.

Devonian

The Devonian period (416–359 mya) continued to be dominated by brachiopods, bryozoans, crinoids, and corals in the marine environment. Great barrier reefs extended a thousand kilometers around the Devonian continents, built by sponges (stromatoporids), corals (tabulate and rugose), and calcareous algae. Trilobites were still very common. Armored otracoderms and placoderms were the most abundant fishes of the Devonian, coexisting with the first sharks and ray-finned fish. The first shark, *Cladoselache,* which appeared in the Devonian, was 1.2 meters in length, and exhibited a strange combination of ancestral and derived characteristics. Placoderms went on to inhabit and dominate almost all known aquatic ecosystems, including freshwaters. Canowindra (New South Wales, Australia) is a Konservat-Lagerstätte that contains excellent fossils of fishes, including placoderms and lobe-finned crossopterygians. Originating from within the nautiloid, the ammonites first appeared in the early Devonian. The ammonoids are excellent index fossils for the Upper Paleozoic and Mesozoic. Their shells usually take the form of planispirals, although some of them were trochospiral (helicoid) or nonspiraled. The most primitive group of ammonoids is the goniatitids, which were superficially similar to the nautiloids. Excellent lagerstätte-type outcrops with well-preserved marine fossils (trilobites, corals, brachiopods, sponges, arthropods, trace fossils, etc.) come from the Hunsrük Slates (Germany). In the terrestrial environment, primitive plants created the first soils, which sheltered such arthropods as myriapods, scorpions, and mites. The early Devonian plants still did not have true roots, but the rapid appearance of plant groups with roots occurred during the Late Devonian: lycophytes, sphenophytes, ferns, and progymnosperms. Rhynie chert Konservat-Lagerstätte (Scotland) includes significant well-preserved fossils of Devonian vascular plants. This rapid evolutionary radiation of plants has been called the Devonian explosion, and includes the first appearance of *Archaeopteris*. This is the first tree-like fern, and it can be found in worldwide outcrops. It was a genus of the extinct progymnosperms, plants with gymnosperm-like wood but that produce spores rather than seeds. The development of soils probably acted as a carbon dioxide sink, dropping the levels of greenhouse gases. This may have cooled the climate and caused the mass extinction event toward the end of the Devonian (the Frasnian-Famennian boundary event, 374 mya). The Late Devonian extinction was one of five major extinction events and affected about 82% of the species, including trilobites, ammonites, brachiopods, conodonts, and acritarchs. Ostracoderms and placoderms were extinguished. Meteorite impacts at the Frasnian-Famennian boundary have been suggested as possible agents for the Late Devonian mass extinction.

Carboniferous

The Carboniferous period (359–299 mya), subdivided into two subperiods (Mississippian and Pennsylvanian) in North America, is characterized by large expanses of soils, which remained successively buried, building up important coal deposits. Atmospheric oxygen levels probably increased, causing gigantism among Carboniferous insects and amphibians. The protodonata (griffin flies) are an extinct group related to dragonflies that reached a wingspan of more than 75 centimeters. The Mazon Creek Fossils (Illinois) Konservat-Lagerstätte contains well-preserved fossils of arthropods (insects, millipedes, spiders, scorpions, etc.) and of the other paleontological groups. Some labyrinthodont amphibians were longer than 6 meters, including the largest known amphibian, the 9-meter-long *Prinosuchus* of Brazil. The labyrinthodonts also include well-known amphibians like temnospondyl *Eryops* and anthracosaurian *Seymouria,* and they were accompanied by smaller lepospondyls. There is a controversy over the origin of lissamphibias, which include modern anuras (frogs and toads) and urodeles (newts and salamanders), although it is now considered that they evolved from lepospondyls. One of the greatest evolutionary innovations of the Carboniferous was amniote eggs among the earliest sauropsid reptiles. The earliest known reptiles are the theropsid *Archaeothyris* and the sauropsid *Hylonomus* from Middle Carboniferous sediments of Nova Scotia (Canada). Carboniferous terrestrial plants include an extensive diversity of equisetales (horsetails), sphenophyllales (vine-like plants), lycopodiales (club mosses), lepidodendrales (scale trees), filicales (ferns), pteridospermales (seed ferns), cordaitales, "pre"-cycadales, and volziales. *Lepidodendron* and *Sigillaria* evolved among the lepidodendrales, which are closely related to cycadales. *Calamites,* tree-like horsetails, is other significant genus of the Carboniferous period. An evolutionary event comparable with the appearance of eggs in the tetrapods was the evolution of seeds among the terrestrial plants (gymnosperms). This innovation occurred toward the end of the Devonian, but it was developed during the Carboniferous. It occurred in a primitive plant group called pteridosperms or seed ferns (e.g., *Lyginopteris*), which are considered to be the common ancestor of all gymnosperms (cycads, ginkgos, and conifers). *Cordaites* (a tree about 30 m high) is the most significant genus of cordaitales, a primitive and extinct group related to conifers. True conifers appear in the latest Carboniferous and belong to the voltziales, which are believed to be ancestral to living conifers (cedars, cypresses, junipers, pines, firs, redwoods or sequoias, spruces, and yews). In the oceans, ammonoids, brachiopods, foraminifera, corals, bryozoans, echinoderms (mainly crinoids), and chondrichtyes (sharks) flourished. The Bear Gulch Limestone (Montana) is an excellent outcrop

(Konservat-Lagerstätte) with well-preserved fossils of marine groups (sponges, starfish, conulariids, worms, brachipods, bryozoans, mollusks, as well as fishes such as lampreys, acanthodians, sharks, coelacanths, etc.). The fusulinids are very abundant in the Carboniferous fossil record. They are excellent index fossils for the Pennsylvanian and Permian shallow marine rocks, such as *Fusulina*. Brachiopods also were abundant and are excellent index fossils, including the well-known productids, spirifierids, rhynochonellids, and terebratulids. Bivalves and gastropods, echinoderms—mainly the crinoids like *Cyathocrinus*—were also very numerous. Among the cephalopods, the straight and curved-shelled nautiloids and the goniatitid ammonoids were common. Finally, fishes increased their diversity during the Carboniferous, becoming abundant: the elasmobranch chondrichtyes, that is, sharks such as *Psammodus* or *Symmorium*. From among the osteichtyans, palaeonisciformes and rhizodonts evolved. The first ones include the most primitive or earliest known actinopterygians (ray-finned fishes). The second ones are an extinct group of sarcopterygians (lobe-finned fishes). Freshwater fishes were common, such as the actinopterygian *Cheirodus* and the acanthodian *Acanthodes*. Hamilton Quarry (Kansas,) is an excellent outcrop (Konservat-Lagerstätte) with a diverse assemblage of Carboniferous marine, freshwater, and terrestrial fossils, including reptiles, amphibians, fishes, insects, conifers, echinoderms, and brachiopods.

Permian

The Permian period (299–251 mya) began with fauna and flora similar to the Carboniferous, but about the Middle Permian there was a major paleogeographic, paleoclimatic, and palaeobiologic turnover. All of the earth's major land masses were collected into a single super continent called Pangea, changing the ocean currents and causing deserts to increase. The dry conditions favored the gymnosperms, since the protective cover of the seeds represented a selective advantage with regard to the ferns and other pteridophytes that dispersed spores. The first modern gymnosperms—cycadophytes (cycads), ginkgophytes (ginkgos), and pinophytes (conifers)—appeared during the Permian. In the oceans, ammonoid and nautiloid cephalopods, echinoderms, brachiopods, and foraminiferal fusulinids were common. Permian marine sediments are rich in fossils of these groups, with ammonoid, brachiopod, and fusulinid being important Permian index fossils. Among the terrestrial fauna, insects and tetrapods (amphibians and reptiles) dominated. A number of important new insect groups appeared during the Permian, including the first coleoptera (beetles) and diptera (flies). Permian amphibians consisted of temnospondyls, lepospondyls, and batrachosaurs. They dominated the Early Permian terrestrial fauna together with reptilian pelycosaurs, being replaced by the therapsids (mammal-like reptiles) during the Middle and Late Permian. The therapsids evolved from a group of pelycosaurs, the sphenacodontids, and included the first large herbivores (anomodonts as *Eodicynodon*) and carnivores (theriodonts like gorgoniopsians and therocephalians). They also included the ancestors of mammals, the cynodonts, which probably appeared toward the end of the Permian. The other main group of reptiles, the sauropsids, was represented by anapsids such as millerettids, nyctiphurets, pareiasaurs, and procolophonids. The latter survived into the Triassic and probably include the ancestor of the testudines (turtles). In the marine environment, gastropods, bivalves, echinoderms, brachiopods, ammonites, and fusulinid foraminifers were very abundant. These two last groups contain the most significant Permian index fossils. The Permian

Allosaurus was a powerful predator that walked on two powerful legs, had a strong, S-shaped neck, and had vertebrae that were different from those of other dinosaurs (hence its name, the "different lizard"). It was up to 38 feet long (12 m) and 16.5 feet tall (5 m).

Source: Bob Ainsworth/Morguefile.

ended with the most extensive mass extinction event recorded in the earth's history: the Permian-Triassic (P-T) boundary event. It has been estimated that more than 95% of marine species and 70% of land vertebrate species became extinct. Although the cause of the Permian mass extinction is under debate, a multiple scenario including glaciations, volcanic eruptions, and meteoritic impacts is broadly accepted.

Mesozoic Fossil Record: From the P-T Extinction Event to the K-T Extinction Event

Triassic

The P-T mass extinction event marks the Paleozoic-Mesozoic boundary, with the Triassic (251–199 mya) being the first period of the Mesozoic. The Triassic climate was generally hot and dry and therefore suitable for gymnosperm trees and reptiles. Triassic land plants include forms that survived the P-T event, including vascular plants both without seeds (lycophytes, cycads) and with seeds (glossopterid pteridospermatophytes, ginkgophytes, and conifers). The conifers flourished during the Triassic period, mainly in the northern hemisphere (the Petrified Forest in Sonoma County, California, is the most significant fossil record of Triassic conifers, consisting mostly of extinct *Araucarioxylon*). Although the archosaur reptiles first appeared toward the very end of the Permian, they evolved into more advanced types during the Triassic, including crurotarsans, phytosaurs, aetosaurs, and rausichids. In addition, the first crocodylians (*Saltoposuchus*), pterosaurs (*Scleromochlus*), and dinosaurs (*Marasuchus, Lagerpeton*) appeared in the Middle and Late Triassic. Amphibians such as temnospondyls and lissamphibians, the earliest turtles (*Proganochelys, Proterochersis*), and lepidosauromorphs (similar to tuataras) complete the land fauna. In marine environments, the ammonites diversified from a few survivors of the P-T event. The previous goniatitids and ceratitids were replaced by true ammonitids, the evolved Phylloceratina. In addition to ammonites and fishes, the marine fauna were characterized by such marine reptiles as pachypleurosaurs, nothosaurs, placodonts, plesiosaurs, and ichthyosaurs. Finally, new modern groups of corals, the scleractinians, appeared in the Early Triassic. One of the best Triassic outcrops is the 237-million-year-old Monte San Giorgio Konservat-Lagerstätte (Lake Lugano region, northern Italy and Switzerland), where abundant well-preserved fossils of fishes and marine and terrestrial reptiles are recorded. Other Triassic Konservat-Lagerstätten are Ghost Ranch (New Mexico) and Karatau (Kazakhstan). The Triassic ended with one of the five major mass extinctions of the Phanerozoic: the Late Triassic extinction event, which affected 70% of species, including sponges, ammonites, conodonts, brachiopods, insects, and many vertebrate groups (archosaurs, dicynodonts, and cynodonts). The latest Triassic extinction event was probably a cluster of smaller events, with at least two of them standing out: the 208-million-year-old Norian event and the 199-million-year-old Triassic-Jurassic boundary event. The origin of these finitriassic extinctions is poorly known, but such extinctions allowed the dinosaurs to expand into many niches that had become vacant.

Jurassic

The Jurassic period (199–145 mya), together with the subsequent Cretaceous period, is known as the Age of Dinosaurs. It was the golden age of the great herbivorous sauropods, for example, *Diplodocus, Brachiosaurus, Apatosaurus,* or the giant *Supersaurus* (40–45 m in length, 50–60 tons), and carnivorous theropods like *Ceratosaurus, Megalosaurus,* and *Allosaurus*. The first birds evolved from small coelurosaur theropods, with the famous Jurassic *Archaeopteryx* being the earliest and most primitive known bird. Solnhofen Limestone (Germany) is a Jurassic Konservat-Lagerstätte that includes excellent preserved fossils of *Archaeopteryx*. Both sauropods and theropods are saurischian dinosaurs and were more abundant than the other major group of dinosaurs, the ornithischians. Nevertheless, this latter dinosaur group also played an important role in the land environment as small herbivorous, the stegosaurids as *Stegosaurus,* and nodosaurids like *Panoplosaurus*. Other significant Jurassic reptiles were the pterosaurs. The warm, humid climate that characterized the Jurassic period allowed much of the landscape to be covered by lush jungles dominated by conifers (e.g., extinct Cheirolepidiaceae or extant Araucariaceae and Pinaceae). Bennettitales, cycads, ginkgos, and tree ferns were also common. The bennettitales are curious extinct cycad-like plants that had hermaphrodite strobili with ovulate and staminate sporangia in a flower-like arrangement. This plant group has been connected to angiosperms (true flowering plants), although the relationship is under debate. In the sea, ammonites, belemnites, fishes, and marine reptiles, including ichthyosaurs, plesiosaurs, and crocodiles, were the predominant fauna. Holzmaden Konservat-Lagerstätte (Germany) includes well-preserved Jurassic fossils of ichthyosaurs and plesiosaurs as well as ammonites. The rudists, a group of bivalves, formed reefs in the shallow seas of the Cretaceous. Well-preserved fossils of coeloid cephalopod (octopus and vampire squids) are found in the Konservat-Lagerstätte of La Voulte-sur-Rhône (France). In the protista world, new groups appeared, like the evolved planktonic foraminifera and calpionelids. Both are planktonic groups and are good Jurassic index fossils.

Cretaceous

The Cretaceous period (145–65 mya) was very warm and humid worldwide, allowing fossils of warmth-adapted plants and dinosaurs to be found at outcrops as far north as Alaska and Greenland and as far south as 15 degrees from the South Pole. Conifers continued being predominant in the flora, but angiosperms (flowering plants) spread during this period (e.g., magnolias) whereas bennettitales died out before the end of the Cretaceous. *Archaefructus,* found in the Yixian Formations (China), has been proposed as one of the earliest known angiosperms. The land fauna was dominated by dinosaurs, which were at their most diverse. Some of them are popularly known such as *Tyrannosaurus, Apatosaurus* (= *Brontosaurus*), *Triceratops, Iguanodon,* and *Ankylosaurus or Velociraptor.* Some reached giant size, like the sauropod *Argentinosaurus* (30–35 m in length, 90 to 110 tons) and *Bruhathkayosaurus* (40–45 m in length, 175 to 220 tons). *Maniraptora* include transitional forms between dinosaurs and birds, whereas mammals were small and still a minor component of the land fauna. The best fossil record of dinosaurs are found in well-preserved outcrops (Konservat-Lagerstätte) of Auca Mahuevo (Patagonia, Argentina), the Río Limay Formation (Neuquén, Argentina), the Santana Formation (Brazil), and the Yixian and Chaomidianzi formations (Liaoning, China). The Xiagou Formation (Gansu, China) is a Konservat-Lagerstätte with well-preserved fossils of *Gansus,* the earliest true modern bird. Insects began to diversify in a coevolutionary process with flowering plants, with new insect groups like Hymenoptera (ants), Isoptera (termites), Lepidoptera (butterflies), and Orthoptera (grasshoppers) now appearing. The Konservat-Lagerstätte of the Zaza Formation (Baissa, Siberia) contains numerous exceptionally well-preserved insects. Ammonites, globotruncanid planktic foraminifera, ichthyosaurs, plesiosaurs, mosasaurs, rays, sharks, and modern teleost fishes dominated the oceans. A radiation of diatoms, a significant phytoplanktonic group of protist algae with siliceous shells, occurred during the Cretaceous. Planktic foraminifers and ammonites are the best index fossils of the Cretaceous. The Cretaceous period ended with one of the major mass extinction events, caused by the impact of a meteorite 10 kilometers in diameter. Dinosaurs, pterosaurs, ammonites, belemnites, marine reptiles, rudist bivalves, and globotruncanid foraminifers become completely extinct. More than 75% of species were affected by the K-T extinction event.

Cenozoic Fossil Record: From the K-T Extinction Event to the Present

Paleogene

The Paleogene period (65–23 mya) is subdivided into three epochs: Paleocene (65–56 mya), Eocene (56–34 mya), and Oligocene (34–23 mya), and is notable for being the time during which mammals evolved from small insectivores that survived the Cretaceous-Tertiary event and diversified into large forms that dominated the land. Paleocene mammals included monotremes, marsupials, multituberculates, and primitive placentals (mesonychids). Birds also began to diversify during the Paleocene, including large carnivorous birds like *Gastornis.* Flowering plants continued to develop and proliferate, coevolving with the insects. In the oceans, sharks became the top predators after the K-T extinction of the marine reptiles. The Eocene epochs started with one of the most rapid and extreme global warming events recorded in geologic history (the Paleocene-Eocene boundary event), causing an extinction event in the deep ocean environment (benthic foraminifera) but significant radiation in the shallow seas and land fauna and flora. Fossils of subtropical–tropical trees have been found even in Alaska and Greenland. Modern mammals, like artiodactyls, perissodactyls, proboscidians, bats, and primates, appeared during the Eocene. Significant Eocene Konservat-Lagerstätte come from London Clay (England), Monte Bolca (Italy), Messel Oli Shale (Germany), and the Green River Formation (Colorado, Utah, and Wyoming). A gradual extinction event triggered by severe climatic and vegetational changes occurred across the Eocene-Oligocene transition. At this time, the world experienced a global cooling that caused the formation of the Antarctic ice cap and rearranged many of the existing biomes. Tropical areas, such as jungles and rainforests, were replaced by more temperate savannahs and grasslands. The Late Eocene event drastically affected land mammals (the *Grande Coupure*), including the extinction of mesonychids. Oligocene mammal assemblages include the well-known perissodactyl *Brontotherium,* rhinocerotid *Indricotherium,* creodont *Hyaenodon* or equid *Mesohippus,* among others. In the seas, the cetaceans (whales) had just evolved from their ancestors, the archaeocetids, which had first appeared during the Eocene, evolving from artiodactyls (perhaps from hippopotamids). Riverleigh (Queensland, Australia) is a significant Oligocene-Miocene Konservat-Lagerstätte containing ancient marsupials (*Thylacinus,* a Tasmanian tiger; *Silvabestius,* a giant wombat; *Ekaldeta,* a carnivorous rat kangaroo; *Nimiokoala,* an ancient koala, etc.).

Neogene

The Neogene period (23–0 mya) is subdivided in four epochs: Miocene (23–5.3 mya), Pliocene (5.3–1.8 mya), Pleistocene (1.8–0.01 mya), and Holocene (the past 10,000 years). It is a unit of geologic time during which birds and mammal evolved considerably, culminating with the appearance of the genus *Homo*. Due to a generally cooler and drier climate during the Miocene, grasslands underwent a major expansion at the expense of forests. Miocene mammals and birds, as well as other continental and marine fauna were fairly modern. Significant Konservat-Lagerstätte-type outcrops of the Miocene epoch come from 15- to 20-million-year-old Clarkia Fossil Beds (Idaho) and 10-million-year-old Ashfall Fossil Beds (Nebraska). The Pliocene climate became still cooler and drier than that of the Miocene, forming the Arctic ice cap; reducing tropical plants worldwide; spreading deciduous forests, coniferous forests, grasslands, and tundra; creating deserts in Asia and Africa; and evolving essentially modern fauna (mastodonts, elephants, rhinos, giraffes, tapirs, saber-toothed tigers or smilodons, dogs, hyenas, horses, cows, antelopes, etc.). The primates continued their evolution, appearing as *Australopithecus* in the late Pliocene (more than 4 mya). The cooling of the climate culminated in the Pleistocene, an epoch characterized by repeated glacial cycles. A significant Pleistocene Konservat-Lagerstätte is found in the 20,000-year-old La Brea Tar Pits (Los Angeles, California), a tar pit that trapped numerous animals and plants, including ancient bison, American camels, coyotes, jaguars, mammoths, American mastodons, and even humans. The genus *Homo* first appeared during the Pliocene-Pleistocene transition, with *H. habilis* and *H. rudolfensis* being their first representatives. Other *Homo* species evolved progressively across the Pleistocene, such as *H. ergaster, H. erectus, H. antecessor, H. heildenbergensis, H. neanderthalensis, H. rhodesiensis,* and finally *H. sapiens*. The best outcrops of *Australopithecus* and *Homo* come from Hadar (Ethiopia), Olduvai Gorge (Tanzania), Lake Turkana (Kenya), Kimberley (South Africa), Solo River (Java), Zhoukoudian (China), Atapuerca (Spain), Mauer (Germany), La Chapelle-aux-Saint (France), and Shanidar (Iraq).

The beginning of the Holocene corresponds with a period of warming (Holocene climatic optimum) after of the last ice age, and with the development of human cultures. Humans have evolved into a significant agent of extinction. Deforestation, agricultural practices, pollution, overhunting, and numerous other human activities are causing the so-called Holocene extinction event, including numerous species of plants, mammals, birds, amphibians, reptiles, and arthropods. It is also beginning to be called the sixth extinction, since it may become as important as the five major extinction events of the Phanerozoic: the Late Ordovician, Late Devonian, P-T boundary, Late Triassic, and K-T boundary mass extinction events.

Ignacio Arenillas

See also *Archaeopteryx;* Chronostratigraphy; Coelacanths; Dinosaurs; Evolution, Organic; Extinction; Extinction and Evolution; Extinctions, Mass; Fossils, Interpretations of; Geological Column; Geologic Timescale; Geology; Ginkgo Trees; Glaciers; Hominid-Pongid Split; Paleontology; Phylogeny; Stromatolites; Trilobites

Further Readings

Benton, M. J. (Ed.). (1993). *The fossil record 2.* London: Chapman & Hall.

Harland, W. B., Holland, C. H., House, M. R., Hughes, N. F., Reynolds, A. B., Rudwick, M. J. S., et al. (1967). *The fossil record.* London: Geological Society of London.

Knoll, A. H. (2003). *Life on a young planet: The first three billion years of evolution on Earth.* Princeton, NJ: Princeton University Press.

Margulis, L. (1970). *Origin of eukaryotic cells.* New Haven, CT: Yale University Press.

Paul, C. R. C., & Donovan, S. K. (1998). An overview of the completeness of the fossil record. In S. K. Donovan & C. R. C. Paul (Eds.), *The adequacy of the fossil record.* Chichester, UK: Wiley.

Schoph, J. W. (1999). *Cradle of life: The discovery of the earth's earliest fossils.* Princeton, NJ: Princeton University Press.

Taylor, F. J. R. (1979). Symbionticism revisited: A discussion of the evolutionary impact of intracellular symbioses. In *Proceedings of the Royal Society of London,* Series B, Biological *Sciences, 204*(1155), 267–286.

Fossils, Interpretations of

Fossils, the remains of once-living organisms or their behavior, have long been known to humankind, but interpreted differently depending on time and place. Since their first recorded discovery by ancient Greeks, Romans, and Native Americans, fossils have been explained as the remains of gods and giants, used to support notions of natural magic, treated as petrified organisms killed in Noah's Flood, and ultimately regarded as some of the strongest evidence for Darwinian evolution. The scientific study of fossils began in the 16th century and has changed dramatically, depending on the prevailing views of the scientific community and the technology available to researchers. Today, the science of paleontology is a vibrant discipline strongly integrated with geology, biology, chemistry, and other sciences.

Although fossils were discovered and often interpreted by the ancient Greeks, Romans, and Native Americans, the first rigorous and systematic studies of fossils were carried out by 16th-century European naturalists. To these naturalists, the word *fossil* referred to a range of natural curiosities dug from the earth, including stones, gems, and the remains of once-living organisms that comprise today's concept of fossils. Early naturalists, however, had a difficult time recognizing the organic nature of fossils, due both to philosophical constraints and to the very practical difficulty of identifying often fragmentary and eroded specimens. Several encyclopedic works, including Georg Bauer's (1494–1555) *On the Nature of Fossils* and Conrad Gesner's (1516–1565) *On Fossil Objects,* recognized the extraordinary similarity between some fossils and living organisms, but were hesitant to describe these specimens as the remains of once-living creatures. Instead, many naturalists of the time considered fossils to be the result of natural magic or a "plastic force" that could reproduce the shapes of common objects in situ in solid rock. These views were tied into an overarching natural philosophy that saw the world as a harmonious and interlocking web of affinities, guided by supernatural powers.

Although often hinted at by philosophers (including Xenophanes of Colophon and Leonardo da Vinci), the organic nature of fossils was first rigorously demonstrated by Nicolaus Steno (1638–1687), a Danish anatomist and crystallographer. In dissecting the head of a giant shark that washed up near Livorno, Steno noticed an uncanny resemblance between the creature's teeth and glossopetrae, a type of odd stone common on Malta that was thought to have curative and magical powers. While others had previously noted the resemblance, they were at a loss to explain how petrified sharks' teeth were found on land, often on mountains thousands of feet above sea level. Noting that glossopetrae resembled a modern shark tooth in every respect, Steno wrote that these stones must be the remains of once-living organisms, a conclusion he generalized to other fossils that resembled living creatures or their organs, such as bones, shells, and leaves. This conclusion was strongly supported by early microscopist Robert Hooke (1635–1703), who used this new instrument to examine the microscopic composition of fossils, which he found to be nearly identical to the microstructure of the living organisms they resembled.

With the organic nature of fossils now secure, most researchers at the time regarded fossils and their entombing rocks as products of Noah's Flood. However, based on field excursions in Tuscany, Steno recognized that rocks are found in layers made of different materials, which he hypothesized as representing a sequence of different events in the history of the earth. The notion of sequential periods in earth history was supported by noted French anatomist Georges Cuvier (1769–1832), whose careful comparisons of fossil sloth and elephant specimens to their modern counterparts recognized the former as distinct species. By now, exploration of the New World made it implausible that these fossil species would be found alive in an unexplored corner of the globe, indicating to Cuvier that they must have gone extinct. Up until this point, early naturalists such as Martin Lister (c. 1638–1712) and John Ray (1627–1705) regarded extinction as impossible, as it would imply imperfection in God's creation. To Cuvier, the reality of extinction suggested that earth history could be divided into distinct periods punctuated by "revolutions," an idea that soon found support in the geological fieldwork of Jean-André De Luc (1727–1817). Furthermore, Cuvier himself carefully studied the thick rock sequences exposed in the gypsum quarries at Montmartre, and found evidence of several very different faunas of fossil mammals, which gradually became increasingly differentiated from modern faunas further back in time. Additional exploration, especially in Great Britain, revealed several distinct periods in geological history, including an era dominated by reptiles (dinosaurs, plesiosaurs, ichthyosaurs, etc.).

Cuvier roundly denied the possibility of evolution, but his research and that of others conclusively demonstrated that new species must have arisen over time to explain the distinct new faunas appearing after his "revolutions." At the same time, James Hutton (1726–1797) and Charles Lyell (1797–1875) provided decisive evidence that the Earth was ancient, not several thousand years old as theorized by Biblical scholars. Although most of his argument focused on living species and selective breeding, Charles Darwin (1809–1882) used evidence of distinctive faunas and an ancient Earth to argue for the reality of evolution by natural selection. Two years after the publication of Darwin's *On the Origin of Species* (1859), the discovery of the Jurassic bird *Archaeopteryx* in Germany provided the first convincing "missing link," as its combination of reptilian (teeth and a long tail) and avian (feathers and wings) features indicated an evolutionary transition between these two groups. In the following decades, a nearly complete assemblage of horse fossils from the newly opened American West was used by Thomas Henry Huxley (1825–1895) and O. C. Marsh (1831–1899) to illustrate gradual progressive evolution over time. Additional discoveries by Marsh, including several toothed Cretaceous birds, revealed the early evolutionary history of living animal groups. From the time of Darwin, Huxley, and Marsh to the present day, fossils have been interpreted in an exclusively evolutionary context, and continue to help scientists understand the patterns and processes of evolution. The recent hypothesis of punctuated equilibrium, which postulates that longtime evolutionary stasis is punctuated by rapid speciation, was supported with careful study of extensive trilobite fossil faunas from the eastern United States.

Today, the science of paleontology is a dynamic and vibrant discipline that is becoming increasingly integrated with other fields of research. The discovery, preparation, and study of fossils are constantly changing with the development of new technology, such as molecular DNA analysis and CT scanning. The philosophical framework of paleontology has changed as well, and cladistic methodology is routinely used to study the genealogical relationships of organisms, and sophisticated statistical techniques are used to examine patterns of evolution. As is evident from its history, paleontology will continue to change over time with the development of new research methods, new technology, and new scientific philosophy.

Stephen L. Brusatte

See also *Archaeopteryx;* Darwin, Charles; Dinosaurs; Evolution, Organic; Fossil Record; Geologic Column; Hutton, James; Huxley, Thomas Henry; Lyell, Charles; Paleontology; Steno, Nicolaus; Stromatolites; Trilobites; Xenophanes

Further Readings

Mayor, A. (2000). *The first fossil hunters: Paleontology in Greek and Roman times*. Princeton, NJ: Princeton University Press.

Rudwick, M. J. S. (1976). *The meaning of fossils: Episodes in the history of palaeontology*. Chicago: University of Chicago Press.

Ruse, M. (2000). *The evolution wars: A guide to the debates*. Santa Barbara, CA: ABC-CLIO.

Fossils, Living

Evolution is not a constant but rather an unpredictable process. Some organisms undergo multiple and significant physical alterations over a span of a few centuries. Others endure millions of years with little change, leaving their present-day form almost a mirror image of a distant ancestor; these latter life forms are commonly referred to as "living fossils" and are unique residuals of time.

Enduring Organisms

Coelacanth

The present-day coelacanth, *Latimeria chalumnae,* is believed to be a fish from which the first amphibians may have evolved approximately 400 million years ago (mya). The discovery of a living specimen during the mid-20th century caught scientists unaware since such fish were thought to be extinct. Through subsequent investigations, the *Latimeria chalumnae,* which resembles coelacanths from 100 mya, was determined to live off the Comoro Islands at depths of more than 500 feet. Ichthyologists believe that limited competition and a lack of natural predators provided *Latimeria chalumnae* with a stable environment in which to survive relatively unchanged. Whatever circumstances made it possible for a coelacanth species to survive, and no matter the distinctive differences between *Latimeria chalumnae* and its predecessors, there is no question of the coelacanth's status as a living fossil.

Coniferous Trees

Vast grasslands covered much of North America when Native Americans first explored the continent over 12,000 years ago. Even then, coniferous trees, including pine and spruce variants, existed; a great span of time in terms of humanity's antiquity, but a mere instant in the life of conifers.

Coniferous trees surfaced toward the end of the Paleozoic era, over 200 mya. A plant variety we consider so ordinary today, using pine and spruce for lawn decoration and even holiday fixtures, has an antiquity rivaling dinosaurs, making conifers living fossils hidden in plain sight.

Dragonflies

A multitude of dragonfly species exist today, all of which possess bodies that are as lethal as they are elegant. Dragonflies are predators, subsisting on a diet of mosquitoes, midges, and other small insects. Two sets of strong wings enable them to hover and then accelerate rapidly. Remarkably, these persistent insect-hunters are continuing on an evolutionary trek encompassing more than 300 million years. As for contemporary species, they started surfacing roughly 100 mya. A recognizable form of that antiquity certainly qualifies the dragonfly as a living fossil.

Ferns

Fern species are as diverse as they are ancient, the variety of fern designs seemingly endless. Yet, such diversity does not mean that modern ferns do not bear any significant resemblance to older forms. In fact, the complex designs of modern ferns mirror those of ferns that appeared approximately 300 mya. Then, as now, ferns endured changing climates and survived while other plant and animal species disappeared. This endurance of fern species, as potent now as it was millions of years ago, is what earned ferns the title of living fossils.

Goblin Sharks

The infamy of *Carcharodon carcharias* (great white shark) continues to capture the attention of researchers and beach enthusiasts alike. Consequently, our understanding of *Carcharodon carcharias* has increased dramatically to include a clearer knowledge of its earliest (modern) ancestors, which emerged approximately 60 mya. Yet, with even so lengthy a history, *Carcharodon carcharias* is far from being an elder among shark species. Today, a number of sharks reflect nearly 100 million years of relative stasis, earning them the title of living fossil. Of these, *Mitsukurina owstoni* (the goblin shark) is arguably the most unique.

With a flat, extended snout positioned above its mouth, resembling a horn or similar projection, *Mitsukurina owstoni* is an oddity. With specimens first being acquired and described at the end of the 19th century, *Mitsukurina owstoni*'s similarity to ancient sharks (long believed extinct) quickly became apparent. *Mitsukurina owstoni*'s ancestry was ultimately traced to the Cretaceous period, extending the terrestrial presence of similar species to over 100 million years.

Horseshoe Crabs

The armored body of the horseshoe crab, *Limulus polyphemus,* is hard and nearly impenetrable. After an examination of the fossil record, it is also apparent that the horseshoe crab's design is long-lived.

Horseshoe crabs appear ancient, complete with an armor-plate-covered body reminiscent of several dinosaur species. Yet, given the design of horseshoe crabs, it is astonishing how resilient these creatures are. Although very resilient, horseshoe crabs do suffer continual fluctuations in their environment, enduring varying moisture and salinity levels and even high levels of pollutants. The casual observer of these creatures will undoubtedly be astounded by the reality of horseshoe crab hardiness. Yet, when looking at the fossil record, the durability of these creatures becomes understandable.

The current species of horseshoe crabs are quite similar to ancestors living 300 mya. For such a biological design to endure that long, horseshoe crabs must be engineered well, considering the dramatic changes the planet continues to undergo.

Future Living Fossils

Archaeologists and paleontologists use picks, shovels, and trowels to uncover the past and reveal fossils of species that once inhabited the planet. Living fossils, such as the species aforementioned, provide a similar glimpse into the past, and in the process make the remote past seem more tangible, more real. It is inviting to speculate which of the species that are common today will become the living fossils of the distant future.

Neil Patrick O'Donnell

See also Coelacanths; Extinction and Evolution; Gingko Trees

Further Readings

Ellis, R. (1976). *Book of sharks*. New York: Grosset & Dunlap.

Maisey, J. G. (1989). Evolution of the shark. In J. D. Stevens (Ed.), *Sharks* (pp. 14–17). New York: Facts on File.

Parsons, G. R., Ingram, G. W., Jr., & Havard, R. (2002). First record of the goblin shark *Mitsukurina owstoni,* Jordan (family Mitsukurinidae) in the Gulf of Mexico. *Southeastern Naturalist, 1*(2), 189–192.

Ward, P. D. (1992). *On Methuselah's trail: Living fossils and the great extinctions*. New York: W. H. Freeman.

Ware, J., May, M., & Kjer, K. (2007). Phylogeny of the higher Libelluloidea (Anisoptera: Odonata): An exploration of the most speciose superfamily of dragonflies. *Molecular Phylogenetics and Evolution, 45,* 289–310.

Fossils and Artifacts

Individually, artifacts and fossils offer archaeologists, historians, and paleontologists glimpses of the past, with artifacts reflecting technological developments and fossils indicating life forms that once inhabited a biome. When examined together, artifacts and associated fossils, in both primary and secondary contexts, provide additional insight into an archaeological site's formation processes and, ultimately, an idea as to a site's and its affiliated life forms' place in time.

Occupation of North America

It was in 1927 that excavators first discovered Paleoindian projectile points near Folsom, New Mexico, a discovery with immediate and substantial ramifications. Before 1927, scholars thought that Native Americans had traversed North America only a few thousand years earlier. The projectile points, often fluted, which are now referred to as "Folsom" points, were found associated with the fossilized remains of an extinct species of bison, suggesting Native American occupancy more than 5 thousand years earlier than previous believed. What made the discovery even more convincing was that Folsom points were found embedded in some of the remains. Today, we have radio-carbon dating to verify the Folsom discoveries. In 1927, the excavators relied on the simple collaboration of artifacts and fossils to understand the site's temporal implications, a method far from absolute, but effective nonetheless.

The Emergence of Tool Traditions

The Sterkfontein site, a collective of cavern remnants located in South Africa, continues to yield fossil remains of early hominid species and a variety of early lithic tools, including *Australopithecine* and *Homo habilis* specimens for the former and hand axes for the latter. The overlapping of specimens at Sterkfontein contributes to ongoing debates on when and by whom Oldowon and later tool traditions were created. With Sterkfontein hominid remains estimated at over 1.5 million years old and the associated tools resembling Acheulean traditions, which would be an early Acheulean discovery, it is clear that hominids had created stone tools nearly 2 million years before the present (BP); an understanding gained through an analysis of artifacts and associated hominid fossils.

Environmental Change and Technological Innovation

The understanding of plant domestication, particularly in the Near and Middle Eastern regions where initial domestication efforts took place, remains a strong research objective of paleoanthropologists and paleontologists alike. Consequently, an endless collection of artifacts and fossilized pollen grains has been gathered and partially analyzed, providing clues as to the process by which humanity learned to manage plants for consumption purposes. A consequence of this research is knowledge of paleoenvironments and the technological adaptations made by human populations responding to environmental changes through time. As with previous associations of artifacts and fossils, but with fossilized plants instead of fossilized animal remains, the examination of assemblages provides greater insight than natural or manufactured collections alone, ultimately providing a better understanding of humanity through time.

Neil Patrick O'Donnell

See also Anthropology; Archaeology; Boucher de Perthes, Jacques; Fossil Record; Olduvai Gorge; Paleontology

Further Readings

Clarke, R. J. (1988, June). Habiline handaxes and paranthropine pedigree at Sterkfontein. *World Archaeology, 20*(1), Archaeology in Africa [Special issue], pp. 1–12.

Eastwood, W. J., Roberts, N., & Lamb, H. F. (1998). Palaeoecological and archaeological evidence for human occupance in southwest Turkey: The Beysehir occupation phase. *Anatolian Studies, 48,* 69–86.

LeTourneau, P. D. (2006). Folsom culture. In H. J. Birx (Ed.), *The encyclopedia of anthropology* (pp. 975–978). Thousand Oaks, CA: Sage.

Susman, R. L. (1991, Summer). Who made the Oldowon tools? Fossil evidence for tool behaviour in Plio-pleistocene hominids. A quarter century of paleoanthropology: Views from the U.S.A. [Special issue]. *Journal of Anthropological Research, 47*(2), 129–151.

Frankenstein, Legend of

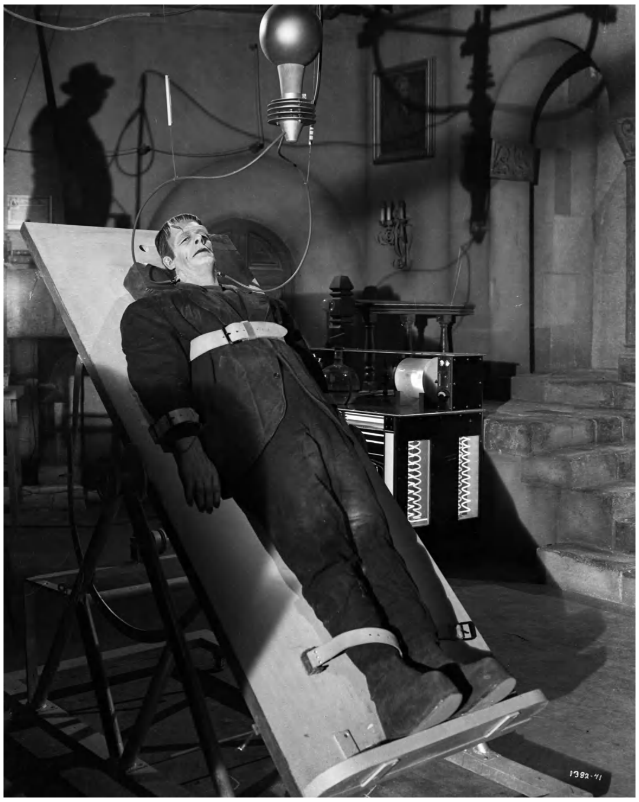
Frankenstein, or The Modern Prometheus, was composed in the summer of 1816 by the 19-year-old Mary Wollstonecraft, later the wife of poet Percy Bysshe Shelley, during a vacation she spent on the shores of Lake Geneva with Shelley and their friend the poet George Gordon, Lord Byron. The weather was cold and rainy; to pass the time, she, Shelley, and Byron engaged in a contest to craft the best horror story. Published anonymously in 1818, Mary Shelley's gothic novel has continued to exert an influence on literature and popular culture for nearly 200 years. The theme of man's overreaching in an effort to take on godlike powers and create an immortal life form has resonated deeply in the popular imagination as a warning against scientific hubris and the consequences of tampering with the forces of nature. It has been credited with giving rise to the horror genre, with variants of the Frankenstein story portrayed in dozens if not hundreds of stage and film adaptations. Although most such adaptations have been based only very loosely on the novel, the hideousness of the monster's appearance and the rejection that this disfigurement creates has remained a constant element.

In the novel, Victor Frankenstein, a young medical student, studies biology and chemistry at the University of Ingolstadt in Switzerland. He becomes obsessed with creation, and in following the scientific advances of his professors, he experiments with reanimation to bring dead tissue back to life. During his studies, Victor Frankenstein takes up a reclusive existence. He abandons and rejects family and friends as his work takes him from clandestine experiments in his makeshift laboratory to committing acts of grave robbery to gather the raw materials from which he hopes to create a new life form that could live indefinitely. When his offspring awakens, we witness not a scientist jubilant in success but a man horrified by his actions, shocked by the monstrosity of his work. Victor Frankenstein abandons the life he has created and shuns and rejects his creation.

The monster, now frightened and isolated, begins to experience feelings and sensations just as any small child would, but unlike an infant or child who has a parent or guardian to guide him, the creature is alone. He realizes this, and in learning to exist in exile, mistreated and rejected by villagers, his heart hardens and he swears revenge. When monster and creator are reunited, the monster articulately defines the sins of his father. The monster says that he was born good and benevolent, but that misery and rejection have turned him into a fiend. He then curses Frankenstein and demands a companion. In exchange, the monster promises to go into hiding with his mate forever.

The novel achieved almost immediate notoriety; within just 5 years of its publication several theatrical versions emerged, gaining wide attention across Europe. The first theater performance was a three-act play, *Presumptions; or The Fate of Frankenstein,* by Richard Brinsley Peake. Many changes were made in this adaptation, including the addition of a clumsy and comedic laboratory assistant who became a stock figure in subsequent versions of the story. In this version, he is named Fritz and Victor is called "Dr. Frankenstein." In addition, in this and later adaptations, the monster is unable to speak or to learn, unlike the creature in Mary Shelley's original.

Over time, the Frankenstein monster evolved into a popular cultural icon through many stage and film adaptations of the tale. The first Frankenstein film was Thomas Edison's 16-minute film, *Frankenstein* (1910). The German version, *Golem,* was released in 1914. In 1931 Universal Studios released James Whale's *Frankenstein* into mainstream popular culture. The actor Boris Karloff portrayed Shelley's articulate, educated, and sensitive creature as a mute and maniacal beast without soul or conscience. For 2 decades Universal Studios produced a series of Frankenstein movies, including



Bela Lugosi (1882–1956) takes his turn as Frankenstein's monster in Frankenstein Meets the Wolf Man, *directed by Roy William Neill.*

Source: Getty Images.

The Bride of Frankenstein (1935), *The Son of Frankenstein* (1939), *Ghost of Frankenstein* (1942), *Frankenstein Meets the Wolf Man* (1943), and *House of Frankenstein* (1948). In each film, a stitched forehead, lumbering lanky limbs, and sunken eyes branded the monster's appearance. Electrodes jutted from each side of his neck to complete the iconic monster mask. Mary Shelley's original intent to portray the creature as a lost soul, abandoned and scorned, was jettisoned in favor of inciting fear and revulsion in the audience.

In 1957, Hammer Films produced *The Curse of Frankenstein* with Peter Cushing as Victor Frankenstein and Christopher Lee as the monster. It is in this film that we see the first reference to Frankenstein's well-known "mistake" of using a defective brain in the creation of the monster, thus providing a rationale for the monster's violent nature.

The 1994 film *Mary Shelley's Frankenstein,* directed by Francis Ford Coppola and starring Kenneth Branagh, Robert DeNiro, and Helena Bonham Carter, was the first cinematic version to attempt to maintain fidelity to the story as Mary Shelley had written it, allowing audiences to see and understand Victor Frankenstein and his creature as the author had intended.

Debra Lucas

See also Dracula, Legend of; Vampires; Werewolves

Further Readings

Hunter, J. P. (Ed.). (1996). *Frankenstein* (A Norton Critical Edition). New York: Norton.

Nardo, D. (Ed.). (2000). *Readings on Frankenstein.* San Diego, CA: Greenhaven Press.

Shelley, M. W. (1992). *Frankenstein or the modern Prometheus.* New York: Penguin. (Original work published 1816)

Frege, Gottlob (1848–1925)

Gottlob Frege was a German mathematician and logician as well as a philosopher. He is considered the major founder of modern logic. His uniquely profound research led him from pure mathematics, like the methodizing of natural numbers or "the proof," to a highly philosophical approach to mathematical logic and the foundation of mathematics, and even to consequential findings in the field of linguistics. Applicable to most fields of logic, Frege's research exerted an influence far beyond pure mathematical logic. He is considered to have advanced logic beyond Aristotle, despite the fact that he failed in constructing a consistent axiomatic foundation for logic. Consequently, Frege holds a significant place in the historical development of logic and mathematics from ancient Greece to our modern times.

Life and Work

F. L. Gottlob Frege was born on November 8, 1848, in Wismar, northern Germany, in the state of Mecklenburg. He was the son of Alexander Frege, the principal of a private high school in Wismar. It is probable that the influence of his teacher at the local gymnasium, Leo Sachse, motivated Frege to study after school. Subsequently he enrolled as a student in mathematics, chemistry, physics, and philosophy; first from 1869 to 1871 at the University of Jena under the encouragement of the famous physicists Ernst Abbe and Karl Snell; next he expanded his studies for 2 more years at Göttingen University, where he eventually obtained a doctoral degree in 1873 with the valued geometrical thesis translated as *On a Geometrical Representation of Imaginary Figures in a Plane.* Just one year later, Frege received his second doctorate (habilitation) for his work *Methods of Calculation Based Upon an Amplification of the Concept of Magnitude,* comprehending some initial steps of his theory of higher (complex) mathematical functions.

Also in the year 1874, upon recommendation of his academic teacher Abbe, Frege became a lecturer in mathematics at the University of Jena, where he would remain all his professional life. He taught extensively in all mathematical disciplines. His research, however, concentrated on the philosophy of logic. Persistent dialogue—noteworthy because Frege was extremely reserved in general—with his Jena colleague and one of his few friends Rudolf Eucken, later a winner of the Nobel Prize in literature, supported Frege's philosophically mathematic thinking.

In 1879, Frege's seminal first work *Concept Script, a Formal Language of Pure Thought Modelled Upon That of Arithmetic* (*Begriffsschrift*) was published. He developed a principle for the construction of a logical language. In the aftermath of the *Begriffsschrift,* Frege was made associate professor at Jena University. Frege married Margarete Lieseberg, but unfortunately neither of their two children survived into adulthood, so they adopted a boy named Alfred.

Frege's book *The Foundations of Arithmetic* (*Grundlagen*) appeared in 1884. It comprised for the first time a complete system for the foundation of arithmetic based on a set of mathematically logical axioms. To gain higher recognition for his work, this book was written in completely nontechnical, natural language.

In conjunction with his profound research into the logical system of mathematics, Frege felt impelled to develop a philosophy of language. His major work on a linguistic system supporting the philosophy of logic is *On Sense and Reference* (1892). In this book, Frege's two famous linguistic puzzles were presented, distinguishing between sense and the denotation of terms in order to resolve the ambiguities of language.

In 1893, with the first volume of *Basic Laws of Arithmetic* (*Grundgesetze*), Frege's major opus on the philosophy of mathematics was published. Frege used to say that "every good mathematician is at least half a philosopher, and every good philosopher is at least half a mathematician." Because almost no colleague of his in the world was able to understand what Frege had managed to find, none of his publications achieved immediate success, and he even received some very poor reviews.

Nonetheless, Frege was promoted to honorary professor in Jena in 1896, giving him a regular income for the first time in his life. Years of bad luck followed. In 1902, Frege received a letter from Bertrand Russell who modestly pointed out that he had discovered a paradox caused by a severe inconsistency in Frege's set of logical axioms. Also, the second volume of the *Basic Laws* was based on the misarranged axioms but was already finished and was (at that exact time) with the printer. Unfortunately, even the amendment to his axiomatic system that Frege added as an appendix proved to be inconsistent; as some say, Frege must have known this but was unable to accept his failure. Frege gave up writing the intended third volume of the *Basic Laws* and never again published any research. His late attempt to base logic on geometry instead of arithmetic could not be elaborated any further.

During the First World War, Frege retired and after the death of his wife he left Jena; he lived in increasing reclusiveness and died on July 26, 1925, in Bad Kleinen, Germany.

Influence

Frege left deep traces in two fields of philosophical research: in the logic of mathematics and in the philosophy of language. In the first, he marks the beginning of modern science. His invention of quantified variables (predicate calculus) to replace the ambiguous meaning of natural language not suitable for the denotation of complex mathematical terms was seminal to the development of mathematics. His influence arises not only from separate theorems Frege published himself, but also is founded on the diffusion of his very elementary logic and philosophical findings into countless studies.

Frege's analytical philosophy is connected with Locke's and Hume's empiricism. In a far-reaching empiricist manner and as a central point in his logic, which is founded on the sole relevance of the logical truth of an argument, Frege did not accept any nonfalsifiable fact or instance; hence he was in deep doubt about transcendental phenomena, and epochs do not seem to have attracted his attention.

Personality

For a man in determined pursuit of new scientific findings, Frege was extremely conservative in his political attitude. Especially in his later years, the embittered Frege was an enthusiastic monarchist, anti-democrat, anti-French, anti-Catholic, and anti-Semite.

Frege displayed signs of immoderate self-regard and refused to accept or even to consider the criticism of his colleagues. To the contrary, he reacted with embitterment and polemic attacks on his critics, which seems an inadequate response in light of Frege's undoubtedly immense and lasting scientific achievements in the fields of logic and the philosophy of mathematics and language.

Matthias S. Hauser

See also Aristotle; Hume, David; Language

Further Readings

Beaney, M. (Ed.). (1997). *The Frege reader.* Oxford, UK: Blackwell.

Dummett, M. (1991). *Frege: Philosophy of mathematics.* Cambridge, MA: Harvard University Press.

Sluga, H. (1980). *Gottlob Frege.* London: Routledge & Kegan Paul.

Freud, Sigmund

See Consciousness

Futurology

Futurology is an interdisciplinary field that analyzes past and current conditions, events, and trends for the purpose of forecasting future developments. Alternate terms include *future studies, futuristics, forecasting,* and *futurism.* During this time of rapid technological, scientific, and social change, futurology is more important than ever. However, the goal of futurology is not to predict specific events or one-time occurrences, but to improve our probable or alternative futures.

Futurology is a relatively new field of study, first espoused by science fiction author H. G. Wells, who called for the establishment of "Departments and Professors of Foresight" during a 1932 BBC broadcast. The term *futurology* was first used during World War II by political scientist Ossip Flechteim, to describe this new field of knowledge based on a probable and systematic analysis for the future. During the Cold War, Herman Kahn, Olaf Helmer, and other experts at the RAND Corporation think tank laid the methodological foundations for futurology by employing the scenario technique, game theory, and systems analysis to analyze military strategy.

With these foundations set, it was possible to conduct the first course devoted to futurology, taught by Alvin Toffler at The New School for Social Research in New York in 1966. Most of Toffler's key ideas are encapsulated in his book *Future Shock,* about the effects of accelerated rates of change on society, including "super-industrialization" and "information overload." Toffler named some well-known and influential futurists of his time in his 1972 edition of *The Futurists,* such as R. Buckminster Fuller, Marshall McLuhan, and Margaret Mead. During the 1960s and 1970s, many futurist groups were formed, including the World Future Society in 1966.

Sir Arthur C. Clarke was another leading futurist and active member of the World Future Society, as well as a foreteller of global network communication satellites. He maintained that no one could predict the future but it was feasible to map "possible futures." Other futurists, some more specialized than their predecessors, include Ray Kurzweil in the field of artificial intelligence, Eric Drexler in nanotechnology, Patrick Dixon in business, Arnulf Grubler in energy and environment, and Greg Stock in genetic engineering.

Today, futurists can include professional and academic visionaries, consultants, policy analysts, professors, and writers from many disciplines, including anthropology, computer science, economics, education, engineering, environmental science, history, library and information science, mathematics, physical sciences, political science, and sociology.

Regardless of a futurist's profession or academic expertise, all encourage "big picture" or cross-disciplinary thinking. According to futurist Edward Cornish, there are six "super trends" to understand if one wishes to see the big picture or the "Great Transformation" of what is shaping our future. They include technological progress; economic growth; health improvement; mobility increase; environmental decline; and deculturation. Futurists may advise companies, government agencies, and various organizations on possible scenarios and outcomes based on these super trends.

Based on these trends, futurists, or futurologists, employ a wide range of methodologies to examine and forecast the possible, probable, and preferable. The "possible" refers to what *could* happen; the "probable" refers to what would likely happen under circumstances subject to human control; the "preferable" is a prescriptive judgment as to what *should* happen. Forecasting is the attempt to estimate or predict future conditions based on current trends. It is important to define time periods in regards to short-term (1 to 5 years), medium-term (5 to 20 years), and long-term (20 to 50 years or beyond) forecasting of the future.

Another method often employed is that of "backcasting"—asking what changes in the present would be required to arrive at foreseen alternative futures. It is useful to analyze the many possible points of divergence from a timeline, as forecasting will construct multiple scenarios. Scenarios are one of the more popular methods used in futurology, especially by government, corporate, and military analysts who use them to aid decision making. A scenario is not a precise forecast of the future, but a probable description of what might happen. Driving factors of a situation are identified and plausible scenarios based on different outcomes are constructed.

The Delphi method is a type of forecasting that involves a panel of experts who judge the timing, probability, and implications of situations, trends, and events surrounding a particular problem. Participants maintain anonymity, frequent feedback is given, and the process is repeated several times until a consensus emerges. This method was used by RAND experts during the Cold War when they were asked to give their opinion on the probability, frequency, and intensity of possible enemy attacks.

In any attempt to forecast the future, a certain amount of risk, uncertainty, and unpredictability will exist. When the theory becomes more specific or forecasts farther into the future, the amount of uncertainty increases. This topic of uncertainty and unpredictability of forecasts is a source of controversy and debate among futurologists. Some argue that the future is at heart unpredictable, and that the true way to predict the future is to create it yourself. Others believe that advances in science, technology, models, and statistics will allow us to improve our understanding of probable futures.

Futurology is not only a discipline or profession, but also a state of mind. Futurologists have a passion and a skill for visualizing the risks and opportunities that we may face and how we can shape our futures.

Rebecca M. Blakeley

See also Bradbury, Ray; Clarke, Arthur C.; Toffler, Alvin; Verne, Jules; Wells, H. G.

Further Readings

Cornish, E. (2004). *Futuring: The exploration of the future*. Bethesda, MD: World Future Society.

Thompson, A. E. (1979). *Understanding futurology: An introduction to futures study.* North Pomfret, VT: David & Charles.

Toffler, A. (1970). *Future shock*. New York: Random House.

Toffler, A. (1972). *The futurists*. New York: Random House.

G

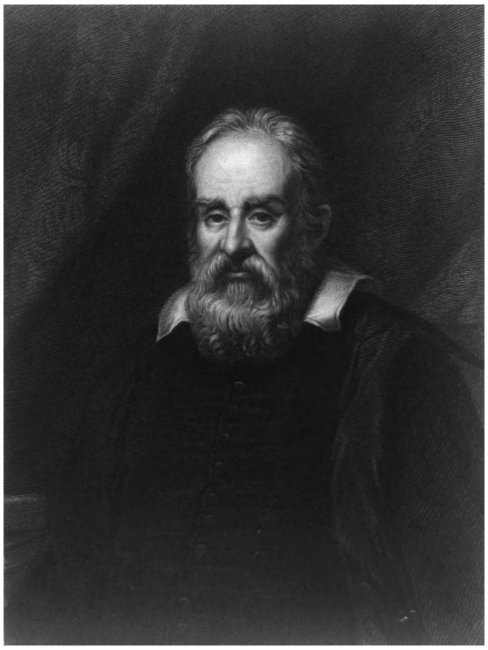
GALAXIES, FORMATION OF

See NEBULAR HYPOTHESIS

GALILEI, GALILEO (1564–1642)

Italian mathematician, astronomer, and physicist Galileo Galilei is considered to be the founder of the modern scientific method. He pioneered verification by experimentation and critical analysis of phenomena. Galileo was the first person to use a telescope to make and interpret systematic astronomical observations and made many discoveries regarding the solar system. Galileo's observations of the eclipses of Jupiter's moons led to his discovery of a cosmic clock that, in effect, recorded absolute time. The Galilean transformations of space and time variables led to the development of the Newtonian laws of mechanics. His theoretical work in physics laid the groundwork for the future exploration of relativity and the laws of motion. Although Galileo himself did not invent the pendulum-regulated clock, his initial designs inspired others to do so. His preliminary research and design of an escapement mechanism led to the development of the first pendulum-regulated timepiece. Galileo's quest to measure very small quantities of time accurately paved the way for discoveries about sound and light waves that eventually led to modern investigations of quantum physics.

Galileo was born in Pisa, Italy, on February 15, 1564. He was the first of six, possibly seven children born to Vincenzo Galilei, a musician, composer, and wool trader; their mother was Giulia Ammannati of Pesscia. Three days later the famous artist Michelangelo died. Leonardo



Galileo first put forth his observations on the moons of Jupiter in his book Siderius Nuncius. *He studied Jupiter over the course of a month and was able to show the movement of the satellites around Jupiter.*

Source: Library of Congress, Prints & Photographs Division, LC-USZ62-7923.

da Vinci had passed away 45 years prior to Galileo's birth. Nicholas Copernicus had been dead for 21 years. William Shakespeare would be born 2 months later. This was the time of the Renaissance. A new awakening had arrived for philosophy, music, art, the sciences, literature, and discovery.

Early Life

At age 7, Galileo was sent off to a monastery to prepare to study medicine. Galileo enjoyed life at the monastery and soon decided he wanted to become a monk. His father did not agree and, complaining about his son's untreated eye infection, removed Galileo from the monastery. Back at home young Galileo was strongly influenced by his father's experiments on the nonlinear relationship between the tension and pitch of stretched lute strings. Working with his father, Galileo learned how to experiment and gather data. By attaching carefully measured weights to a range of strings of different lengths and thicknesses, the Galileis listened to the tones produced. Each modification altered the frequency of the vibration, producing a different note. The length of the string altered the pitch, or cycles per second of the vibrating string, in much the same way the rate of the swinging of a pendulum was related to the length of its cord. This led to the discovery that the interval between two notes was related to the inverse squares of the length of the string, when the same weight was attached and the same interval observed. For a vibrating string, the frequency or sound heard is inversely proportional to the square root of the string's weight per unit of length, so thicker, heavier strings produce lower notes. This mathematical law contradicted traditional musical theory. Galileo learned from his father that it was foolish to accept anything as truth without examining the evidence in support of it. He was taught in the tradition of Plato's student Aristotle that theory must follow facts. It has been argued that Galileo's devotion to the Catholic Church inspired him to seek evidence about the world in order to protect the church from disseminating misinformation.

Contributions to Medicine

In 1582, at age 18, Galileo began his study of medicine at the University of Pisa. Years later, Galileo wrote about the state of medical education by describing an anatomical dissection. The topic was the origin of the nervous system. According to Aristotle, the heart was the source of the nerves, but the anatomist clearly demonstrated the brain was the true source of the nerves. The Aristotelian philosopher replied that the evidence before his eyes would clearly indicate the brain as the origin of the nerves and he would believe it to be so, if it were not for the words of Aristotle!

While attending services at Pisa's cathedral, Galileo noticed a swinging lamp and, using his resting heart rate as a timepiece, he observed that each swing of the lamp appeared to take the same number of pulses in his wrist and therefore approximately the same amount of time, regardless of the length of the swing. One could imagine him reminiscing about weights hanging from lute strings at home. His observations and discussions of this isochronicity of the pendulum led a friend of his, Santorre Santorio, a physician in Venice, to design a small pendulum that could be used to calibrate the human heartbeat rate. This device, called the *pulsilogium*, could be used to get an objective measurement of the heart rate of a medical patient. By observing changes in the pulse rate, physicians could now obtain data on the vitality of their patients and the efficacy of their treatments. In addition, Galileo was the first to invent a device to measure changes in temperature. With Santorio, Galileo worked to improve the science of experimental medicine, including the study of human metabolism. Although Galileo chose not to complete his study of medicine, his research led to major contributions to the scientific study of human anatomy and physiology.

Physical and Mathematical Investigations

Leaving the study of the medical arts behind, Galileo embarked on a lifelong journey in mathematics. Galileo's exploration of the geometry of Euclid of Alexandria and the physics of Archimedes of Syracuse and of Aristarchus of Samos inspired his creative genius. Stimulated by exploration of the foundations of astronomy from Hipparchus of Samos and Claudius Ptolemaeus, Galileo's mind was preparing to wrangle with ideas of cosmic proportions. Here Galileo cultivated a philosophy of scientific realism and a belief that there were explanations for natural phenomena that are revealed through observation and reason.

Inspired by the story of Archimedes and the golden crown of suspect purity, Galileo experimented with floating objects and developed a precise balance scale he called the *hydrostatic balance,* which could compare the weight of an object to an equal volume of water. He described this invention in a book he titled *The Sensitive Balance* (*La Bilancetta*) in 1586. He would later use measured volumes of water to calibrate elapsed time precisely in his acceleration experiments.

In 1587, Galileo was asked to cast a horoscope for Francesco de Medici, the Grand Duke of Tuscany. Galileo had disdain for astrology, which he considered to be heretical, but felt it was unwise to thwart the wishes of this generous benefactor. Drawing up a chart for the 46-year-old Grand Duke, Galileo announced that it indicated a long and fruitful life. Within a week the Duke was dead. In January of 2007, an analysis of the Duke's remains revealed an extremely elevated level of arsenic that was indicative of deliberate poisoning.

By 1593, Galileo had moved to the University of Padua where he taught mathematics and military engineering. It was here that he met and fell in love with Maria Gamba. While never married, they did have three children. His two daughters entered the convent and his son Vincenzo was by his side when he died. Galileo worked on many inventions, including a device that used horses to raise water from aquifers. In 1604, a "New Star," as it was called then, appeared in the constellation Sagittarius. Here was evidence for all to see that the heavens were not fixed and permanent, as Aristotle had decreed. If the great philosopher Aristotle could be wrong about this fundamental quality of the heavens, what else could he be in error about? We now know that what Galileo had witnessed was not a new (Nova) star, but rather a very old star in its last stages of stellar evolution.

Financial success came from Galileo's invention of a military compass that could be used to calculate the ideal firing angle for cannons as well as the gunpowder charge and projectile weight for maximum effect and accuracy. A civilian compass model that could be used for land surveying followed. This invention is considered by many to be the world's first pocket calculator. His text describing the use of the compass, titled *Operations of the Geometric and Military Compass (Le Operazioni del Compasso Geometrico e Militare)* was published in 1606. This invention also introduced Galileo to the unpleasant world of patent infringement, as he eventually had to prove that others had copied his work.

Galileo's lecture series on the location, shape, and dimensions of Dante's Inferno helped to earn him a 3-year appointment at the University of Pisa to teach mathematics. It was there, according to legend, that Galileo demonstrated that falling bodies of varying sizes and weights fell the 54 meters from the top of the Leaning Tower of Pisa at the same rate. By disproving one of Aristotle's alleged laws of nature, Galileo showed that blind acceptance of doctrine must yield to scientific experimentation. Galileo was adept at thought experiments. He reasoned that if two weights, one heavier than the other, were supposed to fall at different speeds, then why did hailstones of a wide range of weights fall together? He also pondered the question of whether, if a lighter and heavier weight were tied together, their rate of descent would change. Galileo asked whether, if the two were tied together, would the lesser one subtract velocity from the fall or would the two weights added together increase the rate of fall? If the lighter one subtracted velocity from the heavier one, then they should fall more slowly. Or, if the two together now weighed more than the original, would they fall all the faster? His conflicting results led inevitably to the conclusion that they must fall at the same rate regardless of their weight. Galileo used these kinds of thought experiments to help others to visualize the fundamental elements of motion.

When the objection was raised that a feather did indeed fall much more slowly than a cannonball, Galileo realized that air resistance accounted for the difference and that if this variable could be controlled, the two objects would fall at the same rate.

Galileo experimented with resistance in different media such as water and oil. He was not able to perform the experiment in a vacuum, the production of which was then technically unattainable. In July of 1971, 365 years later, Apollo 15 astronaut David Scott dropped a falcon feather weighing 0.03 kilograms and a geological hammer weighing 1.32 kilograms from a height of 1.6 meters on the moon. With no air resistance, they landed simultaneously, and Commander Scott duly noted that Galileo had been right.

Galileo sought an accurate way to measure the change in the speed of a falling object over time. Galileo, a talented musician and composer, had a well-developed internal rhythm and would be able count off beats in his head quite accurately to measure seconds. The tools available to measure time in those days were extremely limited in accuracy and reliability. Sundials and hourglasses would be useless to measure the brief intervals that Galileo sought to investigate. Mechanical clocks had appeared in Western Europe around 1330. A few years later a clock was built by Giovanni de'Dondi in Padua, Italy, that displayed the position of the sun, moon, planets, and the timing of eclipses. It was beautiful to behold, but its accuracy was limited. The timepieces available to Galileo could measure hours with reasonable accuracy; however, the quantities of time involved in calibrating acceleration would require accuracy not just to the minute, but to the "second minute," which we now know as the "second." It appeared to be virtually impossible to calculate events occurring in fractions of seconds.

Galileo needed a way to quantify time objectively. He tackled this daunting problem from two directions. First he devised a way to slow the falling object's rate of speed. By building a diagonal ramp he, in effect, diluted gravity. Now he could study acceleration at a more leisurely pace by rolling a ball down the highly polished inclined plane. Using his military compass, he could carefully determine the angle of descent of the plane. The second part of the problem involved measuring very small intervals of time. His familiarity with the lute would most likely lead him to include frets or slightly raised ridges on some of his inclined planes. By doing so, he could hear the ball striking the frets as it descended. By spacing the frets in a way that the time interval between each sound was identical, Galileo would have a measurable unit of distance to indicate acceleration. He had previously measured the isochronicity of a pendulum's swing using his own resting pulse rate; but from his observations with the pulsilogium, he knew that the pulse rate was too variable and therefore not a reliable enough clock to gauge acceleration. Added to this was another element arguing against using his own pulse as a clock. As his experiments began to reveal the laws of motion, his excitement would no doubt raise his pulse rate, rendering the measurement useless.

Another of his inventions, the hydrostatic balance scale, would provide the inspiration for a quantifiable unit of acceleration. Galileo designed a water clock to measure velocity indirectly. By starting the ball down the ramp and beginning the release of water simultaneously, and stopping the flow of water when the ball reached the end of the ramp, he could weigh the amount of water released in a given time. In this fashion Galileo was able to make an accurate comparison of the amount of time a rolling object spent in each portion of its descent down the ramp. He found that the distance the ball rolled down the plane was proportional to the square of the elapsed time. Galileo observed that balls of different weights increased their speed at the same rate. The development of modern science is based on the idea of mathematically measurable sequences. One such measure, a unit of acceleration, is known as a "Galileo." Galileo's struggle with the accurate measurement of time laid the foundation for those who followed. His calculations would be used in 1687 by Sir Isaac Newton to formalize the laws of motion in *Principia Mathematica*.

Another observation of nature that stimulated Galileo's inquisitive mind was the apparent difference between the speed of light and the speed of sound. Since lightning precedes thunder and the cannon's flash precedes the boom, Galileo knew that here was another mystery that could be solved mathematically. He attempted to design an experiment using lanterns spaced miles apart but could report only that light traveled so much faster than sound that light speed could not be measured with the instruments available at the time. Today, scientists can measure time to the attosecond, which is one quintillionth of a second!

Optics and Astronomy

While visiting Venice in 1609, Galileo first heard of the spyglass that a Dutch spectacle maker had invented. Galileo realized that a device that made distant objects appear closer had obvious military and potential financial value. His prior experience with the military compass and artillery inspired him to improve and capitalize on this invention. By experimenting with various combinations of concave and convex lenses he was able to improve on the original design by increasing its magnifying ability and righting the image. Without the proper combination and spacing of lenses, images appeared upside-down. Viewing an upside-down ship with the sea above and the sky below was disconcerting and detracted from the general usefulness of the spyglass. Galileo presented his improved 10-power telescope to the senate of Venice and demonstrated how ships at sea could be identified as friend or foe hours before a look-out without such a device could make such an identification. He was proclaimed a genius and given a generous salary increase and lifetime tenure. This granting of tenure, along with the appearance shortly thereafter of a large influx of cheap spyglasses from Northern Europe, angered some and may have contributed to problems he would face later in life.

Galileo continued to improve his telescope. With higher magnifying power and improved lens shaping and polishing techniques, he began his observations of the heavens. His preliminary investigations of the moon immediately revealed that it was uneven, rough, and full of cavities, craters, and prominences. It was not the smooth, polished, perfect heavenly body everyone believed it to be. By carefully observing the shadows cast by lunar mountains, he was able to make estimates of their altitudes. To those who insisted that the moon was covered with a smooth transparent crystal, he replied that they should grant him the equal courtesy of constructing with that same crystal mountains, valleys, and craters.

Galileo's explorations of the night sky brought new discoveries every clear evening. The Milky Way, which was considered to be a pale vapor of light, revealed itself to be an uncountable number of stars vast distances away. The Seven Sisters, a star cluster also known as the Pleiades, in the constellation Taurus the Bull, when magnified became hundreds of stars. The Great Sword of Orion, when closely examined displayed a marvelous cloud embedded with tiny newborn stars. Galileo's examination of Ursa Major, the Great Bear or Big Dipper or Plough, revealed an amazing double star that he observed during a failed attempt to measure parallax and therefore demonstrate Earth's revolution around the Sun.

In January 1610 Galileo turned his new and improved telescope on Jupiter. With modifications to the lenses, Galileo was now able to magnify the apparent diameter of an image 30 times. He noted a star to the left of Jupiter and two on the right, all in a straight line. One could only imagine Galileo's amazement when on the next evening he saw that all three of the stars were now on the left and still in a straight line. Weeks of observations and further improvements that widened the field of view of his telescope revealed a fourth star that circled around Jupiter. Galileo realized that these were moons that orbited Jupiter just as our moon orbited Earth. Here was evidence that not everything revolved around the earth. Seeing Jupiter's moons revolve around Jupiter also discredited the idea that if the earth revolved around the sun it would leave its moon behind. Additional calibration of the orbits of Jupiter's moons inspired Galileo to consider that their regular orbital periods could serve as a cosmic clock for ships at sea. This could aid in the accurate timekeeping that was essential for the determination of longitude. Galileo continued his telescopic observations and developed a table of the eclipses of Jupiter's moons to be used by ship's captains as a cosmic timepiece to determine longitude while out of sight of land. He even developed a telescopic device one could wear like a hat to observe Jupiter while keeping the hands free to pilot the ship. Apparently it was difficult to use and was abandoned. Galileo did notice a slight abnormality in the timing of eclipses of Jupiter's moons. It was not until 66 years later, in 1676, that the Danish astronomer Oleaus Romer was able to calculate that the 10-minute systematic error of Jupiter's observed synodic period was because light does not travel instantaneously. Years later it would be understood as a function of the varying distance between Earth and Jupiter. This parallax effect is a manifestation of our changing viewpoint as we revolve around the sun. Galileo named Jupiter's moons the "Medician Moons" in honor of his benefactors. Simon Mayr created the names we use today—Io, Europa, Ganemede, and Callisto—in 1614.

Galileo observed the planet Mars and saw that its apparent diameter increased when it was closer and diminished significantly when it was farther away from Earth. This was additional evidence that Mars revolved around the sun. When Mars and Earth were on the same side of the sun, Mars appeared twice as big as it did when Mars was on the far side of its orbit around the sun. This could not be clearly seen with the unaided eye, but was readily apparent when viewed through the telescope. In his honor, there is a crater on Mars called Galilaei as well as an asteroid named Galilea.

Another important observation first made by Galileo was that the planet Venus showed phases like the moon. When it was at its greatest distance from Earth, and more directly illuminated by the sun, it appeared as a small sphere. As its orbit took it around the sun and closer to Earth, it appeared as a progressively larger waning crescent. These observations lent credence to the Copernican idea that the sun was at the center of the solar system. Countless hours of watching the planets convinced Galileo of the validity of the Copernican heliocentric view. Seeing sunspots parading across the solar disc clearly demonstrated that our star, the sun, was not the perfect heavenly object described by the ancients.

Galileo was fascinated and perplexed by his observations of Saturn. The limited resolving ability of his telescope rendered a tiny, blurry image of Saturn and its ring system that was not a sphere like Jupiter but looked rather elongated or shaped like an American football. Could this be more evidence against the Aristotelian belief in perfectly spherical heavenly bodies? Galileo assumed that he was seeing three separate bodies. It is interesting to note that Galileo's observations of the planet Saturn led to an ironic cryptic message. In a coded letter, Galileo wrote that the last planet was triune or three-mooned. In the year 2005, the Hubble space telescope revealed that Pluto, which was considered at the time to be the last planet in our solar system, had three moons, which were named Charon, Hydra, and Nix. A contemporary analysis of Galileo's notes indicates that he probably was the first person to observe the planet Neptune, in the year 1612.

Galileo described his astronomical observations made using a telescope in a small book he called *The Starry Messenger (Siderius Nuncius)* in March of 1610. It received a great deal of attention and generated much heated discussion. In it, Galileo explained his view of scientific realism. He was certain that there were explanations of natural phenomena that would be revealed through observation and reasoning. There were those who felt that some of Galileo's findings contradicted the teachings of the Catholic Church. Objections were raised that certain passages in the Bible appeared to indicate that the sun went around the earth and that to believe otherwise was heresy. Galileo responded that while the Bible could never be wrong, it was not meant to be taken literally and that mistakes of interpretation could lead to confusion. This led others to complain that only the clergy could interpret the Bible and that Galileo had to be stopped. With the Protestant Reformation of Martin Luther and John Calvin and The Thirty Years War to contend with, the Catholic Church had little tolerance for dissension within the ranks. Galileo had met Giordano Bruno, who in 1600 was found guilty of heresy and burned to death. He knew others who had suffered at the hands of the Inquisition and was aware that he had better tread lightly. An investigation of the charges against Galileo found him innocent of heresy, but he was cautioned not to teach the Copernican system as a proven fact.

In 1618, three comets were visible over Europe. A Jesuit mathematician, Father Horiatio (Orazio) Grassi, who wrote using the pseudonym Lotario Sarsi, argued that the highly elliptical orbit of the comets argued against Copernicanism, which postulated circular orbits. Galileo replied in an essay titled *The Assayer (Il Saggiatore),* published in 1623. Here Galileo established norms and rules for the investigation of nature. It is considered to be one of the great works of scientific literature. In it, Galileo describes how the grand book of the universe is written in the language of mathematics.

Geocentrism, Heliocentrism, and Conflict With Established Authority

Galileo's attraction to the sea and things nautical led him to a contemplation of the causes of the tides. He believed that here he would develop the strongest evidence for Earth's motion around its axis and around the sun. As it turned out, he was wrong in discounting the moon's influence on the tides, which is much greater than the influence of the sun. Galileo sought permission from Pope Urban VIII to write a book about the motions of the solar system. The pope agreed, provided that the book gave a balanced view of the two conflicting theories of geocentrism and heliocentrism. The pope also requested that Galileo mention the pope's personal views that the heavenly bodies may move in ways that man cannot comprehend. Instead of writing his findings in the form of a scientific report, Galileo choose to present his ideas as a conversation among three individuals. *His "Dialogue Concerning the Two Chief World Systems: Ptolemaic and Copernican" (Dialogo sopra i due massimi sistemi del mundo, tolemaico e copernicano)* was published in 1632. The December 2006 issue of *Discover* magazine listed Galileo's *Dialogue* as the fourth greatest scientific book of all time. This dialogue featured a character named Salviati, a proponent of Galileo's ideas. Salviati's heliocentric or sun-centered views were presented as witty, intelligent, and well informed. Sagredo, the bystander, who served as the mediator, was usually persuaded by Sagredo. Simplicio, the proponent of geocentrism or an Earth-centered solar system, was portrayed as somewhat slow-witted and easily befuddled. As an expert on Aristotelian thought, Simplicio represented those who ignored evidence and preferred to cling to dogma rather than explore new ideas. The dialogue on the two great systems of the world presented Copernican theory as the logical and intelligent man's preference. It was considered by many to be a literary and philosophical masterpiece. It was considered by Pope Urban VIII to be a grievous insult to have his views presented by the dim-witted character Simplicio, the simpleton.

Word reached Rome that Galileo was teaching Copernicanism; and worse, it was suggested that he had modeled the fool in his dialogue after the pope. Some said that *The Dialogue* made a mockery of the pope's intellectual authority and undermined his temporal power. Galileo had, in effect, challenged the Catholic Church's authority in the interpretation of scientific knowledge. He was ordered to appear before the Holy Office of the Inquisition to face charges of heresy. Aware of the potential for torture and death, Galileo confessed that he had been wrong to say that the earth moved around the sun. Galileo was found guilty of suspicion of heresy and forced to recant his heliocentric beliefs. He was sentenced to life imprisonment, later commuted to house arrest, and forbidden to discuss his views with anyone. Publication of anything he had written or would write in the future was forbidden. It is interesting to note that Copernicus had never been accused of heresy and that his book, *De Revolutionibus,* was not banned but rather withdrawn for corrections. In his 2001 book, *Galileo's Mistake,* author Wade Roland argues that the church's main problem with Galileo was not his belief in the Copernican system but rather in Galileo's belief in a mechanistic, materialistic philosophy that seeing is believing.

While confined to his home, Galileo continued to investigate other areas of science. He applied mathematics to a variety of problems. He explored geometry and went from the study of lengths, areas, and volumes to the contemplation of motion, mass, and time. For his last, and some consider his greatest, literary masterpiece he returned to the literary device of three gentlemen discussing a wide variety of issues and arguing their points of view. Here, Galileo developed the fundamentals of relativity. He went into great detail regarding the nature of matter. Galileo was able to have his notes smuggled out of Italy and published in 1638 by a Dutch publisher named Luis Elzevir as *Discourses About Two New Sciences* (*Discorsi e dimostrazioni matematiche intorno a due nuove scienze*). This work proved to be the foundation for the modern science of physics.

Galileo's last astronomical discovery was the lunar librations. Galileo discovered that the moon's equator is inclined to its orbital plane. This causes a slight wobble in the moon's axis and allows us to see a bit of the far side of the moon periodically. A lunar crater 15 kilometers in diameter is named in honor of Galileo. It is located just west of the one named for Copernicus.

Galileo and Modernity

At the end of his life, Galileo, who had seen farther than any man before him, became completely blind. He passed away on January 8, 1642, with his son and students by his side. Isaac Newton was born 11 months later. Newton referred to Galileo when he said that the reason he had seen farther was because he had stood on the shoulders of a giant. Stephen Hawking, the Lucasian Professor of Mathematics at Cambridge University and author of *A Brief History of Time,* describes Galileo as the single individual most responsible for the birth of modern science. He notes that Galileo was one of the first to argue that man can understand how the world works by observing the real world.

It was not until 99 years after Galileo's death, in the year 1741, that Pope Benedict XIV lifted the ban on Galileo's scientific works. In 1979 Pope John Paul II asked the Pontifical Academy of Sciences to conduct an in-depth study of the Galileo case. In 1992, the church formally and publicly cleared Galileo of any wrongdoing, 350 years after his death. Pope John Paul II expressed regret for how the Galileo affair had been handled. In his summary of the conclusions he noted that Galileo showed himself to be more perceptive of the criteria for scriptural interpretation than the theologians who opposed him. The pontiff paraphrased Saint Augustine's words that truth can never contradict truth, and that where the Holy Scriptures appear to contradict the natural world, it is the error of interpretation that must be resolved.

Edward J. Mahoney

See also Aristotle; Bruno, Giordano; Clocks, Mechanical; Copernicus, Nicolaus; Einstein, Albert; Hawking, Stephen; Kuhn, Thomas S.; Newton, Isaac; Nicholas of Cusa (Cusanus); Telescopes; Time, Measurements of

Further Readings

Bixby, W. (1964). *The universe of Galileo and Newton.* New York: American Heritage.

Drake, S. (1978). *Galileo at work: His scientific biography.* Chicago: University of Chicago Press.

Frova, A., & Marenzana, M. (2006). *Thus spoke Galileo.* Oxford, UK: Oxford University Press.

Hilliam, R. (2005). *Galileo Galilei, father of modern science.* New York: Rosen.

Reston, J., Jr. (1994). *Galileo, a life.* New York: HarperCollins.

Rowland, W. (2001). *Galileo's mistake.* New York: Arcade.

Gamow, George (1904–1968)

George Gamow, Russian-born physicist, was noted for his contributions to interdisciplinary understanding and for his synthesis of modern physics with both a cosmological and evolutionary framework. Taking a comprehensive view of modern physics, Gamow presented the evolution of the universe and human life as a chance product of chemical interaction/reaction within the spatiotemporal parameters of the universe. From the initial theory of the big bang that resulted in our expanding universe, the conceptual framework of time, space, and distance poses unique problems for both traditional physics and scientific epistemology. Gamow explained the impact of these problems and the theoretical basis for our current understanding of the universe and its implications for life on this planet.

The conceptual framework of time and humankind's perception of the natural world became the basis for continual theoretical advances. Gamow articulated this open-ended perspective by illustrating the historical progress, both philosophical and scientific, made in mathematical understanding of the physics that govern the universe. Contrary to cultural perceptions of the temporal and static nature of the universe, Gamow depicted the spatiotemporal nature of the cosmos as an expanding and temporally changing universe, filled with innumerable planets, stars, and galaxies. This uniform expansion of the universe was suggested as being approximately 2 to 3 billion years ago, with comparable ages of the oldest celestial bodies. The age of our solar system, specifically our planet and the sun, has deep implications for life. Although our sun and planet were estimated to be relatively young, around 3 to 4 billon years and 2 billion years, respectively, Gamow's calculations put the lifespan of our sun at around 50 billion years. Fueled by nuclear reactions within the bending of time and space, the birth and death of star(s) becomes a tethered line for life on this planet and possible life on other worlds. Though Gamow speculated on the probability of life elsewhere in the universe (including the immensity of distance between planets), the chemical sequence and the emergence of life from inorganic matter became a probability and a particular point of scientific wonder.

The spatiotemporal nature of the universe is paradoxical. Concepts of infinity within finitude are deeply rooted within the human psyche. Although new developments in mathematics, physics, and chemistry continue to inform our ever-growing understanding of the universe, these dual concepts of time seem to preclude any definitive and comprehensive theory of both life and the physics of the universe by which life itself is governed. Gamow's substantial contributions to cosmology, even in light of recent advances, allow us to appreciate more fully both the finitude of human existence and the need for further understanding of the complex relationships that obtain within the universe.

David Alexander Lukaszek

See also Big Bang Theory; Hawking, Stephen; Lemaître, Georges Edouard; Time, Emergence of; Universe, Evolving; Universe, Origin of

Further Readings

Gamow, G. (1954). *One two three . . . Infinity.* New York: Viking Press.

Gamow, G. (1961). *The creation of the universe.* New York: Viking Press.

Gamow, G. (1972). *Cosmology, fusion & matter: George Gamow memorial volume.* Boulder: Colorado Associated University Press.

Gehlen, Arnold (1904–1976)

Arnold Gehlen is known as a cofounder of philosophical anthropology and was one of Germany's leading postwar sociologists; he was also a significant time diagnostician. His understanding of man as an organically "deficient being" paved the way for a theory of institutions that is not only substantial but also empirically adaptable. His anthropological views served asa foundation for his contemporary analyses of Western industrial societies, which were farsighted and, as a result of his conspicuous conservatism, also controversial at the same time.

Gehlen received his PhD in 1927 after studying under the philosopher and biologist Hans Driesch; 3 years later he qualified for a tenured professorship under, among others, Hans Freyer, after having written his habilitation. During the Third Reich, Gehlen had a shining career and quickly received professorships in Leipzig, Königsberg, and Vienna. After serving in the army's administrative council (1941–1942), he was sent to the front and was severely wounded. In 1947, after his denazification, he received his first teaching position as a university professor in Speyer, then later in Aachen, where he taught sociology from 1962 until his retirement.

Like most of his colleagues from Leipzig, Gehlen joined the Nazi Party in 1933 and became a member of the National Socialist German University Lecturers League. He demonstrated his approval of the National Socialistic regime in several ways; for example, in his inauguration lecture in Leipzig 1935. His reference to the "highest systems of leadership" in his first anthropological study (1940) can also be understood as opportunistic. Such declarations of loyalty were never part of Gehlen's scientific thinking, however. His understanding of man as a deficient being (*Mängelwesen*) did not refer to any racial differences. In his opinion, from a biological point of view the "Aryan" is as inadequate as every other human race. Consequently, Gehlen's anthropology was contrary to official Nazi ideology from the beginning; and he himself was always considered an "uncertain type" by Nazi leadership.

Gehlen's ideological home was not totalitarian National Socialism. It was the world of conservative thinking and order. So it is possible to find him referring specifically to the tradition of political thought where the state was the center of focus—as in the work of Hobbes or Hegel. But Gehlen's philosophy was also influenced by many other ideas that were quite diverse: His first phase was shaped partly by existentialist ideas, which are dealt with in his 1931 dissertation. His intensive study of German idealism, especially Fichte, influenced his theory of the freedom of the will and characterized, to a certain extent, the second phase of his work. His anthropological phase began specifically in the mid-1930s. During that period of time Gehlen was one of the first German philosophers to discover American pragmatism, particularly citing the works of John Dewey and George Herbert Mead. The philosophy of life (Schopenhauer, Nietzsche, Bergson) had a major influence on Gehlen's research; he also dealt with Driesch's concept of neovitalism in his dissertation. In the end, the idea of combining philosophical and anthropological studies may have been enhanced by the transdisciplinary atmosphere at the University of Leipzig, which included, among others, the sociologists Hans Freyer and Helmut Schelsky, the psychiatrist Hans Bürger-Prinz, and the philosopher Gotthard Günther.

Works and Ideas

Gehlen's main anthropological work, *Man, His Nature and Place in the World,* was first published in 1940 and has been reprinted several times. In his study of late-modern civilization (1956) Gehlen worked on the deficits of his concept of action, which had essentially been instrumentally conceived, and presented a differentiated institutional theory. His highly acclaimed writings *Man in the Age of Technology* (1957) and his 1969 work on ethics were particularly relevant from the perspective of critical time diagnostics.

The main concern of philosophical anthropology consists of discussing questions that deal directly with the way humans see themselves. According to Gehlen, it is in this context that it is of primary importance to cast off idealistic ballast and to overcome the dualism of the body and the soul. Gehlen begins with a concept of action: Like Nietzsche, he sees in man the "still undetermined animal," a being whose life is at risk. Man cannot feel secure in his environment because he lacks protective instincts. As a result of his deficient biological makeup there is no natural environment for him. Everything and everyone can be his enemy. So man has no other alternative but to create his own relationship to the world around him and to himself through his actions. Man's nature is civilization: Man not only has a life, he needs to lead a life—and thus compensates for his deficient being.

Yet, following Gehlen, man is not only at the mercy of his environment; he is also dangerous. Vague but driven by physical desires, he is latently subject to the danger of mutating, becoming an enemy of his own kind or even of himself. So he doesn't just have to lead his own life, he also has to be led, in particular by institutions. Institutions are the substitute for missing instincts; they give man something to hold onto by requiring him to act in a certain way. Their "unquestioning manner" of guiding human behavior in certain directions relieves the individual of the duty to constantly make decisions. For instance, a letter must be answered—at least in times of postal communication; it requires contemplation, at best concerning the content; but this is also simplified by use of socially standardized forms of address, endings, gratitude, and more. In Gehlen's opinion, institutions are therefore different from mere organizations. They don't serve just one particular purpose and then lose their significance when the job is done. They are created by mutual social interrelations within a community that they also symbolize. Consequently, institutions possess an inherent worth that commits the individual and motivates him to act.

In his writings on time diagnostics, Gehlen especially points out the social processes that develop a force capable of destroying institutions: They are closely connected to a technology that pervades all areas of existence and leads to a degradation of human senses and an intellectualization of life. Everything seems possible, everything can be tried out—in this sense, "anything goes" exemplifies the typical contemporary attitude, in Gehlen's opinion; it is of an experimental nature but also nonbinding and formal, supported by a subjectivism that constantly calls for self-identity: Everyone can imagine everything. The real world becomes virtual in the process of a continuous "psychologization." In order to evoke a response, the cause has to be catchy and easy to remember, never subtle, and preferably shrill. Today's world, as Gehlen said back then, is trivial and busy—unproductiveness at high speed, a racing standstill.

So it is easy to assume that modern society has come to an end. Things could still be recycled and combined, but man has essentially reached the end of history. Man in modern times has come to accept this inevitability from which he can no longer be lured—"*rien ne va plus*."

Gehlen's thesis has been extensively criticized, one objection to his anthropology of the deficient being is that it is too pessimistic. The deficits of man are exaggerated in comparison to his rational abilities, which enable him to be highly flexible and adaptable. Furthermore, by profoundly emphasizing the differences between man and animal, the variations of human existence are completely neglected. Specifically from an ethical point of view, it is of utmost importance to differentiate between the human and the inhuman, but Gehlen's theory leaves no room for such thoughts. Similarly, a great deal of criticism targets the lack of criteria used in his institutional theory. Gehlen's approach is concerned only with the stability and justification of the status quo. From today's perspective, a large part of this criticism seems justified; basically it is necessary to criticize his philosophical as well as his sociological ideas for excluding substantial normative principles without omitting extensive critical evaluations of society. Nevertheless, people often do not realize that his action theory stresses man's openness and productivity in his relationship to the world and to himself. In that sense, it is possible to imagine that his institutional theory can be critically reconstructed within the framework of a normative intention.

Gehlen's primary achievement is that he developed a theoretical view of society that does not simply deal with individual rational actions or the structures of social systems. It also points out the links between the individual and the system that serve as the basis for his time diagnostic analyses. By using these analyses, it is possible to discover the grayness of an apparently modern conformity amidst the colorful world of new postmodernism.

Oliver W. Lembcke

See also Anthropology; Bergson, Henri; Fichte, Johann Gottlieb; Hegel, Georg Wilhelm Friedrich; History, End of; Nietzsche, Friedrich; Schopenhauer, Arthur

Further Readings

Berger, P. L., & Kellner, H. (1965). Arnold Gehlen and the theory of institutions. *Social Research, 32*(1), 110–115.

Gehlen, A. (1978ff). *Gesamtausgabe* [Works]. (K.-S. Rehberg, Ed.). Frankfurt a.M.: Klostermann.

Gehlen, A. (1980). *Man in the age of technology* (P. Lipscomb, Trans.). New York: Columbia University Press. (Original work published 1957 as *Die Seele im technischen Zeitalter.* Hamburg: Rowohl)

Gehlen, A. (1988). *Man, his nature and place in the world* (C. McMillan & K. Pillemer, Trans.). New York: Columbia University Press (Original work published 1940 as *Der Mensch: Seine Natur und Stellung in der Welt*. Berlin: Junker and Dünnhaupt)

Thies, C. (2000). *Arnold Gehlen zur Einführung* [Introduction to Arnold Gehlen]. Hamburg: Junius.

Weiss, D. M. (Ed.). (2002). *Interpreting man.* Aurora, CO: Davies.

Genesis, Book of

Genesis is the first book of the Hebrew Bible and Christian Old Testament. The basic premise of this book is to recount the stories of the Hebrew patriarchs and their covenant relationship with God. The Book of Genesis connects the God of the patriarchs with the beginning of time as the creator of the universe.

The book is a book of beginnings, as its Hebrew title suggests—*bĕrē'šît* meaning "In the beginning." The name "Genesis" comes from the transliteration of the Greek for the first word of the book, which means "origins." Both titles appropriately describe the contents of the Book of Genesis. The book tells of the creation of the universe, the dawn of humanity, the origin of sin, and the beginning of the Hebrew people.

The book centers around the promise God gave to Abram (renamed Abraham, Gen 17:5), which is to make him the father of a multitude of people who would become a nation (12:1–3) living in a specific land (13:14–15). This promise divides the book into two sections. The first part (chapters 1–11) explains how the world came to be, why it is the way it is at the time of Abraham, and that God was involved the entire time. Time passes quickly in these chapters through genealogies that connect the stories of creation, the introduction of sin, the flood account, and God's promise to Abram. This section contains two stories of God creating the world, each having a different sequence of events. In the first account (1:1–2:3) God made light and separated it from darkness. Next he made the heavens, sea, and land, then the plants, then the sun, moon, and stars, and then he created the birds, fish, and land animals. Finally, God created humans, both male and female. This event completed Creation. In the second Creation account (2:4–25), God made the heavens and Earth and then he created a man named Adam. Next, God created Eden, an idyllic garden full of plants, where he placed Adam. Afterward, God created animals and birds and finally he made a woman whom Adam named Eve.

While Eve lived in the garden, a serpent had a conversation with her and deceived her. Adam supported her and silently consented. They yielded to temptation by eating forbidden fruit from the tree of the knowledge of good and evil and thereby introduced sin into the world. Sin quickly spread throughout Creation and intensified, as demonstrated in fratricide among Adam and Eve's two sons, Cain and Abel. During 10 long generations sin increased to such an intolerable point that God sent a flood to destroy the world with the exception of a righteous man, Noah, and his family. Noah built an ark that saved him from the destruction of the flood. After the flood, one of Noah's sons sins, an indication that the flood did not rid the world of this problem; thus God would have to find another solution. This dilemma leads to the promise to Abram, the next attempt at the problem of sin. Genealogies following the flood story provide an explanation for all the different people groups, nations, and languages in the world at the time of Abram and set the stage for Abram's appearance.

Genesis 12–50 is the second part of the book. Time in this section slows as the author concentrates on the stories of four generations of patriarchs—Abraham and his descendants—and their struggles to fulfill God's promise. Abraham, the original recipient of the promise, had various difficulties in producing children and staying in the promised land. His son Isaac had similar problems but managed to have twin sons who were in competition for their father's inheritance and blessing. Jacob, the victorious twin, had his own problems establishing a place for himself. However, God reiterated the promise to Jacob and changed his name to Israel. Jacob married two sisters and their two servants and produced 12 sons and a daughter. These sons became the fathers of and namesakes of the Twelve Tribes of Israel and they represent the birth of the nation.

The Book of Genesis ends with a series of stories about Joseph, one of Jacob's sons, and his adventures in Egypt. By the end of the book, not only was Joseph in Egypt but his father, all his brothers, and their families and flocks as well. This ending sets the stage for the Book of Exodus and God's deliverance of his people from Egypt to the promised land.

Thus the Book of Genesis describes God as the creator of the universe who created everything including the first humans. Because humanity's sin brought about the fall of Creation, Genesis tells that God took an active role in humanity's salvation and in world events. In doing so, the book covers a time from the beginning of the universe to the second millennium BCE.

Stories from the Book of Genesis, especially the Creation stories, have been used as common themes in literature throughout history from John Milton's *Paradise Lost* to Gary Larson's *Far Side* cartoons to the *Star Trek* movies.

Terry W. Eddinger

See also Adam, Creation of; Bible and Time; Christianity; Cosmological Arguments; Creationism; God as Creator; Milton, John; Moses; Noah; Sin, Original; Time, Sacred

Further Readings

Towner, W. S. (2001). *Genesis* (Westminster Bible Companion Series). Louisville, KY: Westminster John Knox.

Wenham, G. J. (1987). Genesis 1–15. *Word biblical commentary, Vol. 1*. Waco, TX: Word Books.

Wenham, G. J. (1994). Genesis 16–50. *Word biblical commentary, Vol. 2*. Waco, TX: Word Books.

Genghis Khan (c. 1162–1227)

The Mongolian emperor Genghis Khan's audacity and ingenuity fueled the vast expansion of the Mongol Empire during the 12th and 13th centuries, securing him a place of note in world history. His empire eventually extended over most of Asia, including portions of Russia.

Genghis Khan (born Temujin) remains among the most influential people of all time, having revolutionized the conduct of war and establishment of laws in addition to instilling fear and awe in those he led and those he encountered on the battlefield. As for military convention, Genghis Khan implemented tactics that helped the Mongol forces attain one of the largest empires in history. Dependent on well-trained cavalry, Genghis Khan's forces used hit-and-run tactics to disrupt and slowly carve away at enemy forces, beginning with enemy commanders. Genghis Khan's strategies made it possible to attack and disperse larger forces, reflecting the daring and brilliance of the Mongol leader so many came to fear. Arguably, it is these cunning tactics, along with his methodology of concealing his army's size and whereabouts, that ultimately won Genghis Khan land and reputation.

Though Genghis Khan's military tactics instilled fear in his enemies, it is his compilation of laws (*Yassa*) that reflects his understanding of people and adds considerable depth to his legacy. Genghis Khan incorporated longstanding traditions and his own decrees to formulate one canon of laws. This combining of the traditional and the contemporary ensured legitimacy for the Yassa and, consequently, for Genghis Khan's reign.

Chinggis, or Genghis, Khan is the title bestowed on Temujin on his attaining the Mongol throne. The year of Chinggis Khan's birth and the exact location of his tomb remain unknown, though several dates and locations have been postulated. Further, a complete copy of Chinggis Khan's Yassa has yet to be found, making it difficult to ascertain the extent of his transformation of traditions to generate his laws. What is known is that he created one of the greatest empires in history, employing both harsh and ingenious methods to do so. Chinggis Khan's death in 1227 is documented as to the day and his final actions as ruler, yet even with documentation from a number of texts, questions remain.

Portrait of warrior-ruler Genghis Khan (1167–1227), founder of the Mongolian Empire, 1200. One of history's more charismatic and dynamic leaders, Genghis Khan during his lifetime conquered more territory than any other conqueror, and his successors established the largest contiguous empire in history.

Source: Time & Life Pictures/Getty Images.

Neil Patrick O'Donnell

See also Attila the Hun; Nevsky, Saint Alexander

Further Readings

Grousset, R. (1966). *Conqueror of the world*. New York: Orion Press.

May, T. (2007). Genghis Khan: Secrets of success. *Military History, 24*(5), 42–49.

Morgan, D. O. (1986). The great Yasa of Chingiz Khan and Mongol law in the Ilkhanate. *Bulletin of the School of Oriental and African Studies, University of London, 49*(1), 163–176.

Sinopoli, C. M. (1994). The archeology of empires. *Annual Review of Anthropology, 23,* 159–180.

Vernadsky, G. (1938, December). The scope and contents of Chingis Khan's Yasa. *Harvard Journal of Asiatic Studies, 3*(3/4), 337–360.

Geological Column

The geological column is a composite diagram that shows in a single column the vertical or chronologic arrangement of the subdivisions of geologic time, or the sequence of rock units of a given region. Geologic time includes the part of the earth's history that is represented by and recorded in the successions of rocks, or the time extending from the formation of the earth as a separate planetary body to the beginning of written history. Earth scientists use a common language to talk about geologic time. That common language is standard, and it is ruled by the Geologic Timescale (GTS). The modern GTS consists of two different scales: the relative timescale, which is made of chronostratigraphic units, and the chronometrical or absolute timescale, which consists of geochronologic units. Due to the complexity and duration of geologic history, both scales are divided into hierarchical levels that are used by historical geology to analyze the history of our planet and of life on Earth.

Principles and Development

The standard geological column represents an ideal succession containing rocks from all ages, the earliest rocks on Earth at the bottom of the column and the youngest ones at the top. The construction of the geological column is based on the underlying principles of stratigraphy, first proposed by Nicolaus Steno around 1669. According to his *principle of superposition,* the oldest stratigraphic units are located at the bottom of the column and the youngest at the top, with dips adjusted to the horizontal. The resulting geological column indicates the relations between the stratigraphic units and the subdivisions of geologic time, and their relative positions to each other. The principle of superposition is the basis for establishing the relative ages of all strata and the fossils that they contain.

The geological column was developed largely during the early 19th century, and its origin probably begins with the story of the first geological map of England, published by William Smith in 1815. Smith was the first to realize that fossils were arranged in order and regularly in strata, always in the same order from the bottom to the top of a section, each stratum being characterized by particular types of fossils. These observations led him to propose the *principle of faunal succession.* Furthermore, the relative order of the formations was proved to be the same even in distant locations of Great Britain. The application of these two simple principles (superposition and faunal succession) led to the construction of the first geological column. In addition, the geological column was based on the uniformitarian principles (the present is the key to the past, i.e., processes operating in the past were constrained by the same laws of physics that operate today) first proposed by James Hutton in the mid-18th century and further developed by Charles Lyell.

The standard geological column aims to establish a classification system to organize systematically the rocks of the earth's crust into formal units corresponding to intervals of geologic time. Such units must be of global extent to allow correlation. Among the formal units for stratigraphic classification, chronostratigraphic units—units based on the time of formation of the rock bodies—offer the greatest potential for worldwide application because they are based on their time of formation, and are therefore the most accepted units to mark positions in the stratigraphic column. Other units such as lithostratigraphic, biostratigraphic, and unconformity-bounded units are all of limited areal extent and thus unsatisfactory for global synthesis. The biostratigraphic units are nevertheless unique in the sense that the fossils they contain show evolutionary changes through geologic time that are not repeated in the stratigraphic record. Due to the irreversibility of evolutionary change, biostratigraphic units are indicative of geologic age. However, owing to the imperfection or incompleteness of the fossil record, and the dependence of the fossil-producing organisms on biogeography and depositional facies, the boundaries of the biostratigraphical units commonly lie at different stratigraphic horizons and, similar to unconformity-bounded units, they may be diachronous and represent all or parts of one or several chronostratigraphic units. Magnetostratigraphic polarity units approach synchronous horizons because their boundaries record the rapid reversals of the earth's magnetic field. Although magnetostratigraphic polarity units may be useful guides for chronostratigraphic position and have a potentially worldwide extent, they have relatively little individuality because one reversal looks like another, and they can usually be identified only by supporting age evidence. Therefore, magnetostratigraphic polarity units require extrinsic data such as biostratigraphic data or stable isotope analyses for their recognition and dating. All these stratigraphic units are based on one property each, and they will not necessarily coincide with those based on another.

Chronostratigraphic Scale

For convenience, a chronostratigraphic scale has been created to divide the rock record into chronostratigraphic units, which are relative time units. Chronostratigraphic units are divisions of rock bodies based on geologic time. They are studied in Chronostratigraphy, the branch of Stratigraphy that deals with the relative time relations and ages of rock bodies. The purpose of the chronostratigraphic classification is to organize systematically the rocks of the earth's crust into chronostratigraphic units corresponding to intervals of geologic time. These intervals of geologic time are called geochronologic units, and they actually measure time in years before the present. The geochronologic scale helps to calibrate the chronostratigraphic scale to linear time. Chronostratigraphy aims to provide a basis for time correlation and to create a reference system to record events of geologic history; in order to achieve these goals, the scale is standardized by the International Commission on Stratigraphy (ICS).

Chronostratigraphic units are tangible stratigraphic units because they encompass all the rocks, layer upon layer, formed within a certain time span of the earth's history regardless of their compositions or properties. By definition, they are worldwide in extent, and their boundaries, which are called chronostratigraphic horizons or chronohorizons, are synchronous, everywhere the same age. Whereas other kinds of stratigraphic units are identified on the basis of observable physical features, chronostratigraphic units are distinguished and established on the basis of their time of formation as interpreted from these observable properties. Several hierarchical levels may be distinguished among chronostratigraphic units, namely eonothem, erathem, system, series, and stage (from the most to the least comprehensive levels). Their rank and relative magnitude are a function of the time interval represented by their rocks. The oldest eonothem is the Archean, and it is followed by the Proterozoic, and by the most recent Phanerozoic. The names of the different erathems are related to the ideas of evolution, representing major changes of the development of life. The oldest erathem of the Phanerozoic is thus called Paleozoic, which means "ancient life," and it is followed by the Mesozoic, meaning "middle life," and by the Cenozoic, which means "recent life." The names of most formal stratigraphic units more commonly consist of an appropriate geographic name (usually, the geographical regions where they were first found and studied) combined with an appropriate term indicating the kind and rank of the unit. Position within a chronostratigraphic unit is expressed by adjectives indicative of position, such as basal, lower, middle, upper, and so on. Stages can be subdivided into substages or grouped into superstages. A stage is defined by its boundary stratotypes, that is, sections that contain a designated point in a stratigraphic sequence of almost continuous deposition, chosen for its correlation potential. The lower and upper boundary stratotypes represent specific moments in geologic time, and the geologic time between them is the time span of a stage (generally between 2 and 10 million years). Special attention is paid to the selection of the lower boundaries of chronostratigraphic units, since the upper boundary of a given chronostratigraphic unit corresponds to the lower boundary of the succeeding unit. Therefore, each chronostratigraphic unit is defined in the rock record by a boundary stratotype that is formally known as a Global Stratotype Section and Point (GSSP), which provides an unequivocal definition of the chronostratigraphic units in the stratigraphic record. If possible, boundary stratotypes must be identified in marine, fossiliferous, and continuous sections that are well exposed and easily accessible, and they should contain synchronous marker horizons that allow long-distance correlation. An example of a geologically synchronous boundary stratotype is the Cretaceous/Tertiary boundary stratotype, whose GSSP is located at the El Kef section in Tunisia. This boundary stratotype contains multiple markers, including evidence of the mass extinction of marine and terrestrial groups such as calcareous plankton or dinosaurs, the restructuring of other faunal groups such as benthic foraminifera, the deposition of a rusty-red layer with an anomalous concentration of iridium, microtektites, shocked quartz grains, and Ni-rich spinels, isotope anomalies (negative shift in C-13), and so forth. These palaeontological, mineralogical, geochemical markers are related to a global event, the impact of an asteroid on Earth, and they allow worldwide correlation of the Cretaceous/Tertiary boundary. Boundary stratotypes are important because, apart from defining stages, they also define series (whose time spans range from 13 to 35 million years) and systems (normally from 30 to 80 million years each).

A chronozone is a chronostratigraphic unit of unspecified rank, and it includes all rocks formed everywhere during the time span of some designated stratigraphic unit or geologic feature. Although chronozones are formal chronostratigraphic units, they are not part of the hierarchical chronostratigraphic classification.

Geochronologic Scale

The time during which a chronostratigraphic unit was formed corresponds to a geochronologic unit, which corresponds to a unit of time, a subdivision of geologic time. The geologic timescale is based on geochronologic units, and it is the time-intangible-equivalent to the physical geological column, which is based on chronostratigraphic units. Time cannot be found in a rock body, but we can assign a certain age to rock bodies through the analysis of tangible features. Therefore, the geological column can also be divided into geochronologic units. The geologic timescale is usually presented in the form of a chart showing the names of the various stratigraphic units, including chronostratigraphic units and geochronologic units. Unlike the chronostratigraphic scale, which is based on relative time units, the geochronologic or chronometric scale measures time in years before the present. The geologic timescale results from joining the chronostratigraphic and the geochronologic scales.

As in the chronostratigraphic units, several hierarchical levels can be distinguished among geochronologic units, namely eon, era, period, epoch, and age, with eons being the most comprehensive levels and ages the smallest levels. Eras are divided into periods, the periods are further divided into epochs, and the latter into ages. These units are equivalent to chronostratigraphic units: for example, an age represents the time during which a stage was formed and it takes the same name as the corresponding stage, and an epoch is the geochronologic equivalent of a series. Eras and eons take the same name as their corresponding erathems and eonothems. Position within a geochronologic unit is expressed by adjectives indicative of time, such as early, late, latest, and so on. The time span during which a chronozone was deposited corresponds to a chron. Although the *International Stratigraphic Guide* states that "a chronozone includes all rocks formed everywhere during the time span of some designated stratigraphic unit or geologic feature," most chronozones and their corresponding chrons are derived from previously established biozones or biostratigraphical units (bodies of stratified rocks that are characterized by their fossil content).

Standard Global Chronostratigraphic (Geochronologic) Scale

All units of the standard chronostratigraphic and geochronologic hierarchies are theoretically worldwide in extent. They provide a standard scale of reference, what is known as the Standard Global Chronostratigraphic (Geochronologic) Scale, that aims to date all the rocks everywhere and to relate all rocks everywhere to the earth's geologic history. The standard geological column and its equivalent geologic age system have been built up by superposition of local columns from many different localities. A local geologic column is called a "geologic section," and it consists of any sequence of rock units found in a given region either at the surface or below it. Although the geologic column is not found complete at any place on Earth and the representative sediments common to all the major divisions cannot be found all together in a single section, the relative order of the formations still remains the same; in addition, such relative order also fits the geologic column.

Geochronometry

The quantitative (numerical) measurement of geologic time is dealt with by geochronometry, a branch of geochronology. The improvement of radiometric techniques since 1917 has allowed scientists to determine the absolute ages of rocks and to work out the duration of the intervals of geologic time, which had been previously established by means of fossils. More recently, enhanced methods of extracting linear time from the rock record have enabled high-precision age assignments. Apart from high-resolution radiometric dating, some of these calibration methods include the use of geochemical variations, Milankovitch climate cycles, and magnetic reversals. Radioactivity allowed scientists to date chronostratigraphical units, contributing to the development of the modern GTS. Technologic advances in measuring magnetic properties of rocks, together with the intense drilling of oceanic sediments and their biostratigraphical calibration by means of microfossils, have led to an improved chronology (magnetobiochronology). Moreover, the rapid development of cyclostratigraphy during the past decades has led to the construction of an astronomical timescale for dating events in the geologic record, based mainly on the relation between sedimentological, geochemical, or palaeontological cycles and variations in the earth's orbital parameters.

Recent Developments and Future Directions

The construction of the geological column has been under way for the last 2 centuries, and it has overcome several obstacles such as the precision and accuracy of correlation and dating tools, the limits of the stratigraphic database, or problems of nomenclature. In March 2005 the current available stratigraphic and geochronologic information was compiled by the project "Geologic Time Scale 2004" and published by a team designated by the International Commission on Stratigraphy. The results of this project summarized the history and status of boundary definitions of all geologic stages, compiled integrated stratigraphy (biologic, chemical, sea-level, magnetic, etc.) for each period, and assembled a numerical age scale from an array of astronomical tuning and radiometric ages. A combination of zones, polarity chrons, stages, and ages was carried out in order to calculate the best possible timescale. Earth scientists thus keep concentrating their efforts on the construction and improvement of the GTS. Research on Ocean Drilling Program (ODP) cores, and on Integrated Ocean Drilling Program (IODP) cores in the near future, will improve the calibration of various biostratigraphical scales, and together with the development of new tuning strategies will probably extend the astronomical timescale downward. Even so, there are still some stratigraphic and geochronologic issues to be resolved in the next updated version of the Geologic Time Scale, the GTS2008, which is expected to include a consensus on all stage boundary stratotypes, which is one of the main challenges for the future.

Laia Alegret

See also Chronostratigraphy; Dating Techniques; Geologic Timescale; Geology; Hutton, James; Lyell, Charles; Smith, William; Steno, Nicolaus; Time, Planetary

Further Readings

Gradstein, F. M., Ogg, J. G., & Smith, A. G. (2004). *A geologic time scale 2004.* Cambridge, UK: Cambridge University Press.

Hedberg, H. D. (Ed.). (1976). *A guide to stratigraphic classification, terminology and procedures.* New York: Wiley.

Holmes, A. (1960). A raised geological time-scale. *Transactions of the Geological Society of Edinburgh, 17,* 183–216.

NASCSN (North American Commission on Stratigraphic Nomenclature). (1983). North American stratigraphic code. *American Association of Petroleum Geologists Bulletin, 67,* 841–875.

Geologic Timescale

The geologic timescale is the framework for deciphering the history of planet Earth. It is used by geologists and other scientists to describe the timing and relationships between events that have occurred during the history of the earth.

Nomenclature

The history of the earth is broken up into a hierarchical set of divisions for describing geologic time. In increasingly smaller units of time, the generally accepted divisions are eon, era, period, epoch, and age. The Phanerozoic eon represents the time during which the majority of macroscopic organisms, algal, fungal, plant, and animal, lived. When first proposed as a division of geologic time, the beginning of the Phanerozoic, approximately 542 million years ago (mya), was thought to coincide with the beginning of life. In reality, this eon coincides with the appearance of animals that evolved external skeletons, like shells, and the somewhat later animals that formed internal skeletons, such as the bony elements of vertebrates. The time before the Phanerozoic is usually referred to as the Precambrian. The Phanerozoic consists of three major divisions: the Cenozoic, the Mesozoic, and the Paleozoic eras. The *zoic* part of the word comes from the root *zoo,* which means animal. *Cen* means recent, *meso* means middle, and *paleo* means ancient. These divisions reflect major changes in the composition of ancient faunas, each era being recognized by its domination by a particular group of animals. The Cenozoic has sometimes been called the age of mammals, the Mesozoic the age of dinosaurs, and the Paleozoic the age of fishes. This is an overly simplified view; it has some value for the newcomer but can be a bit misleading. For instance, other groups of animals lived during the Mesozoic. In addition to the dinosaurs, animals such as mammals, turtles, crocodiles, frogs, and countless varieties of insects also lived on land. In addition, there were many kinds of plants living in the past that no longer live today. Ancient floras went through great changes too, and not always at the same times that the animal groups changed.

Few discussions in geology can occur without reference to geologic time, which is often discussed in two forms: (1) Relative time (chronostratic), subdivisions of the earth's geology in a specific order based upon relative age relationships; these subdivisions are given names, most of which can be recognized globally, usually on the basis of fossils. (2) Absolute time (chronometric), numerical ages in millions of years or some other measurement. These are most commonly obtained via radiometric dating methods performed on appropriate rock types.

History

The first people who needed to understand the geological relationships of different rock units were miners. Mining had been of commercial interest since at least the days of the Romans, but it wasn't until the 1500s and 1600s that these efforts produced an interest in local rock relationships. By noting the relationships of different rock units, Nicolaus Steno in 1669 described two basic geologic principles. The first stated that sedimentary rocks are laid down in a horizontal manner, and the second stated that younger rock units were deposited on top of older rock units. To envision this latter principle, think of the layers of paint on a wall. The oldest layer was put on first and is at the bottom, while the newest layer is at the top. An additional concept was introduced by James Hutton in 1795, and later emphasized by Charles Lyell in the early 1800s. This was the idea that natural geologic processes were uniform in frequency and magnitude throughout time, an idea known as the principle of uniformitarianism. Steno's principles allowed workers in the 1600s and early 1700s to begin to recognize rock successions. However, because rocks were locally described by the color, texture, or even smell, comparisons between rock sequences of different areas were often not possible. Fossils provided the opportunity for workers to correlate geographically distinct areas. This contribution was possible because fossils are found over wide regions of the earth's crust.

For the next major contribution to the geologic timescale we turn to William Smith, a surveyor, canal builder, and amateur geologist in England. In 1815 Smith produced a geologic map of

England in which he successfully demonstrated the validity of the principle of faunal succession. This principle simply stated that fossils are found in rocks in a very definite order. This principle led others who followed to use fossils to define increments within a relative timescale.

Arthur Holmes (1890–1965) was the first to combine radiometric ages with geologic formations in order to create a geologic timescale. His book, *The Age of the Earth,* written when he was only 22, had a major impact on those interested in geochronology. For his pioneering scale, Holmes carefully plotted four radiometric dates, one in the Eocene and three in the Paleozoic, from radiogenic helium and lead in uranium minerals, against estimates of the accumulated maximum thickness of Phanerozoic sediments. If we ignore sizable error margins, the base of the Cambrian interpolates at 600 mya, curiously close to modern estimates. The new approach was a major improvement over a previous "hourglass" method that tried to estimate maximum thickness of strata per period to determine their relative duration, but had no way of estimating rates of sedimentation independently. In 1960, Holmes compiled a revised version of the age-versus-thickness scale. Compared with the initial 1913 scale, the projected durations of the Jurassic and Permian are more or less doubled, the Triassic and Carboniferous are extended about 50%, and the Cambrian gains 20 million years at the expense of the Ordovician.

W. B. Harland and E. H. Francis as part of a Phanerozoic timescale symposium coordinated a systematic, numbered radiometric database with critical evaluations. Items in The Phanerozoic Time-Scale: A Symposium, were listed in the order as received by the editors. Supplements of items were assembled by the Geological Society's Phanerozoic Time-Scale Sub-Committee from publications omitted from the previous volume or published between 1964 and 1968, and items relating specifically to the Pleistocene were provided primarily by N. J. Shackleton. The compilation of these additional items with critical evaluations was included in *The Phanerozoic Time-Scale: A Supplement* published in 1971 by Harland and Francis. In 1978, R. L. Armstrong published a reevaluation and continuation of The Phanerozoic Time-Scale database. This publication did not include abstracting and critical commentary. These catalogs of items and of Armstrong's continuation of items were denoted "PTS" and "A," respectively, in later publications.

In 1976, the Subcommission on Geochronology recommended an intercalibrated set of decay constants and isotopic abundances for the U-Th-Pb, Rb-Sr, and K-Ar systems with the uranium decay constants by Jaffey et al. in 1971 as the mainstay for the standard set. This new set of decay constants necessitated systematic upward or downward revisions of previous radiometric ages by 1%–2%.

In *A Geological Time Scale,* Harland et al. standardized the Mesozoic–Paleozoic portion of the previous PTS-A series to the new decay constants and included a few additional ages. Simultaneously, in 1982 G. S. Odin supervised a major compilation and critical review of 251 radiometric dating studies as Part II of *Numerical Dating in Stratigraphy*. This "NDS" compilation also reevaluated many of the dates included in the previous "PTS–A" series. A volume of papers on The Chronology of the Geological Record from a 1982 symposium included reassessments of the combined PTS–NDS database with additional data for different time intervals. After applying rigorous selection criteria to the PTS–A and NDS databases and incorporating many additional studies (mainly between 1981 and 1988) in a statistical evaluation, Harland and coworkers presented *A Geological Time Scale 1989*.

The statistical method of timescale building employed by *GTS82* and refined by *GTS89* derived from the marriage of the chronogram concept with the chron concept, both of which represented an original path to a more reproducible and objective scale. Having created a high-temperature radiometric age data set, the chronogram method was applied that minimizes the misfit of stratigraphically inconsistent radiometric age dates around trial boundary ages to arrive at an estimated age of stage boundaries. From the error functions, a set of age/stage plots was created (Appendix 4 in *GTS89*) that depicts the best age estimates for Paleozoic, Mesozoic, and Cenozoic stage boundaries. Because of wide errors, particularly in Paleozoic and Mesozoic dates, *GTS89* plotted the chronogram ages for stage boundaries against the same stages with relative duration scaled proportionally to their component chrons. For convenience, chrons were equated with biostratigraphic zones. The chron concept in *GTS89* implied equal duration of zones in prominent biozonal schemes, such as a conodont scheme for the Devonian.

The Bureau de Récherches Géologiques et Minières and the Société Géologique de France published a stratigraphic scale and timescale compiled by Odin and Odin. Of more than 90 Phanerozoic stage boundaries, 20 lacked adequate radiometric constraints, the majority of which were in the Paleozoic.

The International Stratigraphic Chart is an important document for stratigraphic nomenclature (including Precambrian), and included a summary of age estimates for stratigraphic boundaries.

During the 1990s, a series of developments in integrated stratigraphy and isotopic methodology enabled relative and linear geochronology at unprecedented high resolution. Magnetostratigraphy provided correlation of biostratigraphic datums to marine magnetic anomalies for the Late Jurassic through Cenozoic. Argon–argon dating of sanidine crystals and new techniques of uranium–lead dating of individual zircon crystals yielded ages for sediment-hosted volcanic ashes with analytical precessions less than 1%. Comparison of volcanic-derived ages to those obtained from glauconite grains yielded systematically younger ages, thereby removing a former method of obtaining direct ages on stratigraphic levels. Pelagic sediments record features from the regular climate oscillations produced by changes in the earth's orbit, and recognition of these "Milankovich" cycles allowed precise tuning of the associated stratigraphy to astronomical constants.

Aspects of the *GTS89* compilation began a trend in which different portions of the geologic timescale were calibrated by different methods. The Paleozoic and early Mesozoic portions continued to be dominated by refinements of integrating biostratigraphy with radiometric tie points, whereas the Late Mesozoic and Cenozoic also utilized oceanic magnetic anomaly patterns and astronomical tuning. A listing of the radiometric dates and discussion of specific methods employed in building *GTS2004* can be found in Gradstein, Ogg, and Smith's *A Geologic Time Scale 2004*.

Calibration

Because the timescale is the main tool of the geological trade, insight on its construction, strengths, and limitations greatly enhances its function and its utility. According to Gradstein, all scientists should understand how the evolving timescales are constructed and calibrated, rather than merely using the numbers in them.

The calibration to linear time of the succession of events recorded in the rock record has three components: (1) The international stratigraphic divisions and their correlation in the global rock record, (2) the means of measuring linear time or elapsed durations from the rock record, and (3) the methods of effectively joining the two scales.

For convenience in international communication, the rock record of Earth's history is subdivided into a chronostratigraphic scale of standardized global stratigraphic units, such as "Paleogene," "Eocene," "*Morozovella velascoensis* planktic foraminifera zone," or "polarity Chron C24r." Unlike the continuous ticking clock of the chronometric scale (measured in years before the present), the chronostratigraphic scale is based on relative time units in which global reference points at boundary stratotypes define the limits of the main formalized units, such as Neogene. The chronostratigraphic scale is an agreed convention, whereas its calibration to linear time is a matter for discovery or estimation. By contrast, Precambrian stratigraphy is formally classified chronometrically; that is, the base of each Precambrian eon, era, and period is assigned a numerical age.

Continual improvement in data coverage, methodology, and standardization of chronostratigraphic units implies that no geologic timescale can be final. *A Geologic Time Scale 2004* (*GTS2004*) provides an overview of the status of the geological timescale and is the successor to *GTS1989*.

Since 1989, there have been several mayor developments. Stratigraphic standardization through the work of the International Commission on Stratigraphy (ICS) has greatly refined the international chronostratigraphic scale. In some cases, traditional European-based geological stages have been replaced with new subdivisions that allow global correlation. New or enhanced methods of extracting linear time from the rock record have enabled high-precision age assignments. An abundance of high-resolution radiometric dates has been generated and has led to improved age assignments of key geologic stage boundaries. Global geochemical variations, Milankovitch climate cycles, and magnetic reversals have become important calibration tools. Statistical techniques of extrapolating ages and associated uncertainties to stratigraphic events have evolved to meet the challenge of more accurate age dates and more precise zonal assignments. Fossil event databases with multiple stratigraphic sections through the globe can be integrated into composite standards.

The compilation of *GTS2004* has involved a large number of specialists, including contributions by past and present chairs of different subcommissions of ICS, geochemists working with radiometric and stable isotopes, stratigraphers using diverse tools from traditional fossils to astronomical cycles to database programming, and geomathematicians. The set of chronostratigraphic units (stages, eras) and their computed ages, which constitute the main framework for *A Geologic Time Scale 2004,* are summarized in the chart available online from the ICS.

Eustoquio Molina

See also Chronostratigraphy; Darwin, Charles; Dating Techniques; Earth, Age of; Geological Column; Geology; Neogene; Paleogene; Synchronicity, Geological; Time, Measurements of

Further Readings

Berry, W. (1987). *Growth of a prehistoric time scale: Based on organic evolution* (Rev. ed.). Palo Alto, CA: Blackwell Scientific Publications.

Gradstein, F. (2004). Introduction. In F. Gradstein, J. Ogg, & A. Smith (Eds.), *A geologic time scale 2004* (pp. 3–19). Cambridge, UK: Cambridge University Press.

Gradstein, F., Ogg, J., & Smith, A. (Eds.). *A geologic time scale 2004.* New York: Cambridge University Press.

Harland, W. B., Armstrong, R. L., Cox, A. V., et al. (1990). *A geologic time scale 1989.* New York: Cambridge University Press.

International Commission on Stratigraphy. (2004). *International stratigraphic chart.* Available from http://www.stratigraphy.org/chus.pdf

Remane, J. (2000). *International stratigraphic chart, with explanatory note.* Sponsored by International Commission on Stratigraphy (ICS), International Union of Geological Sciences (IUGS), and UNESCO. 31st International Geological Congress, Rio de Janeiro.

Geology

Geology is the scientific study of planet Earth and its history, through 4,600 million years to the present. This natural science is traditionally divided into two branches: physical geology and historical geology. Physical geology focuses on physical structure, materials, and geological processes of the earth. Historical geology examines the origin of our planet and life, and all the climatic, geographic, oceanographic, and biological events that have taken place across geological time. This dual division is rather arbitrary, therefore both points of view (physical and historical) are found currently integrated within the framework of plate tectonics, the current paradigm of geological science.

Physical Geology

Physical geology includes such disciplines as: geophysics (applies principles of physics to the study of the earth); geochemistry (the study of the chemical characteristics of minerals and rocks); mineralogy and petrology (the study of the origin, properties, structure, and classification of minerals and rocks, respectively); hydrogeology (the study of the origin, occurrence, and movement of water masses); structural geology (the study of the deformational history of rocks and regions and of the forces responsible); geomorphology (the study of the origin and modification of landforms); volcanology (the study of volcanoes and magma formation processes); sedimentology (the study of sedimentary rocks and the processes by which they were formed); and engineering geology (the study of the interactions of the earth's crust with human-made structures such as tunnels and mines).

Some areas of specialization for professional geologists related to physical geology include exploration and extraction of natural resources (mineral deposits, coal, oil, etc.), prediction and evaluation of geological hazards (landslides, earthquakes, volcanic eruptions, or meteoritic impacts), evaluation of the stability of construction sites, the search for supplies of clean water, and analysis of environmental problems such as soil and coastal erosion.

Historical Geology

A consubstantial part of geology is the study of how Earth's materials and continents, surface environments, processes, and organisms have changed over geological time. Processes, fossils, and geological events are recorded in rocks. Thus the main objective of historical geology is the analysis of the geological record in order to reconstitute and understand the earth's history. Historical geology is based on paleontology (the study of life in the past from the fossil record, including evolutionary relationships, and its applications in environmental reconstructions and in the relative dating of rocks); stratigraphy (the study of stratified rocks in terms of mode of origin, original succession, relative dating, and geologic history), and paleogeography (the reconstruction of the ancient geography of the earth's surface). Other important disciplines closely related to historical geology are: paleoclimatology (the application of geological science to determine past climatic conditions) and paleoceanography (the reconstruction of the history of the oceans, with regard to circulation, chemistry, or patterns of sedimentation).

When geologists come to interpret the earth's history, they rely on two complementary types of dating of rocks: relative dating and absolute dating. Relative dating places historical events in their correct temporal order, and absolute dating provides a numerical age for a rock and establishes how many years ago a geological event took place.

Relative Dating

The relative ages of rocks and events in geologic sequences can be established by interpreting the fossil record and utilizing several basic principles in stratigraphy. The four most important are: the principle of original horizontality (sedimentary rocks are formed in essentially horizontal beds named strata; nonhorizontal strata have been disturbed after lithification), the principle of superposition (in any undisturbed stratigraphic sequence, older strata are buried beneath younger strata), the principle of intersection (when a fault or igneous intrusion cuts across a formation of sedimentary rocks, the fault or the intrusion is younger than these strata), and the principle of inclusions (the inclusion of a rocky body in a sequence of strata is older than the sedimentary rocks that contain it). Since the 19th century, the application of these rules to establish the relative ages of rocks contributed to developing the standard geological column in geological sites undisturbed or minimally disturbed, such as the Zumaya stratigraphic section in Spain.

Geologists soon understood that to develop a global geological timescale, a comparison of rocks of similar age located in different regions or continents was required. This process is known in stratigraphy as "correlation." Correlation involves matching up rock layers of similar age that are in different regions. When conditions of exposure are good, the litho-correlation across short distances can be done by applying the principle of lateral continuity (sediments are deposited forming strata over a large area in a continuous sheet). When correlation involves a long distance (even

Overview to coastal Zumaya stratigraphic section, a classic European locality for the study of the Cretaceous and Paleogene periods, due to its richness in fossils, continuity of sedimentation, and good exposure of rocks.

Source: Photo by Asier Hilario Orus. Used with permission.

between two different continents), geologists depend on the fossil remains of ancient organisms. In this case the bio-correlation is carried out using the principle of faunal succession (in a stratigraphic sequence, fossil species succeed one another in a definite and determinable order, so any time period can be recognized by its fossil content).

Fossil species appear and disappear throughout the fossil record as a consequence of the evolution (speciation and extinction) of species. As each fossil species lived during a specific interval of geological time, its presence (or sometimes absence) may be used to provide a relative age for the strata in which it is found. Each fossil species also lived at the same time in a more or less extensive geographical region. For this reason, paleontologists can use fossils to establish a bio-correlation of strata among different localities, where fossils of one species or of a species assemblage were present.

Correlation based on fossils is the focus of biostratigraphy, a discipline that deals with the distribution of fossils in the stratigraphic record, and the organization of strata into correlatable units (biozones) on the basis of the fossils they contain. Most species lived for tens of millions of years before they became extinct or evolved into new species. Nevertheless, some species lived for only hundreds of thousands of years or a few million years. If they were limited to a short period of time, had a wide geographic distribution, and are abundant in the fossil record, these species are considered "index fossils." Index fossils provide a precise means for estimating the relative age of sedimentary rock, and for correlating biozones. For example, many species of trilobites, ammonites, or foraminifera are ideal for biostratigraphy in marine series, and micro-mammals, grains of pollen, and spores are good index fossils for continental deposits.

Absolute Dating

The discovery of radioactivity and the development of the mass spectrometer in the 20th century permitted many radioactive elements to be used as geologic clocks. These techniques are based on the natural decay of radioactive elements (unstable isotopes) that cause the radioactive parent elements to decay to stable daughter elements.

Through the radioactive decay of isotopes in rock, exotic daughter elements are introduced over time. By measuring the concentration of the stable end products of decay, coupled with knowledge of the half-life and initial concentration of the decaying elements, the age of a rock can be calculated. This technique is known as radiometric dating, a powerful tool for reconstructing the earth's history.

Potassium-40, for example, decays into argon-40 after a half-life of 1.25 billion years, so that after 1.25 billion years half of the potassium-40 in a rock will have become argon-40. This means that if a rock sample contained equal amounts of potassium-40 and argon-40, it would be 1.25 billion years old. Other isotopes used in radiometric dating are: uranium-235, uranium-238, thorium-232, and rubidium-87.

Relative Versus Absolute Dating

Relative dating provides a relative timescale formed by bio- and chronostratigraphical units. Absolute dating provides an absolute timescale composed of geochronological units. But how are both scales correlated and integrated in the geological timescale if fossils occur in sedimentary rocks, and most minerals that contain radioactive isotopes are in igneous rocks?

The simplest method to correlate both scales is the radiometric dating of volcanic ash or of oceanic basaltic layers that are interbedded between sedimentary rocks. The age of the volcanic rock is younger than the underlying sedimentary rocks and older than the overlying sedimentary rocks. If these sedimentary rocks contain fossils, they are very relevant since they can be correlated with the biozones defined in this area. Thus, rocks whose ages have been determined by absolute dating can be incorporated into a succession of strata determined by relative dating. Then geologists can use correlations to infer the ages of rocks and fossils that cannot be directly dated. In fact, the combined absolute/relative timescale is always being revised in order to produce an even more precise picture of Earth's history.

A Brief History of the Earth

From the modern methods of radiometric age dating, we know that the earth is around 4.6 billion years old. Historical geologists divide all this geological time into three major divisions (eons):

Archaean, Proterozoic, and Phanerozoic, although a fourth pregeologic eon is considered: Hadean. All of them are made up of eras that usually ended with profound changes in the disposition of the earth's continents and oceans, and are characterized by the emergence of new forms of life or by the disappearance of ancient ones.

Hadean Eon (4550–3900 Million Years Ago)

The Hadean eon is the geologic time extending from the birth of the solar system and the earth's formation 4,600–4,550 million years ago, to the formation of the oldest rocks 3,900–3,800 million years ago (mya). The Hadean is the first eon in the earth's History, but very little geological record was preserved because the earth's surface was molten.

The solar system's planets, including the earth, were formed by accretion from a cloud of gas and dust known as solar nebula. Grains in orbit around the central primitive sun (protoplanetary disk) began to join, collecting in bodies called planetesimals. In a few million years, several large planets grew through low-velocity collisions between nearby planetesimals. The planets and satellites formed in the inner solar system—Earth, Mars, and Venus—were composed mainly of materials with high melting points, such as silicates and metals (iron and nickel).

Since the Hadean lacks any official status, this eon has been arbitrarily subdivided in three informal periods, taking into account the primitive geological history of the moon: Cryptic (4,550–4,500 mya), Ryderian (4,500–4,100 mya), and Nectarian (4,100–3,900 mya). The first period includes the accretion time of Earth from the solar disk, the big whack event, and the formation of the moon. The big whack is a hypothetical event that occurred roughly 4,530 mya in which a Mars-sized body, usually called Theia, impacted the proto-Earth at an oblique angle. The giant impact destroyed Theia, ejecting into space most of its mass together with a significant portion of the earth's silicate mantle. A ring of debris began to orbit near the earth's equator, coalescing into the moon about 100 years after the huge impact. The Ryderian era includes the progressive cooling of the earth (and the moon) and the process of differentiation of the earth's core, mantle, and protocrust, when the earth acquired a primitive inner structure.

A great number of asteroidal and cometary objects remained among the newborn planets, starting a well-known period called the Late Heavy Bombardment (LHB) during the Nectarian era. The LHB happened about 4,100–3,800 mya, resulting in a large number of impact craters on the earth as well as on the rest of the planets and satellites in the solar system. This cataclysm period created an enormous amount of heat, completely melting the earth and allowing its materials to separate definitively into three main layers: iron core, silicate mantle, and thin outer crust. This intensive bombardment probably destroyed the primitive earth's protocrust, retaining only individual zircon crystals that were redeposited in most modern sediments. The oldest known zircons were radiometrically dated to about 4,400 million years and are found in the Acasta Gneiss in western Canada. The study of some of these zircons suggests that there was liquid water at that period, indicating that primitive atmosphere and oceans must have existed then. The rock vapor might condense around the young Earth, resulting in a dense atmosphere of carbon dioxide, water, methane, nitrogen, and hydrogen.

Archean Eon (3,900–2,500 Million Years Ago)

The Archean eon is the geologic time that extends from the formation of the oldest rocks 3,900–3,800 mya to 2,500 mya. It is formally subdivided into four eras: Eoarchaean (3,900–3,600 mya), Paleoarchean (3,600–3,200 mya), Mesoarchean (3,200–2,800 ma) and Neoarchean (2,800–2,500 mya). A significant event occurred at the beginning of the Archaean eon: the origin of life, in a scenario with an atmosphere composed mostly of carbon dioxide.

The oldest known rocks on Earth are found in the Issua Greenstone Belt (southwestern Greenland) and include well-preserved volcanic, metamorphic, and sedimentary rocks dated at 3,800–3,700 million years. Archean volcanic activity was probably considerably more intensive than it is today, and plate tectonics were surely very active because the inner earth was much hotter at that time. A greater rate of recycling of crustal material should have occurred then, preventing the formation of continents. For this reason, only some Archean rocks survive, including metamorphized igneous rocks, such as granites, peridotites, and unusual ultramafic mantle-derived volcanic rocks called komatiites. Archean rocks also include stromatolites (the oldest fossil traces of prokaryotic organisms), and hard metamorphized deepwater sediments.

Only when the mantle cooled and convection slowed down could the tectonic activity slow down. Small protocontinents (*cratons*) were the norm during the Archean eon. Several Archean cratons have been identified, including a hypothetical first continent now called Vaalbara. According to radiometric dating, the Vaalbara continent existed at least 3,300 mya during the Paleoarchean era. This continent collected the two only known Eoarchean cratons: Kaapvaal craton (South Africa) and Pilbara craton (Western Australia). Other continents were probably formed 3,000 mya in the Mesoarchean era, grouping small cratons of present western Australia, eastern India, eastern Antarctica, and southeastern Africa. It is now called the Ur continent.

During the Neoarchean era, 2,700 mya, the earliest known supercontinent, called Kenorland, was born. It formed as result of a series of events of accretion, comprising several cratons: Laurentia (including Canada and Greenland), Baltica (including Scandinavia and the Baltic area), Yilgarn (Western Australia), and Kalahari (Botswana, South Africa, and Namibia).

Proterozoic Eon (2,500–542 Million Years Ago)

The Proterozoic eon began 2,500 mya, and ended with the disappearance of the complex Ediacaran biota 542 mya. The geological record of the Proterozoic is much better known than that of the Archean, since Proterozoic rocks are less metamorphized and are more abundant. Many Proterozoic sedimentary rocks were deposited in extensive shallow epicontinental seas, and their study suggests that Proterozoic plate tectonics were both massive and rapid.

The Proterozoic eon has been formally subdivided into three eras: Paleoproterozoic (2,500–1,600 mya), Mesoproterozoic (1,600–1,000 mya), and Neoproterozoic (1,000–542 mya). Both the start and the end of the Proterozoic were marked by widespread glaciation: the Huronian and Varangian glaciations, respectively.

Paleoproterozoic Era (2,500–1,600 Million Years Ago)

The Huronian glaciation began 2,400 mya and lasted until 2,100 mya. It was one of the most severe ice ages, and it is possible that the earth's surface was entirely covered by ice. It is perhaps related to the decrease of atmospheric carbon dioxide, consumed and captured by photosynthetic microorganisms, and the virtual disappearance of the greenhouse gas methane due to chemical oxidation.

The neoarchaic Kenorland supercontinent began to break up at the start of the Siderian period (2,500–2,300 mya) when two Baltic fragments, the Kola and Karelia cratons (today in Russia), began to drift apart. During the Rhyacian (2,300–2,050 mya), several continents were created out of Kenorland when it broke up: Arctica (including today's Canada and Siberia), Atlantica (including today's eastern South America and western Africa), and Baltica (northern Europe). Cyanobacteria developed in the Siderian and Rhyacian seas, producing a great quantity of photosynthetic oxygen that resulted in a large increase of this gas in the atmosphere. The combination of oxygen with the iron dissolved in the oceans formed a distinctive Archaic–Paleoproterozoic type of rock called banded iron formations (BIFs) that are composed of iron oxides like magnetite and hematite.

The atmosphere became oxygen rich during the Orosirian period (2,050–1,800 mya) with a progressive decrease in iron dissolved in the ocean. The formation of BIFs ceased, but the deposition of the so-called red beds began. These rocks are tinged with hematite, indicating an increase in atmospheric oxygen. The progressive accumulation of oxygen in the atmosphere might have caused the extinction of numerous groups of anaerobic bacteria, the only type of life that existed up to that time. This event has sometimes been called the oxygen catastrophe. From the point of view of plate tectonics, collisions between cratons were common during this period, forming multiple orogens worldwide that were the prelude to the formation of the supercontinent Columbia.

The last period of the Paleoproterozoic, the Statherian (1,800–1,600 mya), was characterized by its tectonic stability. At the beginning of the Statherian, the supercontinent Columbia was formed and lasted from approximately 1,800 to 1,500 mya. It consisted of almost all of Earth's continents: Laurentia (proto-North America), Nena (Arctica, Baltica, and eastern Antarctica), Atlantica (Amazonia and western Africa), Ur (Australia, India, and northern Antarctica), and possibly northern China and Kalahari (southern Africa). At the beginning of the Statherian a new type of cell appeared, eukaryotic cells, that experienced great evolutionary exits in later periods of mass extinction.

Mesoproterozoic Era (1,600–1,000 Million Years Ago)

The Mesoproterozoic era began with the breakup of Columbia and ended with the formation of a new supercontinent: Rodinia. By about the Mesoproterozoic era, 80% of the earth's continental crust had been formed. Columbia began to fragment at the start of the Calymnian period (1,600–1,400 mya), forming several continents that drifted apart, including Laurentia, Nena, Australia-Antarctica, Amazonia, Sahara (northern Africa), Congo (west-central Africa), Kalahari (southern Africa), and Sao Francisco (southeastern South America).

Rodinia began forming in the Ectasian period (1,400–1,200 mya) and finished assembling during the Stenian period (1200–1000 mya). The Laurentian continent was the core of Rodinia, and was sandwiched between two large blocks: East Gondwana (the original continent of Ur) and West Gondwana (the original continent of Atlantica). Moreover, Baltica and Siberia were nearby, to the southeast and northeast of Laurentia, respectively. Rodinia was surrounded at that time by a great superocean called Mirovia, in which the first cells with sexual reproduction appeared.

Neoproterozoic Era (1,000–542 Million Years Ago)

The Neoproterozoic era was a time of complex continental drift that followed the breakup of Rodinia. The breakup of this supercontinent started in the Tonian period (1,000–850 mya) and continued through the Cryogenian period (850–630 mya). In the first phase, 800 mya, Rodinia split into two large segments. The lands of East Gondwana and Congo (the Proto-Gondwana continent) moved north while rotating counterclockwise, beginning the formation of the Panthalassic superocean. The great block composed of Laurentia, Siberia, Baltica, South China, and West Gondwana (the Proto-Laurasia continent) drifted southward, rotating clockwise. The Panafrican Ocean formed between these macrocontinents.

Recent studies indicate that at least seven independent continents must have existed around 750 mya: Laurentia-Baltica-West Gondwana, North China, Siberia, Australia-East Antarctica, South China, Malani (India, Iran, Arabia, and Madagascar), and Congo-Kalahari. During the Ediacaran period (630–542 mya), most of the earth's large continents came together again in the southern hemisphere. They formed the Pannotia supercontinent, which was short lived since it lasted only about 60 million years.

The Cryogenian period is characterized by the massive Varanginian glaciations that are represented by worldwide tillite deposits, suggesting that the earth suffered the most severe ice age of its history with glaciers extending as far as the equator. It is believed that all the planetary oceans were deeply frozen, a phenomenon known as Snowball Earth. Finally, the last Neoproterozoic period, the Ediacaran, is unusual because it contains strange soft bodied fossils known as Ediacaran biota. The severe Neoproterozoic glaciations caused profound changes in oxygen levels and ocean chemistry, which could explain why life developed intensively during the Ediacaran and later during the Cambrian.

Phanerozoic Eon (542 Million Years Ago to the Present)

The Phanerozoic eon left a rich fossil record, starting with the Cambrian explosion about 540 mya. It is formally subdivided into three eras: Paleozoic (542–251 mya), Mesozoic (251–65 mya), and Cenozoic (65 mya to the present).

Earth seems to have gone through alternating icehouse (with ice caps) and greenhouse (without ice caps) phases during the Phanerozoic, perhaps partly controlled by how the continents and oceans were distributed. At least three icehouse phases are known: Late Ordovician–Silurian (about 460–416 mya), Late Carboniferous–Permian (about 318–251 mya), and the Oligocene–Neogene period (34 mya to the present). Throughout the Phanerozoic new continents and oceans appear and disappear, assembling and separating until reaching their present locations. This is a complex history, and the reader is invited to visit the Paleomap project's Web page where several full-color paleogeographic maps are available that show the changing distribution of lands and seas, as well as the various continental and oceanic plates that developed in the earth's recent history.

Paleozoic Era (542–251 Million Years Ago)

The Paleozoic era covers the geological time from the first occurrence of an abundant fossil record (Cambrian Explosion) to the greatest mass extinction event in the earth's history: the Permian–Triassic boundary event. The Cambrian Explosion was the greatest evolutionary radiation in the earth's history, bringing forth nearly all the major groups or phyla of animals, including the trilobites. The Paleozoic began with the breakup of the Pannotia supercontinent and ended with the formation the last known supercontinent, Pangea.

Pannotia started to break up at the beginning of the Cambrian period (542–488 mya) and formed four continents: Laurentia (North America), Baltica (Northern Europe), Siberia, and Gondwana. The three first drifted toward the north and Gondwana drifted toward the south, with most of the land staying in equatorial latitudes. The Panthalassic superocean covered most the northern hemisphere, and two new minor oceans began to form: Proto-Tethys and Iapetus. Proto-Tethys formed between the proto-Laurasian continents (Laurentia, Baltica, and Siberia) and Gondwana. Iapetus formed between Baltica and Laurentia. The Cambrian oceans seem to have been broad and shallow, causing a climate significantly warmer than that of the preceding periods dominated by ice ages.

At the start of the Ordovician period (488–443 mya), Gondwana began to drift toward the South Pole. The Ordovician climate was very warm, and Laurentia, Baltica, and Gondwana were widely covered by warm shallow seas, allowing the development of shelled organisms and the deposition of great amounts of biogenic limestone. While the Panthalassic superocean still covered most of the northern hemisphere, another ocean was born, the Paleo-Tethys, which was taking over territory at the expense of ancient Proto-Tethys. The new Rheic Ocean was the result of the formation of the Avalonia microcontinent (composed mainly of Newfoundland and England) that had broken off from Gondwana and drifted toward Baltica. That ocean was gaining territory at the expense of the old Iapetus Ocean. By the end of the Ordovician, Gondwana was approaching the South Pole and was largely glaciated. The extensive glaciation of Gondwana and the subsequent fall of the sea level may have triggered the Late Ordovician mass extinction event between 447–444 mya, in which the 85% of species died off.

The icecaps of the Silurian period (443–416 mya) were less extensive than those of the Late Ordovician, and the melting of the Silurian icecaps and glaciers contributed to a rise in the sea level. During this period, continents drifted near the equator and the earth's climate entered a long greenhouse phase with warm shallow seas covering much of the equatorial landmasses. Coral reefs expanded, and land plants began to colonize the barren continents. Baltica and Laurentia started to collide, completely closing off the Iapetus Ocean and forming the Euramerica macrocontinent. Such collisions folded the sediments deposited in the previous Iapetus basin, forming the Caledonian orogen (Appalachian Mountains, the Anti-Atlas in Morocco, and the Caledonian Mountains in Great Britain and Scandinavia). At that time, the Rheic and Paleo-Tethys oceans occupied the area between Euramerica and Gondwana, and between Siberia and Gondwana, respectively. During the Silurian a new ocean was formed, the Ural Ocean, located between Siberia and Baltica.

The Devonian period (416–359 mya) was a time of great tectonic activity as the continents drew closer together. The Ural Ocean disappeared toward the end of the Devonian when Siberia collided with the Baltica coast of Euramerica, forming the Ural Mountains and the Laurussia macrocontinent, also called the Old Red Continent. Sea levels were high worldwide during the Devonian, with broad areas of continents widely submerged under shallow seas where tropical reef organisms were plentiful. The deep waters of the giant Panthalassic superocean covered most of the earth, Paleo-Tethys continued spreading, and other minor oceans the Rheic Ocean began to close off. The Devonian ended with a major mass extinction event that affected up to 82% of all species, probably caused by several meteorite impacts like those forming the 120-kilometer–diameter Woodleigh crater (Australia).

The well-known Pangea supercontinent began to form in the Carboniferous period (359–299 mya). Laurussia and Gondwana collided during this period, definitively closing the Rheic Ocean. The collision occurred along the eastern coast of North America (where the Alleghenian orogen was formed) and the northwestern coast of South America, Africa, and South Europe (where the Hercinian orogen emerged). Finally, North China collided with Siberia at the end of the Carboniferous, closing off another old ocean, the Proto-Tethys. Most the continents were grouped together toward the end of the Carboniferous, although South China was still separated from Laurussia by the Paleo-Tethys Ocean. The Carboniferous was a period of active mountain-building. There was also a drop in south polar temperatures, glaciating the southern portion of Gondwana. Nevertheless, the tropical latitudes were warm and humid, allowing for the development of extensive forests and swamps.

Except for the South China continent, all of Earth's major land masses were grouped together as Pangea in the Permian period (299–251 mya); Pangea reached from the equator toward both poles. This affected ocean currents in the Panthalassic superocean and the Paleo-Tethys, which was located between the Asian part of Laurussia and Gondwana. At the beginning of the Permian, a rift started to open from the north of Gondwana to form a new ocean: the Tethys Ocean. The Permian ended with the most extensive mass extinction event in geological history: the Permian–Triassic extinction event, affecting more than 90% of species. The Late Permian glaciations, Siberian Traps volcanism, severe drop in sea levels, and even several large meteorite impacts, among other causes, have been proposed to explain the massive extinction.

Mesozoic Era (251–65 Million Years Ago)

The Mesozoic era spans geological time from the Permian–Triassic boundary event 251 mya to the Cretaceous–Tertiary boundary event 65 mya. It was an era of intensive tectonic, climatic, and evolutionary activity.

During the Triassic period (251–199 mya), almost all of the earth's landmasses had collected into a single supercontinent, Pangea, that was surrounded by the Panthalassic superocean. The recently formed Tethys Ocean continued opening at the expense of the Paleo-Tethys. Since Pangea's large size limited the moderating effect of the oceans, the Triassic climate became very hot and dry, forming typical red bed sandstones and gypsum. This kind of terrestrial climate was suitable for reptiles. The Triassic ended with another major mass extinction episode that affected mainly marine environments. The cause of this extinction is uncertain, but global cooling or even meteorite impacts have been proposed. These extinctions allowed the dinosaurs to expand, initiating the Age of Dinosaurs that spanned the Jurassic (199–145 mya) and the Cretaceous (145–65 mya).

In the Early Jurassic, the oceanic crust of the Paleo-Tethys was completely subducted. This episode resulted in the collision of South China with Laurussia, initiating the Cimmerian orogeny that created mountain ranges as high as today's Himalayas. Pangea was shaped like a "C" at that time, curling around the Tethys Ocean with the concave area occupied by the Tethys Ocean. Both Pangea and Tethys were surrounded by the huge Panthalassic superocean. As in the Triassic, the Jurassic climate was warm; there is no evidence of glaciation since no continent was near either pole. During this period, Pangea began to break up into two major landmasses: Laurasia (North America and Eurasia) and Gondwana (South America, Africa, Australia, Antarctica, and India), which began the opening of the Central Atlantic Ocean. Toward the end of the Jurassic, the Panthalassic superocean converted into the current Pacific Ocean.

Pangea was definitively broken up during the Cretaceous into today's continents, although the continents had positions substantially different from today's. The progressive drift of the Laurasian and Gondwanan landmasses opened the western Tethys Ocean (today's Mediterranean Sea) and separated North America and South America, forming a continuous ocean current around the equator. The North Atlantic Ocean opened, separating Iberia from Newfoundland and England-Scandinavia from Greenland. The separation of South America and Africa formed the South Atlantic Ocean. Finally, the drift of India northward formed the Indian Ocean, which was gaining territory at the expense of eastern Tethys. This active rifting during the opening of the Atlantic Ocean raised mountain ranges (including the giant American Cordillera: the Rocky Mountains, the Sierra Madre, and the Andes Mountains) around the entire coastline of old Pangea. This intensive tectonic activity raised the sea level, forming broad shallow seas over North America (the Western Interior Seaway) and Europe. The Cretaceous climate was very warm, devoid of ice at the poles. The Cretaceous ended with the most recent major mass extinction event: the Cretaceous–Tertiary event 65 mya, affecting more than 75% of species. A meteorite impact that formed the approximately 180-kilometer-diameter Chicxulub crater (Yucatan, Mexico) appears to be its cause.

Cenozoic Era (65 Million Years Ago to the Present)

The Cenozoic era covers geological time from the Cretaceous–Tertiary mass extinction event to the present. During the Cenozoic, mammals evolved from a few small insectivores that had survived the Cretaceous–Tertiary extinction. The continents moved to their current positions, causing remarkable climatic and oceanographic changes.

During the Paleogene period (65–23 mya), the Laurasian and Gondwanan plates formed in the Cretaceous continued to split apart, with North America, Eurasia, South America, Africa, India, and Antarctica-Australia pulling away from each other. India continued its migration toward central Eurasia, and Africa also headed north toward western Eurasia, slowly closing the Tethys Ocean during the Paleocene epoch (65–56 mya). The rifting and splitting apart of Eurasia, Greenland, and North America increased hydrothermal and volcanic activity in the North Atlantic. This tectonic episode combined with the movement of the Indian plate northward, restricted the Tethys oceanic current, and helped to trigger the Paleocene–Eocene Thermal Maximum event 56 mya. During the Eocene epoch (56–34 mya), Antarctica and Australia began to split, leaving Antarctica isolated in its current location at the South Pole. Moreover, the Indian microcontinent collided with central Eurasia, folding the Himalayas upward and closing off the eastern Tethys Ocean. The western Tethys was converting into the present Mediterranean Sea, which was being progressively narrowed by the drift of Africa (including Arabia) toward Europe. The Alps started to rise in Europe as the African continent continued to push north into the Eurasian plate. All these continental movements culminated in the Oligocene epoch (34–23 mya). At that time Antarctica was isolated definitively, forming the circumantarctic ocean current and allowing a permanent ice cap to develop. A global cooling occurred during the Late Eocene and the Oligocene, causing a gradual major extinction episode.

The Neogene period covers the past 23 million years, during which modern birds and mammals, including humans, evolved. Continents continued to drift toward their current positions. During the Miocene epoch (23–5.3 mya), global mountain building continued to take place, raising the western American cordilleras, the Alps, and the Himalayas. Arabia, which became part of the Africa plate, collided with Eurasia, forming the Caucasus Mountains, separating the Indian Ocean and the Mediterranean Sea and closing off the remnants of the old Tethys. The rise of mountains in the western Mediterranean (the Betic Cordillera in southern Spain and the Rif Mountain in northern Morocco), combined with the global drop in sea level due to formation of Antarctica ice cap, caused what is known as the Messinian Salinity Crisis in the Mediterranean Sea approximately 6 mya. The Mediterranean Sea has dried up several times due to repeated closings of the old Straits of Gibraltar, thus forming enormous evaporative deposits throughout the Mediterranean. When the present Strait of Gibraltar eventually opened, the Atlantic would have poured a vast volume of water into the dry Mediterranean basin in a gigantic waterfall much more than 1,000 meters high and far more powerful than Niagara Falls. During the Pliocene epoch (5.3–1.8 mya), South America and North America joined, creating the Isthmus of Panama. This tectonic episode had major consequences for global temperatures: warm equatorial ocean currents were cut off and the climate became cooler and drier, resulting in the formation of the Arctic ice cap 2 mya. Both the Antarctic and the Arctic became much colder. During the Pleistocene epoch (1.8 million to 11,500 years ago), the modern continents were essentially at their present positions, initiating repeated glacial cycles. Four major glacial episodes have been identified (usually called Günz, Mindel, Riss, and Würm in the Alps; Nebraskan, Kansan, Illinoian, and Wisconsin in North America; Weichsel or Vistula, Saale, Elster, and Menapian in Northern Europe; and Devensian, Wolstonian, Anglian, and Beestonian in Britain), separated by interglacial episodes. The Holocene is the geological epoch that spans the last 11,500 years of the earth's history (from 9,500 BCE to the present), starting with the retreat of the Pleistocene glaciers. It was preceded by the Younger Dryas cold period, the final part of the Pleistocene, and it is characterized by global warming. The optimum climate of the Holocene has favored the flourishing of human civilizations.

José Antonio Arz

See also Chronostratigraphy; Decay, Radioactive; Earth, Age of; Fossil Record; Geological Column; Geologic Timescale; Hutton, James; Lyell, Charles; Paleontology; Plate Tectonics; Steno, Nicolaus; Stratigraphy; Wegener, Alfred

Further Readings

Grotzinger, J., Jordan T., Press F., & Siever R. (2006). *Understanding Earth* (5th ed.). New York: Freeman.

Poort, J. M., & Carlson, R. J. (2004). *Historical geology: Interpretations and applications* (6th ed.). New York: Prentice Hall.

Stanley, S. M. (2004). *Earth system history* (2nd ed.). New York: Freeman.

Wicander, R., & Monroe J. S. (2003). *Historical geology: Evolution of Earth and life through time* (4th ed.). London: Brooks/Cole.

Web Sites

Paleomap Project: http://scotese.com/earth.htm

Gerontology

Although research into human aging has been conducted sporadically for many years, it is only in the past several decades that it has gained enough momentum in the social sciences to become an established program of formal academic study—under the title "gerontology." Gerontology is the study of the processes of aging. The term comes from the Greek *γεροντοσ*, an old man and *λογοσ*, word, science, or study. A closely related term is *geriatrics,* the medical care of the elderly, coined by Ignatius Leo Nascher in 1909 from the Greek *γεροντοσ* and *γστροσ*, to cure.

Historical Perspective

The care of aging and injured individuals has a long record in the (pre)history of humankind. Some of the earliest evidence for such care comes from Neanderthal remains in Europe and the Middle East: for example the La Chappelle-aux-Saints fossils in France and those from Shanidar Cave in Iraq. In the case of the individual ("the Old Man") from La Chappelle-aux-Saints (the type specimen of *Homo neanderthalensis*), the bones indicate an individual who suffered from arthritis of the jaws, spine, and legs. It is unlikely that such an individual would have been capable of food procurement in a Paleolithic society of the type supposed for Neanderthals. The only way such an individual could survive to a relatively advanced age was through the care of others.

Ralph Solecki excavated the remains of an individual at Shanidar Cave in Iraq who appears to have survived the amputation of his right arm. He had been injured and possibly blinded in the left eye. He also showed a healed injury to the right parietal bone. Although he survived these injuries, he was eventually killed by a slab of falling limestone, while he stood upright. It is not unreasonable, therefore, to assume that there was some sort of care for such older (by Neanderthal standards) individuals who most likely would have been unable to forage for themselves.

In a brief history of gerontology, Joseph Freeman delineates nine periods in the "scientific" study of old age in the past 5,000 years; that is, since the dawn of recorded history. These periods include the Archaic period, which extended from the emergence of writing to the development of early civilizations. His second period lasted from the efflorescence of Mesopotamian, Biblical, and Egyptian cultures to the advent of Minoan and Greek civilizations and includes descriptions of the aged and codes of behavior toward them. The third period, the Greco-Roman, included Hippocrates and Aristotle among the Greeks and Galen and Cicero in Rome. During this period these individuals began to assemble a body of literature pertaining to the treatment of ailments that attend aging. The general belief was that "innate heat" from the heart began to diminish over time, and that this "cooling" led to aging.

During Freeman's Judeo-Arabic period, Moses Maimonides, Arnoldus de Villa Nova, and Avicenna described the differences between young and old and recommended regimens for older people, including less frequent blood-letting—only once per year for septuagenarians.

The period of European Emergence brought with it the first book specifically devoted to geriatrics: Gabrielle Zerbi's *Gerontocomia,* published in 1489. Roger Bacon argued reasonably in *De retardanis senectutis accedentibus, et de sensibus conservandis,* printed in Oxford in 1590 (300 years after Bacon's death) that if people were as zealous in their efforts to conserve health as to restore it, they would lead longer lives free of disease. Bacon recommended the use of magnifying glasses for older people with poor vision shortly before the appearance, in Italy, of vision-correcting eyeglasses.

A Renaissance publication in 1534, *The Castel of Healthe,* by Sir Thomas Elyot, advised the elderly to follow a prudent diet consisting of a number of small meals per day rather than a few large ones. Sir John Floyer wrote in *Medicina Gerocomica* that old age is the result of an imbalance of bodily humors, with a preponderance of cold and dry.

During the seventh period, Benjamin Franklin published translations of earlier works on senescence and expressed interest in the variety of ways with which to increase health and stave off old age. Shortly after Franklin's death, Christoph Wilhelm Hufeland published *The Art of Prolonging the Life of Man* in which he prescribed a *Makrobiotik* approach.

In 1804, Sir John Sinclair translated classical works, reviewed statistics, and summarized much of the previous work on aging. Later, Sir Anthony Carlisle published *Essay on the Disorders of Old Age* and advised young people to take care of themselves early in life if they wished to secure longevity. Carl Canstatt wrote on general theories of aging in 1839 and hypothesized that the death of cells led to irreplaceable tissue death. In Paris, Jean-Martin Charcot lectured that the diseases that accompany aging have a latency period, which, it appears, some such as cancers do. The primary concern still was to look upon senescence as pathology, rather than as a normal continuance of the lifelong aging process, but by the 1890s C. A. Stephens opened a laboratory in Maine for the study of old age and began a magazine called *Long Life.*

Although quite a bit of data on biological and environmental factors in longevity were generated during the 1940s, advances in gerontology have accelerated since 1950 because of advances in medicine, emphasizing physical and mental health in later years. Demographic and economic studies have been concerned with the effects changes in the age structure would have on the social and financial sectors. For example, what changes would occur in taxation structures should the mandatory retirement age change from 65 to 70 or to 60 years?

Recent Theories and Research

A major impetus to aging studies was disengagement theory introduced by Elaine Cumming and W. E. Henry in *Growing Old: The Process of Disengagement,* based upon the Kansas City Study of Adult Life. Previously, much of the literature on aging was material gathered from research on other topics, or it was concerned with cataloging characteristics of the aged. Cumming and Henry proposed that elderly people around the world perform mutual disengagement from their societies. Disengagement was supposed to be an inevitable developmental event in the life cycle, although its start and pattern might vary from culture to culture. This was thought to lead to (or at least correlate with) passivity in later life.

However, David L. Gutmann's study of the highland Druze demonstrated that disengagement is not inevitable, and passivity does not necessarily accompany it. Gutmann felt that in traditional folk societies with strong religious orientations, older people's passivity may be a central and necessary component of their *new* engagement with social roles and traditions associated with their new status. What is taken for passivity in modern societies is a move toward religious engagement—mastery of the supernatural realm—in traditional societies. According to Gutmann, what Cumming and Henry found in American society is not universal, but is an "artifact of secular society" that rejects a normative order dependent upon older persons' traditional, moral roles after passing the "parental and productive life periods." Gutmann argues that this shift to Passive and Magical Mastery does not necessarily lead to disengagement and death, but to social rebirth through the religious role that turns destructive passivity in older persons into vehicles of social power.

Activity theory is an alternative to disengagement based upon the observation that some people not only do not *choose* to disengage, but also that they *do not* disengage. Activity theory, or "reengagement," like disengagement theory, is concerned with the relationship between levels of activity and psychological health in the last trimester of life. Activity theory proposes that there may be a natural tendency for older people to associate with other persons and to be active in community affairs. Contemporary retirement practices block this natural inclination and may lead to poor adjustment. By allowing continued engagement in community activities, or by prompting reengagement in society, older persons may maintain (or regain) psychological health. Robert Havighurst noted that for the three dimensions of aging studied by the Kansas City group, activity, satisfaction, and personality, it is personality that is the key factor in patterns of aging and life satisfaction. He concluded that both activity and disengagement theories are unsatisfactory, as they do not deal with personality differences within the older population.

Continuity theorists, such as Robert Atchley, feel that a simple relationship between activity levels and psychological health is insufficient to explain social aging. Continuity theorists propose that one's levels of engagement and psychological well-being are the results of lifelong patterns of activity or inactivity and psychological health or ill health. Linda George argues that continuity theory has value not only for historical interest, but because it accounts for individual differences—something that previous theories did not. George tested the impact of personality and social status variables upon levels of activity and psychological well-being in 380 white males and females aged 50 to 75 years to determine if one may predict continuity across life stages. She found that, contrary to disengagement and activity theories, there was only a weak correlation between activity levels and psychological well-being; that is to say, different variables predict the two phenomena. Personality factors were better predictors of psychological well-being than were social status factors, and social status factors better predicted activity.

Thus, one may conclude that neither disengagement nor activity and psychological well-being are outgrowths of the aging process. Rather, they are the products of long-term personality or social processes that are effective on an individual basis. To put it more simply, some older people have high or low activity levels because they always have had high or low activity levels; the same may be said for psychological well-being.

After the Second World War, modernization theorists and age stratification theorists began to view societies developmentally with regard to urbanization and industrialization. People lived longer in more developed cultures, which resulted in more older people surviving. This resulted in competition for jobs, forced retirement, and/or disengagement, as technological advances caused the need for relocation and the loss of their status as older people became more common and were no longer something "special." One possible result of this is a collapse of traditional family structures, according to Donald Cowgill and Lowell Holmes.

Matilda White Riley's theory of age stratification from the 1970s looked at the relationship between social structure and age across the life course. Those individuals who are born in the same age cohort (roughly similar to age sets in many traditional societies) will have many experiences in common. These experiences will be different for each generation even when the experiences have been generated by the same events, for example when a population has experienced a war or natural disaster: Children are impacted differently than are adults; older adults are impacted differently than are younger adults. This theory allows us to view the different ways in which age cohorts may react to life events, and how such life events affect the structure of the society.

By the 1990s aging research had shifted to family gerontology, according to Katherine R. Allen, Rosemary Blieszner, and Karen A. Roberto. Allen and her colleagues examined 908 articles and 30 books on family gerontology published in the 1990s and discovered a shift in the field of aging individuals with regard to family social relations. By far the largest focus of the articles was on caregiving (32.6%); the next largest category was social support and social networks at only 13.7%, followed by parent–adult child relations at 10.1%, and marital status transitions at 9.5%. Further, they found that the students of later life are developing an appreciation for pluralism and resilience strengthened by the incorporation of feminist and life course approaches. Likewise, there has been greater sophistication in the use of longitudinal data, especially as the focus has shifted from exclusively studying the aging individual to the individual within the familial matrix. This, they say, forces a chronological variable into the research, especially as there is no agreed-upon chronological definition of middle age (e.g., becoming a parent or grandparent) and major life events no longer can be predicted even by gender). Indeed, the family within which one ages may be a chosen family rather than a biological one, through adoption or choosing a favorite niece or nephew to become analogous to a daughter or son. The feminist approach began to focus on female intergenerational dyads (mother–daughter ties); daughters are three times more likely to give care to aging parents than are sons, even if the sons live closer. Ironically, daughters-in-law are more likely to be the caregivers than are sons, as demonstrated by Kathleen Lynch's and Eithne McLaughlin's observations on caring labor and love labor in modern Ireland.

For Allen and colleagues, the life course perspective is the major theoretical advance in gerontology during the 1990s. Life course studies focusing on historical and social processes and their impacts upon individuals answer two important considerations: how individuals change over time and how their changes are linked to other members of their families. Longitudinal approaches increasingly are employing narrative methods to discover subjective meanings that individuals use to construct their lives. Through the narrative interplay of historical events and self-perception we can create our "selves" as we need them to be.

Michael J. Simonton

See also Dying and Death; Longevity; Malthus, Thomas

Further Readings

Aldrich, C. K. (1964). Personality factors and mortality in the relocation of the aged. *The Gerontologist, 4(*2), 92–93.

Aldrich, C. K.,& Mendkoff, E. (1963). Relocation of the aged and disabled: A mortality study. *Journal of the American Geriatric Society, 11,* 185–194.

Allen, K. R., Blieszner, R., & Roberto, K. A. (2000). Families in the middle and later years: A review and critique of research in the 1990s. *Journal of Marriage and the Family, 62,* 911–926.

Botwinick, J. (1978). *Aging and behavior: A comprehensive integration of research findings*. New York: Springer.

Bromley, D. B. (1974). *The psychology of human ageing*. Harmondsworth, UK: Penguin.

Cumming, E., & Henry, W. E. (1961). *Growing old: The process of disengagement*. New York: Basic Books.

Freeman, J. T. (1979). *Aging: Its history and literature*. New York: Human Sciences Press.

George, L. K. (1978). The impact of personality and social status factors upon levels of activity and psychological well-being. *Journal of Gerontology, 33*(6), 84.0–84.7.

Gormley, M. (1964, Winter). The care of the aged in Ireland. *Administration, 12,* 297–324.

Gutmann, D. L. (1974). Alternatives to disengagement: The old men of the highland Druze. In R. A. LeVine (Ed.), *Culture and personality: Contemporary readings* (pp. 232–245). Chicago: Aldine.

Havighurst, R. J. (1968). Personality and patterns of aging. *The Gerontologist, 8*(2, II), 20–23.

Loustaunau, M. (2006). *Aging in society*. San Diego, CA: National Social Science Press.

Lynch, K., & McLaughlin, E. (1995). Caring labour and love labour. In P. Clancy, S. Drudy, K. Lynch, & L. O'Dowd (Eds.), *Irish society: Sociological perspectives* (pp. 250–292). Dublin: Institute of Public Administration.

Streib, G. F. (1968). Old age in Ireland: Demographic and sociological aspects. *The Gerontologist, 8*(4), 227–235.

Streib, G. F. (1970). Farmers and urbanites: Attitudes toward intergenerational relations in Ireland. *Rural Sociology, 35*(1), 26–39.

Gestation Period

The gestation period is the length of time, in viviparous (live-bearing) animals) needed for a fetus to develop inside the body of its mother. Gestation begins with conception (the implantation of the embryo in the uterus) and ends with labor and birth.

The length of the gestational period is species-specific, correlating somewhat with the body size for any given species, with larger species generally having a more prolonged gestational period. The gestational period is therefore quite short for very small mammals (21 days for mice), is longer for medium-sized animals (approximately 60 days for cats, dogs, and raccoons), and is quite lengthy for such large animals as rhinoceros (16 months) or whales (18 months). The shortest gestation period is that of the opossum (12 days), and the longest known gestation period for any animal is that of the elephant (18–22 months). For humans, the gestation period is normally 40 weeks (280 days), measured from the first day of the mother's last menstrual period.

Neonate Type

Although the length of the gestation period is generally correlated to an animal's body size, it is also determined by the state of development at birth for offspring of that species. Among mammals, there are three different groups that can be defined by the level of gestational development of their offspring at birth, and these groupings have proven (through fossil evidence) to be remarkably consistent throughout evolutionary history. Marsupials, which have the shortest gestation periods of all animals, are considered "superaltricial," with offspring that are very underdeveloped at birth and usually crawl into a pouch of some kind to continue their development before being able to survive detached from their mother's body. A second group of mammals includes insectivores, carnivores, and rodents. They have somewhat longer gestational periods and give birth to "altricial" offspring, which are generally poorly developed and typically must develop in a nest or burrow for some period after birth so that they can continue to grow and learn how to move around independently. Altricial offspring are still underdeveloped at birth, being usually hairless and with their eyes and ears sealed off by membranes. Altricial animals bear multiple offspring in litters and tend to have shorter gestation periods, reflecting the fact that the mother has limited space in her womb for completing development prior to birth. In contrast, a third group of mammals (primates, whales, dolphins, and hoofed mammals) has very long gestational periods and usually gives birth to only one or two well-developed "precocial" offspring that are relatively active soon after birth; they are born with fully developed vision and hearing, and are protected by fur and hair. This type of gestation is most common in animals that live out in the open, exposed to the elements, and are unable to conceal their young in burrows or caves.

Each main mammal group is therefore characterized by the type of neonate (altricial, superaltricial, or precocial) that its members produce, and by the length of gestational period typical of that group. Insectivores, tree shrews, carnivores, and many rodents have short gestational periods and bear altricial offspring; hoofed mammals, hyraxes, elephants, cetaceans (whales), pinnipeds (walruses, seals, and sea lions), primates, and hystricomorph rodents (Old World porcupines) bear precocial offspring after a fairly long gestational period. In fact, phylogenetic groupings have more impact on the length of the gestational period than animal body size does; the gestation period for an animal that bears precocial offspring will typically be three times longer than that for an animal of the same body size that bears altricial offspring.

Gestational Age

The gestational age of a fetus is a measure of how far along it is in the gestational period. Since the exact time of conception is not always known, the beginning of gestation is usually dated from a particular point in the reproductive cycle of any given species, or is estimated based on the size of the developing fetus. In humans, for example, gestational age is projected by a measure of time elapsed since the first day of the mother's last menstrual period, or is calculated with an ultrasound examination (usually administered between the 8th and 18th weeks of pregnancy), which uses the size of the developing fetus as the most accurate measure for dating conception and projecting when full development and birth will occur.

The gestational period is divided into three major phases: the preimplantation phase (from fertilization to implantation in the mother's womb), an embryonic phase (from implantation to the formation of recognizable organs), and a fetal phase (from organ formation to birth). These phases are called trimesters. In humans, each phase lasts about 3 months; the first trimester lasts from weeks 1 through 12, the second from weeks 13 through 27, and the third from weeks 28 to 40. In some mammals, the gestation period is extended to include an additional phase known as delayed implantation, or embryonic diapause, that precedes the embryonic phase. In these instances, the fertilized egg develops into a blastocyst (forming a hollow ball of cells), but then it stops developing and remains free in the womb rather than implanting in the wall of the womb (the usual next step in gestational development for most mammals). Delayed implantation is a strategy used by animals to delay the birth of a fetus until such external variables as food or weather are favorable for the survival of offspring, or in some cases as a way of holding potential offspring in reserve to immediately replace older offspring that do not survive long after birth. Other factors that influence the length of the gestational period in minor ways include gender (males take a few days longer than females), the number of young (single young take a few days longer than multiples), and heredity through the maternal line. In general, though, there is very little variation in the length of the gestational period within the same species, that is, 4% or less variability.

Helen Theresa Salmon

See also Birthrates, Human; Clocks, Biological; Duration; Evolution, Organic; Fertility Cycle; Gestation Period; Life Cycle; Maturation

Further Readings

Assali, N. S. (1968). *Biology of gestation: Vols. 1 and 2.* Burlington, MA: Academic Press.

Davies, J. (1960). *Survey of research in gestation and the developmental sciences.* Baltimore, MD: Williams & Wilkins.

Gilbert, S. F. (2006). *Developmental biology.* Sunderland, MA: Sinauer Associates.

Grzimek, B., Schlager, N., & Olendorf, D. (2003). Life history and reproduction. In D. G. Kleiman, V. Geist, & M. C. McDade (Eds.), *Grzimek's animal life encyclopedia* (Vol. 12, pp. 95–96). Farmington Hills, MI: Thomson Gale.

Gibran, Kahlil (1883–1931)

The writings of Kahlil Gibran, the popular 20th-century poet, philosopher, and artist, have been admired by millions and translated into over a dozen languages. By the time of his death, he had established a reputation in both the English and Arabic-speaking worlds. He never won critical or scholarly acclaim, but his style prompted the coining of a literary term, *Gibranism*, to describe the poised and poetic quality of his prose, which expressed an intense need for self-reflection and self-fulfillment. Throughout his life, he was primarily religiously nondenominational, seeking wisdom and truth from within instead. His writings reflect a preoccupation with mysteries and with deep spiritual meaning; he describes and reflects on his encounters with, and understandings of, godliness and addresses perennial themes such as Time.

Gibran was born in Bsherri (Bechari), Lebanon, in 1883. When he was 12, his family moved to the United States and settled in Boston, Massachusetts. After 2 years, Gibran went to Paris to study art under Auguste Rodin, at the famous Ecole des Beaux Arts. In Paris, Gibran also began to write plays and short stories in the Arabic language.

In 1904, he moved back to the United States and spent time living in both Boston and New York. While working in New York, he wrote his most popular literary works, *The Prophet* (1923), and *Jesus the Son of Man: His Words and His*

Deeds as Told and Recorded by Those Who Knew Him (1928). *The Prophet* included a series of poems on topics such as love, marriage, and children, and included a passage titled *On Time,* in which Gibran says time, like love, is undivided and spaceless.

Gibran's ability to paint and draw enabled him to illustrate many of his own books. Critics often cited the influences biblical literature had on Gibran's writings, and his lyrical passages are commonly read at baptisms, funerals, and weddings throughout the Western world.

Some of his other works include *Nymphs in the Valley* (1948), *Tears and Laughter* (1949), *The Madman: His Parables and Prose Poems* (1918), *Spirits Rebellious* (1946), *The Wanderer: His Parables and His Sayings* (1932), and *The Garden of the Prophet* (1933). His relationship with Mary Haskell, a teacher in Boston, is captured in *Beloved Prophet: The Love Letters of Kahlil Gibran and Mary Haskell, and her Private Journal* (1972).

In 1999, the Arab American Institute founded an annual *Kahlil Gibran Spirit of Humanity Award* that recognizes individuals, organizations, corporations, and communities whose actions demonstrate leadership in supporting and promoting coexistence, diversity, cultural interaction, inclusion, and democratic and humanitarian values across racial, ethnic, and religious groups.

Debra Lucas

See also Bible and Time; Humanism; Poetry; Qur'an

Further Readings

Waterfield, R. (1998). *Prophet: The life and times of Kahlil Gibran.* New York: St. Martin's.

Ginkgo Trees

Ginkgo biloba is the last surviving species of Ginkgophyta, a phylum of long-lived, vascular plants that evolved during the Permian period some 250 million years ago. Ginkgo trees, once thought extinct, are sometimes called living fossils due to the strong resemblance between the modern form and ancient remains preserved in the geologic record. The popularity of ornamental ginkgo trees in Asia has led to their widespread cultivation and dissemination.

The ginkgo tree is one of the best-known examples of a living fossil. This ancient tree represents a primitive family of trees common 160 million years ago in China. The ginkgo thrives in well-drained, loamy soil and is particularly resistant to modern pollutants, wind, pests, and disease.

Source: Michael Pettigrew/iStockphoto.

Ginkgos are medium-large trees that can live for hundreds of years, attaining a height of 30 meters and a trunk diameter of 2 meters. A few exceptional specimens may exceed 1,000 years in age and proportions far in excess of these. They comprise a unique division of the gymnosperms, an important seed-bearing plant group that includes cycads, conifers, and ferns. Ginkgos are easily recognized by their leaves, which look like a two-lobed fan (hence *biloba*).

Ginkgos are dioecious plants, meaning that male and female reproductive organs are borne on separate trees. Male trees form a small cone that produces motile sperm. On the female tree, fertilized seeds mature into a tan, fleshy fruit 25–40 millimeters long. These fruits are rich in butyric acid, which when crushed can release an odor likened to rancid butter. These sorts of naturally occurring chemicals in the tree are thought to have evolved for better resistance to insects and bacteria, or even to help ward off herbivores.

Ginkgophyta trees arose during the Permian, approximately 250 million years ago, and to the present day have left numerous fossils of their distinctive leaves, stems, seeds, and wood. After their emergence the group continued to spread and diversify, surviving the relatively arid Triassic to form part of the great forests of the Jurassic when the genus *Ginkgo* itself first evolved—approximately 170 million years ago. Since the end of the Cretaceous, the ginkgo has suffered from a steady constriction of its range, abundance, and diversity. The precise reasons are unknown, but today the ginkgo is all but extinct in the wild; a few small native populations remain in the Zhejiang province of China, scattered in elevated broadleaved forests.

In some ways, the ginkgo has been reclaiming its former territory. In China the trees have long been cultivated in the gardens of Buddhist temples (and occasionally as a food source). From there they spread to Japan, and in the 17th century to Europe and other Western countries. In modern cities all over the world, they have become a shade tree of choice. The ginkgo is well suited to the urban landscape, as it requires minimal maintenance. It also has a high tolerance for pollution and resistance against disease.

Ginkgo seeds are used in traditional Asian medicine, and the cooked seeds can even be eaten. More recently, ginkgo leaf extract has been packaged to treat a variety of ailments. This utilizes the plant's naturally occurring concentration of flavonoids, a group of antioxidants found in certain fruits and vegetables. Although scientific research has not yet supported the health benefits attributed to ginkgo, some promising lines of pharmaceutical research are investigating its effects on dementia and Alzheimer's disease.

Ginkgos are true icons of long-term survival; their modern form is quite similar to that of fossils 250 million years old. The tree has survived trampling hordes of herbivorous dinosaurs and major environmental catastrophes. Its extremely limited native populations, however, testify to enormous ecological pressure—the ginkgo has been struggling to survive in the present era. In the wild their relatively inefficient reproductive system, slow regeneration, and lack of diversity have exacerbated the damage from habitat loss. *Ginkgo biloba* faces a very high risk of extinction in the wild; it is currently classified as an endangered species. After successfully adapting to nature's challenges over hundreds of millions of years, let us hope that ginkgo remains a *living* fossil rather than a literal one.

Mark James Thompson

See also Coelacanths; Dinosaurs; Evolution, Organic; Extinction and Evolution; Fossils, Living

Further Readings

Hori, T., Ridge, R. W., Tulecke, W., Del Tredici, P., Trémouillaux-Guiller, J., & Tobe, H. (Eds.). (1997). *Ginkgo biloba—A global treasure*. Tokyo: Springer-Verlag.

Sun, W. (1998). *Ginkgo biloba*. In *2006 IUCN red list of threatened species*. Cambridge, UK: IUCN.

Tidwell, W. D. (1998). *Common fossil plants of western North America*. Washington, DC, and London: Smithsonian Institution Press.

Glaciers

Glaciers have been an important feature of the earth's landscape during the present Cenozoic era, which spans about 65 to 70 million years. Cooling near the end of the era began in the Pliocene epoch, and mountain glaciation in the western United States occurred somewhere between 1 and 2 million years ago. The Cenozoic era is divided into the Tertiary and Quaternary periods, with the most recent glaciation occurring during the Quaternary period, which covers approximately one million years before the present (BP). This period is divided into the Pleistocene and Holocene or Recent epochs. During the Pleistocene, four major glacial advances and three interglacial stages occurred. The Holocene or Recent epoch spans a period of approximately 11,000 years BP. During this time, the fourth interglacial stage or a temperature increase has been occurring, including melting ice and a rise in sea level. This may last for tens of thousands of years, and may be followed by another future period of cooling and the growth of glaciers.

Prior to this present age of Pleistocene glaciers, there were at least five other known glacier periods, dating back to two occurrences of glaciation in Precambrian times. Toward the end of the Permian period glaciers appeared again, and they were rather widespread. During the early and late portions of the Cretaceous period glaciers appeared once more. The occurrence of glaciers is evidently a cyclical phenomenon, but the precise cause of their appearance is not known.

During the Pleistocene glaciers were widespread, covering both polar regions and extending outward a considerable distance, covering approximately 30% of the earth's total land area. In the present Holocene epoch, the earth is witnessing a global warming as well as a global dimming: Both of these appear to be antagonized by increased human interference. All glaciers are receding, and have been for thousands of years, but at seemingly a much faster rate now than when they were flowing forth. Consequently, the sea level rose at an average rate of about 6 inches per 100 years during the Holocene. A noticeable increase has been noted during the last several hundred years, however, and this is expected to continue.

In the 19th century, Louis Agassiz, like James Hutton and other scientists in the century before, asserted that the large boulders in the valleys were not placed there by Noah's flood, but were once plucked by erosion out of the advancing ice, sometimes a mile or more deep, and then deposited by a receding ice flow. Agassiz's views were initially met with skepticism and hostility by most of the audience at a meeting of the Swiss Society of Natural Sciences; widespread acceptance came only gradually, later on.

Glaciers are commonly defined as either continental or mountain types. Continental glaciers begin in an area with polar temperatures and extremely large accumulations of snow. There were three areas in the northern hemisphere where this most strikingly occurred during the Pleistocene; in Europe over the northern Baltic Sea and much of Norway, in North America over Hudson Bay and north central Canada, and over northern Siberia. Not to be overlooked are the general expanse of the Arctic icecap including Greenland and other parts of the northern hemisphere, as well as the massive Antarctic continent in the southern hemisphere. These continental glaciers appear to be located on or very near shields consisting of Precambrian igneous and metamorphic rock. With regard to mountain glaciers, the Alps, Andes, Rockies, and the vast Himalayan chain are all fine examples of mountainous glaciated terrains. Also, snow and ice occur on isolated mountain peaks in Hawaii, Japan, and Kenya, to mention a few.

Continental Glaciers

Continental glaciers begin with a decrease in temperature and an accumulation of snow, over a long period, tens of thousands of years. The snow is compacted by its own weight. Eventually, the snow at the deepest level begins to form ice. Glacial or moving ice is subjected to immense pressure and is transformed molecularly into an extremely hard metamorphic rock. Subsequent snows provide added weight and pressure, and the deepest ice begins to move outward by the force of gravity into lobes that move more rapidly along lines of least resistance. The lobes are guided by original terrain features such as mountains, hills, and plains, and the relative resistance of the various types of earth materials and rock structures. The magnitude of accumulation at the glacier's source is believed to be more than 10,000 feet in some cases, and the outward movement is estimated at more than a thousand miles, perhaps at speeds of 30 miles per year or even more.

Continental glaciers sculpt the land by erosion, carving out a variety of landforms. The moving ice deposits the carried sedimentary materials as depositional features upon melting. Some of the eroded features that can be seen today are due to abrasion by rocks carried along by the ice, leaving behind striations, grooves, and polished surfaces. Also left behind are gouged-out valleys that were deeper and wider areas of softer rock, forming depressions such as the Great Lakes, *cuestas* or edges of land surfaces formed by resistant rock strata such as that of the Niagara Cuesta including Niagara Falls, and smaller hills known as *roche moutonée* formed by resistant rock. The materials are deposited in recessional and terminal moraines, or in ridge-like terrains that are accumulated during stand-still periods. As the ice recedes in a sometimes erratic manner, it leaves behind landforms such as ground moraines consisting of glacial till, also known as tillite, along with such features as kames and kettles, drumlins and eskers, resulting in a hummocky topography. Braided streams also result from retreating glaciers, as well as "misfit" valleys where the valley width is much narrower or wider than it should be for the width of the stream currently flowing through it. For example, the upper Mississippi, the Des Moines, and some of the other streams in the midwestern United States are considered misfit streams. In general, the landscape where continental glaciation has taken place is quite depressed compared to unglaciated areas, and exceedingly complex as compared to stream, eolian, or coastal landscapes. This is, in part, due to a yet-to-be-integrated drainage pattern and the periglacial landscape of outwash materials.

Mountain Glaciers

Mountain glaciers begin with a cold temperature and an accumulation of precipitation at the highest elevations. Over a long period of time, as with continental glaciers, snow is compacted, eventually forming ice. The glacial ice begins to move downward by gravity along lines of least resistance, forming tongues, usually in former stream valleys. In many cases these tongues of ice find their way to sea level, and when the ice recedes the fjords remain behind as remnants.

Mountain glaciers sculpt valleys by eroding various types and hardnesses of rock. Then the melting ice leaves the sculpted materials in depositional features. Eroded features include *cirques* or bowl-shaped indentations near the peaks, or matterhorns where the glaciers begin, the knife-like ridges between the valleys called *arêtes*, and low places in the ridges called *col*s. Valleys that were originally V-shaped due to stream action become U-shaped due to ice action, and some have depressions called *tarns*. Retreating glaciers deposit terminal and recessional moraines during stillstands, as well as lateral moraines along their edges as they retreat and medial moraines where two lateral moraines have merged. Glacial till carried from the eroded areas is dropped by the melting ice to form braided streams and outwash plains. In general, mountainous terrain that has been glaciated appears much more concise, complex, and abrupt when compared to unglaciated mountains. For example, the Matterhorn and its descending glaciers in the Swiss Alps are much more sharply unique in appearance as compared to Mount LeConte and other unglaciated peaks and their descending streams in the Great Smoky Mountains of the United States.

Time, distance, and speed play their part in sculpting the earth. Glaciers, like wind, streams, waves, and currents, flow. How fast does the ice flow? How far does the ice flow? How long does the ice take to flow? Winds move much faster than ice and travel the farthest, across land and sea, while streams are restricted to the land, and waves and currents are restricted to the sea. Glaciers move slowly across the land and out into the sea. If they didn't, there would be no icebergs today!

Glacial Movement and Climate Change

Glaciers, at their maximum extent during the Pleistocene, were widespread, covering more than an estimated 45 million square kilometers. Glacial ice moves much like a stream, in that the fastest motion is found in the center of the lobe or tongue. That is, the slippage and flowage is considerably slower closer to the rock formations where plucking and erosion by the ice adds friction. This is tempered by variations in rock hardness and degree of slope. Consequently, there is a huge variation in the mean rate of ice advance. Some of the intermittent advances of mountain glaciers with short duration vary between 2.4 and 32.3 meters per day, with advances between 606 and 4,850 meters per year. For long-term advances of mountain glaciers, the mean rate varies between 80 and 128 meters per year over a period of 100 years.

Continental glacier movement is much more difficult if not impossible to measure, as continental glaciers either no longer exist or are in a recessional mode. It is known that four major ice advances and accompanying recessions occurred during the Pleistocene, with their nomenclature varying depending on location and language. But these major advances included minor advances and recessions. For example, seven substages of the Wisconsin glacial stage in the midwestern United States have been observed. In the western hemisphere, numerous lobes descended from the Laurentide of Canada across the plains of the midwestern United States, forming a complex landscape. From radiocarbon dating it is known that ice receded from north-central Iowa less than 3,000 years before the present, and that near the bottom of the Des Moines lobe the oldest drift is older than 40,000 years before present. This is presumed to be during the Wisconsin, which began about 70,000 years before present. The maximum glacial extent during the Wisconsin occurred about 14,000 years before present, and a considerable amount of glacial activity occurring before and after, including loess deposition and the development of the present day paleosols, all occurred during the interglacial stages. It can be assumed that similar circumstances occurred in Europe and Siberia.

Climate fluctuations during the Pleistocene and Holocene, coupled with periglacial effects, are felt around the world, especially eustasy—worldwide change in sea level. The outwash from glaciers is the most obvious periglacial activity, along with the less obvious permafrost. Also, glacial rebound is evident where the deepest ice has melted away, such as Hudson Bay. Then too, there is the migration of vegetation poleward as temperature and moisture changed. Humankind soon followed the retreating glaciers.

Today, scientists worldwide are monitoring climate change, including rising sea levels, something that has been happening since the late 17th century. Ancient shorelines around the world show that when glaciers were near or at their minimum extent, sea level was about 400 feet higher than it is today. If the sea level continues to rise, then it may reach that stage again; how soon no one knows for sure, but it will continue to rise if global warming and global dimming continue. On the other hand, when and if the present interglacial stage ends, the sea level may fall. During the Illinoisan glacial stage when ice was at its maximum, the sea level is estimated to have been 600 feet below the present level, a condition that is difficult for many people even to imagine.

Although glaciers worldwide are receding at the present time, within the next 90,000 years or so they will again expand across large portions of the earth's landmasses, especially those located in the higher latitudes and altitudes.

Richard A. Stephenson

See also Erosion; Geologic Timescale; Global Warming; Ice Ages; Nuclear Winter

Further Readings

Flint, R. F. (1957). *Glacial and Pleistocene geology.* New York: Wiley.

Martini, I. P., et al. (2001). *Principles of glacial geomorphology and geology.* Upper Saddle River, NJ: Prentice Hall.

Weiner, J. (1986). *Planet Earth.* Toronto, ON, Canada: Bantam Books.

Wright, H. E., Jr., & Frey, D. G. (Eds.). (1965). *The quaternary history of the United States.* Princeton, NJ: Princeton University Press.

Globalization

Globalization refers to the close relationship and interdependence of economic, social, political, cultural, and ecological connections of places in our world. It refers to the intensification of interconnectedness on a global scale. With increased means of communication and travel from 20th-century innovations in technology there is no doubt that our world is shrinking. Never before has it been so easy for people, things, capital, and ideas to move around. Further, globalization has reordered the experience of time and space. Because economic and social processes have shrunk, distance and time are less of a constraint on the organization of human activity. Technological and economic advances have eliminated barriers of space by time and have reorganized time to overcome barriers of space. For example, the same media events are covered all over the world, making it possible for people in, say, the United States and Japan to have access to the same information. Also, this has allowed extremely remote areas of the world to interact with cosmopolitan cities and perhaps with places on the other side of the globe. In other words, time is shortening and space is shrinking. The pace of life is increasing, and the amount of time needed to do things is becoming much shorter. Something that is happening on the other side of the globe can deeply impact people and places vast distances away. Increasingly, economic and social life is becoming standardized around the world.

Globalization in a Historical Context

Forms of globalization were present as early as the 17th century with the rise of the Dutch East India Company, which is said to be the first multinational corporation because it was the first company to share the risk and create joint ownership by offering shares. During the 19th century, liberalization resulted in a rapid growth of international trade and investment between Europe, its colonies, and the United States. This "First Era of Globalization" began to crumble at the onset of World War I and collapsed entirely during the 1920s and 1930s. Arguments and critiques arose against imperialism and the exploitation of developing nations by developed nations.

International trade has grown tremendously since the 1950s; according to estimates, trade has increased from $320 billion to $6.8 trillion. As a result, people from around the world have access to a greater selection of products.

Much of what we are witnessing in the world today concerning globalization started in the 1970s with what is termed a "crisis of overaccumulation" based on the Henry Ford system of mass production. The Ford model, which is based on the mass production of standardized parts, became so successful that Western nations began to overproduce. This resulted in mass layoffs of employees in addition to reducing the demand for products as markets became saturated. There were not enough consumers for all of the goods produced, making corporate profits and government revenues dwindle. Attempts to solve the problem by printing extra money only created inflation. In the midst of this crisis, a new system emerged that depended upon flexibility in labor markets, products, and consumption. During this time new sectors of production emerged and niche markets as well as a greater increase of commercial, technological, and organizational improvements. Labor markets were widened with outsourcing and subcontracting strategies along with the hiring of large numbers of part-time, temporary, and seasonal workers. Markets began to cater to fashion niche markets, recreational activities, and lifestyles, making the pace of economic and social life speed up (popular culture, fashion, sports and leisure, video and children's games). Also, in an attempt to increase profits, many multinational corporations are outsourcing their work. Outsourcing is defined as the delegation of non core activities that the organization was once responsible for but has now hired an outside entity to do. The most common outsourcing jobs include call centers, e-mail services, and payroll. The trend grew during the 1980s as a major way for corporations to save money. Much of the outsourced jobs have gone to China, India, Pakistan, and Vietnam. Advances in technology have reduced the cost of trade tremendously. Satellite communications deployed since the 1970s have increased communications and at a lower cost. Air freight rates have been reduced drastically along with the cost of sea and rail transport. The resulting economic growth also has brought about economic, political, and social disruption. Consequently, the World Trade Organization (WTO) was created to mediate disputes with regard to trading and to create a platform of trading along with GATT (General Agreement on Tariffs and Trade), which was formed to reduce barriers to trade after World War II. In recent times, globalization can be seen in the agreements on trade among countries, such as the one created by NAFTA.

North American Free Trade Agreement

The North American Free Trade Agreement (NAFTA) was created on January 1, 1994, as a free trade agreement between Canada, the United States, and Mexico. The plan was to phase out the majority of tariffs between the countries to encourage trade. Several economists have analyzed the effects of NAFTA and have reported that it has been beneficial because poverty rates have lowered and real income has increased. Over the years trade has increased dramatically between the three countries. Between 1993 and 2004, total trade with U.S. partners increased by 129.3% (Canada 110.1% and Mexico 100.9%).

Social Aspects of Globalization

Interestingly, social life is equally and utterly impacted by these alterations of time and space. Throughout the course of human history, people have interacted with one another mostly face to face. Daily human life is filled with interactions during localized activities. Today, however, more often than not, a person's physical presence is not required. Many tasks can be handled remotely, something made possible by transportation and communication systems. In that sense, social life is altered by the absence of locality, and it fosters relations between people who are too far apart for face-to-face contact. Place becomes less important as the physical setting for social activity, and modern localities are created over long distances. Although place and locale are still significant in daily life, social connections become less dependent on face-to-face interactions, making the local and global intertwined as never before. And, as people continue to live their "local" lives they inevitably are connected globally. Distant events impact local happenings and local developments can have global repercussions that stretch beyond national boundaries.

Culture and Globalization

In the anthropological sense, *culture* refers to a group of individuals—a nation, an ethnicity, a tribe—who share a system of beliefs that define their world and who interpret meaning based on their shared set of beliefs. Traditionally, this definition has been tied to a specific territory. We used terms like "American culture" or "Latin culture" loosely; they brought up images of a specific geographic region or particular country. These images often have certain attributes associated with that particular region. Conversely, in the present context of globalization it is unreasonable to equate a specific culture with a particular geographic area because locales are woven intricately into one another. In other words, the boundaries are blurred. For example, Western cultural objects like clothing, food, and music are now present in nearly all parts of the world. Anthropologists have defined the weakening of the ties between culture and place as "deterritorialization," meaning cultural processes that we once thought of as taking place in a specific region have transcended these specific territorial bounds. This is not to say that cultures are free floating, but there is an uprooting and a reinserting of culture going on due to the flexibility and movement in our current world. Anthropologists have defined cultures as sharing a certain space or "community." A community setting can signify anything from a village to a nation-state. Creating a group of people within a bounded area assumes that this community shares a strong bond within this space. In addition, this space is used to reinforce a worldview and a set of rules to live by, thus creating a certain cultural coherence. In the past, we have understood the "anthropological other" by comparing community with community. Migration is one event that has historically challenged social spaces, such as along the U.S.–Mexico border. Since the 1960s, however, transnational capitalism and migration have strongly influenced remote societies and have changed ideas of culture. For example, in remote villages like Aguililla, Mexico, almost all families had a family member abroad; the local economy depended heavily on the influx of dollars, and many farms were being sustained by family remittances. As large-scale industrial agriculture takes over the Mexican landscape, small-scale subsistence farmers are no longer able to sustain themselves using their traditional practices. The cultivation of maize has been present in Mexico as a primary means of subsistence for 6,000 years. The fact is that people in rural villages can no longer rely solely on local resources to meet their needs. In a globalized world where the local intersects with the global, markets have forced small communities to change and people to migrate. Patterns of transnational migration are prevalent between Mexico and the United States. Most Mexican migrant workers come to work menial jobs in the service sector as dishwashers, janitors, hotel workers, and gardeners. The majority stay in the United States briefly, and those who stay longer remain deeply connected to their families. Their main goal is to finance local dreams by having access to outside funds. Further, the

U.S. economy has become dependent on these workers who occupy society's economic "bottom rung," creating social spaces and communities that transcend geopolitical borders, and finding that their most important kin and friends live hundreds of miles away from them.

Adverse Effects of Globalization

Although trade has increased and indexes for poverty seem to have been lowered according to economists' standards, there are dilemmas with this particular style of free trade. Some would argue that free trade agreements such as NAFTA have damaged and further marginalized large segments of the world's population. It has been demonstrated that although globalization does help to grow economies, it does not do so evenly. The meager share of global income gained by the poorest people in the world has dropped from 2.3% to 1.4% over the past 10 years. While it is true that transportation and communication have made it easier and quicker for people to get around, it is not true for all people in all places. Some people have the social and economic resources to take advantage of these advancements; others do not. Some people have little or no access to electricity, telephone, and Internet service or the opportunity to buy an airplane ticket. Chances are these people will never have this opportunity in their lifetime. Not everybody on the planet is feeling the benefits. There are several places in Latin America and Africa that are literally not even on the map of telecommunications, world trade, and finance. Even so, they can feel the pressure of the market. Such places have few or no circuits connecting them to the outside world other than the communication and transportation that passes over or through them. In this rapid-paced and changing world they are the ones who are forgotten.

Maquiladoras

Maquiladoras are foreign-owned assembly plants in Mexico, primarily located along the border between the United States and Mexico. Maquiladoras first appeared in Mexico in the 1960s; by 1990 there were 2,000 operating with 500,000 workers. These factories produce mainly electronics, clothing, plastics, furniture, appliances, and auto parts. Between 80% and 90% of the goods produced in Mexico are shipped to consumers in the United States. Most people who move from rural settings in search of better opportunities and work in maquiladoras find deplorable living conditions. And, while some company owners have worked to improve the working conditions of their employees, numerous factories misuse their workers. In some instances, reports tell of maquiladora owners subjecting employees to more than 75-hour workweeks without proper breaks. Some 80% of the employees are women because they are fast at repetitive tasks and they get paid a lower wage than men. Minimum wage is $3.40 per day (vs. $6.55 per hour in the U.S.). There have been numerous sexual harassment incidents or the firing of women if they become pregnant. Also, Mexican men resent that women are being hired over men for jobs, leaving women subject to retaliation and violence. In the city of Juarez, alone, more than 200 women who worked for the factories have been murdered. Further, Juarez and other cities lack infrastructure like electricity, sewage, and safe drinking water to sustain the influx of migrants to the cities with factories. For example, since NAFTA the employment rate in Juarez has risen 54%, yet Juarez has no waste treatment facility to treat sewage from the 1.3 million people who live there. Other related problems are that factories set up in these border towns are not held to strict guidelines for environmental protection, which leads to contamination of the air and water supplies. And workers are exposed to dangerous chemicals without any protective wear.

Anti-Globalization or Global Justice Movements

There are many worldwide who do not support the current political and economic system of neoliberal globalization. People involved in global justice movements advocate anarchism, socialism, or social democracy and are against the ruling elites who wish to expand and control world markets for their own gain. These movements call for reforms in the current capitalist model where multinational corporations control 70% of trade in the world market, and for moving toward greater social welfare reforms. Global justice seekers place greater emphasis on equal rights, environmental awareness, and cultural diversity. Alternative ways of growing economies are also present in the movement, where small-scale producers band together to create alternative economies for the goods and services produced. One example is Kallari, an organization of Indigenous Kichwa artisans and farmers in Ecuador who produce coffee, chocolate, handcrafts, and jewelry and sell locally and globally. The Kichwa face strong pressure from the world market through encroachments and a shrinking land base due to outside multinational corporations that drill for oil and mine for gold. Since the Kichwa lacked infrastructure and the support of local and national governments, they needed to organize their own economy. With the assistance of the Jatun Sacha Foundation and its director, Judy Logback, they have been able to enter the world market and to be paid a fair and living wage. In addition, the have opened their own café where they sell their products in Ecuador. Further, they ship goods internationally to niche markets that support environmentally conscious and fairly traded goods. The project has been active for nearly 10 years and has met with great success, with nearly 25 Kichwa communities participating.

Conclusion

For some, globalization is about free trade between countries and the growing of economies that include new job opportunities, while for others it is another way for the rich to prosper at the expense of the poor with little regard for social welfare, human rights, or the environment. Further, globalization has altered space and time for social intercourse and the meaning of community. It remains to be seen how we will redefine our world and our social relationships along with our political economy based upon our values and where we are "located" on the globe.

Luci Latina Fernandes

See also Economics; Evolution, Cultural; Evolution, Social; Materialism; Postmodernism

Further Readings

Fernandes, L. L. (2004). The Kallari Handcraft Cooperative of Ecuador. *Grassroots Economic Organizing: The Newsletter of Democratic Workplaces and Globalization From Below*.

Giddens, A. (1990). *The consequences of modernity.* Stanford, CA: Stanford University Press.

Giddens, A. (1991). *Modernity and self identity.* Cambridge, UK: Polity Press.

Harvey, D. (1989). *The condition of postmodernity.* Oxford, UK: Blackwell.

Inda, J. X., & Rosaldo, R. (Eds.). (2002). *Anthropology of globalization.* Malden, MA: Blackwell.

Rouse, R. (2002). The social space of postmodernism. In *The anthropology of globalization*. Malden, MA: Blackwell.

Global Warming

Even though the global temperature has been changing for millions of years, this is the first century in which we are seeing global changes occur quickly relative to the time that human and animal life activity has been documented. Human-induced changes to global temperature are now evident, whereas the changes in the past were seen as natural phenomena. For example, in the preindustrial era the concentration of CO_2 measured 280 parts per million; by 2005, that had increased to 382 parts per million.

Despite mounting empirical evidence of global temperature change over the past few centuries, it is only relatively recently that scientists have taken note of global temperature changes and publicized them. The 1970s was the first decade in which the general public began to take note of environmental issues. In the United States this occurred through the efforts of environmentalists and scientists who pressured government to institute sweeping changes to U.S. environmental policy. Subsequently, more than 15 national acts of environmental legislation have focused on a range of issues from clean water to endangered species. These new forms of environmental legislation did not, however, take into account increases in fossil fuel emissions that occur with increased global dependence on manufacturing, energy generation, and automobile use. The U.S.

Environmental Protection Agency, created in 1970, did not provide the U.S. auto industry with fuel emission or miles-per-gallon standards, which eventually resulted in millions of tons of carbon entering the atmosphere every year. By not recognizing this serious emission problem, policymakers did not acknowledge changes in potential carbon loads to the atmosphere. Scientists now estimate that global warming will continue, despite our actions to slow the changes. There is concern that we will quickly near what is said to be the ultimate carbon threshold of 480 parts per million in our planet's atmosphere.

The science behind global climate change is complicated. It takes time to establish patterns and understanding of the problem. The U.S. Congress heard first testimony on global warming in 1973; following that, an international campaign was launched to explain the future dangers if such a problem were to be ignored. Scientists predicted global catastrophes such as the melting of the polar ice caps, coastal flooding, and widespread migration of affected populations. We have finally begun to acknowledge the connection between fossil fuel emissions and increased global temperature. However, there remains ongoing debate over whether the problem exists as fact or is a theory.

Increased media coverage of global warming has been due in part to former Vice President Al Gore's 3-decade-long research and investigation into climate change, which culminated in the Academy Award-winning documentary, *An Inconvenient Truth,* a national theatrical film release; a book of the same title; and an international lecture series. Public awareness of this issue has increased, and individual and community efforts to help reduce the impact of global climate change are more widespread. It is not yet clear to what extent social behavior is following public sentiment that now supports societal action to curb the impacts of global climate change. Longitudinal, empirical research will be needed to determine these outcomes.

It has been projected that even if we decrease our carbon output now, it would have very little impact on current and future climate change trends. Notwithstanding, action is still encouraged in order not to escalate the problem. It has taken decades of data collection to determine if a global climate change pattern even exists. Even given this evidence, some still question the validity of the global climate change claims and data. Those who doubt the conclusions argue that longitudinal evidence has not shown that global warming is occurring, let alone creating serious environmental harm. This position, opponents claim, is being fueled by those who are closely allied with the fossil fuel industry and other manufacturers who stand to lose money if their primary source of business is replaced with less environmentally damaging alternatives. Proponents of alternative fuels have been encouraging these companies to invest in alternative, environmentally friendly technology, but with limited success to date.

Much of this debate is centered on time. On the one hand, advocates who support the need to recognize global warming argue that time is of the essence. They advocate for change now, given the likelihood that a planetary overload of carbon will reach dangerous levels in the next 20 years. In 2007, U.S. automobile fuel efficiency standards were 22 miles per gallon (mpg), and the U.S. government requires only a slight increase to 23.5 mpg by 2010. In November 2007, the U.S. Court of Appeals demanded that the Bush administration change the standards and answer some basic questions about why not all vehicles have to meet the current standard; for example, minivans and sport utility vehicles are allowed to be less fuel efficient than cars. The gathering of world leaders for the Kyoto Protocol of 1997 and in Bali, Indonesia, in 2007 indicated an urgent need to establish limits on carbon output to at least slow the effects of global climate change.

On the other hand, opponents argue that more time is needed to establish data trends that support the reality and consequences of global warming. U.S. energy policy does not support the global guidelines set forth in Kyoto, nor are current U.S. policymakers, along with China, willing to support any kind of mandatory carbon and fossil fuel emission reductions. However, there are movements toward tax incentives for voluntary reduction actions.

The full consequences of global warming will emerge only with time. Recognition of the importance of research in this area is reflected in the awarding of the 2007 Nobel Peace Prize to Al Gore and the scientists working with the United Nations International Panel on Climate Change. If momentum toward curbing global warming continues, perhaps the potential disastrous effects on human populations and the environment will be avoided. Yet, even with acknowledgment of the problem, significant changes to the national energy infrastructure have been slow in coming.

Scientists often rely on time through longitudinal studies to develop data trends over which people come to conclusions and take action. In response to the question of how quickly we need to begin to change our lifestyles and behaviors to make a difference in carbon output, some leading scientists claim that we have only 10 remaining years to reverse the effects of global climate change. Many others are calling for an 80% reduction in carbon emissions by 2050. The success of such reforms requires not only the time but also the will to implement far-reaching policy changes such as fuel economy standards, manufacturing caps on carbon, and clean energy options.

Erin E. Robinson-Caskie

See also Ecology; Extinction and Evolution; Glaciers; Ice Ages; Nuclear Winter; Values and Time

Further Readings

Godrej, D. (2001). *The no-nonsense guide to climate change.* Oxford, UK: Verso.

Gore, A. (2006). *An inconvenient truth: The planetary emergency of global warming and what we can do about it.* New York: Rodale Press.

McKibben, B. (2007). *Fight global warming now.* New York: Holt Paperbacks.

Michaels, P. (2005). *Shattered consensus: The true state of global warming.* Lanham, MD: Rowman & Littlefield.

God, Sensorium of

Sensorium of God is a phrase Isaac Newton (1643–1727) used in his discussion to describe his notion of space and time. Newton saw space and time intricately associated with God, thus he used science and religion to explain how the universe functioned.

Newton saw space and time as being absolute and independent of any physical object. He believed space extended without limit in any direction and was immovable. He saw time as infinite both in the past and the future. He also noted that making measurements in absolute space would require using an object within absolute space, thus an absolutely stationary object. This is not possible given the law of gravity, according to which every object, including stellar objects, is influenced by universal gravitational forces. Therefore, no stationary object exists so no such measurement can be made. Instead, objects must be measured relative to another object, both of which are moving.

The sensorium of God was Newton's way of answering an old question in stellar physics: How do particles move? The assumptions of this theory are (1) all objects have substance and therefore have a place in space and (2) these objects are subject to time. Physicists of Newton's time could not imagine another possibility. Newton believed stellar and planetary movement could be determined and predicted using mathematics and mechanics based on Euclidean geometry and his theory of gravity. Building on the work of Galileo, Copernicus, and others, he developed a method of plotting an object in motion. His method uses a coordinate system to plot an object on the three spatial axes and one temporal axis. Thus, one can know the exact location of an object at a particular instant in time. He believed space was geometrically ordered and that objects moved in a straight line unless otherwise influenced by gravity or centripetal force. Thus, Newton's sensorium of God is connected to his famous three laws of motion and his law of universal gravity.

Newton was raised in the Protestant tradition, died a Roman Catholic, but held to a Unitarian belief system that was neither traditional nor orthodox. In his quest to unite knowledge and religious belief, Newton, being somewhat of a theologian as well as a scientist, connected this concept of absolute space with God. He saw God as not restricted to the physical universe; that is, God is both omnipresent (not limited to space) and eternal (beyond the bounds of time). Space and time serve as his sensorium, where God intimately and thoroughly perceives and understands objects and events. God is always present everywhere and is a part of every event. For Newton, God constitutes time and space, being equally present in all space and time.

Newton's work on space and time was revolutionary, with his book *Philosophiae Naturalis Principia Mathematica* considered the most important work ever written in the field of science. Although his attempt to unite belief and science has been largely downplayed, his theories continue to be foundational to the physical sciences.

Terry W. Eddinger

See also Design, Intelligent; Einstein and Newton; God and Time; Newton, Isaac; Newton and Leibniz; Space, Absolute; Time, Absolute

Further Readings

Barbour, J. B. (1989). *Absolute or relative motion: The deep structure of general relativity: Vol. 1. The discovery of dynamics.* Cambridge, UK: Cambridge University Press.

Hodgson, P. E. (2005). *Theology and modern physics* (Ashgate Science and Religion Series). Burlington, VT: Ashgate.

Newton, I. (1999). *The principia* (I. B. Cohen & A. Whitman, Trans.). Berkeley: University of California Press. (Original work published 1687)

God and Time

At the core of most religions is the concept that God, or the Transcendent, may be personal or impersonal. God is the creating power without being created. God is timeless and eternal. With the act of Creation, time came to exist. God is not only the first cause outside of time, but also the basis of time. Especially in Christianity, God is regarded as the starting point of being and time, as well as the end of both. Statements from the ancient world on these ideas can be found in Plato's dialogues (e.g., *The State* or *Timaeus*) and in Aristotle's *Physics* and *Metaphysics.* Classical positions are given in the teaching of Saint Augustine, chiefly based on the Platonic and Neoplatonic traditions, and of Saint Thomas Aquinas, based on Aristotelian philosophy. Rationalistic perspectives are represented by such thinkers as Giordano Bruno, Baruch de Spinoza, and Gottfried Wilhelm von Leibniz. They considered monistic thoughts, as well as pantheistic views, or the question of evil in the world. More recently, Pierre Teilhard de Chardin and Alfred North Whitehead present again considerations on God and time.

Plato and Aristotle

With his idea (form) of the Good, Plato (428–348 BCE) did not directly mention God. But the universal good, as characterized in *The State,* has qualities similar to those of God in the Christian tradition: eternal, indivisible, beyond space and time. In the Platonic dialogue *Timaeus,* God is spoken of as the *dêmiourgós* (demiurge), who built the world out of basic material. But this God is neither the Christian God, nor a creator out of nothing. He has only the function of giving order and reason to the qualities of the cosmos.

Aristotle (384–322 BCE), student-scholar of Plato, speaks in the *Physics* and in the *Metaphysics* of the (first) Unmoved Mover. This first principle, which gives motion to everything in the cosmos, does not itself move. The first principle is loved by everything, so all things in the cosmos move toward it as an aim (*télos*) in circles. By this nonmoving quality, the Unmoved Mover is beyond time, because moving can be measured only within time. The first principle is always the same; it is the "thinking of thinking" (*nóêsis noêseôs*), unchangeable like God. Though it is not the Christian God, the first principle is called "God" (*theós*) by Aristotle.

Augustine and Aquinas

Saint Augustine's (354–430) thoughts on time are embedded in his interpretation of Genesis as he presented them in book X, and especially in book XI, of his *Confessions.* According to Augustine, time (*tempus*) is linked with the Divine Creation (*creatio*). "Time" has no meaning before the Creation. Time did not exist before God created the universe. However, one could say that time was within God before the Creation. So it makes sense to speak of "time" only when there are processes of becoming and vanishing. Time gives natural processes both a basis and a framework in which they can progress.

Augustine is very honest when he says that he knows quite well what time is, as long as he is not asked to describe it. But when he is asked what time is, he does not know how to answer this question: "What is 'time' then? If nobody asks me, I know it; but if I were desirous to explain it to one that should ask me, plainly I know not" (*Quid est ergo tempus? Si nemo ex me quaerat, scio; si quaerenti explicare velim, nescio*). Therefore, one can say that time is very difficult to explain, but at first easy to understand. This sounds a bit paradoxical, but Augustine wants to reach a deeper philosophical understanding of time. So, he goes on with his own investigation.

Time is located in the mind (*animus*): past, present, and future (the three kinds of time) are all represented in mind as dimensions of mind. This also sounds a bit paradoxical, because past, present, and future are basically at the same time in the mind. Though a human only lives in the present, both the past and the future can be represented within the human mind. The past is represented in memory. In a further step, Augustine says that time is measured by the soul: "'Tis in thee, O my mind, that I measure my times" (*In te, anime meus, tempora mea metior*). Therefore, time is an extension of the human mind. Time is a representation in the mind and not an objective physical motion. We can see that Augustine's concept of time is very subjective, because time can be represented and measured only in the subject's mind. In this case, his position is different from the more objective point of view of the Platonic and Neoplatonic traditions.

Augustine points out that Christian eschatology, the doctrine of last things, teaches us that a human cannot fulfill time on his or her own. God will fulfill time when God returns in Christ at the end of our time. So, the perfection of everything can be done only by God, and it is nothing that happens in time; it is, in fact, the perfection of time out of time. Therefore, Augustine wrote that, in time and in the world, we can only use things, and God is the only one who can be enjoyed. In the last books of *The City of God,* especially in book XXII, Augustine shows us that Christian eschatology differs from political eschatology; the latter tries to create an earthly paradise with only political considerations, often linked with political ideologies and violence.

The love of God for a human and the love of a human for God keeps a human, during time, in relationship with God. If one is within the love of God, one can do whatever one wants to do, as it cannot be against the Almighty: "Love, and do what thou wilt."

God, the Sacred Trinity, is independent of time. God is over, behind, or next to time, because God is the eternal, pure being (*esse*) and has never been created. God is and always was, is and always will be; God is timeless without any changes. The universe, created by God, is within time. But the created universe is contingent, it is not a necessary being like God. God, existing out of time, is the only necessary being as a basic ground of contingent being in the universe and in our world.

With his early considerations on time in the 4th and 5th centuries, Augustine is the starting point of Christian theories of time. He influenced later thinkers deeply, especially thinkers during the scholastic period, such as Saint Thomas Aquinas (1224/1225–1274). But Augustine also influenced thoughts about "time" beyond Christianity: modern thinkers like Edmund Husserl (1859–1938), with his phenomenology of time; Henri Bergson (1859–1941), in whose thinking the durative aspect of time (*durée,* duration) is central; and Martin Heidegger (1889–1976), with his main work *Being and Time* (1927), refer directly or indirectly to Augustine's thoughts about time.

Time (*tempus*) for Saint Thomas Aquinas, as for Saint Augustine, is a phenomenon that has to do with the Divine Creation (*creatio*). God creates, as he is the first cause (*prima causa*). All the beings in the created world are creatures in time. Outside the world and the cosmos, time has no meaning and no use. Time appears together with Creation. All natural developments happen in time. Without time, humans could not recognize developments. Also, human processes, even social and moral processes, need time as a framework. As Saint Thomas pointed out in his early commentary to the sentences of Saint Peter Lombardus, time is also necessary for those processes in the mind, because it serves as a measurement for what we have in the mind.

In his main work, *Summa Theologiae,* Saint Thomas investigated time as an important phenomenon. Here, Aquinas differentiates time (*tempus*), which was for him well known as one of the 10 Aristotelian categories, from real eternity (*aeternitas*) and from eternal time (*aevum*). Aevum, "eternal time," is a kind of "infinite time" for Saint Thomas, as an infinite sum of time, which is not a real eternity. It stands in the middle between time and eternity: "And by this way can be measured eternal time, which is the middle between eternity and time" (*Et ideo huiusmodi mensurantur aevo, quod est medium inter aeternitatem et tempus*). Time can be a continuum, or be separated into parts of time. Time can be imagined or real. This distinction is different from Augustine's view, which taught that all three kinds of time (past, present, and future) are only representations in the mind and therefore dimensions of it. But similar to Augustine, Aquinas says that there are three kinds of time: the first time is the beginning, the second time is the following time, and the last time is the end of time ("time has a beginning and an end" (*tempus autem habet principium et finem*), and "between two instants, there is a middle time" (*inter quaelibet duo instantia sit tempus medium*). But again, in contrast to Augustine, Aquinas admits that, according to Aristotle, time is a kind of motion. Time can be measured as the number of changes (e.g., dark to bright, night to day) or of motions ("movement, whose measurement is time" (*motus, cuius mensura est tempus*) and "because time is the number of motions" (*quia tempus est numerus motus*). Time serves also to represent a metaphysical, not only a physical, development or motion: as angels come to their nature at once, humans come to theirs eventually, because they have to discover the nature of a human as a creature of God.

Also for moral actions, time is an important indicator. Humankind needs sufficient time in order to act morally (*Tempus autem est una de circumstantiis quae requiruntur ad actus virtutum*). Therefore, nobody can be forced to immoral action by reducing his or her time to act or to react properly.

Within time, there are temporal things that are contingent, not necessary. These temporal things, which are all material things, come into existence and vanish after a certain amount of time. They cannot exist eternally in time. However, in his mainly philosophical work *De aeternitate mundi* (c. 1271), Saint Thomas shows that the universe itself is eternal, because the substance, the "basic material" (*materia prima*), is not made and is eternal. This does not mean that our world in its present concrete existence is eternal, but the world and the universe are eternal in their "basic material" (*materia prima*). With this argument, Saint Thomas wanted to increase the philosophical value of the pagan philosopher Aristotle to Christian theology. According to Aquinas, species are not eternal; they will, like other temporal beings or material things, appear and vanish in time. Without *materia prima,* the universe would have been a serious vacuum, which is, according to Saint Thomas, impossible.

Furthermore, humans cannot end time. According to Christian eschatology, it is only God who is able to fulfill time, when Christ returns and separates the good from the evil. So, God is the creator and the dominator of time. "To Him belongs time and the ages" (*Eius sunt tempora et aeternitas*), as it is written in the Office of the Easter Vigil of the Roman Catholic Church. God is outside of time and he is the timeless, eternal being (*esse*). God is the creator of everything and has never been created. He is and always was, is and will always be, without any changes. God, the Sacred Trinity, is the origin of time and the basic ground of being. Similar to Augustine, it is not sensible for Aquinas to speak of time before Creation.

Saint Thomas Aquinas deeply influenced Christian doctrine. His considerations on the property of time and other related subjects were philosophically and theologically investigated in many books and treatises. With his thoughts, Saint Thomas stands in the tradition of the *philosophia perennis,* the Everlasting or Permanent Philosophy, which has its starting point in the philosophy of Plato and Aristotle.

In the early 20th century, *neo-Thomism* emerged: neo-Thomistic philosophers and theologians kept up Aquinas's thoughts in a very comprehensive way: the French thinker Jacques Maritain (1882–1973), the Jesuit Erich Przywara (1889–1972), and the German philosophers Max Müller (1906–1994) and Josef Pieper (1904–1997), among others, represent Thomistic thought in our present time.

Bruno, Spinoza, and Leibniz

All three thinkers—Bruno, Spinoza, and Leibniz—have a rationalistic approach to the question of God. Giordano Bruno (1548–1600) was a monk and philosopher who presented a daring cosmology. Some of his thoughts were adopted by two other philosophers, Spinoza and Leibniz. Bruno and Spinoza are, in general, pantheists and monists. Leibniz is a monotheistic thinker but not a monist; however, he has a rationalistic method in common with Bruno and Spinoza.

Bruno presumed that the world and God are, in the end, both together, because reality has its origin in the eternal imagination. For Bruno, the universe is infinite and there are an infinite number of beings in the cosmos. The universe is infinite because God as the creator of the cosmos is almighty and infinite. A finite cosmos would be too sharp a contrast to honor an almighty and infinite God. So, both God and the universe are infinite, but within time. In Bruno's opinion, there exist an infinite number of eternal worlds. Also, according to Bruno, it is possible to measure time accurately in our world. Before Bruno, most of the thinkers followed Aristotle, who was convinced that only in the sphere of the fixed stars could there be a correct measurement of time. Time can be measured by motion; Bruno developed a pendulum system that could measure time accurately by the motion of the pendulum. Furthermore, he was against the Ptolemaic geocentric model of the universe. Because of his heretical opinions, Giordano Bruno was condemned to death by the Roman Catholic Church in 1600.

Influenced by Bruno and Descartes (1596–1650), the philosopher Baruch (or Benedict) de Spinoza (1632–1677) was convinced that the substance of nature and of God is the same, as is pointed out in the sentence *deus sive natura* ("God or Nature"). He is therefore an exponent of monism and pantheism. God is natural and living, and cannot be separated from matter. He is within every being. Some presumed that Spinoza was an atheist, because all materialistic things are finite in contrast to God, who is immaterial and eternal. However, the Spinozistic concept of nature is not only materialistic, but also something much more complex. For Spinoza, nature has a divine quality even though it also has material qualities. God is the necessary, eternal, and infinite substance of nature or the universe. It follows that there is only *one* substance in the universe (monism), because God and nature are of the same substance. For this reason, God exists necessarily and, furthermore, he was forced to create the universe because of this monistic union of God and nature. The main structures of the universe are causality and necessity. Beyond space and time, there is only the real existence of beings in the universe. The world exists as an infinite sequence of natural processes throughout time. God exists as the eternal substance, but within endless time.

Gottfried Wilhelm von Leibniz (1646–1716) was a scientist, mathematician, and philosopher. He argued that there is a preestablished harmony in the world that is based on the infinite number of monads that are the nonmaterial elements of reality. The first monad is God, who has created the world as the best of all possible worlds. The evil in the world is thus reduced to a minimum, because God has compared our universe to every other possible universe, and he has decided this world to be the best possible world. The metaphysical, physical, and moral evils that exist have their origin in the imperfect and finite cosmos. God is the eternal reason and necessary being of the finite world. Space and time are not absolute, but relative as parts of the world. God and the universe are not of the same substance. In contrast to Bruno and Spinoza, Leibniz was neither a monist nor a pantheist. Leibniz earned his great reputation posthumously, perhaps most notably in Bertrand Russell's (1872–1970) writings.

Teilhard de Chardin and Whitehead

The French Jesuit priest, paleontologist, and philosopher Pierre Teilhard de Chardin (1881–1951) attempted to reconcile Christianity, especially the Roman Catholic position, with the results of his scientific research into evolution. God is the alpha and the omega point of the evolving universe, so God is outside of time and its dynamic framework. For Teilhard, the omega point is the last stage of the evolving noosphere, at the end of human time. From this point of view, God is not only a spectator of the evolution of the universe, but also its aim and goal. Teilhard, who was present at the discovery of

Peking man in 1923–1927, gave these arguments in his controversial major work, *The Phenomenon of Man*, which was denied publication by the Roman Holy Office during Teilhard's lifetime. Later, Pope John XXIII rehabilitated him, and his work became an influential contribution to the church's position on evolution.

With his dynamic philosophy presented in his book *Process and Reality: An Essay in Cosmology* (1929), the mathematician and later philosopher Alfred North Whitehead (1861–1947) defended theism and represented the starting point for process theology; for Whitehead, the whole universe is in fluent change. Therefore, God as the creator of the universe is also in a fluent process and is not able to predict each process in the universe precisely. God is also understood within the framework of time, and God makes possible the change, growth, and flux of reality. Whitehead's argument defends theism, but God is not almighty. Therefore, Whitehead's position is different from the Judaic and Christian positions. Nevertheless, theologians such as Charles Hartshorne, John B. Cobb, Jr., and David Ray Griffin followed Whitehead and contributed to process theology.

The positions of Teilhard and Whitehead make it clear that, in the 20th century, the distance between God as the timeless being and the universe as a creation within time became less and less, because the Creator and the cosmos are constantly interrelated in an ongoing process of eternal creativity.

Hans Otto Seitschek

See also Aristotle; Aquinas, Saint Thomas; Augustine of Hippo, Saint; Bruno, Giordano; Christianity; Eschatology; Husserl, Edmund; Leibniz, Gottfried Wilhelm von; Newton, Isaac; Plato; Spinoza, Baruch de; Teilhard de Chardin, Pierre; Time, Sacred; Whitehead, Alfred North

Further Readings

Barnes, J. (Ed.). (1995). *The Cambridge companion to Aristotle*. Cambridge, UK: Cambridge University Press.

DeWeese, G. J. (2004). *God and the nature of time*. Aldershot, UK: Ashgate.

Ganssle, G. E., & Woodruff, D. L. (Eds.). (2001). *God and time: Essays on the divine nature*. Oxford, UK: Oxford University Press.

Garrett, D. (Ed.). (1995). *The Cambridge companion to Spinoza*. Cambridge, UK: Cambridge University Press.

Gatti, H. (Ed.). (2003). *Giordano Bruno: Philosopher of the Renaissance*. Aldershot, UK: Ashgate.

Jolley, N. (Ed.). (1994). *The Cambridge companion to Leibniz*. Cambridge, UK: Cambridge University Press.

Kenny, A. J. P. (2002). *Aquinas on being*. Oxford, UK: Oxford University Press.

Kraut, R. (Ed.). (1992). *The Cambridge companion to Plato*. Cambridge, UK: Cambridge University Press.

Mercier, A. (1996). *God, world and time*. New York: Verlag Peter Lang.

Padgett, A. G. (1992). *God, eternity and the nature of time*. New York: St. Martin's.

Poe, H. L., & Mattson, J. S. (Eds.). (2005). *What God knows: Time, eternity, and divine knowledge*. Waco, TX: Baylor University Press.

Stump, E., & Kretzmann, N. (Eds.). (2001). *The Cambridge companion to Augustine*. Cambridge, UK: Cambridge University Press.

Teilhard de Chardin, P. (1959). *The phenomenon of man* (B. Wall, Trans.). New York: Harper & Row.

Whitehead, A. N. (1979). *Process and reality: An essay in cosmology*. New York: The Free Press.

Wissink, J. B. M. (Ed.). (1990). *The eternity of the world in the thought of Thomas Aquinas and his contemporaries*. Leiden, The Netherlands: Brill Academic.

God as Creator

The idea of God as the Creator is perhaps the most radical theory of time ever conceived, one that imposes a definite beginning to time, along with an explanation of why this should have happened. Before God there was no time, according to this theory, because God created time when he created all things. Theories of God as Creator often, though not invariably, are accompanied by a complementary theory of God overseeing the end of time as well.

Theories of God as Creator are not the common property of humanity, but are the product of specific trends of thought involving monotheism, or the idea of a single god. In cultures that do not subscribe to monotheist notions of God, there is much less evidence of theories of God as Creator or, if such theories can be found, they are much less significant than in monotheist cultures. Creation accounts are also a relatively late development in the evolution of religious thought.

Asian Traditions

When looking at India, for example, amid all the conflicting interpretations one could read into the Vedas, there is little to support the idea of God as a creator from nothing. Among the many speculations is the admission that maybe even the gods do not know, because they emerged after the universe derived its form. The closest parallel to the word *creation* is the Sanskrit word *Srishti,* or "projection." So when it is said that God created things out of nothing, it is meant that the universe is a projection of God, with the extra understanding that the universe creates itself and falls back into itself, in endless cycles, for all time. Other understandings have this projection as a never-ending process of God realizing himself in the universe.

It is also true that no god in the Hindu pantheon was credited with Creation. Brahma is given such an age that even talk of creating the universe seems a paltry exercise. Hinduism divides time into cycles, called *kalpas.* One kalpa consists of 1,000 cycles of 4,320,000 years, which are made up of 12,000 divine years, each of which lasts 360 solar years. And for Brahma one kalpa equals one day.

Another trend in Indian philosophy known as the Kalavada derives its name from *kala,* which originally meant "right moment" but came to mean "time" itself. *Kala* was used in that sense in the Sanskrit writings, where it took on the mantle of being a fundamental principle of the universe and that existed before all other things. It may be that Kali, one of the avatars of Shiva, is also derived from kala. Kali ("the Black One") is, like time, merciless.

In China there is the tale of Pangu (P'an-Ku in the old spelling) who is the child of *yin* and *yang* and who fashioned the cosmos out of the primeval chaos. But he is not a deity to be worshiped, and neither is he credited with actually creating the universe. Then there is the celestial spirit Tai Sui, who presides over the structure of the year. He is, in fact, president of the Celestial Ministry of Time, a prestigious and highly feared office. Tai Sui was venerated as the deity able to influence human destiny. Astrologers were kept busy analyzing dates for auspicious signs that a new project would meet with Tai Sui's approval. The Yuan dynasty (1280–1368) began the practice of sacrificing to Tai Sui before any momentous project was undertaken.

Western Traditions

Among the Greeks, as well as in the great Eastern civilizations, the universe had always existed and creation stories, where they existed at all, told more of fashioning order out of primeval chaos than of creation ordered from nothing. In the *Timaeus,* Plato portrays God as that which imposes order on a preexistent matter. Finding the universe in a state of "inharmonious and disorderly motion," God "reduced it to order from disorder, as he judged that order was in every way better." The same account is given in Book One of Ovid's *Metamorphoses,* and it has been argued that a similar approach can be found in the Hebrew Bible, in, for instance, Psalm 74:12–17 or 89:9–13.

Aristotle was more specific in denying any primal creation role to the gods. Rather, God was the "prime mover" who "moves" the world. As time is eternal, so change is also eternal, which, in turn requires an eternal overseer of that change. This is the prime mover. It is important not to confuse the prime mover with any notion of a personal God as understood in the Christian tradition. The prime mover is nonmaterial and as such occupies no space. It is not distinct from nature, but is the animating principle within nature. Aristotle's God, being eternal, is the sum total of thoughts and animating principles that transcend temporality.

Even more naturalistic was the account of the universe in Lucretius's masterpiece *De rerum natura* (*On the Nature of the Universe*), which was completed in about 60 BCE. Nothing, Lucretius insisted, not even divine power, can create something out of nothing. It was not the principle of divinity that was being challenged but that of supernaturalism. Elsewhere, Lucretius spoke of a limitless universe with no center and composed of indestructible matter.

Nowhere is the difference between monotheist and other cosmologies more apparent than in the idea that the cosmos is the product of a God that operates in history. It is the monotheistic traditions of Judaism, Christianity, and Islam that have the most elaborate accounts of God as Creator. While various interpretations of biblical creation narratives exist, the most influential has been that of *Creatio ex nihilo,* or "creation out of nothing." The Hebrew Bible begins with the assertion: "In the beginning God created the heaven and the earth." There are, however, two accounts of creation in the first books of Genesis. The earlier account can be found in Genesis 2:4–25 and is attributed to an unnamed source called the Yahwist, or simply J, who wrote in the interests of Judah, probably in the eighth or seventh centuries BCE. The J account differs significantly from the later account, in Genesis 1:1–2:4, which is attributed to P, or the Priest, and probably does not predate the Babylonian Captivity of the 6th century BCE.

The J account gives lip service to the creation of the earth and the heavens and gives greater emphasis to the use made of existing materials, such as bringing rain to fructify the earth and creating man out of the dust of the earth. J begins with dry earth from which water later emerges. The later account reverses this and begins with water as the default condition, out of which land emerges. Among other items, this is evidence of P's closer debt to Mesopotamian mythology, which derived from living in a river lowland, unlike the arid land of Palestine, where J wrote. It is also significant that the earlier J Creation account seems contradictory with man being created first, out of the dust (*adam* from *adamah*) whereas the earlier P account has man being created last, as the pinnacle of creation.

These differences in detail and order are symptomatic of a larger difference in underlying attitude. J's account is more organic and closer to the mythological accounts then prevalent. P's account, for instance, makes sure to credit God with the creation of light, departing from many mythological accounts where light is, along with its sister condition darkness, a primordial element of chaos. P's later account is more abstract and rarefied, and serves to strengthen the case of ecclesiastical authority, whose charge it is to interpret these great themes to the unlettered and stand in as their mediators before God.

None of these distinctions played a major role in Christian creation theology before the 19th century. *Creatio ex nihilo* was decreed orthodox theology at the Council of Nicaea in 325 CE and Saint Augustine developed P's account, accentuating the utter majesty and sufficiency of God in overseeing this creation. Augustine also attacked Greek ideas of time having no beginning and there having been no creation. Those who claimed the world was without beginning and consequently not created by God, he wrote, "are strangely deceived, and rave in the incurable madness of impiety." This remained the standard interpretation for more than one and a half thousand years.

The Qur'an is, if anything, even more insistent on the *Creatio ex nihilo* thesis than the Bible. There is little description or explication beyond a bald assertion of Allah's total, entirely sufficient, and generous-hearted creation. Allah is praised as he who "created the heavens and the earth, and made darkness and light." Moreover, he created it with truth, to serve as a sign for the believers and was not fatigued in any way by this creation. These claims are often made in the context of rebuking those who would doubt or warning those who would disbelieve. The Qur'an is no less anthropocentric than the Bible, with several passages allowing for humanity as the highest point of creation by virtue of most resembling Allah the Merciful. As the actual and inviolate words from Allah, this Qur'anic account is, formally at least, the only acceptable Muslim account of the creation of the world.

Despite all the differences among the Greeks, they agreed that *Creatio ex nihilo* made no sense and that creation meant ordering what was already there, rather than starting from scratch. But the triumph of the *Creatio ex nihilo* doctrine changed all that. It also has several important theological ramifications. First, it serves to heighten the focus on God's awesome power to perform such a feat, and our debt to him. Second, it reinforces the distance between the Creator and his creatures, and that God/Allah did not need to create the universe so as to fulfill Himself, or somehow to bring things to a final resolution, because God/Allah was himself already finally resolved.

Third, it extends his power to being above and beyond time.

Perhaps the most specific rendering of God as Creator is the notorious date given by Archbishop James Ussher in 1617. Working from the genealogies of the Hebrew Bible, Ussher dated the creation of the world to October 23, 4004 BCE, with Adam being created 5 days later. This contradicted the Jewish scholars, who decided that October 7, 3761 BCE, was the more likely date. These attempts to discern a specific date for God's act of creation are the ultimate consequence of assuming the biblical narratives to be literally true accounts of what has happened.

Problems with the science and theology of God as Creator idea reappeared with the great advances in science being made in the 17th century. At the very time Archbishop Ussher was devising his chronology based on the biblical genealogies, Galileo, Giordano Bruno, and Isaac Newton were constructing an altogether new account of the universe. This drastic expansion of the universe, and its orientation away from being Earth-centered to sun-centered, had important consequences for ideas about God.

The most imaginative response at the time was deism, which retained for God the role as Creator but attributed everything that has happened since then to the working of nature. Few of the ideas popularized by the deists were original to them. Instead, they reworked ideas articulated by Lucretius, Cicero, and others, in the light of the new understanding of the universe as envisaged by Newton. Problems with deism soon became apparent, in particular, why its vision of God as Creator was any more acceptable than the conventional accounts it sought to replace. There was also the problem that the god of deism was useless for any normal religious function. Another response was pantheism, which subsumed God in Nature, divinizing the latter and secularizing the former. Pantheism was more corrosive to ideas of God as Creator than deism, although it suffered some of the same intellectual objections.

Some scientists in the 19th century, particularly those of a religious persuasion, argued that, as well as the mystery of creation, there was still so much that was unknown and could be attributed only to God's will. But as successive unknown areas have been opened up and provided with naturalistic explanations, the field of God's sphere of influence has been reduced. This was recognized as a problem and by the end of the 19th century was called the "God of the Gaps."

Among nonscientists another response was to relinquish all thoughts of demonstrating the rational and logical veracity of any God-talk, whether in his capacity as Creator or in any other role. Belief in God, in whatever capacity, was a matter of faith alone, in which reason played no part. Variations on this theme were articulated, at the radical end, by the Danish philosopher Søren Kierkegaard, and in more conservative language, by the Oxford movement and Ultramontane Catholicism. A secular variant was arrived at toward the end of the 19th century in early pragmatism, which argued that disputes over the existence of God and his role as Creator were largely irrelevant and incapable of final resolution. What mattered was the benefit such beliefs conferred on the believer.

The most recent response within the religious world to the advances in scientific understanding of the universe and its origins has also been the most conservative. Fundamentalism is the insistence that what is decreed in the scripture of one's religion is literally true in all respects. Thus, God really is the creator of the universe as outlined in the Bible (or the Qur'an), and whatever inconsistencies in the scriptural accounts are either illusory or the result of an unwillingness to believe the truth with the required degree of faith.

Most people, however, have reconciled themselves to the collapse of traditional accounts of God as Creator. By the beginning of the 21st century the general scientific consensus was that the universe is between 13 and 16 billion years old, and came into existence as a result of the big bang. And that the earth is about 4.5 billion years old and is one of countless planets in an expanding universe of unimaginable proportions. Those who have remained religious believers have been content to see the creation accounts as allegories with poetic rather than normative power. There have also been attempts to equate the big bang with accounts of God the Creator, but without success. As several scientific observers have commented, such a move tends to work only if God is reduced to a series of mathematical equations. Those who do not subscribe to any formal religious system simply take the scientific account as the best available account of how things began.

Bill Cooke

See also Aquinas, Saint Thomas; Aristotle; Augustine of Hippo, Saint; Bible and Time; Big Bang Theory; Christianity; Creationism; Genesis, Book of; God and Time; Gosse, Philip Henry; Lucretius; Plato; Qur'an; Time, Sacred

Further Readings

Augustine. (1878). *The city of God* (M. Dods, Trans.). Edinburgh, UK: T & T Clark.

Edis, T. (2002). *The ghost in the universe.* Amherst, NY: Prometheus.

Gribbin, J. (2003). *Science: A history.* London: Penguin.

Plato. (1974). *Timaeus and Critias* (D. Lee, Trans.). London: Penguin.

Watson, P. (2005). *Ideas: A history of thought and invention from fire to Freud.* New York: HarperCollins.

Whitrow, G. J. (1988). *Time in history.* Oxford, UK: Oxford University Press.

Gödel, Kurt (1906–1978)

Kurt Gödel was a mathematical logician who is best known for his incompleteness theorem. He also developed a theory of time travel based on Einstein's theory of relativity.

Gödel was born on April 28, 1906, in Brünn, Austria (now known as Brno, Czech Republic), and was baptized as a Lutheran. He began studying physics at the University of Vienna in 1924, but in 1926 he switched to mathematics, in which he excelled. Eventually he settled into the field of mathematical logic, which originated in the work of Gottlob Frege and was more fully developed by David Hilbert, Bertrand Russell, and Alfred North Whitehead.

In 1926, Gödel began participating in the Vienna Circle, a group of mathematicians and philosophers headed by Moritz Schlick. The group's members devoted themselves to propagating logical positivism, the philosophy that all that can be known about nature or reality must be deduced from immediate sensory experience. In spite of his participation, Gödel, like Albert Einstein, would become a lifelong opponent of positivism, arguing that intuition has a proper role to play in science and mathematics. Both he and Einstein rejected the Kantian notion that one can know only the appearances of things and not the things themselves. Because of Gödel's preference for the idealistic philosophies of Plato and Husserl, the philosophical establishment, dominated by the philosophy of Wittgenstein, either ignored or scorned much of his philosophical work.

In 1930, Gödel obtained his Ph.D. In 1931, Gödel published a response to David Hilbert's formalist attempt to develop a system of first principles (or axioms) from which one could apply rules of syntax to derive all the theorems of a mathematical domain. He undermined Hilbert's program by showing that no set of formalist axioms can ever fully capture the complete set of mathematical truths. There will always be some truths about integers, grasped intuitively, that cannot be proved true or false by any fixed set of axioms. He also showed that a system of axioms for arithmetic could not prove its own consistency. His incompleteness theorem (also known as Gödel's proof) ranks with Einstein's theory of relativity and Heisenberg's uncertainty principle as one of the three most revolutionary scientific findings in the 20th century. The recursive functions that he developed as part of this work were later used by Alan Turing and others in the development of the computer.

From 1933 to 1938, he alternated teaching stints between the University of Vienna and the Institute for Advanced Study (IAS) in Princeton, New Jersey. In 1938, he married Adele Porkert, a divorced nightclub performer. They had no children. After being declared fit for German military service, he and his wife emigrated to America in the winter of 1939–1940 by way of Siberia, Japan, and San Francisco, arriving in March at Princeton where he became a temporary member of the IAS. This status was renewed annually until he became a permanent member in 1946. In 1948, he became a citizen of the United States.

Gödel and Einstein became close friends in 1942 and remained so until Einstein's death in 1955. They joined each other in daily half-hour walks to and from the institute, during which they discussed politics, philosophy, and physics. During this time, Gödel's work focused on proving that Georg Cantor's continuum hypothesis (which dealt with the number of points on a line) was consistent with set theory and therefore could not be disproved.

In 1949, Gödel wrote an essay on the connection between the theory of relativity and idealistic philosophy, which was included in a volume in honor of Einstein's 70th birthday. Gödel developed solutions to the field equations of general relativity that resulted in a possible world (called the Gödel universe) whose spacetime structure is warped or curved so extremely as to form a closed, rotating loop. If a spaceship traveled fast enough along one of the continuous time-like paths in this structure, it could travel to the past or to the future. He then concluded that, if one could travel to the past, then time does not exist as an objective reality. Like Parmenides and Kant, he challenged the intuitive understanding of time as a linear ordering of events in which the past no longer exists, the future is yet to exist, and only the present truly exists. In essence, he showed that if relativity theory is true, then time understood as a succession of never-ending "nows" cannot exist as an objective reality.

Einstein was impressed with the results but doubted that physical data would support the existence of such a universe. In fact, lack of evidence for the rotation of the universe suggests that time travel is not possible in the actual universe (unless scientists can figure out how to create wormholes, which are shortcuts between two points in spacetime). Since its publication, the essay has received some attention from those interested in the topic of time travel, but its conclusion that time is an illusion has been largely ignored. In 1992, Stephen Hawking proposed the "chronology protection conjecture" in order to refute Gödel's argument and other theories of time travel. Hawking postulated that the laws of physics rule out the physical possibility of macroscopic bodies carrying information to the past.

In 1951, Gödel was co-recipient with Julian Schwinger of the first Einstein Award and delivered the Gibbs Lecture for the American Mathematical Society. After that, he became increasingly reclusive and isolated. In 1953, he was elected to the National Academy of Sciences and was promoted to professor at IAS. He published his last paper in 1958. During the 1960s, he developed an ontological argument for the existence of God, building on the arguments of his favorite philosopher, Leibniz. He never published it, perhaps for fear of damage to his reputation if his sympathies toward theism became known. He also continued his quest to develop axioms that would settle the continuum hypothesis. In 1975, he was awarded the National Medal of Science.

After Einstein's death, the economist Oskar Morgenstern became Gödel's friend and caretaker. The logician Hao Wang also became a close associate in the closing years of Gödel's life, and after his death Wang published recollections of conversations with Gödel.

Throughout adulthood, Gödel was plagued by depression, hypochondria, anorexia, and paranoia, and his symptoms worsened as he grew older. He retired from the IAS on July 1, 1976. In 1977, Morgenstern's death and his own wife's deteriorating health exacerbated Gödel's mental and physical disorders. He died of self-starvation on January 14, 1978, weighing only 65 pounds, and was buried in Princeton Cemetery. His wife died in 1981.

Gregory L. Linton

See also Einstein, Albert; Hawking, Stephen; Idealism; Intuition; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Relativity, General Theory of; Russell, Bertrand; Space and Time; Spacetime, Curvature of; Time, Illusion of; Time, Nonexistence of; Time, Relativity of; Time Machine; Time Travel; Time Warps; Whitehead, Alfred North; Worlds, Possible; Wormholes

Further Readings

Dawson, J. (1997). *Logical dilemmas: The life and work of Kurt Gödel*. Wellesley, MA: A. K. Peters.

Gödel, K. (1949). A remark about the relationship between theory of relativity and Kantian philosophy. In P. A. Schilpp (Ed.), *Albert Einstein: Philosopher-scientist* (pp. 557–562). La Salle, IL: Open Court.

Nagel, E., & Newman, J. R. (2001). *Gödel's proof* (D. Hofstadter, Ed.; Rev. ed.). New York: New York University Press.

Yourgrau, P. (2005). *A world without time: The forgotten legacy of Gödel and Einstein*. New York: Basic Books.

Goethe, Johann Wolfgang von (1749–1832)

Johann Wolfgang von Goethe was born on August 28, 1749, in Frankfurt am Main, and died on March 22, 1832, in Weimar. After studying law in Leipzig, he worked as a lawyer in Frankfurt and then underwent further practical training at the Court of Appeal (Reichskammergericht) of Wetzlar. Influenced by the Sturm und Drang movement, he wrote dramas and poems such as *Prometheus, Götz von Berlichingen,* and *The Sorrows of Young Werther* (*Die Leiden des Jungen Werthers*). A rough draft of what later became *Faust* goes back to his time in Frankfurt; in this drama, the topic of time has an important role.

In 1775, Karl August, the duke of Weimar, asked Goethe to join his court (*Weimarer Hof*) and work with him as a state representative. In 1786, Goethe made his first visit to Italy, which lasted 2 years and had a significant influence on his life. Of particular importance for him was his becoming familiar with classical works of art and the scientific research he made on the journey. A meeting with Friedrich Schiller in 1794 encouraged Goethe to increase his literary productivity again. He wrote *Xenien, Wilhelm Meister's Apprenticeship* (*Wilhelm Meisters Lehrjahre*), began writing his autobiographical *Poetry and Truth* (*Dichtung und Wahrheit*), and continued working on *Faust.* However, international political events such as the French Revolution and in 1806 the fall of the German Reich deeply influenced Goethe's thinking, as did numerous innovations in science and technology and their consequences for the life of the people. He became one of the central figures of the Weimar classical period (*Weimarer Klassik*).

Faust and the Theme of Time

Since Goethe worked on *Faust* throughout his life, this drama reflects the whole continuum of his research and interests, and also reveals the changes his thinking had undergone. An important aspect of the drama is the question concerning the relationship among human beings, time, and eternity. In the *Prolog im Himmel (Faust I),* Goethe's concept of eternity is conventional and depends on the Christian worldview. This concept changes with the last scene, titled *Bergschluchten (Faust II),* into something transcendental. The connection between the periods past, present, and future plays a particularly important role. Goethe assembles the scenes into an order that is remote from ordinary human perceptions and experiences of time. The meeting and union of Faust and Helena encompasses a period of more than 3,000 years, whereas the story time of *Faust I* comprises less than one year. The union of antiquity and modernity is not only the reason for the break in the structure of time. Timelessness also arises because Helena symbolizes eternal beauty while Faust stands for eternal striving.

Another type of time is the lifetime of Faust. It limits the period of impact concerning the bet he made with Mephistopheles. Only as long as Faust is alive can Mephistopheles try to satisfy his desires with earthly pleasures and thereby give him a feeling of complete contentment. Consequently, in Goethe's *Faust,* three important spheres of time are united: eternity; the union of past, present, and future; and Faust's own lifetime.

Faust's desire to experience the eternal is in sharp contrast to his limited existence as a human being. His aim "to get to know everything" fails. He realizes that the studies of science, the Bible, and magic cannot help him in his endeavors, which is the reason why he abandons them and turns to everyday life. As he grasps that the act and not the word is the beginning of realization, Faust becomes aware of the importance of the present moment.

In his pact with Mephistopheles, Faust is interested in the quality of a certain moment he wishes to experience. The problem is that the two partners in the contract have different opinions about time. Mephistopheles affirms this worldliness and inevitable death, so eternity itself is hostile to him. According to Faust, however, time that passes is hostile, because he sees eternity as a cycle of life, growth, death, and rebirth.

In the pact, Faust demands total fulfillment in one moment. Only then is he ready to give his soul to the devil. Mephistopheles tries to win the bet by offering Faust various types of sensual pleasures, but he underestimates Faust's spiritual nature. It is very convenient for Mephistopheles that Faust seems to reject eternity in favor of the moment; this is because God represents the eternal, while Mephistopheles stands for the single moment. In the beginning, Mephistopheles confronts Faust with the pleasant aspects of life in Auerbach's cellar, trying to cheer him up and ease his thoughtful mind.

Concerning individual pleasure, time is a succession of moments that are not related to one another. Faust's striving in the company of Mephistopheles represents the timeless element in human beings. For Faust, momentary pleasures are not sufficient for complete fulfillment. This seems analogous to the beauty of Helena, which is also timeless because beauty is hidden in the law of nature. Therefore, the union with Helena is important for Faust. Faust's situation begins to change when he recognizes past events as important. He develops a new attitude toward sensual experiences, because in his union with Helena he realized how fulfilling a moment can be. His failure to combine eternal beauty, represented by Helena, with present time leads to the need for significant actions. Act IV of the second part of *Faust* shows Faust's development, his willingness to do things for their own sake. At this point, the dangers and consequences of his activities become clear. The need for power and property (land reclamation) brings with it destruction (of landscapes and buildings) and death (Philemon and Baucis).

The process of acceleration is manifested in Faust as well as Mephistopheles. Faust curses slowness; he is marked by precipitated striving, which is cultivated by Mephistopheles. He forges plans and carries them out quickly (money economy at the emperor's court, draining of the coast to gain land). As a consequence, others are damaged and he destroys himself. Lemurs dig Faust's grave under Mephistopheles' supervision. Faust, as an old, blind man, interprets the noises as a continuation of his project to drain the marshland. In this moment, in a vision of a future, free society, Faust asks, with the words, "Stay, thou art so beautiful!" for the moment to stay. He dies, and the devils come to take his soul. But his immortal soul could be saved.

The polarity of moment and eternity corresponds to Goethe's development from youth to old age. The importance of the moment is a quality associated with the Sturm und Drang movement; classical antiquity, however, offers timelessness and permanence.

For the phenomenon of acceleration, Goethe formed the expression *velozifearisch*. It consists of *velocitas* (hurry) and Luzifer (devil). For Goethe, the acceleration of time is the origin of modernity. Modern civilization, which is characterized by rapidity and acceleration, also affects the mental states, thinking, and acting of modern human beings. Faust values progress and so he becomes restless and unscrupulous; omissions, mistakes, and violence result.

Goethe's Historical Interests

In the field of historical research, which was important to Goethe all his life, the polarity of permanence and fast change plays a significant role. In the early decades of his life, Goethe's historical interest can be found in his dramas *Götz von Berlichingen* and *Egmont*.

During his stays in Italy, Goethe realized nature and art were permanent and reliable because history was present in the antiquities. Back in Weimar, he was caught up in the events of world history and his belief in stability began to fade. He regarded the French Revolution as chaotic and as responsible for accelerating the historical process. Goethe wished to understand events and acted accordingly, but felt helpless. He realized that his own desires could not affect the progress of history, and recognized the arbitrariness and unpredictability of events, which reminded him of natural changes. Looking for stability, he discovered his roots and began his autobiographical work, *Poetry and Truth* (*Dichtung und Wahrheit*). Nonetheless, Goethe continued to place a high value on progress.

Botanical Investigations

The ambiguity between Goethe's interests in progress and his own thoughts on development (metamorphosis) come out clearly and are put into perspective. According to Goethe, time plays an important role in nature. One of his fundamental ideas was the organic development from the simple to the absolute. He believed he recognized a special type of original plant (*Urpflanze*) in every plant. To verify this idea, Goethe undertook biological research during his journeys to Italy and at his home, on his idea of an original plant type.

He looked for something that is common in all plants. This led him to make generalizations different from those of Linné (Linnaeus), who tried to find a classification based on the differences between plants. With his generalizations, Goethe progressed from the original plant to the original leaf (*Urorgan Blatt*). In his opinion, all parts of the plant emerged from this leaf. Two laws are responsible for changes in the plant: A law of nature constructs the plant, and a law of the external circumstances modifies it.

Later, Goethe gave up his idea of an original plant type in favor of the theory of types (*Typus*). He subsequently made his theory of the evolution of plants more general so that it included animals. In contrast to the theory of metamorphosis, his type theory represents a constant in natural biodiversity. Nevertheless, both terms (*Leitbegriffe*) in Goethe's scientific studies are connected and lead to biodiversity. The type sets limits that metamorphosis cannot exceed, though it can shine though as an original principle (*Urprinzip*) because of the creation of organisms brought about by metamorphosis.

The concept of duality of moment (type) and eternity (metamorphosis) are implicit or explicit in Goethe's theoretical writings.

Sophie Annerose Naumann

See also Becoming and Being; Eternity; Evolution, Organic; Novels, Time in; Poetry

Further Readings

Goethe, J. W. von. (1987). *Collected works*. Princeton, NJ: Princeton University Press.

Gray, R. (1967). *Goethe: A critical introduction*. Cambridge, UK: Cambridge University Press.

Vincent, D. (1987). *The eternity of being: On the experience of time in Goethe's Faust*. Bonn: Bouvier.

Williams, J. R. (1998). *Life of Goethe: A critical biography*. Malden, MA: Blackwell.

Gospels

The early Christians used the Latin term *evangelium* to refer to the spoken message about Jesus Christ; in Old English, the translation was "god spel" (good tale), which eventually became "Gospel" as a generic label for written narratives of the life, death, and resurrection of Jesus. Four Gospels were accepted into the Christian canon, and around 40 other "apocryphal" Gospels have been identified. The four canonical Gospels were attributed to Matthew, Mark, Luke, and John, and they appear in that order in the Christian canon. Matthew and John were numbered among the 12 disciples of Jesus. Early church tradition associated Mark with Simon Peter, and Luke was an associate of Paul. Scholars generally accept the validity of the early church traditions about the authorship of the Gospels of Mark and Luke, but many are skeptical about the degree to which Matthew and John were responsible for the Gospels associated with their names.

The Gospels bear some similarities with the conventions of ancient biographies, but overall they are unique among ancient writings. As narratives, each Gospel has a beginning, middle, and end, but they do not follow strict chronological order in describing the events of the life of Jesus. Instead, they often group the sayings and deeds of Jesus by theme or topic.

Of the four Gospels, only Matthew and Luke begin their narratives about Jesus by describing his birth. They also include genealogies that describe Jesus' roots in the history of Israel, going back as far as Abraham in the case of Matthew and as far as Adam in the case of Luke. Only Luke describes an event from Jesus' childhood, namely, his visit to the Temple when he was 12 years old.

The first event recorded by Mark and John is the ministry of John the Baptist and his baptism of Jesus. All four Gospels emphasize John's role as a prophet who was preparing God's people for the coming of the Messiah and his kingdom. Immediately after Jesus' baptism, Matthew, Mark, and Luke describe Jesus' temptation by Satan during his 40 days in the wilderness. This initial, decisive confrontation with the forces of evil serves as the overture for his public ministry, during which Jesus repeatedly frees people from the domination of evil by means of healings and exorcisms.

The four Gospels differ in their description of the next events of Jesus' life. Matthew and Mark describe the beginning of his preaching in Galilee and the call of his 12 disciples. Luke also refers to

Jesus' return to Galilee, but then he recounts his sermon in the synagogue in Nazareth. This story serves to introduce important themes developed more fully in the Gospel of Luke and the Acts of the Apostles. After Jesus' baptism by John, the Gospel of John describes Jesus' call of four disciples and the miracle of changing water into wine at the marriage celebration in Cana. After these stories of the beginning of Jesus' ministry, Matthew, Mark, and Luke follow each other closely in terms of content and order. Because of their similarities, they are referred to as the "Synoptic" Gospels, a term that means "to see together." John is significantly different from the other three in both order and content.

All four Gospels describe an event in Jesus' life that serves as the turning point in the narrative. For the Synoptics, this event is Peter's confession of Jesus as Messiah followed by Jesus' first prediction of his suffering, death, and resurrection. That event is followed by the Transfiguration during which the heavenly voice declares that Jesus is God's Son. From then on, each narrative moves inexorably toward Jesus' arrest, trial, and death in Jerusalem. For the Gospel of John, the turning point is associated with Jesus' raising of Lazarus from the dead, an event that crystallized the intention of the Jewish leaders to plot Jesus' death.

All four Gospels contain a lengthy account of the last week of Jesus' life, which is called "the Passion Narrative." This narrative may have existed as a written document before its use by Mark, the first person to write a Gospel. The Passion Narrative begins with Jesus' triumphal entry into Jerusalem on Sunday, continues with various discourses and events that culminate in the Last Supper on Thursday night, and ends with his crucifixion on Friday. All the Gospels conclude with narratives of Jesus' appearances to his disciples after his resurrection on Sunday morning.

The Gospel writers were motivated to write narratives about Jesus because of their conviction that Jesus brought about the beginning of the end of history. Many Jews at that time believed that history would be divided into two parts. This present age, which is dominated by sin and death, would be replaced by the age to come. The event that would usher in the age to come was the Day of the Lord, when the Messiah would establish God's kingly rule on Earth. The resurrection of the dead was associated with the Day of the Lord.

Saint Matthew writing his Gospel under the Inspiration of Christ. From a miniature in a manuscript of the ninth century, in the Burgundian Library, Brussels (drawn by Count H. de Vielcastel).

Christians believed that, through his death and resurrection, Jesus conquered the powers of sin and death and therefore inaugurated the age to come. Because the age to come has broken into the present, the Gospel writers describe the kingdom of God as both present and future. Each Gospel attempted to show how the turning of the ages occurred through Jesus.

The majority view among scholars since the early 1900s is that Mark wrote the first Gospel about 40 years after Jesus' death and that Matthew and Luke used Mark as the framework for their Gospels, which were written 10 to 20 years later. Matthew and Luke supplemented Mark with a written source they had in common, which is called "Q" (from the German *Quelle,* which means "source"). Each included his own distinctive material, which is referred to as "M" and

"L," respectively. A minority of scholars have defended the centuries-old belief that Matthew was the first Gospel. Some have argued against the existence of Q, and some have posited a more complex interaction over time among all the Gospel writers.

Most scholars date the Gospel of John near the end of the first century. The narrative claims to be based on the eyewitness testimony of the Beloved Disciple, who has often been identified with John the son of Zebedee. Various scholars have proposed that the book was revised more than once by different editors. Most would concede that an editor (who was different from the original author or authors) compiled the final version that appears in the Christian canon.

Gregory L. Linton

See also Bible and Time; Christianity; Eschatology; God and Time; Time, Sacred

Further Readings

Bockmuehl, M., & Hagner, D. A. (Eds.). (2005). *The written Gospel.* Cambridge, UK: Cambridge University Press.

Hengel, M. (2000). *The four Gospels and the one gospel of Jesus Christ: An investigation of the collection and origin of the canonical Gospels* (J. Bowden, Trans.). Harrisburg, PA: Trinity Press International.

Stanton, G. (2002). *The Gospels and Jesus* (2nd ed.). Oxford, UK: Oxford University Press.

Gosse, Philip Henry (1810–1888)

In the middle of the 19th century there emerged a serious concern about time. Ongoing discoveries in geology, paleontology, and archaeology were challenging the then-held age of our Earth, fixity of species, and recent appearance of the human animal on this planet. Rocks, fossils, and artifacts were suggesting a new worldview, in terms of pervasive change throughout time, far different from the traditional static philosophy of nature. There was a glaring discrepancy between the scientific perspective of naturalists and the biblical framework of religionists. Inevitably, a major conflict developed between facts and beliefs. The empirical evidence for evolution contradicted the story of Genesis: Is the earth millions of years old, or was it divinely created only a few thousand years ago? A resolution seemed to be impossible, especially for those fundamentalists who held to a strict and literal interpretation of the Holy Scriptures.

Philip Henry Gosse made a bold and unusual attempt to reconcile the creationism of revealed religion with the evolutionism of the earth sciences. He was a fundamentalist creationist who belonged to the Plymouth Brethren sect in Victorian England. As such, his acceptance of the Mosaic cosmogony included a rigid adherence to both the sudden creation of Adam and the later Noachian deluge, each of these two events caused by the personal God of Christianity. However, Gosse was also an avid naturalist who could not easily dismiss the overwhelming and compelling factual evidence for organic evolution. Nevertheless, he rejected outright the dynamic concepts and disturbing implications (for him) of the evolutionary perspective. Therefore, his own personal beliefs required that he somehow resolve the contradiction between evolutionist science and fundamentalist religion. Gosse presented his incredible resolution in two books, *Life* (1857) and *Omphalos: An Attempt to Untie the Geological Knot* (1857).

Gosse's bizarre explanation for divine creation gave priority to biblical beliefs and immediate experience, rather than to science and reason. It is an interpretation ultimately based on an essential distinction between two different modes of existence: preternatural or ideal time in the perfect and infinite mind of a personal God prior to the act of creation, and the later natural or real time of objects and events in this material world of ongoing change and evolutionary development. In short, there is a crucial difference between prochronic time and diachronic time. Moreover, Gosse claimed that the course of everything inorganic and organic in nature is a circle.

Gosse firmly held that both the geological column of rock strata and the paleontological record of fossil evidence were suddenly created, all at once, along with the earth's existing plants and animals (including our own species) through the divine act of a personal God. In fact, Gosse further argued that this planet suddenly came into existence as an ongoing world already containing a sequence of fossil remains in a series of rock layers. Consequently, rocks and fossils only suggest both an extensive natural past for the earth itself and a vast evolutionary history for all previous life forms on this planet. Briefly, due to this instant creation with its built-in geological column and fossil record, the earth only appears to be as old as the geopaleontological evidence suggests to the evolutionary naturalists; the stratigraphic layers with their fossil remains were suddenly formed merely to suggest an ancient planet and the process of organic evolution.

According to Gosse, the appearance of our Earth together with its life forms occurred at a specific point, which was the violent irruption of natural time, at the beginning of cosmic reality from ideal time. Gosse thought that the empirical evidence of science is deceptive, and the untold eons of planetary time are simply an illusion. Consequently, he believed that his unique interpretation of creation would allow him to accept the evidence for evolution without accepting the process of evolution.

In a fantastic thought experiment, Gosse imagined himself experiencing plants and animals living on a pristine Earth just after the instant of creation. All of these organisms would appear to him to have had a planetary history but, he argued, in reality, this was not the case. He even claimed that Adam had been suddenly created with a navel so that it would appear as if he had had a natural birth! Furthermore, the observed rock strata and fossil record had been deliberately placed in the earth by God so that our planet would appear to have had a vast evolutionary history. It was a divine scheme to test the biblical faith of fundamentalist believers (or perhaps even to deceive them). For Gosse, the evolutionary naturalists are merely discovering the divinely imprinted evidence for geological history and biological evolution, although each had never occurred; neither geological nor biological changes had taken place over the assumed sweeping eons of planetary time.

Not surprisingly, Gosse's explanation for the creation of our Earth did not convince scientists or philosophers or theologians. Naturalists remained evolutionists, philosophers debated his ideas, and theologians grappled with the startling implications of the earth sciences. Gosse himself was devastated because his serious effort to reconcile science and religion was rejected by both evolutionists and fundamentalists. Ironically, since he believed in an instant creation of everything, his own theistic cosmogony is not compatible with either the biblical 6-day account of Genesis in the Holy Bible or the vast perspectives of modern process theologians.

Gosse's worldview is supported by neither science nor reason. Any fixed date for the sudden moment of divine creation would be arbitrary; in fact, one could argue that all reality (including natural time and our species) is still in the mind of God, with the origin of this material universe yet to take place. Invoking the law of parsimony, one would be wise to accept the temporal frameworks of cosmic evolution and earth history over Gosse's improbable worldview. However, the creation/evolution controversy over time continues, despite the ongoing advances in the special sciences. Gosse's desperate attempt at reconciliation remains an interesting relic of an outmoded religious-oriented cosmogony. A progressive understanding of and appreciation for time requires that one remain open to the continuing discoveries in science and the new perspectives in philosophy.

H. James Birx

See also Cosmogony; Creationism; Experiments, Thought; God and Time; God as Creator; Religions and Time

Further Readings

Gosse, E. (2004). *Father and son.* New York: Scribner.

Gosse, P. H. (1998). *Omphalos: An attempt to untie the geological knot.* Woodbridge, CT: Ox Bow Press.

Thwaite, A. (2002). *Glimpses of the wonderful: The life of Philip Henry Gosse, 1810–1888.* London: Faber & Faber.

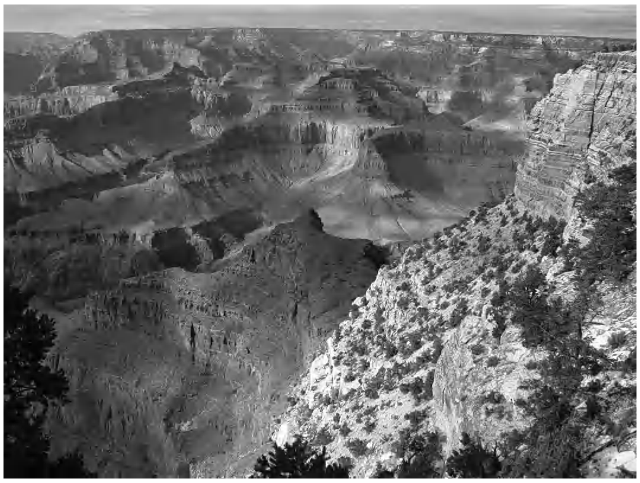
Grand Canyon

The Grand Canyon, located in Arizona in the United States, is usually regarded as one of the world's seven natural wonders. The canyon, carved by the Colorado River and home to many ecosystems and artifacts, still has scientists wondering exactly how and when it was formed. Each year, nearly 5 million people visit the Grand Canyon.

The canyon is expansive, stretching 277 miles from Lake Powell at the Utah–Arizona border down into Lake Mead, near Las Vegas. The canyon is 6,000 feet at its deepest point and 15 miles across at its widest point.

The wildlife and plant matter found within the Grand Canyon are diverse, attributed in large part to its size, depth, and variation. While the Grand Canyon is very large and wide at some locations, its range of height and size vary along its course and its weather is diverse. Weather varies as much as 5.5 degrees Fahrenheit with each 1,000 foot change in elevation. At certain points, then, the temperature may vary an average of 33 degrees from the upper rim to the river walls. These weather variations allow for the presence of five of the seven life zones and three of the four desert types in North America. The five life zones represented are the Lower Sonoran, Upper Sonoran, Transition, Canadian, and Hudsonian.

The origin of the Grand Canyon is still something of a mystery. Scientists continue to study and hypothesize about its age and origin, but cannot come to a consensus. Despite agreement that the layers of granite at the deepest portions of the gorge are 1.7 billion years old, it is widely accepted that the canyon itself is nowhere near as old.



The Grand Canyon in Arizona. Layers of the Grand Canyon were formed over a period of about 2 million years.
Source: The National Park Service.

Modern geologists are puzzled by the seemingly faster erosion in some portions of the canyon than others. This may be explained by the most widely accepted theory of the canyon's formation—the upper sedimentary layers were the base for several small shallow lakes that existed for hundreds of thousands of years. Over time, the rock rose through tectonic forces to create the Colorado plateau. All the while, the Colorado River cut down through the rock, but was thwarted by the harder portions of igneous rock, which now are some of the narrowest portions of the canyon. This whole process was said to have begun about 70 million years ago. Some researchers argue, however, that the landscape of the canyon is far too immature and must be newer than 5 million years old.

Yet another theory suggests that two separate river systems, not lakes, existed and merged to form what is now the Colorado River. They speculate that the westward river absorbed the eastward river in a process called headward erosion. This theory suggests that the headward erosion process would have begun about 15 million years ago.

Some of the most recent research suggests that the gorge may have been carved within the past million years. Scientists suggest that it was only recently that we have understood just how quickly erosion can take place, drastically affecting the timeline of the creation of the canyon.

Although the age of the Grand Canyon remains in dispute, it is home to some of the oldest, most diverse natural elements in the world.

Amy L. Strauss

See also Erosion; Geological Column; Geologic Timescale; Geology; Ice Ages; Old Faithful

Further Readings

Anderson, M. (Ed.). (2005). A gathering of Grand Canyon historians: Ideas, arguments and first-person accounts: *Proceedings of the inaugural Grand Canyon History Symposium, January 2002*. Grand Canyon, AZ: Grand Canyon Association.

Fletcher, C. (1989). *The man who walked through time: The story of the first trip afoot through the Grand Canyon*. New York: Knopf.

Ranney, W. (2005). *Carving Grand Canyon: Evidence, theories, and mystery.* Grand Canyon, AZ: Grand Canyon Association.

Young, R., & Spamer, E. (Eds.). (2003). *Colorado River: Origin and evolution.* Grand Canyon, AZ: Grand Canyon Association.

GRAVITY

See RELATIVITY, GENERAL THEORY OF

GREECE, ANCIENT

See PRESOCRATIC AGE

GRIM REAPER

In Western cultures, the Grim Reaper is the most commonly known personification of death. Its current form as a macabre and sinister image has evolved over time, beginning as a feminine figure in the ancient world and transforming into the masculine form in ancient Greek literature. These personifications and images are preserved in art, literature, and film. In the future, the form assumed by this figure will naturally reflect the philosophies, ideologies, and technologies of the culture of the time, and the image of the death guide will reflect the notions of death held by tomorrow's generations. The personified death image may be portrayed as an assistant or travel guide, or it may be a more diabolical instigator, a big brother, or a computer-generated entity that perpetrates the dance of death.

Before the 19th century, the Grim Reaper was more commonly referred to as an Angel of Death. This icon of death was a winged angel that waited to escort the living to their place in the afterlife. The image of this angel was much less menacing and gruesome than today's Grim Reaper, a hooded and cloaked skeleton. The skeleton as a symbol resonates deeply within the human psyche, signifying the importance and the inevitability of death. The Grim Reaper carries a scythe or a sickle, an agricultural instrument that for centuries has been used to cut down and harvest crops. He uses his instruments to harvest or gather the living and take them to their death. Using various disguises such as illness, sudden accidents, and catastrophes, he randomly strikes and unquestioningly takes the lives of young and old, male and female, rich and poor, without discrimination.

The Grim Reaper's modern appearance originates in Greek literature and art, which associates the god Cronus with the passing of time. The god Cronus harvested crops with a sickle, which he later used to castrate his father, Uranus. Cronus later went on to swallow all of his children, except Zeus, out of fear that they might in turn retaliate against him in the same way he had retaliated against his father. Cronus is often seen carrying this scythe, a tool similar to the sickle, and is also depicted with an hourglass in his role as Father Time.

In oral tradition, some similarities between Cronus and the Grim Reaper developed, and that is why we often see the Grim Reaper brandishing the scythe. Sometimes, the Grim Reaper is also seen carrying an hourglass, an image intended to remind us that time never stops and that we are mortal. With each grain of sand that falls, we are moving closer to the end of our time on Earth.

Debra Lucas

See also Cronus; Dying and Death; Father Time; Longevity; Satan and Time; Youth, Fountain of

Further Readings

Lonetto, R. (1982). Personifications of death and death anxiety. *Journal of Personality Assessment, 46*(4), 404–407.

Williamson, J., & Schneidman, E. (1995). *Death: Current perspectives.* Mountain View, CA: Mayfield.

GUTH, ALAN

See COSMOLOGY, INFLATIONARY

H

Haeckel, Ernst (1834–1919)

Greatly influenced by reading Charles Darwin's *On the Origin of Species,* Ernst Haeckel accepted the fact of evolution and became known as the "Darwin of Germany" for his own extensive researches and copious publications. He had studied medicine, become interested in botany and zoology (especially marine organisms and comparative embryology), and eagerly extended the consequences of evolution to philosophy and theology. His focus on time change included a serious consideration of the origin and history of our species within a cosmic framework.

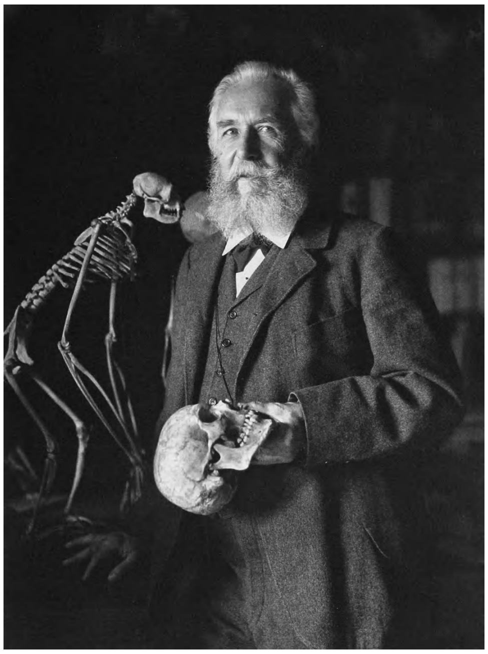
Unlike the cautious Darwin, the bold Haeckel did not hesitate to consider both the philosophical implications and theological ramifications of evolution for understanding this universe in general and appreciating life on Earth in particular. He argued for the essential unity of this dynamic cosmos. His worldview acknowledged the origin of life from matter in the remote past, and then, over eons of time, the enormous diversity of plants and animals that appeared throughout organic history.

Haeckel did not know the true age of this universe or of the earth. He was unaware of the vast durations of time represented by the geologic column of our planet, with its fossil record. Even so, his mind always remained open to those new facts, concepts, and perspectives that were being contributed by the evolutionary sciences. Likewise, Haeckel never hesitated to criticize severely those individuals (particularly religionists) who refused to accept the fact of evolution and its devastating consequences for all earth-bound and human-centered interpretations of reality. For him, cosmic immensity and the probability of life forms and intelligent beings existing elsewhere on other worlds was sufficient reason for doubting that our own species occupies a special place in evolving nature.

Before Darwin had done so, Haeckel wrote that the human animal had emerged from an apelike form. He speculated that Asia was the birthplace of the first hominids, hypothesizing that a now-vanished land mass (Lemuria) had been the geographical location where the evolution of humanlike hominoids from apelike hominoids had occurred. He even gave the scientific name *Pithecanthropus alalus* (ape-man without speech) to this assumed "missing link" between fossil apes and the first humans.

Furthermore, Haeckel argued that our species and the three great apes (orangutan, gorilla, and chimpanzee) differ merely in degree rather than in kind, due to the relatively recent separation of the earliest hominid form from a common ancestor with the fossil apes in terms of evolution. He also claimed that all human biological characteristics and mental activities had slowly evolved from earlier apelike forms. Consequently, our species is a recent product of, and totally within, material nature.

Ernst Haeckel's most popular work is *The Riddle of the Universe,* in which he presented the basic ideas of his evolutionary worldview. For him, God and the universe are the same entity,



One of the principal supporters of Charles Darwin's theories of evolution in Germany, Ernst Haeckel wrote wide-ranging books addressed to the general public, and his illustrations inspired many artists.

Source: Getty Images. Photograph by Nicola Perscheid, 1905.

with things endlessly becoming and passing away throughout cosmic time. Moreover, as a result of his lifelong studies in comparative morphology, Haeckel himself drew the first tree of life to illustrate the evolutionary relationships among organisms on earth. The fascinating drawings for his scientific publications on evolution and related subjects may still be seen at the Ernst Haeckel House, now a museum in Jena, Germany.

H. James Birx

See also Darwin, Charles; Evolution, Organic; Huxley, Thomas Henry; Spencer, Herbert; Time, Planetary

Further Readings

Birx, H. J. (1984). *Theories of evolution.* Springfield, IL: Charles C Thomas.

DeGrood, D. H. (1965). *Haeckel's theory of the unity of nature.* Boston: Christopher Publishing.

Haeckel, E. (1992). *The riddle of the universe at the close of the nineteenth century.* Amherst, NY: Prometheus. (Original work published 1899)

HAMMURABI, CODEX OF

The Codex of Hammurabi is one of the oldest sets of laws in the world. The over-2-meter-long slabs with their engraved laws were created at the behest of Hammurabi (presumably c. 1792–1750 BCE), a significant ruler of the Babylonian dynasty and king of Sumer and Akkad. The Codex offers an early document of human law that is defined by its reference to the past; in other words, to the divine commandments and common customs that paved the way for the legitimacy of legal regulations.

Similar to its predecessors, among which the Codex of Ur-Nammu, the Codex of Lipit-Ishtar, and the Codex of Eshnunna are the best-known examples, the concept of a "codex" is misleading, because, in a modern sense, a codex is understood to be a generally valid legal system whose enforcement is guaranteed by the state. The ancient Oriental codices, however, are incomplete collections of individual legal cases that usually express the will of the lawmaker to reform outdated laws or traditions. This also applies to the Codex of Hammurabi. But it is different from earlier codices in that it aspires to exert a standardized system of law on the entire realm of the given ruler. This was unprecedented in the ancient Orient, where a generally binding common law in accordance with state regulations was still unknown; justice was usually administered by virtue of traditional customs. However, there are contradictory reports about whether Hammurabi's project was successful or not: Some historians assume that the individual paragraphs were actually taken from everyday legal practice because many trial certificates express the same point of view in their verdict as the Codex. Other historians consider the Codex to have been a more theoretical manifesto that was never directly put into practice because, among other things, many of the reported verdicts refer to Hammurabi's regulations, but none of them mention the inscriptions.

Also, similar to earlier collections of law, the Codex of Hammurabi consists of a prologue, laws, and an epilogue. Both the prologue and the epilogue serve to legitimize the text: for example, at the beginning, by showing the symbols of power that Hammurabi receives from the hands of the sun god Shamash; and, at the end, by referring to the social justice of the legal ordinances. The collection itself consists of 282 paragraphs that, in addition to regulating a number of classical criminal and civil law cases, deal with such seemingly modern areas as the law of tenants and landlords, building regulations, and tort laws. From a sociological point of view, these reforms were designed to solve problems that derived from the socioeconomic developments of the 2 centuries prior to the Codex, during which Babylon grew from a fortified settlement to a metropolis on the Euphrates with a complex social and economic structure.

The Codex's principles of justice, the talion law as well as mirror punishment, are of particular importance to the history and philosophy of law: Talion (Latin *talio,* revenge; Greek *talios,* equal) was seen as a legal figure who sought to achieve a balance between the damage done to the victim and the damage that was to be done to the perpetrator. The best-known formula is "an eye for an eye," which also found its way into the Judeo-Christian Bible. Mirror punishment goes beyond the idea of enacting the same action upon the criminal as the criminal perpetrated upon the victim. It also implies punishing the part of the perpetrator's body used to commit the crime (e.g., chopping off the hand of a thief).

These punishments not only seem draconian today, they also seemed to some extent draconian in Hammurabi's era in comparison to more ancient codices, such as the Codex of Eshnunna. The Codex of Hammurabi even permitted the death penalty for minor offenses like theft or libel. Certainly one of Hammurabi's central motives was to employ methods of deterrence to consolidate his empire, which covered a large section of Mesopotamia. Another reason might have been that imprisonment was not really part of the nomadic tradition, which essentially knew no prisons. Nevertheless, the concept of justice expressed in the principle of talion was adapted again and again. A number of paragraphs from the Codex of Hammurabi can also be found elsewhere, for example, in the Bible, which is how the Codex exerted an influence on the Occident's sense of right or wrong.

Oliver W. Lembcke

See also Bible and Time; Egypt, Ancient; Ethics; Law; Morality; Ur; Values and Time

Further Readings

Mieroop, M. v. d. (2005). *King Hammurabi of Babylon: A biography.* Oxford, UK: Blackwell.

Richardson, M. E. J. (2000). *Hammurabi's laws: Text, translation and glossary.* Sheffield, UK: Academy Press Sheffield.

Harris, Marvin (1927–2001)

Marvin Harris, American anthropologist, was known for his theoretical contributions to the concept of cultural materialism. His theoretical perspective of cultural materialism, though not a unifying theory of culture, sought to explain variations and commonalities among human cultures. As reflected within previous ethnographic research, the development and advancements of various human cultures exhibit many similarities and differences. Amid documenting these cultural characteristics, anthropologists have formulated various theoretical perspectives to account for these cultural aspects. The comparison of cultures, especially in a spatiotemporal framework, has inherited epistemological and teleological problems. These problems are revealed in the paradigm shifts seen within the history of cultural anthropology. Harris understood these philosophical problems and developed a unique approach to, and interpretation of, humankind's cultural material existence.

Harris questioned the theoretical basis for the idea and evaluation of culture. In cultural materialism, he viewed cultural structure and its components in terms of expressed culture (all aspects) within the process of selection. Focusing on infrastructure, structure, and superstructure, the symbiotic relationships provide the basis for cultural stasis, cultural advancements, and diversification. Lacking an ascribed ontology and teleology, this unique perspective encompasses all aspects of time—for example, synchronic and diachronic—within a social and evolutionary framework. Expressed infrastructural differences between etic/emic modes of production and domestic/political economy are believed to be dynamic variants of the superstructure; albeit the stability of the superstructure appears to remain more dependent on the infrastructure. This would be reflected on the rates of change and the appearance of any contradictions seen between infrastructure components and their related superstructure. These structures, when juxtaposed with social hierarchy, provide a sustaining and practical benefit for its members. Although social and economic equality is elusive, social power (which would include empowerment) was stated as one of the selective forces of social dynamics that influence the complex nature of both infrastructure and superstructure.

Human culture is both unique and complex. From sociobiology to postmodernism, the wide range of theoretical constructs was seen by Harris as a set of segmented perspectives that lack a comprehensive view. Though Harris never claimed cultural materialism as a comprehensive accounting of culture, his modified Marxist approach attempted to provide the best explanation for the conditions of human culture. The categories of infrastructure and superstructure are seen to provide the best possible avenues for objective study, although the exact relationship of the parts to the whole is tenuous and unpredictable. The concept of time, in an evolutionary framework, can be depicted as a fluid continuum by which material culture reflects human behavior. In this manner, his theoretical perspective never claimed to be a social manifesto. Harris defended science (with all its limitations) and human dignity and value from the metaphysical implications of contending cultural theories. His theoretical perspective and social awareness had a profound influence on cultural anthropology and the understanding of human nature and culture.

David Alexander Lukaszek

See also Anthropology; Evolution, Cultural; Evolution, Social; Morgan, Lewis Henry; Tylor, Edward Burnett; White, Leslie A.

Further Readings

Harris, M. (1980). *Cultural materialism.* New York: Vintage Books.

Harris, M. (1991). *Cannibals and kings: Origins of culture.* New York: Vintage Books.

Harris, M. (1999). *Theories of culture in postmodern times.* Thousand Oaks, CA: AltaMira.

Harrison, John (1693–1776)

John Harrison, born in Foulby, England, became one of the world's most renowned horologists. He won the Board of Longitude Prize for developing a chronometer that could be used aboard ship to measure longitude to within 0.5 degree at the end of a voyage to the West Indies. About 1720 he had designed a timepiece that included a compensating apparatus by using different metals for correcting errors due to variations in the weather. Scientifically speaking, Harrison invented a timepiece that allowed for temperature changes or distortion. The first chronometer, which weighed 65 pounds, was completed and submitted to the Board in 1735 and was tested aboard ship the following year. The accuracy of the chronometer was outstanding, but like many inventions it had its detractors. He then built three more; the fourth, in 1761, more than met the standard for the prize, as did the first one. But it wasn't until 1773 that he was fully compensated by the Board.

Up to the early 18th century, ships and their cargoes, along with the mariners, were at extreme risk between ports of call because of not knowing their exact location. After all, an hourglass is not exactly the best timepiece for determining time at sea. John Harrison might well be called the "father" of time at sea, as his invention of an accurate timepiece was the final link in being able to determine longitude, something Galileo thought would be the most precise method for determining an east–west position. In 1730, John Hadley in England, and Thomas Godfrey in America, working independently, perfected the sextant, which accurately found latitude by "shooting" the sun at noon. Latitude, which is part of the earth's coordinate system for measuring relative location, had been rather easily observed and measured for centuries by determining the sun's angle above the horizon, early on using a cross-staff or back-staff. On a globe, latitude is shown as east–west lines that measure distance or position north–south, while longitude is shown as north–south lines that measure distance or position east–west. The earth makes a full revolution on its axis from west to east every 24 hours, or 15° of longitude each hour, the equivalent of one modern-day time zone.

Knowing one's exact longitude at sea is important for determining a ship's position with respect to land. Shipwrecks due to position miscalculations were so common that a Board of Longitude was organized in England in 1714 for the purpose of awarding the sum of £20,000 to anyone who could develop a method for accurately measuring longitude. John Harrison's contribution to measuring this accurately was a timepiece, known as a chronometer, that could be used at sea with a fair amount of accuracy. The timepiece was tested on a voyage to Jamaica with his son William Harrison on board, in 1761–1762, and determined longitude to within 18 nautical miles. Later, in 1764, the chronometer was tested again during a voyage to Barbados with his son on board. The timepiece performed brilliantly and well within the standard prescribed by the Board of Longitude. The fifth chronometer was used by Captain James Cook during his journey across the Pacific Ocean in 1776, although Cook was killed by Hawai'ians before the voyage was completed.

Richard A. Stephenson

See also Astrolabes; Hourglass; Latitude; Time, Measurements of; Timepieces

Further Readings

Bowditch, N. (1966). *American practical navigator.* Washington, DC: Government Printing Office. (Original work published 1802)

Christopherson, R. W. (2004). *Elemental geosystems* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Dunlap, G. D., & Shufeldt, H. H. (1972). *Dutton's navigation and piloting.* Annapolis, MD: Naval Institute Press.

Hartshorne, Charles (1897–2000)

Charles Hartshorne was one of the 20th century's most distinguished philosophers of religion and metaphysicians. He received his Ph.D. at Harvard University, where he was a student of Alfred North Whitehead. Hartshorne taught at the University of Chicago, at Emory University, and at the University of Texas. His ideas about time were influenced by Charles Sanders Peirce, Alfred North Whitehead, and Henry Bergson, as well as by Edmund Husserl and Martin Heidegger.

Hartshorne rests his philosophy on two bases: Its internal coherence and its adequacy in interpreting the facts of experience. Hartshorne believes that the appeal to observation is the sole possible basis of rational knowledge, which includes the purely mathematical. Therefore, the starting point of one's worldview should be one's daily experiences. The world is full of discontinuities, which are measurable as being greater or lesser. One can see them against a background of continuity, such as the continuity of space, time, and color qualities. Since our direct connection to matter is via sensation, the identity of mind and matter is the clue to the nature of things.

Hartshorne agrees with Baruch Spinoza and Whitehead that the primary physical data are within people. However, there is a veil between us and the "external world," and this veil is physiological. Hartshorne himself calls his philosophy *psychicalism*. This means that his philosophy was not derived from physics, but rather from phenomenological observations of sensations as a special class of feelings. The natural sciences tend to abstract from the mind and experience, even though they are (ultimately) derived from experience. But it is not only science that abstracts; even experiences based on the senses are enormous simplifications of the perceived world. Knowledge is not complete until these abstractions are overcome.

What is given to people has two main forms: previous experience by the same person, and other types of events that are not obvious but nonetheless may still be experiences as well, though not experiences by the same person.

The first form occurs in what we usually call memory; the other in what we call perception—the data that always include events in the series of events that have constituted one's own body.

Experiences are directly conditioned by their immediate data, which temporally precede the occurrence of experiences. They must follow and thus may not occur simultaneously with their data. This one-way dependence is a key to time's arrow and to causality: In contrast to classical determinism—which regards the world as a single, tightly interlocked system in which everything causally implies everything else, backward and forward in time—awareness, as in perception or memory, implies the selective and asymmetrical dependence of experience upon the experienced. In memory and perception the experienced events are temporally prior to the experiences.

This directionality of becoming is lost within classical physics. All conditioning involves the temporal priority of the conditions. The conditions are the data, the directly experienced factors. An experience is never identical with its data. No observation could establish an absolute simultaneity. Our categories are positively applicable only in temporal terms. Determinism destroys the structure of time by negating the asymmetry of becoming. The laws of physics that have given an explanation of time's arrow are stated as statistical approximations. Facts of experience give us direct evidence of the reality of contingency.

What the future distinguishes from the present and the past is that future experiences are characterized by their lack of distinct detail: "The future is in principle a rough blueprint, the past a photograph in full color." But the question must be asked as to whether this asymmetry is essential to time or whether it is merely a fact of human psychology. Hartshorne shows that the "not yet" of the future may have a meaning only for a mind not in full enjoyment of all details of what is to come. The future is that in which full consciousness is lacking. We conceive the unity of the different aspects of time—past, present, and future—in the way illustrated by our experiences of memory and anticipation. Without memory and anticipation, "past" and "future" would be meaningless words.

What is the nature of the relation between the past and the present? One explanation is that the cause is past but the effect is present. The cause is the predecessor of the effect. What, then, is the relation of causality? An objective serial order does not require that there be strictly deterministic causal relations. Whitehead, James, Bergson, Immanuel Kant, and others have all answered David Hume's problem in psychological terms. The simplest positive answer furnished by experience is memory. An objective temporal order is explicable if all reality is some form of experience, with each unit endowed with some form of memory. Hartshorne agrees with Whitehead, who has shown how "extension" as well as temporal succession can be described in psychic terms. For Hartshorne there is a world, a temporal–causal process. Things either intrinsically refer to other things, for example, to past events, or they contain no such internal reference to other things. If there is such reference, then it is at least as if the thing perceived or remembered or felt has existed or even still exists. This means that the world is a temporal–spatial network of events. If there is no such reference, then the world has no real connectedness. There would be no world, no real succession of cause–effect at all. Therefore, either everything must be as if idealism were true, or else as if there were no world, no real temporal–causal system. The subject of experience is a wholeness, which is temporally extended through the "specious present" (James), or the quantum of psychic becoming. Spatially, it is one through the voluminous rather than punctiform character of its perspective, or dynamic relationship with other entities.

Joachim Klose

See also Bergson, Henri; Consciousness; Heidegger, Martin; Hume, David; Husserl, Edmund; Idealism; Kant, Immanuel; Memory; Metaphysics; Spinoza, Baruch de; Whitehead, Alfred North

Further Readings

Hartshorne, C. (1932). Contingency and the new era in metaphysics (I). *Journal of Philosophy, 29,* 421–431.

Hartshorne, C. (1937). *Beyond humanism—Essays in the philosophy of nature.* Lincoln: University of Nebraska Press.

Hartshorne, C. (1997). *The zero fallacy and other essays in neoclassical Philosophy.* Chicago: Open Court.

Hawking, Stephen (1942–)

Stephen William Hawking, probably the best-known physicist since Albert Einstein, is Lucasian

Professor of Mathematics at Cambridge University. Hawking's work with the more exotic areas of theoretical physics and his best-selling book *A Brief History of Time* have earned him a place in the public eye as well as in his own chosen world of physics. He is best known for his contributions to black hole theory and scientific cosmology.

Physics: The Background

Hawking's ideas of time were influenced by the work of scientists and philosophers over two millennia. Aristotle, for example, made many statements about the arrangement of the universe. The whole world was spherical and finite, he postulated in the 4th century BCE. The earth was at the center of the Aristotelian universe, surrounded by one concentric sphere each for the sun, the moon, Mercury, Mars, Venus, Jupiter, and Saturn, and one sphere for the stars. The outermost sphere, containing the stars, was considered superior to the sphere in which the earth resided, and was supposed to be composed of an element called the ether. This concept of interstellar ether would persist in various forms through the early 20th century. The space occupied by the earth, however, was made of the four classical elements of earth, air, fire, and water. Furthermore, on the surface of the earth, the heavier of two bodies that had the same shape would fall faster. Many of Aristotle's postulates were eventually proved false, but his ideas nevertheless became firmly entrenched in science.

Nicolaus Copernicus, over a millennium later in the early 1500s, made the next great development in astronomy. His theory, based on observation, stated that the earth makes not only one complete rotation on its axis per day (as well as executing a slight wobble around this axis) but also one complete revolution around the sun each year, producing the seasons. The sun was placed uncompromisingly at the center of the universe. The earth took its place among the other planets in orbit around the star, with an orbital period of one year. Copernicus retained the celestial spheres of the Ptolemaic and Aristotelian theories, but he associated a greater orbital radius with a longer planetary year, which necessitated a rearrangement of the five known planets into their proper order.

British theoretical physicist Stephen Hawking, Cambridge University Professor and Fellow, circa 1985.
Source: Getty Images.

Early in the tumultuous 17th century, an Italian scientist named Galileo Galilei was at the heart of a battle over the Copernican model of the universe. With his innovative new telescope, Galileo discovered Venus's phases, Jupiter's four largest moons, sunspots, and the moon's topographical features. Venus was of particular interest, since its phases proved that the planets revolved around the sun. In addition, Galileo's observations showed that not everything must orbit the sun directly. His discoveries were not limited to the heavens; Galileo conducted experiments that yielded the laws of both falling and projected bodies. His legendary experiment of dropping two objects from the Leaning Tower of Pisa is just one example of Galileo's many attempts to explain the universe. Galileo's work, together with that of Johannes Kepler, led directly to the epitome of classical physics that was Sir Isaac Newton's lifework.

Newton, who was born in the same year that Galileo died, tied together many of the loose ends of classical physics with strings of mathematics. He is the generally accepted founder of modern calculus. Newton sought to explain natural philosophy, as physics and chemistry were collectively known at the time, with his mathematics. His early work was with optics, and led to the invention of the reflecting telescope, which caused fewer color anomalies than Galileo's refracting model. He later turned his attention to gravity, recognizing that the same force kept the earth orbiting the sun and made apples fall to the ground. Newton derived a law that explained almost every behavior of gravity. The inverse square law calculates the strength of gravity dependent upon the distance between two objects. Newton used this equation to calculate the attraction in the solar system and to explain both the tides and the moon's motions to a high degree of accuracy. Though many of his equations are still used today, Newton's work was based upon a model of the universe that would soon be radically changed. The picture of a three-dimensional space full of Aristotle's ether, with an absolute measure of time that never warped, was shattered irretrievably by a Swiss patent clerk named Albert Einstein.

Einstein made the biggest step forward in cosmology since Copernicus rearranged the solar system. He united Newton's and Huygens's theories of light and wrote the special theory of relativity. This second development, which at the time was understood by only a few physicists, secured Einstein a permanent place in the history of physics. The cornerstone of the theory of relativity is what Einstein called the principle of equivalence: there is no difference between constant acceleration and gravity. In the classic example, a person in an elevator that is moving through space with a constant acceleration equal to the gravitational force on Earth feels no different than if stationary in the elevator on Earth. From this postulate, Einstein realized that there is no absolute reference frame; every frame of reference is equally valid. Any of these frames can be considered stationary if it moves at a constant velocity, and anything within one of these frames will obey Newton's laws of physics. The same holds for any person moving at a constant velocity relative to another frame of reference. Not only did Einstein change the definitions of movement and rest, he also rewrote gravity. Out of the relativity theories came the image of spacetime, a four-dimensional medium through which everything moves and that can be pulled or folded like fabric. Ether was expelled from scientific thought. Gravity was no longer a force, but a warpage of spacetime. Any object trying to travel along a straight line would get caught in a massive object's gravity-caused spacetime warp and follow the circular or elliptical path made by the warp—in other words, it would orbit the massive object. In his later work, Einstein tried to unite the weak and strong nuclear forces with the electromagnetic force and gravity. He failed, and many scientists, including Hawking, are still trying to accomplish the same feat 50 years later.

Life

Hawking's interest in cosmology had its roots in his early childhood, long before his mathematical and scientific aptitudes emerged around age 14. He always liked controlling things, and he built a great number of models during his childhood. Hawking enjoyed the theoretical work inherent in designing the models. When he was a young man, his mother watched him walk home one night after the streetlights were turned out. He watched the stars, and she sensed that he always would, despite his dislike of observational astronomy.

Much of Hawking's best work has been done in conjunction with Roger Penrose, the eminent mathematician. When Hawking was one of Dennis Sciama's Ph.D. students, the postgraduate group benefited greatly from attending a series of lectures that Penrose had given on singularities, the unpredictable points of infinite density found at the center of black holes. Hawking immediately began applying Penrose's ideas to the entire universe. Later in Hawking's career, he worked directly with Penrose to investigate the big bang singularity.

Childhood and Adolescence

Hawking was born on January 8, 1942, in Oxford to Isobel and Frank Hawking. His father was a medical doctor who specialized in tropical diseases. When he was 8, the Hawkings moved to the small town of St. Albans. Hawking has since described the place as conformist. His family felt out of place and was considered outlandish by their neighbors.

Isobel was an ex-Communist who still had strong left-wing sympathies that she passed on to her oldest son. She liked to travel while her husband was in Africa, and the family visited many exotic places. Hawking modeled himself after his often-absent father.

He entered St. Alban's, an excellent secondary school, at age 10. He was awkward, lisped, and was poor at anything physical. He developed passions for mathematics and classical music. Hawking gained a group of friends similar to himself, considered rather geeky by their peers. They built a basic computer called LUCE, which they programmed to solve addition problems. In their teens, the group experimented with the metaphysical. After attending a lecture that outlined problems with reports of ESP success, Hawking decided that everything metaphysical was either false or had a scientific, rather than supernatural, explanation. He has retained the same view throughout his life.

When picking classes one year, Hawking had a dispute with his father over a mathematics class. Hawking's father considered mathematics to have few career options. However, Frank lost the argument and Hawking continued his study of math. Hawking applied to University College at Oxford, his father's alma mater. At 17, he made it through the grueling admissions exams and interrogation-style interviews, was accepted, and received a scholarship.

College and Postgraduate Study

The first year of college did not go very well for Hawking. He suffered from depression, had few friends, and was bored with the work. At the time, he has said, no one worked especially hard in Oxford. The academic load was light; for an intelligent person, college was easy. Hawking has said he worked, on average, about an hour per day through his 4 years at Oxford. The second year, he joined the rowing team and became popular almost immediately. Social events suddenly opened to him, and Hawking threw himself into the center of college life with gusto. He admits to drinking his fair share and playing many practical jokes. In this spirit, Hawking finished his studies and realized that he had not prepared properly for his final exams. In England, not all college degrees are created equal. A graduate could finish with a first, second, or lower-class degree. The class depended upon the student's grade on the final exams. Hawking's score was on the borderline between a first- and second-class degree, which necessitated that Hawking explain his plans to the college authorities. He did so, received a first-class degree, and entered Cambridge in October 1962.

Fred Hoyle was the most famous cosmologist in Britain in the early 1960s. Hawking applied for his Ph.D. study with Hoyle as his advisor, but Hoyle turned him down, and Hawking received Dennis Sciama instead. Once over his original disappointment, Hawking realized that Sciama was a better and more available advisor than Hoyle was. However, he was depressed again during his first semester. The work was difficult. Hawking had an insufficient grasp of mathematics, and although he could still stumble along with everyone else, he wasn't doing as well as he was used to doing. During this period, he also began having motor problems. In the morning, Hawking had trouble getting his hands to work to tie his shoes. At one point, he fell down a flight of stairs at school and had temporary amnesia. He took an IQ exam to make sure no permanent damage had been done, but the trouble continued.

As soon as Hawking returned home for the holiday break, Isobel noticed his clumsiness. His father thought, naturally, that Hawking had picked up a foreign disease on a trip. Hawking missed the beginning of the next school term because he was in the hospital for tests. He was told that he had an unusual case, but his diagnosis didn't arrive until after he returned to school: amyotrophic lateral sclerosis (ALS), better known as Lou Gehrig's disease. Hawking's prognosis was 2 years. The disease began developing quickly, forcing Hawking to walk with a cane. He spent a good deal of the next few months in his dorm room, deeply depressed.

Paradoxically, however, Hawking's life was about to turn around. At his parents' New Year's Eve party in 1962, he met a young woman named Jane Wilde. The two fell in love quickly, and were soon engaged. Hawking realized that he needed his Ph.D. to support a family. Frank, Hawking's father, went to see Sciama about shortening the time requirements for Hawking's Ph.D., but Sciama refused. He treated Hawking no differently from any of his other students, which greatly endeared him to Hawking. Hawking's fellow students—George Ellis, Brandon Carter, and Martin Rees—became his best friends and later his colleagues. Soon Hawking looked for a suitable thesis project. He became involved in solving some equations for a student of Hoyle's that related to the expansion of the universe. The subject interested him greatly. When, shortly thereafter, he attended Penrose's lectures on singularity theory and applied it to the big bang model of the universe, the two ideas coalesced into what would become Hawking's thesis project. He graduated in 1965, after producing a manifesto on expanding universes, and married Wilde in July.

Work and Marriage

Hawking received a fellowship in Gonville and Caius College at Cambridge, in the Department of Applied Mathematics and Theoretical Physics (DAMTP). The young couple moved to a two-story cottage on Little St. Mary's Lane.

The Hawkings entertained frequently. Hawking is known to all of his friends to be a very gregarious person and a trickster. During the mid-1960s, he cultivated an incredibly intelligent, cranky savant image. Though Hawking was still relatively unknown in the physics community, this image grew, along with his reputation for asking penetrating and sometimes uncomfortable questions at lectures, academic evidence of his love for mischief.

The mid 1960s were a very important time for Hawking. In 1967, his first child, Robert, was born. The next year, Hawking became a staff member of the Institute of Theoretical Astronomy. By that time, the ALS had restricted him to a wheelchair. His second child, Lucy, was born in November of 1970. Four years later he moved the entire family to California to do some work at Caltech. It was a happy time for the Hawkings, especially when, on their return to England, the Royal Society invited Hawking to be inducted as a Fellow. This accolade meant a great deal to him.

When the Hawkings returned from their trip to California, they moved to a larger, one-story house on West Road. Though it was a little farther away from Hawking's office at the DAMTP, the single level made it easier for him to move around. The ALS had worsened again. From 1975–1976, Hawking's work drew steadily more attention, earning him many awards: the Eddington Medal from the Royal Astronomy Society, the Pius XI Medal from the Pontifical Academy of Science, and the Royal Society's Hughes Medal, among others. During the second half of the decade, the popular publicity Hawking received also rose dramatically. More honorary titles and awards piled up, including the Albert Einstein Award in 1978, esteemed more highly among physicists than the Nobel Prize.

However, things were not so rosy on the home front. Hawking's marriage was undergoing continuous stresses. Jane, a devout Roman Catholic, was aggravated by her husband's efforts to explain everything with science. Hawking argued with Jane more than once about the role and designated abilities of a divine Creator. In addition, Jane wanted to pursue her own career, and felt that she was a mere appurtenance to Hawking. These problems eventually led to their divorce in 1990. In the 1970s, however, that was still far in the future, and in 1979 Hawking's last child, Timothy, was born. The same year, Hawking was made the Lucasian Professor of Mathematics, Newton's chair at the University of Cambridge.

At this point, with a new baby and two private school tuitions to pay for, there was a dearth of money. Without telling anyone, Hawking began working on a popular cosmology book, but the dream wouldn't bear fruit for years. In the meantime, more accolades poured in. In 1981, Hawking was knighted a Commander of the British Empire, and four colleges, including Notre Dame and Princeton University, made him an honorary doctor of science the next year. In 1985, he embarked on a world lecture tour and had his portrait hung in England's National Gallery. However, the same summer his voice was silenced forever. One night in July, he choked in his hotel room. He was diagnosed with pneumonia and Jane was told that she would have to allow the doctors to cut a hole in his trachea to insert a breathing device. Hawking would no longer be able to speak, but he would live. She approved the operation. A short time later, Walt Waltosz sent a computer voice synthesizer called the Equalizer to Hawking. With this program installed on a wheelchair-mounted computer, Hawking can deliver lectures and speak more intelligibly than before the tracheotomy, although at the reduced rate of about 10 words per minute.

In 1990, Hawking and Jane divorced, and he moved in with one of his nurses, Elaine Mason. The reports of abuse that circulated shortly after their marriage have been strongly denied by Hawking, who refused to press charges.

Major Ideas

Hawking has had many ideas that, cumulatively, have changed the faces and directions of cosmology and black hole research. The earliest idea, the one that eventually blossomed into his Ph.D. dissertation, was to apply Penrose's singularity theory to the universe. An offshoot of this concept was the proof, accomplished with Penrose's help, that the big bang was a naked singularity at the beginning of time. At the time, big bang cosmology contended with Hoyle's pet theory of a "steady-state" universe, which did not recognize an expanding and evolving universe from a cosmic point of origin billions of years ago. Hawking no longer agrees with this steady-state hypothesis or his earlier big bang theory. Instead, he now proposes his own "no-boundaries" theorem, which implies a finite universe without a beginning in time before the big bang. This theorem has had an important impact on cosmology, helping to eliminate the steady-state concept altogether.

Hawking also realized, getting into bed one night in 1970, that the event horizon of a black hole does not shrink, but grows with all matter that enters it. His most famous discovery, Hawking radiation, led from this idea. The result of a 1973 argument with a graduate student about entropy also helped Hawking formulate this discovery. The corollary of Hawking's nocturnal epiphany was the surprising fact that black holes, known for dragging everything in their vicinity past the "point of no return," actually emit particles. Hawking also developed the concept of "mini-holes," tiny black holes that can form only in certain conditions and that radiate massive amounts of energy.

More recently, Hawking has taken Richard Feynman's method of finding the most likely path of a particle in quantum physics, known as the "sum-over-histories" or "path integral" approach, and applied it to the entire universe. This groundbreaking concept led to his no-boundaries theorem, developed in the early 1980s, which states that the big bang did not have a spacetime singularity, and neither will a potential big crunch scenario. Hawking is still working at Cambridge, further developing this concept and that of imaginary time.

Publications

Over the almost 5 decades that Hawking has been researching cosmology and black holes, he has published half a dozen important works. Only one of these, *A Brief History of Time,* has found an audience outside theoretical physicists. The first major paper he wrote, "Singularities and the Geometry of Spacetime," was in conjunction with Penrose. It won the duo the Adams Prize in 1966, when Penrose was working for Birkbeck College. This paper detailed their work on the singularity theorems.

Five years later, Hawking was in print again, this time with fellow Sciama student, George Ellis. *The Large Scale Structure of Spacetime* built on this work, giving a description of the general theory of relativity and then explaining the importance of spacetime curvature. Singularities were explained through the structure of spacetime, and proven to be unavoidable in black holes and at the big bang.

General Relativity: An Einstein Centenary Survey, published in 1979 with Werner Israel, was written as a tribute to one of the greatest scientists of the 20th century. It gave an overview of what had been accomplished with Einstein's mathematical brainchild, the general theory of relativity.

Hawking coauthored and coedited *Superspace and Supergravity* with M. Roček. This compilation of essays, published in the United States in 1981, covered the then-current attempts to create the unified field theory, the set of mathematical formulae that would explain every physical phenomenon. This effort has been foiled every time by nonsensical answers produced when the equations for quantum theory and relativity are combined.

The next year Hawking published *The Very Early Universe,* which covered what was then known about the big bang and the moments shortly thereafter.

His most famous publication, *A Brief History of Time,* was published in spring 1988. Hawking's usual publisher, Cambridge University Press, offered him the largest book deal in their history, 10,000 British pounds. Hawking, however, insisted upon more money and instead accepted Bantam's bid of 250,000 American dollars. Manuscript editing began, and problems arose. After learning to be concise so he could communicate more rapidly using the Equalizer, Hawking needed to use many more words to explain his work to laypeople. Eventually, the book was deemed readable. In the meantime, other countries' offers were pouring in: Germany, Japan, China, Russia, and half a dozen others. Bookstores immediately sold out upon *A Brief History of Time*'s release. Five hundred thousand copies had been sold by summer. It remained on the *New York Times'* best-seller list for 53 weeks, and on the *Sunday Times of London*'s for more than 200 weeks. Soon producers were clamoring for film rights, and a documentary, also called *A Brief History of Time,* was released in 1991.

The following sections review Hawking's work and ideas in greater detail.

The Work

Black Holes

Around the time when Hawking began working in the field of theoretical physics, many things that are now well known had yet to be discovered. White dwarf stars—small, brightly burning remnants of stars like the sun—had been observed, but anything denser than these objects was considered impossible. Quantum theory predicted neutron stars, but since most of these are dim, their existence had not been verified. Theoretically, black holes were known to form at around three solar masses, and physicists believed that one of these exotic phenomena would bend spacetime completely around itself.

Hawking's first research project was on black holes, and as soon as he received his Ph.D., he and Penrose began work on finding out more about singularities. They proved mathematically that in our spacetime, certain situations necessitate singularities. At the time, these were considered to be a glitch in Einstein's theory of relativity and even more absurd than black holes. Hawking and Penrose's breakthrough work gave the proof. Penrose's mathematical method was a perfect match for Hawking's understanding and physical applications.

In the 1960s, Hawking helped establish the theory of black holes and brought them out of the realm of science fiction. Penrose had already proved that a black hole could not form without a singularity at its heart, but the entire concept still garnered skepticism until 1973. That year, the new field of X-ray astronomy turned up Cygnus X-1, an X-ray source that has a 95% probability of being a black hole, according to Hawking.

In 1970, Hawking turned his attention to the event horizon of a black hole. The event horizon is defined as the point where all of the trapped light rays that almost escaped hover, also known as the point of no return for incoming matter. Hawking realized that singularity theory could be applied to black holes. An American graduate student, Jacob Bekenstein, published an article claiming that a black hole's entropy, its measure of disorder, was the same as its event horizon. Hawking was horrified; a black hole couldn't have entropy. According to the second law of thermodynamics, the entropy of the universe should increase with time. Hawking, however, thought entropy around a black hole decreases because the black hole swallows disordered matter, leaving nearby space more orderly. When he tried to prove that Bekenstein was wrong, Hawking instead proved the student partially right. This discovery became known as Hawking radiation. The entropy of a black hole is proportional to its surface area, defined by the event horizon. Furthermore, this area can never decrease, but only increase as matter and energy fall inward. These two ideas, Hawking radiation and the increasing event horizon, were major advances in black hole theory.

Hawking radiation is, simply, the radiation that a black hole emits. This radiation adds disorder to the universe at a rate that perfectly maintains the second law of thermodynamics. It can be described by visualizing a particle and its antiparticle, for instance, an electron and a positron. The particle pair comes into existence by borrowing some of the immense stored energy in the black hole and converting it to matter. Such particles are known as virtual pairs, because they are born and annihilate each other so fast that one cannot detect their existence directly. These pairs turn up very close to the horizon, and one particle is pulled away from the other by the hole's gravity.

This pulling channels more of the black hole's energy into the particle that escapes while the other falls into the hole. The escaping particle therefore appears to have been emitted by the hole, and carries part of the hole's mass away with it. Hawking found that in this manner a black hole would, over eons, lose its mass at an accelerated rate, until it became so small that it exploded, spraying radiation in every direction. Hawking was sure his calculations were wrong, but was convinced otherwise by Penrose and Sciama. Upon further investigation, Hawking found that the temperature of a black hole depends inversely upon its mass, and the higher the temperature, the sooner the hole would explode.

History of the Universe

The origin of the universe was not generally considered in the realm of science until the 1950s. The big bang had been predicted through Einstein's equations, and physicist Alexander Friedmann had even calculated the three universes allowed by Einstein's equations. Einstein tried his best to discredit these ideas, preferring the idea of the "cosmic egg," an immense atom-like mass that exploded, releasing the universe's matter. On the whole, however, the subject was merely ignored.

The big bang was, in fact, given its name by its most famous opponent, Fred Hoyle. He proposed the so-called steady-state hypothesis in which the universe expanded very slightly and had no temporal origin or end. The big bang was a label born of sarcasm. However, the name stuck, and Hawking's doctoral thesis proved several problems with the steady-state concept, soon to be discarded entirely. During his work with Penrose from 1965 to 1970, Hawking helped to prove that the big bang had a singularity from which the entire universe expanded, and that the potential big crunch would also have a similar structure.

In 1975, Hawking focused solely on the big bang. During the previous year, he had met his next set of colleagues at Caltech: Kip Thorne and Don Page. Years before, George Gamow, Ralph Alpher, and Robert Herman made predictions for a ubiquitous radiation background left over from the big bang. In 1965, Arno Penzias and Robert Wilson discovered it. The anticipated temperature, about 2.73° Kelvin, and wavelength, microwave range, were confirmed. The background radiation prediction was a success that helped secure the position of the big bang theory. Hawking probed ever farther back, trying to understand the moment of the big bang itself, the point at which time started. Due to the geometry of the big bang, there is no time before the event, and no one can discover what happened before the Planck time, about 10^{-43} seconds. Hawking kept trying, though, and created a more densely populated view of the early universe than previous scientists did. Cosmologists before Hawking, including Hoyle, had described the conditions and time frame that produced the most abundant elements in the universe: hydrogen, helium, and deuterium. These are the elements that stars burn for fuel, creating the heavier elements, like carbon, by nuclear fusion. However, the image of the first few hours and years after the big bang was a picture of radiation and atomic nuclei floating in an evenly distributed, hot morass of expanding space.

Hawking did not like this picture; if everything was evenly distributed, how did galaxies and stars form in the first place? There was some amount of irregularity, he decided, and was vindicated with the discovery of discrepancies in some areas of the background radiation. Hawking drove farther: If there were irregularities, there would be greater gravity in certain areas. These extremely pressurized areas might create unusually tiny black holes that evaporate quickly when compared to their contemporary stellar counterparts. These should still exist, and some might be exploding close enough for us to detect their gamma ray death throes. Unfortunately, most gamma ray bursts detected have been explained using more standard descriptions than Hawking's mini-holes.

Hawking decided to find out how likely the universe is; literally, what the probability was of the universe developing this way. The only way to deduce this was to consider the entire universe to be one body, the same way that an atom or a proton is considered one unit. To accomplish this calculation, Hawking utilized Richard Feynman's quantum sum-over-histories or path integral approach. This involves calculating all of the paths that a particle can take to get from point A to point Z, and each path's probability. Very different paths usually cancel each other out, leaving a few similar, highly probable choices. That is exactly what happened when Hawking used the path integral for the universe. Working together with Jim Hartle, the duo discovered that a finite universe with no boundaries is one of the most likely types. The easiest way to understand the no-boundaries theory is to think of the earth, which is finite yet has no edges. Hawking was also able to eliminate the big bang singularity by introducing the idea of imaginary time, where the singularity can be thought of as the earth's North pole. The earth grows in circumference from this ordinary point, like the universe did from the big bang. The earth also comes back to one point at the South pole, which represents the potential situation of the universe collapsing into a big crunch state. Hawking discovered, furthermore, that time would not reverse in the big crunch. This universe is completely self-contained, and time always moves forward.

Hawking presented his idea at a Vatican scientific conference. He still could not see back to the very beginning, but there was other progress. Quantum theory stated that the density of the original state was not infinite, which would help to explain the irregularities in the early universe; if the density had been infinite, there would have been no room for density variations.

The "chaotic inflation" concept also developed around this time. It states that there is an infinite universe beyond the boundaries of this one, with areas that are expanding and contracting. Some of these areas grow into their own universes. Alan Guth created the original inflation hypothesis, proposing that the universe is very uniform and its curvature nearly flat because it expanded from an extremely small, unstable state to a softball-sized stable state at a high velocity. Hawking vigorously defends both theories.

Hawking's impact on modern cosmology cannot be overstated. He was instrumental in bringing black holes into the light of physical investigation to be considered seriously and, eventually, discovered. He has also given the physics community new tools and insights into the origin and history of the universe. In addition, Hawking has provided a union of important facets of relativity and quantum theory. Outside of his own direct research, he has also brought many of the obscure concepts and near-incomprehensible methods down to the level of the layperson, making the universe a little more accessible to the public.

In fact, social work is one of the areas where Hawking has used his celebrity most. Hawking has lent support and help multiple times to disabled people in battles against various agencies for heightened accessibility. The social and political awareness that Isobel instilled in her son has flowered in his crusades, where he is using his popularity to bring about change.

Ideas and Beliefs

Cosmological

Hawking has never been a person to leave others in doubt about his opinions, especially concerning cosmology. He believes that his no-boundaries theory is the beginning of the complete union of the titans of physics: relativity and quantum theory. Hawking is confident that the answers to all of the questions humans have ever asked about the universe will be found mathematically, and most likely in the near future. He dislikes the anthropic principle's explanation of all phenomena: Simply put, that everything is how humans observe it because if it was different, there would be no humans to observe it. Hawking wants solid, scientific answers to questions. Therefore, he has put his support behind the superstring theory, hoping that the final results of its calculations are as promising as those already known. However, he is reticent to believe in the extra, submicroscopic dimensions that string theories necessitate.

Hawking has also revised some of his earlier conjectures and discussed some exotic topics more closely associated with science fiction than with physics. He now thinks that mini-holes may be less common than he previously believed. He is also considering the possibility that when a black hole gets very small near the end of its life, it may just disappear from its region of the universe, removing its singularity as well. On the subject of determinism, Hawking thinks everything is probably determined, but no one can ever find out if it is. His opinion of time travel is thoroughly scientific. Since the uncertainty of the position and velocity of particles inherent in quantum physics can never be eliminated, quantum fluctuations would most likely destroy the tiny, opening wormhole necessary for time travel. Furthermore, if surrounding particles could travel through the wormhole, they would begin an ever-accelerating loop that would result in radiation too strong for any human to survive passing through. Hawking has called these ideas his "chronology protection conjecture," an answer to the potential time causality problems produced by time travel.

Social

Hawking's social conscientiousness is often found in his work as well as in his outside activism. An explanation of every question should be attempted, he asserts, no matter how daunting or controversial the subject is. No topic should be consigned to metaphysics or religion, in his opinion. The universe should always be under inspection until humanity as a whole understands everything, and this search for information should be conducted freely, without derision on the part of anyone else. Without passing judgment on the subject, Hawking also asserts that human engineering, with great advances in the capacity for knowledge, will occur very soon despite all efforts to stop it. Directed engineering, he states, will overtake evolution. Eventually, in Hawking's opinion, humans will acquire enough wisdom to stop blowing themselves up, avoiding the complete destruction of the human species.

There are many things that Hawking does not believe in, as well. For instance, he avers that no civilization, regardless of where it is or how advanced it is, will ever be able to control the entire universe. In addition, he doesn't believe that any alien civilization has visited Earth.

When discussing religion, Hawking can be extremely ambiguous. He has stated his belief to be that if a Creator does exist, there was a limited number of ways that the universe, initiated by this figure, could have evolved, regardless of that Being's wishes. Hawking strongly advocates the viewpoint that no question should be left to religion. Yet in Hawking's books there are multiple mentions of God, discussing his powers, knowledge, and role in the universe.

Conclusion

Stephen Hawking still works in his little office in the DAMTP at Cambridge. He oversees a few Ph.D. students and runs the relativity group. However, Hawking is largely free to work on his research. He is still pursuing his concepts of imaginary time and the no-boundary universe as the tools to find final cosmological answers.

Hawking's contributions to physics are frequently ranked with the findings of Newton and Einstein. He has discovered many of the main features of black holes, partially united the theories of quantum mechanics and relativity, and proved enough of his work to win widespread recognition of black holes and singularities as real phenomena. Added to these accomplishments, he has managed to popularize a difficult area of science and developed new methods with which to analyze the beginning of the universe. The most productive era of Hawking's work was several decades ago, but he has not retired yet.

Several areas that Hawking has been involved in are among the most widely investigated new sectors of research. Superstring theory has been gaining popularity since the 1980s, and may hold answers to the remaining unanswered cosmological questions. In string theory, the universe contains 11 dimensions—more or fewer depending upon which of the six interconnected theories one considers. What were particles and waves have been reconfigured into one-dimensional loops or strings of pure energy, so tiny that no equipment available can detect their shape. This theory has shown promise, but it is still being constructed and so cannot be used for all situations.

The short gamma ray bursts that Hawking had hoped would prove the existence of mini-holes are still something of a mystery. Most of these radiation events have been identified as colliding neutron stars, but recent reports of slightly longer bursts, in the range of a few seconds to almost 2 minutes long, cannot be explained so easily.

Gravitational waves, which are formed from the fabric of spacetime and, theoretically, ripple outward from colliding black holes, have been studied theoretically for some time. However, there is no concrete evidence to validate their existence. The subject has experienced a recent revival of interest, and the range of error in the calculations is down to about 20%.

Emily Sobel

See also Aristotle; Big Bang Theory; Big Crunch Theory; Black Holes; Copernicus, Nicolaus; Cosmogony; Cosmology, Inflationary; Einstein, Albert; Experiments, Thought; Galilei, Galileo; Newton, Isaac; Quantum Mechanics; Relativity, General Theory of; Singularities; Time Dilation and Length Contraction; Time Warps; Universe, Origin of; Universes, Baby

Further Readings

Cropper, W. H. (2001). Affliction, fame, and fortune. In *Great physicists: The life and times of leading physicists from Galileo to Hawking* (pp. 452–463). New York: Oxford University Press.

Greene, B. (2004). *The fabric of the cosmos.* New York: Random House.

Hawking, S. (1993). *Black holes and baby universes.* New York: Bantam.

Hawking, S. (1996). *A brief history of time.* New York: Bantam.

Hawking, S. (2001). *The universe in a nutshell.* New York: Bantam.

Hawking, S. (2003). *The illustrated history of everything.* Beverly Hills, CA: New Millennium Press.

McEvoy, J. P., & Zarate, O. (1997). *Introducing Stephen Hawking.* New York: Totem.

Overbye, D. (1991). *Lonely hearts of the cosmos: The story of the scientific quest for the secret of the universe.* New York: HarperCollins.

White, M., & Gribbin, J. (1992). *Stephen Hawking: A life in science.* New York: Dutton.

Healing

Healing is the act of repairing or mending, be it tangible or intangible, visible or invisible, over a period of time, whether so lengthy as to be imperceptibly slow or so brief as to appear instantaneous. Time is a key ingredient in any healing, as this process does not in fact occur instantaneously. Rather, in many cases one needs patience to wait for time to pass before the healing reaches its completion or even until the healing had progressed sufficiently to be observed. There is rarely a set time for healing to be completed; rather, one knows when the healing is completed only by the lack of further change taking place.

Healing, whether physical or emotional, is a change; change cannot occur without the passage of time. The passage of time can be measured by the progress seen in the healing—be it a scar forming, bleeding stopping, or a bone knitting itself back together. Although healing can seem like a reversal of time, changing something back to how it once was, in reality it is, of course, always changing to new.

Emotional healing can be harder to perceive, involving as it does the intangible, the unseen, such as the healing of a broken heart or the healing after the death of a loved one. Because the changes in emotional healing are not as easily seen or measured as in the case of physical healing, one may lose track of the progress toward healing at any point on the path the healing has already taken. Such healing may involve rituals that themselves take time, and through these time-based rituals, such as the Catholic anniversary mass or the Jewish kaddish on the anniversary of death, the healing is aided. This time-oriented set of rituals helps with healing that which cannot often be healed through medicine. Time in its sacred aspects is commonly identified with regeneration and renewal.

Sara Marcus

See also Decay, Organic; Dying and Death; Gerontology; Longevity; Medicine, History of

Further Readings

Imber-Black, E. (1991). Rituals and the healing process. In F. Walsh & M. McGoldrick (Eds.), *Living beyond loss: Death in the family* (pp. 207–223). NY: Norton.

Milburn, M. P. (2001). *The future of healing: Exploring the parallels of Eastern and Western medicine.* Freedom, CA: Crossing Press.

Weiss, B. L. (1993). *Through time into healing.* New York: Simon & Schuster.

Heartbeat

The heart is the muscular organ responsible for circulating blood through the body. The average animal heart will beat several billion times throughout life. The human heart, for example, will beat approximately 2.8 billion times over 75 years at 72 beats per minute. The rate at which the human heart beats is controlled by many different factors. The central nervous system controls heart rate with the medulla oblongata. Activation of the parasympathetic nervous system, using the vagus nerve, causes a decrease in heart rate, while activation of the sympathetic nervous system produces an increase in the rate at which the heart beats. The endocrine system controls the heartbeat with hormones, such as epinephrine (adrenaline), which increases heart rate.

Generally, the size of an animal will correlate with how many times its heart will beat in a minute. Smaller animals tend to have a higher resting heart rate, such as the mouse with a heart rate around 500 beats per minute. Larger animals, like the whale or elephant, tend to have a lower resting heart rate, roughly around 20 and 35 beats per minute, respectively. During times of hibernation, the heartbeat in some animals can drop to rates drastically lower than while not hibernating. During summer months, a black bear has a heart rate between 40 and 50 beats per minute. While hibernating, this can slow to as few as 8 beats per minute.

The embryonic heart in humans begins to beat around 3 weeks after conception, at which time it beats at around 75 beats per minute, a rate near the mother's. It then increases linearly to over 170 beats per minute, peaking 7 weeks after conception. The heart rate then decreases to around 145 beats per minute by the 13th week, where it remains until birth. Heart rate remains high throughout childhood, usually not becoming 70 beats per minute until after adolescence.

Young children are often born with heart murmurs. Although these can indicate a defective heart valve, most heart murmurs are from a more benign cause, a patent foramen ovale (PFO). This is an incomplete closure of the wall between the two atria that closes over time as part of normal neonatal development. If a PFO fails to close, as it does in between 20% to 25% of persons, and persists through adulthood, it can increase risk of stroke. This is because minute blood clots in the deoxygenated blood from the peripheral tissues can bypass the lungs, where they are normally filtered out by the microvasculature of the lungs, and pass through the hole between the two atria. These small aggregates can then find their way to the brain and block blood flow. The result can be either a stroke or a transient ischemic attack (TIA), also know as a mini-stroke.

Blood carries oxygen from the lungs to the peripheral tissues and transports nutrients, hormones, and white blood cells. It also aids in waste removal. By beating, the heart is able to pump blood continuously. The rhythmic contractions of the atria and ventricles occur in a synchronized sequence that ensures efficient blood flow. A single heartbeat begins as the result of a spontaneous, rapid depolarization of the pacemaker cells located in the sinoatrial node on the right atrium of the heart. This generates a stimulus for contraction. Pacemaker cells in humans depolarize 70–80 times per minute, resulting in a heart rate of 70–80 beats per minute.

Modern technology has developed artificial pacemakers for patients who suffer from heart problems in which either the natural pacemaker cells in the sinoatrial node do not signal at a high enough rate, or they fail to transmit a stimulus for contraction altogether. The small electronic device is surgically inserted into the chest and connected to the heart with electrodes. The electrodes send electrical impulses to the heart, stimulating each heartbeat. More advanced artificial pacemakers can even control the rate of the electrical impulses, increasing heart rate during physical exertion and decreasing it during times of rest and sleep.

In the late 1960s and early 1970s, around the same time that artificial pacemakers were being successfully implanted and becoming more reliable, the first artificial hearts were being created. Designed by Domingo Liotta, the first artificial heart was successfully implanted in 1969 by surgeon Denton Cooley, although it was used for only a short period of time until a donor heart became available. The Jarvik-7, designed by Robert Jarvik, was used in about 90 patients as a permanent heart replacement before the practice became banned because of the low survival rate of its recipients. Although most patients lived less than a year with the Jarvik-7 as a permanent replacement, it was still used as a temporary device for patients waiting for donor hearts to become available for transplant. In 2004, CardioWest's temporary Total Artificial Heart (TAH-t) was approved by the Food and Drug Administration, the first implantable artificial heart to receive FDA approval. Developed from the Jarvik-7, it is used only to extend life in patients awaiting heart transplant surgery. One patient lived almost one full year with the TAH-t before receiving a donor heart. Over 75% of patients that receive the TAH-t survive through and after the following human donor transplant surgery, most over 5 years.

As the heart ages over time, it can suffer from an array of diseases that ultimately lead to death. Some diseases can be fatal in a very short time; others can take several years until the heart fails. Coronary heart disease is the result of the buildup of plaque in the arteries that supply oxygen to the heart muscle. This occurs over an extended period, sometimes decades. When the plaque then ruptures, the blood forms clots on the plaque and blocks the passage of blood to the heart tissue. Without oxygen it takes only minutes for the heart tissue cells to begin to die and the heartbeat to stop. This is called a myocardial infarction, or heart attack. The heart can also fail as the result of infection by bacteria or a virus. Even poor diet, hypertension, high cholesterol, and structural defects can affect heartbeat and shorten the lifespan of the heart. Although it is possible to survive for prolonged periods of time with some heart diseases, it generally takes only minutes for oxygen-deprived tissues in the heart to die and the heartbeat to stop.

Michael F. Gengo

See also Decay, Organic; Diseases, Degenerative; Dying and Death; Healing; Medicine, History of

Further Readings

Martini, F., & Bartholomew, E. (2007). *Essentials of anatomy and physiology* (4th ed.). San Francisco: Pearson/Benjamin Cummings.

McMillian, B. (2006). *Human body: A visual guide.* Buffalo, NY: Firefly Books.

Tyson, P. (2000). *Secrets of hibernation.* Retrieved July 12, 2008, from http://www.pbs.org/wgbh/nova/satoyama/hibernation.html

Heat Death, Cosmic

The cosmic heat death of the universe is a prediction that, as everything tends to move from order to chaos, the universe will eventually "run down" like an old clock. The second law of thermodynamics states that entropy tends to increase in an isolated system. The arrow of time points to the fact that all heat in the universe will die eventually. This is borne out by the everyday observation that things tend to move from a higher energy state to a lower energy state. High energy states can also be manifested as more highly organized collections of atoms. Any solid will gradually disperse over time. Given enough time, even all the atoms of the universe will break down.

As various physical phenomena have been studied and understood it has become apparent that over time everything moves to this lower-energy, more dispersed state. From the universe's first moments as a single high-energy point of all matter, it is moving toward dispersal as the energy that binds everything runs down. Scientists currently believe we live in an open universe and that everything will continue over time to expand infinitely in all directions. According to current understandings of particle physics and cosmology, in around 10^{100} years the universe will move to a low-energy, steady state of photons and leptons, dispersed through infinite space.

The death will happen in three phases. First the universe will become dark as the stars go out. The death will follow the pattern of increasing entropy as the energy level and matter density of the universe drop to a level at which galaxies and stars cease to form, around 10 to 100 trillion years from now. Some 14 trillion years after that, the last of the long-lived stars (red dwarves) will go out.

The second phase will be the decay of the complex structure of the material universe. At a point some 10^{14} (1,000 trillion) years from now, the visible structure of the universe will begin to degenerate at its lower levels; planets will begin to decay as they leave their orbits as the result of an accumulated weakening of the gravitational force. These changes will be followed approximately 10^{15} years later by degeneration at the highest levels; galaxies will begin to decay as stars leave their orbits. The final level of visible structural disorder will not take place until around 10^{40} years in the future when matter itself begins to break down. All matter is made of elementary particles, chiefly protons, neutrons, and electrons in various combinations. The predicted half-life of protons is 10^{36} years, which means that by 10^{40} years from now virtually no protons will exist.

The last phases of the universe will be visible only at the subatomic level. When more than 10^{100} years have passed, the last remaining macroscopic structures will disappear as the last black holes evaporate into photons and leptons. The universe will be at an absolute minimum temperature and a featureless sea of subatomic particles subject only to random quantum fluctuations.

John Sisson

See also Black Holes; Cosmogony; Cosmology, Inflationary; Entropy; Russell, Bertrand; Time, End of; Universe, End of; Universe, Evolving; Stars, Evolution of

Further Readings

Chow, T. L. (2008). *Gravity, black holes, and the very early universe: An introduction to general relativity and cosmology.* New York: Springer.

Gribbin, J. (2006). *The origins of the future.* New Haven, CT: Yale University Press.

Hegel, Georg Wilhelm Friedrich (1770–1831)

German philosopher Georg Wilhelm Friedrich Hegel (1770–1831). A professor at Heidelberg (1816–1818) and Berlin (1818–1831), he differed with Immanuel Kant in allowing that mankind possessed absolute knowledge. He influenced Karl Marx and the existentialists.

Source: Library of Congress, Prints & Photographs Division, LC-USZ62–130772.

The philosopher Georg Wilhelm Friedrich Hegel was born in Stuttgart, Germany, and educated there and in Tubingen. Along with Schelling and Fichte, he was one of the prime exponents of German Idealism. Over the course of a distinguished academic career, Hegel held positions at several universities including Jena, Heidelberg, and Berlin, and through his teaching and his published works became one of the most influential thinkers in the history of Western philosophy.

Hegel's Analysis of Time

Nature and Spirit

In his first essays, written in his youth, Hegel defines time in an essentially negative way, as a destiny hostile to human beings, or as a finite reality intended to be transcended by reason in the eternal knowledge of Ideas. Directly following the Platonic tradition, time is deprecated in order to give greater importance to eternity. It was only later, during the years 1803–1806, that Hegel developed a positive conception of time in the successive preliminary sketches of his philosophy of nature, which are marked by the major discovery of the *dialectic of time*. Hegel considered that time as such, in its original springing forth, has to be understood as an immemorial element of Nature, which is not yet transformed, neither by language nor by memory, into the time proper to the Spirit, history. Nature is the opposite of Spirit, Absolute Spirit as the other of itself, or the hidden Spirit. As being-other than the Spirit, Nature maintains a double relationship with the latter. It is opposed to it as it is its negative, the *being-other* than the Spirit. But at the same time, it has a hidden relationship of identity with Spirit, since as being-other *than the Spirit,* it is already itself the life of the Spirit that can, by studying Nature, precisely know itself. Philosophy of nature is this knowledge of Nature through Spirit, understood as progressive recognition of Spirit in the being-other.

In the courses given by Hegel at the University of Jena in 1804 and 1805 (the manuscripts of which have been preserved), time is the first moment of the philosophy of Nature, the first form of the exteriorization of Spirit in nature. Time is defined by two concepts, the infinite and the negative. Negativity characterizes the destructive aspect of time, which he later described in detail in his 1817 work, the *Encyclopedia of the Philosophical Sciences.* As for infinity, it leaves open the possibility for a positive determination of time, which is likely to give itself to Spirit. From this double characterization of time flows the dialectic of the three temporal dimensions: present, future, and past. The first moment of time is the present, the Now. The Now manifests itself but does not last; it is immediately suppressed by the future, which comes to take its place. The Now has for its very being no longer being. Once suppressed, the Now becomes the past. The past, in turn, suppresses itself in the sense that it leaves a place for a new Now to come forth. In other words, the future is the negation of the Now, and the past is the negation of the future, and therefore the negation of the negation of the Now. Since double negation is affirmation, the past is the affirmation of a (new) Now. At this point, Hegel distinguishes two forms of time with the help of his logical theory of the two infinites. Either the new Now is a Now without a past, a pure Now without a relationship to the preceding Nows, or time is nothing other than the indefinite repetition of a Now always identical with itself, the bad infinity proper to Nature. In this unending linear movement, there is neither newness nor progress. As Hegel was to say later in Berlin, in nature there is nothing new under the sun. Or, the new Now is a Now of the past, a present that returns to the past, to include it in itself and to enrich itself even more. The image of the circle replaces that of the line. This "real" time is true infinity, which, in a circular movement, goes from the present to the present, through the future and the past. From this real time flows the principle of historicity: the living conservation of the past in the present.

In his 1805–1806 course on the philosophy of nature, Hegel explains the consequences of the primordial role of the past in the dialectic of real time. The past is not only one of the dimensions of time, it is the truth, the goal of time. According to Hegel, the privileged meaning of time is the past, understood not as a moment isolated from time, but as the culmination of "real" time, the concrete present. Against philosophers such as Schelling, who wanted to denigrate if not abolish time, Hegel affirms both the temporality of all Being, in that time is the supreme power imposing itself on all Being, and the rationality of this temporality, in the sense that the true knowledge of beings must consider the latter in light of their historicity. Philosophical knowledge is not the eternal contemplation of the eternal; it is knowledge of being "in its time," according to the temporality that is proper to it. Hegel reverses the traditional relationship of the subordination of time to eternity. The truth of time is not an absolute eternity, since, on the contrary, it is time itself, elevated to its real form, that is the truth of eternity.

Space, Time, and Negativity

The courses on the philosophy of Nature dating to Hegel's Berlin period (1818–1831), which provide commentary on the second part of Hegel's *Encyclopedia* appearing in 1817, do not call into question the philosophical rehabilitation of time undertaken in Jena. Hegel, however, leaves in the background the dialectic of time in order to concentrate on its negativity. According to Hegel, Nature is the Idea in the form of otherness and exteriority. The form of exteriority is divided into the two forms of space and time. The principal difference between space and time is negativity. Space does not allow negativity to deploy itself within it; negativity remains, as it were, paralyzed. The different parts of space coexist next to each other without cancelling each another out. It is not the same for time, the negativity of which incessantly relates to itself and continually suppresses its own moments. In fact, time is the being that, in being, is not, and in not being, is

(*Encyclopedia,* §258). In the *Science of Logic,* Hegel distinguishes pure indeterminate nothingness, which designates the nothingness that is not at all, from determinate nothingness, the non-Being that contains an essential relationship with Being. Negativity is the negation of negation, which ensures the conversion of determinate nothingness into Being. In the light of these logical determinations, it is clear that time is neither pure nothingness nor determinate nothingness, but a type of negativity. Time is the continual passage of Being into nothing—from the present into the past—and from nothing into Being—from the future into the present. It is this double passage that defines the negativity of time. Only the present is; it enjoys in nature an absolute right. But the present contains within it the negativity of time, such that it does not cease to suppress itself and to disappear. Time is a "going-out-of-itself" (*Außersichkommen*), the "negativity going out of itself" (*die außer sich kommende Negativität*). Time projects Being out of itself; it disperses it in a constellation of present, future, and past moments, all exterior to one another. For Hegel, the negativity of time is ecstatic, not so much in Martin Heidegger's sense, but in the *ekstatikon* of Aristotle, who, in his *Physics,* attributes to time the origin of the corruption that is inherent in all natural movement. In Nature, temporal negativity is essentially destructive, the result being pure, indeterminate nothingness, the irreversible disappearance into the past. Hegel uses a play on words in comparing time (Chronos) to the Greek god Kronos (Cronus) who engenders everything and devours his own children.

Becoming

Time not only involves the irreversible disappearance of events into the past. The moment of the disappearance supposes the continual birth of the moments that are destined to disappear. Time includes within itself a certain generation, which Hegel conceives through the category of Becoming. Time is, more exactly, the "intuitioned Becoming." According to its logical definition, Becoming is an alternation of birth and disappearance; it is formed by the unity of these two concepts. But logical Becoming and temporal Becoming could be confused, and the adjective *intuitioned* is there to distinguish them. Intuition traces the boundary between temporal Becoming and logical Becoming, as pure thought. Being, nothing, and Becoming are thoughts, but time is not of thought, and that is why it is intuitioned Becoming, which is experienced in existence. The concept of time is thought, and it is, like all concepts, eternal. Time itself in its existence is intuitioned. That time is a form of Becoming also means that it is not a fixed, permanent framework in which things happen. The only permanent thing in time is the absence of all permanence. Things are not in time, since time itself is in things in the form of an unceasing negativity that devours them from the inside. As Becoming, time is a river that carries everything away with it, including its own banks.

History and Spirit

Hegel clearly distinguishes the domains of Nature and of Spirit. In nature, the past is an indeterminate nothing; events disappear and for the most part leaving no trace. It is not the same for the domain of the Spirit, which is able to give a new opportunity to the past. Time is the "tomb" of the event, but the Spirit preserves the past. That's why history lives only in the Spirit. Most of the time, German idealist philosophers distinguished time from history, but without enquiring into the connection between these two concepts. The originality of Hegel's philosophy is that it allows one to understand the transformation of time in history. It is in the *Phenomenology of Spirit* that we find the clearest development of the transcending of time, that is, the passage of natural, linear time, the indefinite series of Nows, to historical time, which preserves the past within it. The possibility of the passage of time into history rests on the idea that time is the existing concept. This thesis means that time is not opposed to concept, to Spirit, since, on the contrary, it is the Spirit's mode of existence.

How does the passage from time to history take place? It is achieved principally through three operations of consciousness. Transcending the evanescent Now takes place in language, understood as speech and writing. Speech transforms the negativity of the Now into a stable and universal reality, and writing fixes this speech, still in flux, into a permanent sign. Consciousness also preserves the

Now through the work of the interiorization of memory (*Erinnerung*). Interiorization is conceived by Hegel according to the Christological model of the Resurrection. It is what allows the Absolute Spirit to make the present be relived in the past, saving it from oblivion. Through memory, the Spirit converts the indeterminate nothing of the past into a new present, which is the foundation of history. In the ultimate movement of "Absolute Knowledge," Hegel develops a third form of the transcending of time, that of conceptual thought, which overcomes the negativity of natural time in order to extract from it immanent rationality. It is necessary to make an essential distinction between "effective history," which corresponds to the temporal course of events, and "conceived history," which is the retrospective understanding of events in thought by philosophy. The task of conceived history is to organize the chaos of events, giving them the form of the concept, to manifest the movement of the Spirit, which progresses secretly, like a mole, through events.

Hegel affirms that Spirit is time. This identity of time and Spirit is dialectic. On the one hand, Spirit is opposed to the bad infinity of natural time; on the other hand, it transcends the latter in order to unite itself with time in the movement of history. This identity ultimately has the meaning of "*Aufhebung,*" of a transcending by which the Spirit makes itself master of time, by means of language, the interiorization of memory, and conceptual thought. The finite beings that inhabit Nature—inorganic things, plants, and animals—are incapable of transcending the negativity of time that they contain in them, which henceforth manifests itself as a hostile power, a source of destruction and death. For finite beings, time will never be anything other than the destructive negativity of nature—a destiny. On the other hand, human beings possess within themselves the absolute negativity of the concept, which designates thought, and more generally, freedom. The concept is the power of time, in the sense that Spirit transcends its negativity, on the one hand, in the very knowledge of time, and on the other hand, by its capacity to transform natural time into historical time. The distinction, first presented in the *Phenomenology of Spirit,* between effective history and conceived history is made more explicit in the *Philosophy of History,* the aim of which is to decipher and translate, in the language of the concept, the palimpsest of represented history, the *historia rerum gestarum,* in which events and their memories are recorded through writing. The Hegelian conception of time also leads, in its final outcome, to thought of the history and of historicity.

Conclusion

When all is said and done, the Hegelian philosophy of Nature brings at least five original answers to the question of time:

1. *The desubjectivation of time.* Time as such is not an interior form of our consciousness, an "internal sense," but a universal determination of Nature present in all its domains.
2. *The mobility of time.* Time is not a fixed and permanent form in which events take place, but the very Becoming of things. From this point of view, things are not in time; it is time itself that is in all things in the form of their intrinsic negativity.
3. *The negativity of time.* Time is the destructive negativity of Nature; it plunges each being into the non-Being of the past. This concept of negativity allows us to take into account several aspects of time, such as the fleetingness of the instant and the irreversibility of the past.
4. *The dialectic of time.* The negativity of time unfolds according to a dialectic of three moments, from which flow two figures of time: on the one hand the indefinite and repetitive time of Nature, and on the other hand, the progressive and historical time of Spirit.
5. *The logicity of time.* The purpose of the desubjectivation of time is to establish the relationship of Spirit and time on a new basis. Time is not, in fact, a power foreign to Spirit, a destiny, but it can be transcended by Spirit in the sense that it can be spoken of, recollected, interiorized, and thought by Spirit. For this reason, the reflection on time begun in the philosophy of Nature is fully realized only in the philosophy of Spirit.

Christophe Bouton

See also Aristotle; Becoming and Being; Dialectics; Eternity; Hegel and Kant; Heidegger, Martin; Idealism; Intuition; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Metaphysics; Now, Eternal; Ontology

Further Readings

Hegel, G. W. F. (1970). *Philosophy of nature* (M. J. Petry, Ed. & Trans.). New York: Humanities Press. (Original work published 1817)

Hegel, G. W. F. (1977). *Hegel: The essential writings.* London: HarperPerennial.

Hegel, G. W. F. (1977). *Phenomenology of spirit* (A. V. Miller, Trans.). Oxford, UK: Clarendon Press. (Original work published 1807)

Hegel, G. W. F. (1988). *Introduction to the philosophy of history.* Cambridge, MA: Hackett. (Original work published 1837)

Singer, P. (2001). *Hegel: A very short introduction.* New York: Oxford University Press.

Hegel and Kant

Like Immanuel Kant, who sees time as the formal a priori condition of all phenomena in general, G. W. F. Hegel considers time as an absolutely universal determination of nature, which gives it a certain primacy over space. The *Encyclopedia* of Hegel seems to adopt the same presentation as Kant in his *Transcendental Aesthetic:* Time follows space, and the analysis of each of these two moments culminates in an examination of the corresponding sciences. Hegel refers to Kant several times, affirming that time is, like space, a pure form of sensibility or intuition. But behind these apparent affinities hides a systematic critique of the Kantian theory of time developed in the *Critique of Pure Reason.*

In the *Transcendental Aesthetic,* the objective of the metaphysical exposition of time is to analyze its a priori conditions, that which is necessary and universal. And yet, while taking up the main conclusion of this exposition, the very definition of time as a pure form of sensible intuition, Hegel gives it a resolutely different meaning. First of all, he sets out to show the dialectical relationship between space and time, whereas Kant merely juxtaposes them as two forms of our finite human intuition. But above all, Hegel interprets the pure intuition of space and time not through the subject, but through Nature. He thinks that one ought not to make space and time purely subjective forms of human nature, for time is not a condition of becoming; rather, it is becoming itself intuited, the destructive negativity inherent in Nature.

Certainly, Hegel grants Kant the claim that time, like space, is not something real, and is not, as Leibniz thought, an order of things. But the ideality of time does not make it one of the forms of our sensibility. Hegel expresses this Kantian concept in terms of his own thought and replaces the transcendental ideality of time with another form of ideality, designating its negativity, its power to dissolve all reality into the nothingness of the past. According to Hegel, it is therefore useless to want to classify time among subjective or objective beings. As the universal negativity inherent in nature, time might be described as "objective," but as the existence of the Idea in the mode of Being out-of-itself, it is brought back to the mind, and is, in this sense, also "subjective."

In Kant's writing, the purpose of the transcendental exposition is to show the determinations of a concept that constitutes the principles capable of explaining a priori the possibility of certain sciences. Actually, it is rather in the *Analysis of Principles* that this essential aspect of time is described in detail by Kant, who affirms at the beginning of the *Analogies of Experience* that the three modes of time are permanence, succession, and simultaneity. Permanence is the schema of substance by virtue of which I know a priori that substance persists through all changes of phenomena. This permanence is the condition of two other temporal relations: *succession,* which is the schema of causality, and *simultaneity,* which corresponds to the schema of reciprocal action. And yet, based on his understanding of temporality as destructive negativity, Hegel refutes one by one these three fundamental attributes of Kantian time. Simultaneity is thus completely foreign to time, since the latter is defined by its exact opposite, impossible coexistence. The opposite predicate, succession, does not offer an adequate grasp of time, for it masks its specific negativity more than it highlights it. The concept of succession is defective because it represents time as a series of isolated instants split between two domains: the present Now, which is, and the non-present Nows, which are no longer or which are not yet. Being and non-Being are maintained separately by representation, whereas, in truth, the negativity of time that flows from the Now implies an indissoluble unity of Being and nothingness at the heart of each

Now. From this point of view, the future and the past do not constitute other forms of Now but the presence of a negation in Being itself of each Now. By virtue of this negativity, time prohibits all a priori permanence in itself. Of course, certain beings last, but their duration is always of a relative permanence, a deferred death, even for things that we say defy time; for in time nothing persists, nothing remains. According to Hegel, the absolute nonpermanence of temporal things is due to the nonpermanence of time itself, which is ceaselessly transcending itself. Consequently, one should abandon the representation according to which time is a permanent receptacle in which things take place. Kant believes that things change in time, which is, in itself, immutable and fixed. But this, for Hegel, is failing to grasp the very negativity of time. The understanding of time as negativity and becoming therefore implies, in fact, a radical critique of the Kantian theory of time. Time is not that in which things take place, but their very becoming, their own disappearance, as is stated in §258 of the *Encyclopedia*.

In both the transcendental and metaphysical parts, the Kantian exposition of time in the *Transcendental Aesthetic* is therefore criticized by Hegel. Why? Precisely because the transcendental problematic impedes a real understanding of time as negativity, which is at the heart of Hegel's philosophy. The ambiguity of the Kantian conception of time is that it tries to reveal the conditions of the possibility of experience in general and, at the same time, Newtonian physics in particular. This explains why the Kantian understanding of time is predetermined by categories coming from physics, such as causality, substance, and reciprocal action. For Hegel, time is not principally determined by the categories that make possible the physical science of nature, but by its proper dialectical structure, deployed in the present, the future, and the past. Time is the continual, reciprocal passage of Being into nothing—from the present into the past—and from non-Being into Being—from the future into the present.

Christophe Bouton

See also Becoming and Being; Hegel, Georg Wilhelm Friedrich; Idealism; Kant, Immanuel

Further Readings

Hegel, G. W. F. (1970). *Philosophy of nature* (M. J. Petry, Ed. & Trans.). New York: Humanities Press.

Kant, I. (2003). *Critique of pure reason* (N. K. Smith, Trans.). New York/Basingstoke, UK: Palgrave Macmillan. (Original work published 1781 as *Kritik der reinen Vernunft*)

Heidegger, Martin (1889–1976)

Among philosophers of time, Martin Heidegger is one of the most famous. He describes humans as essentially temporal—that is, as "beings in time." Bringing together philosophical currents including phenomenology, philosophy of life, hermeneutics, and ontology, he developed a new philosophy he called Existentialism. His interpretation of the history of philosophy is critical for understanding his works.

Life and Works

Born on September 26, 1889, in Messkirch, in southwestern Germany, Heidegger intended to become a Roman Catholic priest, but after 2 years of theological studies at Freiburg University he switched to mathematics and natural sciences, finally taking a doctorate in philosophy (1913). After completing his postdoctoral thesis, *Die Kategorien und Bedeutungslehre des Duns Scotus* (Doctrine of Categories and Theory of Meaning in Duns Scotus), Heidegger broke with classical Catholic philosophy in 1919 and became an assistant to Edmund Husserl, the founder of phenomenology. In 1923 he was appointed professor at Marburg University and in 1927 Heidegger published *Sein und Zeit* (Being and Time), regarded as one of the most important and at the same time most controversial books in philosophy. He returned to Freiburg one year later as Husserl's successor, where, in 1929, he published three influential books: *Vom Wesen des Grundes* (On the Essence of Ground), *Kant und das Problem der Metaphysik* (Kant and the Problem of Metaphysics), and *Was ist Metaphysik* (What is Metaphysics).

Heidegger's most controversial years were from 1933 to 1945. As a conservative and staunch anti-Communist, he supported some aspects of Hitler's policies and was elected rector of Freiburg University on April 29, 1933. He joined the party shortly afterward—less out of conviction and more to strengthen his position, and although he never embraced Hitler's anti-Semitism, he remained vague about his relationship with the Nazis even after the war. More positively, as rector he prohibited anti-Jewish posters in the university and protected the Jewish professors Hevesy and Thannhauser. He shared a close personal friendship with the Jewish philosopher and political theorist Hannah Arendt in 1925 and again after 1950. His major work *Being and Time* is dedicated to Edmund Husserl, his Jewish predecessor at the University of Freiburg. Heidegger's tenure as rector lasted less than a year, as he was forced to resign after refusing to remove two deans in disfavor with the Nazis. While he never renounced the party, his distance from it was clear in 1944 when he was declared expendable from the university and sent to dig trenches along the Rhine. The relatively few publications from this period include his important essays on Plato's concept of truth (1942–1943). Heidegger's "philosophical turn," which may have begun during the 1930s, seems more evident after the war in his books on Nietzsche and the English publication in 1950 of *Off the Beaten Track* (*Holzwege*). The nature of this turn is contested among scholars, but the theme of philosophical inquiry as a continuous path of understanding is especially appropriate for Heidegger—one that he used repeatedly to describe his own work. He died in 1976 and was buried in Messkirch.

Philosophy of Being and Time

The title of Heidegger's renowned work *Sein und Zeit* (Being and Time) describes the book's key insight about the essential temporality of human existence. In the book, he reveals a remarkably original philosophy that required a whole new vocabulary in order to transcend inadequate understandings of human existence. His lifelong philosophical project attempted to correct a perceived deficiency of Western philosophies from Plato (427–347 BCE) until the rationalistic and scientific worldviews of the 20th century. Many of those philosophies provide great insight into the human condition, especially the classic works of Plato and Aristotle, but according to Heidegger they went astray by inadequately explaining human existence as the precondition for all understanding.

Various English translations preserve his technical terms by keeping them in the original German or by capitalizing them, and often by using hyphens to string together words that together form a unique idea. "Sein" or "Being" is the indefinable concept that begins to convey insight into the human condition when it has been considered carefully—with "Sorge" or philosophically reflective "Care." "Zeit" or "Time" is paired with Being because humans experience reality only within a temporal framework. We experience reality not as a series of present moments, but rather as creatures with memory of the past, awareness of the present, and expectations for the future. Humans come to know Being temporally, in Time, and achieve self-understanding within specific historical circumstances. This insight is conveyed by the term "Dasein" or "There-Being"; illumination, or "Disclosure" of Being's meaning is achieved with reflection upon how humans think about existence in our necessarily limited and temporal way. Humans are thus "beings in the world" and "beings in time."

According to Heidegger, the Being of the human being is fundamentally temporal. This position is the result of an existential analysis of the human being as mortal—Being in relation to death ("Sein zum Tode"). Heidegger's existential analysis of humans' fundamentally temporal nature includes a reflection on this relation to death. Death is the end of each individual's human possibilities ("Sein zum Tode"). Human beings know about their death and are thus able to anticipate the end of their possibilities as their end. Human beings as Beings-in-the-world and Beings-in-time realize that no one else will die their deaths. So the anticipation of death "invites" human beings to live their lives with awareness. If human beings do not take this invitation seriously, they fail to be what they should be. They fail their true nature.

Just as humans do not choose whether to come into existence, the circumstances of particular human lives are also very much given. Heidegger describes this with the term *Geworfenheit* or "Thrown-ness." This means that individuals as Dasein comes to know that they are in Time without having been their own cause.

> Only an entity which, in its Being, is essentially Futural [oriented to the future] so that it is free for its death and can let itself be thrown back upon its Factical "there" by shattering itself against death—that is to say, only an entity which, as Futural, is equiprimordially in the process of having-been, can, by handing down to itself the possibility it has inherited, take over its own Thrown-ness and be in the moment of vision for "its Time." Only authentic temporality which is at the same time finite, makes possible something like Fate—that is to say, authentic historicality. (*Sein und Zeit,* p. 385, translation by Macquarrie & Robinson)

The person as Dasein is thus substantially structured by temporal relationships—in relationship with the past as memory and history, with the future as anticipations that include the inevitability of death, and with the present as a reality shaped by both past and future. The focus on death and mortal limitations is not meant to be morbid, but rather to deepen the understanding and appreciation of human life. Life appears to be diminished in approaching death, but this process reflects the essence of the human being as a presence becoming absence. Awareness of Dasein limitations such as impending death drives home this reality. On the one hand it is frightening, because death implies the end of all potentialities for the person. But on the other hand, the deep awareness of death's ultimate finality brings with it a call to consciousness. Consciousness is not a moral motivation, it is the deep awareness that makes personal freedom possible. This dynamic gets at Heidegger's idea that "Non-Being" makes Dasein ("There-Being") possible. In terms of Time, the reflection of nothingness transforms time and fills us with a wonder for every moment.

Heidegger's Later Philosophy as Philosophy in Time

By the 1930s Heidegger had already begun to revise his ideas in *Sein und Zeit*. The problem is that his philosophical analysis of Time presented it as an eternal and transcendent truth, even as he was attempting to establish the essentially temporal structure of humans as Dasein. This motivated him to struggle with these themes in the philosophical systems of Schelling and Hegel, as well as with the poetry of Friedrich Hölderlin. His goal was to uncover a thoroughly temporal phenomenology, but he was not satisfied with the historical aspects of his thinking and wanted to uncover a more fundamental understanding of the temporal structure of human "Dasein." He used two words that sound similar in German to emphasize the importance of history and time: *Geschichte* means history and *Geschick* means destiny, future, fortune, but also skill. While it is historical, his philosophy is at the same time a skill that makes it possible for the person to accept the future.

Heidegger's investigations into the history of philosophy focused on the question of understanding itself and on the way historical circumstances shape the whole structure of thought. The image he used to describe this situation was a horizon that is formed by the meeting of the land and the sky, that is, between what is given and what is absent. The absence is as important as the existence, or "Dasein," in philosophy as well. Metaphysics is the philosophical enquiry into the nature of Being that began with Plato. From that time until Hegel, philosophers continued to contemplate the nature of Being as divine. The reversal of this connection that came with Nietzsche had great consequences. The natural sciences and technology progressed with great achievements during this time, but they did so according to greatly mistaken assumptions about the nature of existence.

This can be perhaps best shown with an example. Uranium fission creates an object that, in itself, remains insignificant. Only after its possible uses have been considered, such as the creation of energy, can it be meaningfully understood as fuel for "nuclear energy." Nuclear energy, with its both peaceful and wartime uses, serves as a good example because it demonstrates how human understanding is never neutral. A purely technical and practical understanding of objects is an illusion—and an illusion made possible by the modern scientific mindset that had radically alienated careful attention to Dasein. Even while presuming to be neutral in terms of metaphysics and value, it actually assumed an anti-historical metaphysical standpoint. It presented Being as the eternal present—a never-ending "now." Within this worldview, existence is classified according to a functional rationality of technical production. This idea, which Heidegger describes with the term "Ge-stell," explains how such a dangerous technology such as nuclear bombs could be developed by scientists claiming to be neutral. Even so, the chance for a "turn" is possible with new ways of thinking. According to Heidegger later in his career, a new understanding of human existence could reveal itself that is aware of both existential absence and presence, as well as both the holy and the divine.

This later view was an even more radical conception of existence. Being can be grasped intellectually only when it is aware of what is absent. This reality is demonstrated by serious reflection on human history. Yet, as Heidegger reached the end of his career, he became more skeptical about whether humans would "turn" from their objectification of reality.

Heidegger's Significance and Influences

Heidegger has been generally recognized as the most important philosopher to carefully investigate the nature of time and of being. He reached beyond the usual philosophical history from Plato to Nietzsche where the question of human existence had always been assumed as a given. As such, the understanding of existence itself remained shrouded, especially the peculiarly temporal nature of being that is known by its absence. His philosophy is a phenomenology because it considers how Being is revealed in human experience—often in explicit ways, but also in implicit and overlooked ways. Heidegger's is also an existential philosophy, because it considers the structure of all existence from the particular perspective of human existence. He uncovers the nature of human existence as situated in place and time, but also in how humans are capable of contemplating, discovering, and shaping existence. His philosophy is a metaphysics because it is an understanding of existence developed from what is—in other words, from Being itself—and not from a natural science point of view. His philosophy is a hermeneutics (way of interpretation) because it starts from the position that we come to greater understanding of Being by being made aware of our prejudices, and never by observing Being from a supposedly objective perspective. At the same time, by becoming ever more aware of our own prejudices, we can subject them to examination.

Much of Heidegger's philosophy remains in dispute. Analytical philosophers have ridiculed Heidegger's play with language, and linguists have shattered his etymologies. Yet, French existentialists like Albert Camus and Jean-Paul Sartre embraced it and used it to influence a whole generation of educated Europeans and Americans. The autonomous subject was understood to be capable of constructing its own personal existence—an existence potentially independent of reasonable coherence. Hermeneutic philosophers such as Gadamer have further developed many of Heidegger's ideas, especially the notion that preunderstanding (or prejudices understood in a neutral sense) structures more conscious understanding. Heidegger has also profoundly influenced theologians such as Rudolf Bultmann and Karl Rahner. Bultmann developed an existential biblical theology based upon the conviction that the Bible's meaning must be intelligible for modern people and relevant to their existing concerns. Rahner was a former student of Heidegger's who developed a new existential theology that reflects on death, the meaning of freedom, and the nature of God. Without straying from traditional Roman Catholic teaching, Rahner benefited from Heidegger's understanding of God as absolute mystery that, Rahner believed, is revealed as love in Jesus Christ.

Heidegger also influenced ethical thought, especially with his critique of the modern technological way of thinking that has forgotten about Being. Technological progress warrants suspicion because it professes no values and thus its progress is judged according to implicit and hidden principles. The apparent technological successes of the modern period convinced people of its power, and yet blinded people to the dangers that its worldview represented. As environmental and political disasters have demonstrated, technological resources can be used in dangerous ways when guided by wrongheaded principles. Even Heidegger himself was forgetful of this point during the period of his support for the Nazis. Still, Heidegger's philosophical insight remains important, that our understanding of Being requires that we appreciate its relation to Time—to its past, its future; and that this appreciation will continually shape our present.

Nikolaus Knoepffler and Martin O'Malley

See also Becoming and Being; Husserl, Edmund; Jaspers, Karl; Metaphysics; Nietzsche, Friedrich; Ontology; Rahner, Karl

Further Readings

Guignon, C. (Ed.). (2006). *The Cambridge companion to Heidegger.* Cambridge, UK: Cambridge University Press.

Heidegger, M. (1962). *Being and time* (J. Macquarrie & E. Robinson, Trans.). New York: Harper & Row.

Heidegger, M. (1998). *Pathmarks* (W. McNeill, Ed.). New York: Cambridge University Press.

Heraclitus (c. 530–475 BCE)

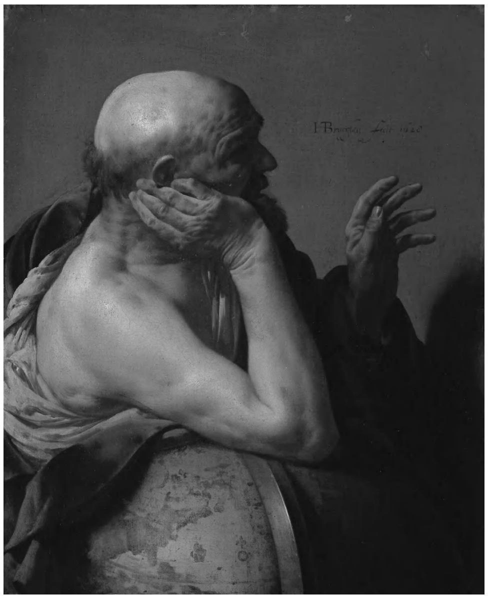
Heraclitus is considered among the greatest of the Presocratic philosophers. Flux and time play particularly important roles in his thinking. Even though the fragments of his book *On Nature* had an enormous impact upon such diverse philosophers as Plato, G. W. F. Hegel, Friedrich Nietzsche, and Martin Heidegger, not much is known concerning the particulars of his life. However, we do know that he was born in Ephesus, came from an old aristocratic family, and looked unfavorably upon the masses. According to Apollodrus, he was about 40 years old in the 69th Olympiad (504–501 BCE).

Relativity of Time

The most influential aspect of Heraclitus' thinking about time is the concept of the Great Year or the eternal recurrence of everything, an idea that was taken up later by Zeno of Citium (the founder of the Stoa) and Nietzsche. However, within his philosophy, Heraclitus also clarifies other aspects of time. He was clearly aware of the relativity of time. When he explains that the sun is needed for the alteration between night and day to occur, it becomes clear that he was conscious that daytime and nighttime are dependent upon certain conditions. A certain time exists only within a specific framework or paradigm. If the framework changes, then the concept of time within it changes, too. We would not have daytime within a world without the sun. Time is dependent upon a specific perspective, and many distinctions concerning time cannot be drawn from only a cosmic or universal perspective.

Unity of Opposites

Heraclitus criticized Hesiod for not having the best knowledge concerning daytime and nighttime. Only the masses regard Hesiod as a wise man, but truly he was not. According to Heraclitus, daytime and nighttime are one, which Hesiod had failed to realize. From a global perspective, one cannot distinguish



Heraclitus, *painting by Hendrick ter Brugghen. Heraclitus was a Greek philosopher who proposed that everything is in a state of flux and that fire is the principal element of matter.*

daytime and nighttime. One has to be a participating spectator in order to employ the distinction meaningfully. Even though the distinction in question works well from a pragmatic perspective, this does not imply that it is correct. From a universal perspective, the distinction between day and night is not supposed to make any sense, as God is supposed to represent the unity of opposites; that is, God is supposed to be the unity of day and night, as well as summer and winter.

Time as Metaphor

Even though opposites do not exist, Heraclitus himself employs opposites. Concerning time, he clearly holds that there are people who are connected to the night and others who are linked to the day, and he attributes different values to these two types of paradigms. According to him, only the night-roamers are the initiated ones. They have wisdom and they do not belong to the masses. The masses are uninitiated and are connected to the day. Even though, from a global perspective, night and day are one, nighttime and daytime stand for something different. Here, they represent people who are either initiated or uninitiated into wisdom.

Time and Order

Only the initiated know what time really is. Time is a type of orderly motion with limits and periods. Heraclitus also specifies in more detail what he understands as order concerning time, and he explains that it is important that the same order exists on various levels. However, time cannot be reduced to only one aspect of order, as Heraclitus also identifies time with a playing child; that is, time is the kingdom of a playing child. Even though the aspect of order is necessary for games, there is more to the process of playing a game, as there are also the aspects of playfulness, freedom, and chaos. To stress also the important disorderly element represented by time, Heraclitus attributes to this concept his idea of the unity of opposites. Wherever there is order, there has to be chaos. However, that chaos is relevant might only mean that even though there is one certain order in the universe, we cannot securely predict the future. Even though everything is necessary, from our perspective anything can happen, as it is impossible for us to foresee the future.

Time Is Cyclical

According to Heraclitus, the order of time is the cycle. Periods and cycles appear at various levels of existence. There is the world cycle or Great Year, but there is also a human cycle, the cycle of procreation. Human beings are born, grow up, and give birth to other human beings so that the cycle of human life can start again, which happens approximately every 30 years. In this way, a man becomes a father and then a grandfather. However, the most important idea in the philosophical reception of his thought is Heraclitus' world cycle, referred to as the Great Year, or the eternal recurrence of everything. Analogous to human lives, there is a period or a cycle in the progression of world history. The world is supposed to be an ever-living fire that is kindled and extinguished in regular cycles. One cycle represents a Great Year, which has the (surely metaphorical) duration of 10,800 human years. By presenting the Great Year in his philosophy of time, Heraclitus also reveals an option for an immanent type of immortality. The concept of the Great Year is of relevance on various levels. It may be analyzed from a metaphysical, natural philosophical, scientific, ethical, and religious perspective.

Stefan Lorenz Sorgner

See also Eternal Recurrence; Hegel, Georg Wilhelm Friedrich; Heidegger, Martin; Maha-Kala (Great Time); Nietzsche, Friedrich; Plato; Presocratic Age; Time, Cyclical; Universes, Evolving

Further Readings

Kahn, C. H. (2003). *The art and thought of Heraclitus: A new arrangement and translation of the fragments with literary and philosophical commentary.* Cambridge, UK: Cambridge University Press.

Sorgner, S. L. (2001). Heraclitus and curved space. In Universidad Tecnica Particular de Loja (Ed.), *Proceedings of the Metaphysics for the Third*

Millennium Conference (pp. 165–170). Loja, Ecuador: Universidad Tecnica Particular de Loja.
Wheelwright, P. (1999). *Heraclitus.* Oxford, UK: Oxford University Press.

Herder, Johann Gottfried von (1744–1803)

Born in Mohrungen, Prussia, Johann Gottfried von Herder attended the lectures of Immanuel Kant in Königsberg for 2 years, beginning at 18 years of age. Herder was most fascinated with Kant's early scientific reasoning, especially his philosophy of nature.

At the age of 21, Herder became a Protestant pastor. In Königsberg, Herder became friends with the counter-Enlightenment figure Johann Georg Hamann. Both Herder and Hamann rejected the later Kantian critical philosophy, and had already rejected any notion of a "faculty." Both had little interest in "time" as an abstraction. Instead, all consciousness should be thought of as language-based. Though his friend Hamann was averse to the entire tradition of rationalism, and though he himself never accepted Kant's critical philosophy, Herder was a rationalist and an idealist when history was the subject.

Herder traveled throughout the German-speaking lands and conversed with many of the greatest minds of his time. He was interested in all things natural, human, and divine. On December 18, 1803, Herder passed away in Weimar.

The German Historical Sense and Herder

Johann Gottfried Herder occupies a permanent, important place in the history of human thought concerning time, for it was he (with his contemporary Hamann) who introduced a "historical sense" to the German nation as a whole. Of course, before Herder there were authors with a strong historical sense. But all these influences and predecessors were non-Germans, especially the figures from the French Enlightenment. And, of course, before the Enlightenment, the Scholastics had understood time and history in the abstract. But they were more interested in "eternity" than in human history. They distinguished *sacred* from *secular* time in order to give absolute priority to the former. The Scholastics lacked a sense centered on natural and human history. Herder provided a new mode of thinking for the German public by offering just such a historical sense.

Most important, this historical sense was lacking in the orientations of Leibniz and Kant. The thought of Leibniz was almost entirely nonhistorical. Mathematics and physics (monadology) do not require a developed notion of human history, because they are largely theoretical, abstract sciences. Perhaps Kant sought to sidestep the question of history (and phenomenology) by focusing largely on the transcendental structures of the ego. His thinking was strikingly nonhistorical, even transtemporal. The reader of Kant is often left with a sense of timelessness and of rationality at rest, a sense of the structure, but not the content, of time.

Herder and Hamann

Herder had a noteworthy German cohort in developing a historical sense, Johann Georg Hamann. Herder's senior and friend, Hamann had also embraced history and sought to instill the German nation with it. Hamann's thought was largely a reaction to the Enlightenment and to the ideas of Benedict Spinoza. The German public, in general, had reacted to the twin specters of Spinoza and Enlightenment science with fear and loathing. Spinoza's ideas were considered deterministic and covertly antireligious. The advance of English science, especially chemistry, was threatening because the "soul" could then perhaps be explained by the chemical processes of the mind within the brain.

Hamann sought to guarantee religion a safe respite. Faced with the advance of Spinoza's ideas, Hamann retreated into irrationalism and a sort of counter-Enlightenment orientation. He sought to link biblical history with modern history, and to prevent any juncture between history and science, materialism, or atheism. Again, Hamann had a sense of history, but it was of a religiously orthodox orientation; history is the story of the divine will. Above all, he viewed *history as entirely sacred;* a strictly secular history could not be conceived of. In short, Hamann viewed history as an irrational but divine phenomenon.

Confronted by the twin specters of Spinoza and Enlightenment, Herder chose a different strategy from Hamann. While Herder still viewed history as a divine phenomenon, he claimed that history is *rational and an object of science.* As the third element of his strategy, Herder chose to incorporate a broad range of natural sciences into his scientific account of history.

Like Hamann, Herder saw history as divine, but in a very different sense. Hamann had sought to develop history out of revealed scripture; Herder, on the other hand, attempted to delete all religious or mythological content from his history. He would accept no divine intervention, no miracles, as a cause in history. In short, Herder's explicit project was to develop a *scientific (nontheological) account of history.* He saw the inevitability of considering time not as entirely sacred but also as secular (natural scientific), and even as an agency of human free will (the historical sense). And so he set off on the project of authoring a coherent history of the universe, nature, man, society, and God, all strictly within a natural scientific methodology.

Herder was not concerned with Spinoza, since his natural science was strongly influenced by Roger Joseph Boscovich, in that his theory of atoms was a point-particle theory rather than the Newtonian corpuscular theory—meaning that instead of Newton's extended atoms, Herder insisted on Boscovich's dimensionless force-points. (Recall that Herder, like Kant, was in the generation of thinkers immediately after Newton, Leibniz, and Boscovich. It seems most likely that Herder discovered Boscovich's ideas when Kant was struggling with them in the early days at Königsberg. Kant finally resolved his struggle with Boscovich by incorporating the theory of force-points into his own natural philosophy in his late work *Metaphysics of Natural Sciences.*) Force-points completely subverted Spinoza's monism and determinism so abhorred by the German sense of piety. Boscovich's natural science (*Theory of Natural Science,* 1776) was a theory of *force,* not *substance.* By adopting an atomism most closely related to Kant and Boscovich, Herder was able to sidestep Spinoza's "deterministic" metaphysics entirely. But Herder could not deny the advance of Enlightenment science, so he chose to concentrate on the natural within history. He began with an explanation of the universe and the origins of nature, and then worked his way through the rise of animal life. Finally, he gave a historical account of human civilizations.

Herder saw that the sciences had to be given a sense of time. Previously the sciences were taught as a hierarchy rather than as having a shared history. The static classifications of Aristotle and Linnaeus could no longer do justice to the advance of science. To account adequately for the development of the universe, Earth, and man, a timeline was necessary with which to distinguish developmental stages. This meant discovering the unidirectionality of time and of a sequence of events following that linear model. The sciences could no longer burst forth fully grown from the brow of Zeus.

Developing an interdisciplinary history of the sciences was a daunting challenge for Herder. Writing well before Charles Darwin, Herder did not have a theory of evolution. Nor did Herder have the advantage of the theory of developmental history authored by Karl Ernst Ritter von Baer. Yet he traced history from the origins of the universe to the rise of humankind across a panorama of the sciences. Breaking completely with Hamann, Herder saw in history not the divine will of God, but instead the actualization of divinity in man.

Herder's Legacy

Herder's contributions to the historical sense—religion, rationality, and science—proved fateful to subsequent German thought on history. After Herder, the first on the scene, Johann Gottlieb Fichte, adopted the religious interpretation of history provided by Herder; history was indeed the actualization of the "absolute ego" in man. Fichte also adopted the notion that there is a deeper logic and rationality to history; it is the gradual actualization of the Idea (logos). Fichte returned to Hamann's tradition of pietism and developed his system of ethical idealism entirely within a quite preachy, harshly moralistic tone. But Fichte ignored the natural sciences in favor of his own principle of ego. Next in the line of succession came F. W. J. Schelling. In keeping with these predecessors, Schelling viewed history as sacred time. He also saw history as the gradual unfolding of an Idea, and so all things are ultimately knowable by reason. In contrast to Fichte, Schelling greatly esteemed the natural sciences. If Fichte's system may be called "ethical idealism," Schelling's system could be called an "idealism of nature" or "objective idealism." Thus Schelling was a more complete replication of Herder's historical sense even if in the strange new idiom of systematic idealism. After Schelling, Hegel advanced the historical sense to perhaps its most extreme form. In fact, Hegel adopted Herder's three contributions, mediated through Fichte and Schelling, as his own. Religion had its eternal safe haven in Hegel's Absolute Spirit, and history was the moving image of eternity. Also, history had its own rational process for Hegel, which may be captured in a system of logic. Rationality is indeed only the standard of knowledge for a historical stage of development. Hegel's Absolute sought to subsume Nature and man entirely within itself. Finally, Karl Marx reworked Hegel's absolute idealism, mediated by Ludwig Feuerbach, the utopian socialists, and later Darwin, into an all-inclusive theory of historical materialism. Directly or indirectly, these thinkers traced several fundamental elements of their historical sense back to Herder.

It should be observed that each stage within Herder's history was equal to every other; there is no progress or higher spirituality as history proceeds (in contrast to Hegel's notion). He did believe, though, that human history should be narrated ultimately in terms of races and nations. Thus Herder truly set the scene for Fichte's entrance onto the stage.

Greg Whitlock

See also Baer, Karl Ernst Ritter von; Boscovich, Roger Joseph; Fichte, Johann Gottlieb; Hegel, Georg Wilhelm Friedrich; Idealism; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Marx, Karl; Schelling, Friedrich W. J. von; Spinoza, Baruch de; Time, Sacred

Further Readings

Beck, L. W. (1965). *Early German philosophy: Kant and his predecessors* (chap. 15). Bristol, UK: Thoemmes Press.

Herder, J. G. von. (1963). *God, some conversations*. Indianapolis, IN: Bobbs-Merrill. (Original work published 1787)

Herder, J. G. von. (2002). *Philosophical writings*. Cambridge, UK: Cambridge University Press.

Herodotus (c. 484–c. 420 BCE)

Herodotus of Halicarnassus in Caria (currently Bodrum on the Aegean coast of Turkey) was one of the earliest known historians and is most renowned for his chronicling of the Greco-Persian Wars. His approach to the writing of history set a precedent for later historians' concern with establishing causal links between past and current events.

At the time of Herodotus' birth, Halicarnassus was a Greek city located on the fringes of the Persian Empire and thus subject to their monarchal control. Herodotus examined the root of the great conflicts between the Greeks and non-Greeks; from its origins in the Lydian kingdom, to the failed revenge of the Persian King Darius at Marathon, to the final unsuccessful efforts of his son King Xerxes at the Battle of Thermopylae and the famous naval battle at the Straits of Salamis off the coast of Attica. Very little is known of the author's life except that he never claims to be an eyewitness to the events he describes, although he often makes mention of conversations with those who were present, as if he were there. It is thought that many of these conversations might have come secondhand via the exiled grandson of the Persian Zopyrus.

Herodotus' *Histories* is composed of nine books starting in Book 1 with the story of the Lydian king Croesus in the mid-6th century BCE and ending with the founding of the Athenian empire following the second Persian War in approximately 480 BCE. The books of Herodotus' *Histories* cover a significant period of time in which the author attempts to uncover how the enmity between Greeks and Persians began. In doing so, Herodotus' main narrative is composed of many smaller narratives in great detail. These narratives focus on a set of chronological events surrounding the reason for the conflict between Greeks and non-Greeks. Often these narratives temporarily move backwards or sideways to describe circumstances or details that Herodotus feels shed light upon the main thrust of the story. Herodotus' historical method not only is one of enquiry into his narrative but also integrates a line of questioning of his sources, not all of which he trusted. Often he writes that while he is under a moral obligation to report what was said to him, he is under no obligation to believe it, and this inability to decide is cited. While Herodotus never disguises the fact that the Greek-speaking world is the geographic and cultural center of his perceptions, he is often very open-minded when describing the cultural details of foreign societies, although he inevitably must compare them to his own, by relating what he views as a rationale for diverging modes of life and religion.

For Herodotus and his historical reasoning, actions are the result of a prior cause or reciprocity. A wrong inflicted in the past will be returned in equal measure in the future; this is especially the case in regard to kinship relations. And this is why Herodotus' work extends to the distant past to find the answer to the events that caused Greeks and non-Greeks to go to war. In addition, the historian does not focus his energies upon the logical explanation of events and human actions, as they often seem random or too easily assigned to fate or the intervention of divine will, and to some readers this will lend to a sense of storytelling. Although some accounts by Herodotus have been charged with straining the reader's credulity, one should not discount all he records. It is believed that Herodotus died sometime in the 420s while living in the Athenian colony at Thurii in Southern Italy.

Garrick Loveria

See also Greeks, Ancient; Homer; Peloponnesian War

Further Readings

Kapuscinski, R. (2007). *Travels with Herodotus.* New York: Knopf.

Strassler, R. B. (Ed.). (2007). *The landmark Herodotus: The histories* (A. L. Purvis, Trans.). New York: Pantheon.

Hesiod (c. 700 BCE)

Hesiod was a probable contemporary of Homer, and the writings of both represent one of the earliest phases of Greek literature. Although a variety of writings are attributed to him (his only known complete works are *Theogony* and *Works and Days*), Hesiod stands out not only as an important source of Greek mythology but also as one of the first Western philosophers to conceive of and elaborate a cyclical view of time. He is said to have been a simple shepherd who was rewarded with deep insight by the Muses, who came to him in a mist. His views reflect a more practical understanding of life than do those of many of the ancient Greek philosophers who were from an elite class.

Theogony, which likely includes a compilation of oral traditions and myths, tells of the origins and chronology of the gods as well as the creation of the heavens and the earth. Like nearly all creation myths, it sets up a view of time and a relationship between humans and the world of the gods. However, it is in his *Works and Days* that Hesiod elaborates his views on the topic of time.

Hesiod divides existence into five stages, or "Ages of Man." The first, the Golden Age, is ruled by Cronus, the god of time. Under his control, it is an era of truth, justice, and peace. People are filled with wisdom, are of a contented nature, and, though considered mortal, are ageless. Zeus, the son of Cronus, takes over at the dawn of the Silver Age. It is one in which differences and discord begin, and morality declines. Human existence is shortened and the necessity to work is born. During the Bronze Age, strife and violence continue to increase, as do human passion and frailty. The fourth stage is the Heroic Age and is connected with the Trojan War. While human attributes seem to improve somewhat, violence dominates. The last is the Iron Age and is associated with the present. In many ways, it is similar to the present age of degradation as conceptualized in Hindu (Kali

Yuga) and Buddhist mythology. Human life is at its shortest, while truth, justice, and peace are suppressed by crime, greed, deceit, and violence. The gods forsake humanity and evil rules.

Ultimately, however, Hesiod uses *Works and Days* to provide a vindication for morality and the righteous. In an eschatological vision, goodness and justice (*dike*) prevail and triumph, while injustice (*hubris*) loses out. A subsequent section of the text is devoted to teachings on morality and ritual propriety.

Hesiod's influence can been seen in the Pythagorian concept of a cyclical reality and possibly in the works of Homer as well. His elaboration of a golden age, his views on the necessity and value of physical work, and his prescriptions on morality have all had a continuing impact on Western thinking.

Ramdas Lamb

See also Herodotus; Homer; Mythology; Presocratic Age; Time, Cyclical

Further Readings

Hesiod. (1991). *The works and days; Theogony: The shield of Herakles* (R. Lattimore, Trans.). Ann Arbor: University of Michigan Press.

Hesiod. (1999). *Theogony, works and days* (M. L. West, Trans.). New York: Oxford University Press.

Hibernation

The term *hibernation* comes from the Latin word *hibernare,* which means to pass the winter. The term is commonly used for a type of deep winter dormancy in some animals (i.e., mammals, birds, reptiles, and amphibians). A similar type of dormancy that occurs in summer is referred to as estivation. Some insects and snails also exhibit a similar state of dormancy in winter that is often called winter estivation or diapause.

Hibernation (winter dormancy) involves a periodic (seasonal) drastic reduction of the animal's metabolic rate and body temperature for an extended period of time. Generally, in hibernation, the body temperature drops almost to that of the surroundings (the bear being a well-known exception). Basic body processes, like breathing and the rate at which the heart beats, are drastically reduced so that the hibernator appears almost to be in a comatose state. The hibernating animal then lives through the winter on a reserve of body fat and/or externally stored food until it awakens in the spring.

Hibernation is therefore considered to be a fundamental adaptation to the environment since it is essentially an adjustment in the animal to allow its survival during those periods of the year when environmental conditions are so severe that exposure to the elements will be fatal. To survive in these harsh conditions, some animals can temporarily migrate from the hostile environment (e.g., birds). Some animals can remain active but adapt by

- growing thicker fur (e.g., weasels and snowshoe rabbits),
- storing extra food for the coming winter months (e.g., beavers, some squirrels and mice),
- changing their diet to that which is available during the winter (e.g., the red fox normally eats fruit and insects but eats small rodents in the winter),
- using shelters to protect them from the cold.

For others (e.g., reptiles, ground squirrels, and certain bears), migration is impossible and other adaptations are either impossible and/or ineffective as protection. These animals then adapt by means of hibernation.

Hibernation is seen mainly in small animals such as marmots, ground squirrels, chipmunks, dormice, and northern bats whose food supply is very limited or nonexistent in winter. Cold-blooded hibernators include such amphibians as frogs and toads and such reptiles as lizards and snakes that pass the winter with body temperatures that are the same as the ambient temperature (i.e., near freezing). More recently, a tropical primate, the fat-tailed dwarf lemur (*Cheirogaleus medius*), endemic to Madagascar, has also been found to hibernate.

Outside of winter, natural hibernators lacking food and facing other adverse conditions cannot *choose* to hibernate to survive. Indeed, unless an animal is genetically disposed to hibernation or other states of dormancy, it cannot become dormant at will to escape inhospitable conditions.

Some refer to hibernation as "time migration" since hibernation allows the animals to skip over the entire period of the inhospitable winter season and truly "live" only in the periods of plentiful food and higher temperatures that occur outside of winter. Indeed, to the hibernating animal, time passes unnoticed since it is insensible and unaware during winter and becomes active or "alive" only at the end of hibernation.

Interestingly, according to an American legend, the hibernating groundhog (woodchuck) can be used to predict a period of time, namely, the length of the winter season. It is said that the groundhog creeps out of its hole on February 2 of each year (Groundhog Day) and that if the day happens to be sunny and the groundhog sees its shadow, there will be 6 more weeks of winter. On seeing its shadow, the groundhog supposedly returns to hibernation again. If, on the other hand, the groundhog does not see its shadow, it stays above ground, cutting short its hibernation. This is supposed to indicate the imminent arrival of spring, or the end of winter. Of related interest is a 1993 comedic movie by the same name, *Groundhog Day.* It describes a television reporter (a weatherman) who, while waiting to report on the arrival of the hibernating groundhog, becomes "stuck in time" on Groundhog Day. In the movie, time stands still since the events of that day are repeated without end, making it impossible to move on to the next day!

Hibernation is very different from sleep since it involves an extreme reduction in metabolism. For example, a black bear's heart normally beats about 60 times per minute but this is reduced to as little as 5 times per minute during hibernation (about a 90% reduction). The blood pressure of an active mouse varies between about 80 and 120 millimeters of mercury (mm Hg). By contrast, blood pressure in a hibernating mouse varies between about 30 and 50 mm Hg. A hibernating marmot may reduce its breathing from 16 to 2 breaths a minute and its heartbeats from 88 to 15 per minute. Hibernating turtles reduce their metabolic rate by as much as 95%.

Terms like adaptive hypothermia, or the lowering of body temperature to adapt to changes in the external environment; torpor (state of dormancy and inactivity); and suspended animation (temporary suspension of vital functions) are often associated with hibernation.

The Hibernaculum

To hibernate, most animals go into shelters such as burrows, caves, and dens as a buffer from the lethally low ambient temperatures. The temperature of these shelters is normally slightly above the ambient temperature and does not fluctuate as much. This shelter is called a hibernaculum. There is no standard type of hibernaculum. For example, most rodents hibernate in underground burrows. Bog turtles (*Clemmys muhlenbergii*) use hibernacula that include abandoned animal burrows, mud cavities, and the base of tree stumps. Tortoises use underground sites such as burrows excavated in soil or rocky caves. Bats choose a hibernaculum that is not only cold but humid. For example, in winter, the Indiana bat (*Myotis sodalis*) hibernates in limestone caves and also in some manmade shelters, like underground mines. Adders (*Vipera berus*) in cold areas hibernate in clusters in underground areas made by other animals, for example, in abandoned mammal or tortoise burrows. Animals that are not in the wild will even use crawl spaces and basements in buildings.

Most hibernacula must remain at temperatures slightly above freezing (not too cold or too warm), must have a relatively high humidity, must be safe from predators and other intruders, and in some cases must have space for the animal to store food. Indeed, hibernacula are usually dark, protected, and secluded to keep the hibernating animal safe. A suitable hibernaculum is key to the survival of the animal when it is so vulnerable during hibernation.

Length of Hibernation

The period of hibernation may vary, lasting several days or weeks depending on the animal's species, the ambient temperature, length of winter, and the animal's latitudinal location. Woodchucks hibernate in underground burrows from September or October until March (about 5 to 6 months). The fat-tailed dwarf lemur hibernates for around 7 months of each year in tropical winter temperatures that are relatively high.

Typically, whatever the exact length of hibernation, it is generally characterized by periods of sporadic arousals. The intervals between these arousals depend on the animal's size, body temperature, and other internal factors. For example, in one study, hibernating hedgehogs were observed to have 12–18 arousals. The average duration of these arousals was 34 to 44 hours. Some arousals are initiated by external stimuli like noise and are called alarm arousals. Other arousals do not appear to be initiated by any external trigger and seem to be under the control of signals internal to the animal (endogenous signals). Final arousal from hibernation always occurs at the end of winter, and it is believed that this may be controlled by a combination of exogenous (environmental) and endogenous signals that work to prevent the animal from reentering hibernation.

What Initiates/Triggers Hibernation

Entry to hibernation may be triggered by environmental factors such as temperature, day length, and shortage of food. Indeed, animals such as hamsters and chipmunks are sometimes called *facultative* hibernators because they hibernate in response to environmental conditions.

For *obligate* hibernators (e.g., ground squirrels, marmots, and white-tailed prairie dogs), on the other hand, the cycle of storing food, hibernating, and arousing seems to be controlled mainly by a signal or cue that originates internally from the animal itself (an endogenous signal). For example, when the golden-mantled ground squirrel (*Spermophilus lateralis*) is kept in the laboratory under constant environmental conditions (i.e., in the absence of environmental triggers), hibernation occurs just as if it were in its natural habitat. This indicates that environmental triggers (exogenous cues) are not essential for hibernation in this animal and so the golden-mantled ground squirrel can be considered to be an obligate hibernator.

On the other hand, some birds, like the common whippoorwill, enter a hibernation-like state once their food is removed (environmental trigger). Similarly, food availability has been shown to play a major role in the start of hibernation in the Japanese dormouse (*Glirulus japonicus*). At the same time, another environmental trigger, low ambient temperature, does not appear to have significant influence on the hibernation of the Japanese dormouse once there is an adequate supply of food. Hibernation in the desert tortoise (*Gophents agassizii*) also appears to be only weakly influenced by exogenous environmental cues.

Thus, for some animals some type of endogenous signal or cue is the main determinant of entry to and exit from hibernation. It is believed that this internal signal is regulated by a biological rhythm based on a 24-hour cycle (called a circadian rhythm). The onset and end of hibernation in most animals appear to be triggered by both endogenous signals and exogenous environmental cues.

Biological Clocks

The endogenous cue that triggers hibernation is believed to be based on an internal or biological clock. The biological clock is believed to control not only the hibernation of animals but also many repetitive physiological functions in humans, as well as the migration of birds and the flowering of plants. It is also believed that the periodic arousals characteristic of some hibernators are regulated in part by the biological clock. Also, final arousal from hibernation in spring may be triggered partly by the biological clock.

Although it is endogenous, it is believed that the biological clock responds to several external environmental cues, in particular day length or more accurately the photoperiod (the ratio of daylight to darkness). The photoperiod is an exogenous environmental cue that is "sensed" by the animal from certain sensory organs, like the eyes and also from light-sensitive receptors in its brain. The location of the biological clock in animals, its properties, and the mechanisms by which it operates are only now beginning to be discovered. Indeed, the study of biological clocks and their associated rhythms has led to the scientific discipline called chronobiology.

Thus, the timing of the entry into and exit from hibernation may be due primarily to an endogenous circannual (about a year) or circadian (about a day) rhythm with the timing being reset annually by environmental factors such as day length.

Effects of Global Warming/Climate Change

There has been some concern that higher global temperatures may have led to shortened winters that could have a negative effect on animals that hibernate. For example, some research done in Italy suggests that climate change is indeed bringing animals out of hibernation early. This is believed to put their feeding and breeding habits out of synchronization with the environment, causing unusual weight loss and stress in the animal. For instance, one study observed the effect of annual temperatures in southern England (between 1983 and 2005) on the body condition of female common toads (*Bufo bufo*). This study suggested that "partial" hibernation (early emergence from hibernation) occurred in the female toad as a result of the mild winters experienced during those years. It is thought that this contributed to a decline in the bodily condition of the toad, which negatively affected its survival.

Another study of the effect of temperature change on several traits of over 1,000 temperate-zone animal species worldwide revealed that springtime events (e.g., blooming of flowers, laying of eggs, and the end of hibernation) now occur about 5.1 days earlier per decade on average. Some studies on marmots in Colorado also show that they are ending their hibernations about 3 weeks earlier than they used to in the late 1970s. It has been reported that dormice now hibernate 5–1/2 weeks less on average than they did 20 years ago. Reports indicate that some bears in Spain (slightly different genetically from bears in other parts of the world) have stopped hibernating altogether, remaining active throughout recent winters. Research and debate continues on climate change and its effects on animals' biology and behavior, including hibernation.

Artificially Induced Hibernation

There has always been interest among medical researchers in the chemical induction of hibernation. The potential benefit of putting trauma patients into hibernation and giving doctors more time to repair severely damaged tissue is just one advantage of artificially induced hibernation in humans. Science fiction writers have also explored the possibility of preserving human life in a reversible state of so-called suspended animation. Supposedly, one could exist in such a state for several years without aging, without the need for food and the elimination of waste, and reawaken unaffected by a journey through space of many years to another planet. Inducing artificial hibernation in humans (even in fiction) is therefore potentially a way of "buying time."

Hibernation cannot be induced in nonnatural hibernators by manipulating the environment, so researchers have searched for a possible blood-borne chemical that could induce hibernation. It has been discovered that a serum extracted from hibernating animals such as the woodchuck, when injected into active animals, can induce a hibernation-like state. This serum contains a substance called the Hibernation Induction Trigger (HIT). Experiments with hydrogen sulfide have also shown potential for inducing a hibernation-like state in nonhibernating animals.

Other Types of Hibernation

The term hibernation is now used widely outside of the life sciences to refer to any period or state of temporary dormancy or inactivity. For example, it is used in computer technology to refer to the state of dormancy that can be achieved by powering down a computer while retaining data about running programs and the status of the input/output devices. When the computer resumes from the state of hibernation (on powering up), it reads the saved state data and restores the system to its previous state.

Companies have been said to go into hibernation as a survival strategy to avoid closure (analogous to animal hibernation, the business operations might be reduced drastically to maintenance levels until, for example, brighter market conditions emerge). Projects that are temporarily dormant have sometimes been said to be placed "on ice" and "in hibernation." The term hibernation is also sometimes used for any temporary loss in function as seen, for example, in organs in the human body.

Jennifer Papin-Ramcharan

See also Clocks, Biological; Cryonics; Ecology; Global Warming; Heartbeat; Seasons, Change of; Sleep; Solstice

Further Readings

Dunlap, J. C., Loros, J. J., & DeCoursey, P. J. (Eds.). (2004). *Chronobiology: Biological timekeeping.* Sunderland, MA: Sinauer Associates.

Harder, B. (2007). Perchance to hibernate. *Science News, 171*(4), 56.

Reece, W. O. (2005). Body heat and temperature regulation. In *Functional anatomy and physiology of domestic animals* (pp. 369–378). Baltimore, MD: Lippincott Williams & Wilkins.

Roots, C. (2006). *Hibernation. Greenwood guides to the animal world.* Westport, CT: Greenwood Press.

Roth, M. B., & Nystul, T. (2005). Buying time in suspended animation. *Scientific American, 292*(6), 48–55.

Whitrow, G. J., Fraser, J. T., & Soulsby, M. P. (2004). Biological clocks. In *What is time: The classical account of the nature of time* (pp. 31–48). New York: Oxford University Press.

Hinduism, Mimamsa-Vedanta

Among the six principal schools that developed in the Brahmanical traditions in India, Mimamsa and Vedanta form the most recent group, the others being Nyaya, Vaisesika, Samkhya, and Yoga systems. These two schools, that is, Mimamsa and Vedanta, are also known as Purva-Mimamsa and Uttar-Mimamsa. Founded by Maharshi Jaimini and Maharshi Samkara, respectively, these schools develop their theories of time in a unique way. Remaining faithful to the core thought of the Upanishads, namely the reality of the immutable Brahma, they explain the phenomena of change in diverse ways.

The Purva-Mimamsa school has two sects, one known as Bhatta or Kumarila Mimamsa, propounded by Kumarila Bhatta, and the other known as Prabhakara Mimamsa, established by Prabhakara Mishra. The two sects differ somewhat in their treatment of time.

In the Jaimini Sutra the concept of time is discussed in connection with action. Some element of time is associated with all actions. Action is in a way determined by time. The Mimamsa school bases its philosophy on the Vedic hymns. According to these, while interpreting Vedic hymns, if the hymns are correctly pronounced, they refer to the laws of time or life. But it is also said in the Jaimini Sutras that time is not the cause of the result of action. Result is due to the effort.

The Vedas never refer to time as the sole cause, for a result never comes simply due to the passage of time. But it is true that sometimes if after several sincere efforts, one fails to achieve results, one can attribute the failure to time. In ancient thought time is associated with decay, death, and failure. Time changes our position. But the Mimamsa text clearly points out that everything happens due to the impelling force, and time is not connected with it. The concept of change is associated with both nature and time. The concept of time is associated with any new being. But time itself is immeasurable as it is without beginning or end. It is through the instrument of intellect that we receive the idea of time. For the purpose of our understanding, the seers have divided time into *yugas, manvantaras,* and *kalpa.* These are nothing but the exercise of our mental faculties. When we analyze the etymological meanings of these terms, the point becomes clearer. The word *yuga* is derived from *yuj,* which means "to fix or concentrate the mind." The word *manvantara* is derived from *manu,* which is the same as mind. Similarly, one of the meanings of kalpa is research or investigation. And the word *kala* for time is itself derived from *kal,* which means to perceive or consider. So, it might be said that the idea of time involves a series of functions of the intellect or the mind.

It is mainly the orderly arrangement of objects or the succession of events that gives us an idea of time. The appearance of a new object in nature reminds us about the role of time.

Though the Mimamsakas are known as theists and God plays a supreme role in their systems, still time cannot be personified as God, as God creates and sustains the universe. But time does not play the role of creator and sustainer, although sometimes it is treated as the greatest destructive force.

After life begins on this earth, time starts acting upon everything of the universe, but time itself remains unaffected. Therefore it is said to exist for other things and not for itself. Like the *prakriti,* or nature, of the Samkhya system, time remains unaffected throughout its functions.

For our practical purposes we divide time into segments but time itself is a continuous whole.

Time is like butter that is beginning to separate out of cream; it partakes of the nature of both the butter and the cream, yet the two can be separated. Like the endless chain of desires, time flows continuously. It has been said that when the mind begins to function, desire arises, hence the idea of time is associated with desire.

The Mimamsa school follows the sacred text known as the Gita. In the Gita it is stated that the number 12 refers to time. This number constitutes the basis of the calculation of the time of day and night, the months of the year, as well as the great ages of time, all of which are multiples of the number 12. The Mimamsa text refers to *dvadasa-satam,* which may mean both 112 and 1,200. These two numbers refer to the passage of time. There are four yugas: *Satya, Treta, Dvapara,* and *Kali.* The entire duration of these yugas make a Manvantara, and a thousand yugas constitute a kalpa. The duration of these four yugas is said to be 1,728,000 years, 1,296,000 years, 864,000 years, and 432,000 years, respectively, of human time. The above figures are nothing but multiples of 1,200, which may be said to refer to prakriti, or time. In the Mimamsa text, the number 12 plays an important role, as it represents time or prakriti.

Bhatta and Prabhakara Schools Compared

Both of the schools of Mimamsa (Prabhakara and Kumarila) admit that substance is that in which quality resides, and they treat time, like space, as substance.

Kumarila, in his commentary titled *Slokavartika on Sabara-bhasya,* an important text of the Mimamsa school, says that time is one, eternal, and all-pervasive. But although time is all pervasive, it is conditioned by extraneous adjuncts for the purpose of empirical usage. And this is the reason that there are various divisions and subdivisions within all-pervasive time. *Tantravartika,* another commentary in prose on *Sabar-bhasya,* describes time as eternal like the Veda. Not only Kumarila but Prabhakara, another philosopher of the Mimamsa school, also treats time as one of the eternal substances.

Regarding the perceptibility of time, the two schools of Mimamsa (Bhatta-Mimamsa and Pravakara-Mimamsa) differ in their viewpoint. The Bhatta school held that time is perceived, whereas the Pravakaras joined the Nyaya-Vaisesika system in maintaining inference to be the valid means for knowing time. Parthasarathi Misra, a noted Bhatta-Mimamsaka philosopher, in his work *Sastradipika* points to the fact that all perceptual cognitions also include the duration of the perception. In our everyday dealings we express such statements as "we are perceiving the pot from the morning . . ." And this statement clearly reveals the fact that time is perceived. While recording a statement, we always use such expressions as "now," "then," and the like. Such expressions would be meaningless if time were not also perceived along with the perception of the object. These words refer to the time-content of the perception itself. The Bhatta-Mimamsaka wants to stress that the temporal dimension of all our perceptions would remain unaccounted for without the contention that time is amenable to perception. The Nyaya-Vaisesika philosophers deny that time can be said to be perceived, as it has no perceptible qualities such as colors and form. It can only be inferred.

But the Bhatta-Mimamsaka retort that absence of color in time does not prove that time is imperceptible. Possession of a quality like color is not a criterion of perceptibility. Thus the contention of the opponent suffers from the fallacy of false generalization. However, the Bhatta-Mimamsakas acknowledge that time as such is never an object of perception, but it is perceived always as a qualification of perceptible objects. Therefore time is perceived as a qualifying element and never independently of the perceptible object. This is why we perceive events as slow, quick, and so forth, which involves a direct reference to time.

In *Manameyadaya,* a notable Mimamsa work, one of the exponents of Bhatta-Mimamsa, Narayana, refutes the claim of Nyaya-Vaiseseka that time is inferred on the basis of such notions as simultaneity. Narayana expands his view with the following example: In our everyday life we experience such events as "Devadatta and Yajnadatta arrived simultaneously" or "Ram arrived late." Here the question is whether such awareness, received through perception, can be denied to have time as its essential component. The point that emerges is that such direct, immediate awarenesses as simultaneity or lateness cannot be ascertained, as in the above examples, through anything but sense-perception. "Devadatta," "Yajnadatta," and "Ram" are related directly to time, and the latter is perceived along with the substances that it qualifies.

Prabhakara also treats time as one of the eternal substances. According to Prabhakara, space and time cannot be perceived as they cannot be seen or touched. Prabhakara considers some degree of magnitude along with color and touch and other such qualities as a necessary condition of proper sense perception. Time, though large, is not perceptible because it is devoid of color and touch.

Vedanta

The Brahmanical tradition finds its full expression in the system of Vedanta. The system follows the literal teaching of the Brahma Sutra, where a complete identity or oneness is shown between the world and the Brahman, hence it denies the reality of the finite world of time and space. The two main commentaries of the Brahma Sutra are the following: Samkara-Bhasya, propounded by Maharshi Samkara, and Sribhasya, propounded by Maharshi Ramanuja. Both of them believe that Reality is non-dual, but their interpretations differ. The school of Samkara is known as *Advaita-vedanta,* and the school of Ramanuja is known as *Visistadvaita-vedanta.* In the school of Advaita-vedanta, the problem of Creation is reduced to a problem of appearance, whereas in the Visistavaita school of Ramanuja, the world is conceived as the body of God. The concept of time is discussed here mainly from the Advaita-vedanta standpoint of Samkaracharya. The conceptual framework of this school has the unique characteristic of expressing its position with the single dictum, "Reality is the-one-without-another." Here the concept of being is treated as timeless, involving the notion of time as appearance. This nondual nature of Brahman (reality) reduces all duality (difference) to a problem of appearance. In this metaphysical system there is no place for the concept of objective real time. To accept time as real is to invite pluralism. But this view cannot be accommodated in the system of Advaita-Vedanta because "Reality is one-without-a-second." So the question arises, What will be the status of time here?

To understand the status of time, it is necessary to discuss the notion of causality of the Vedantins that is known as Vivartavada. In this theory, the effect is characterized as "no-other," that is, *ananya,* to the cause. In his commentary on the Brahma Sutra, Samkara brings out the importance of the term ananya as the effect being no-other in relation to the cause. This is the kernel of the vivartavada of the Advaita Vedanta. In the Vedantaparibhasa, an important work on the Vedanta glossary of technical terms, the significance of the term *vivarta* is explained. The term vivarta is to be understood by contrasting it with the term *parinama.* When the cause and the effect are taken to be realities with the same status, the effect is designated as parinama of the cause; for example, prakriti and its different aspects evolve in Samkhya system. But if the cause and the effect cannot be given the same ontological status, it is termed vivarta, as in the case of the world as effect in relation to its cause, Brahman, the Real, in Advaita Vedanta. Here the effect is indeterminable, related to neither sameness nor difference. The effect is nothing but the *appearance* of the cause—the effect has no separate existence of its own other than a difference of name and form, just as the earthen jug cannot have any reality apart from the clay, its material cause. The Advaita Vedantin asserts that no change or modification can be ascribed to that which is real. In other words, change can never be granted a separate ontological status under any circumstances.

The process of Creation as discussed in the Brahma Sutra shows that the world is in time. And time is characterized by succession and sequence. The steps shown in the creative process involve succession. This succession implies that the world must be in time. The creation and the dissolution of the world are a temporal series.

The Vedantins believe in the rebirth of the soul. The experiences gathered by the finite soul in each birth and death are events in time. The Vedanta schools agree unanimously on one point: that the liberated soul is beyond the domain of the temporal world. Therefore, finite souls live, move, and have their being in time. But here a question arises: How can an eternal and changeless Brahman be held to be preceding the world? Precedence, succession, sequence—these are all time relationships. If Brahman precedes the world and brings the world into existence at a certain point of time, Brahman cannot be called eternal and cannot be beyond time. In the Vedanta texts the word *eternal* is used in different senses. Sometimes the word *eternal* means existing for an unending span of time. Sometimes this word is used in the sense of being beyond time. In other places it is taken as transcending time yet somehow including it. There is a distinction between self-contained Brahman and Brahman-who-creates-this-world in the Vedanta texts. But this distinction is apparent, not real. The temporal order of the world is in Brahman. Thus Brahman is beyond and yet somehow includes time.

In fact, the Advaita Vedanta reduces the problem of creation to a problem of appearance. Just as the earthen jug, which has a distinct name and form, does not have an existence independent of the "clay" from which the jug is made, similarly the world as effect has no independent existence without its cause: Brahman. The Advaita Vedantins do not accept Brahmaparinamavada, a theory where the world is conceived as a real transformation of Brahman. The Vedanta school maintains Brahman as the cause, but cannot accept any transformation or modification of the cause. The empirical world is entirely dependent on the self-existent Brahman, having no reality of its own. Brahman is the indispensable cause of the world-appearance. *Maya,* or illusion, explains the existence of this temporal and spatial world. But it should be pointed out in this connection that the idea of appearance does not imply that the world is merely a subjective dream. Samkara, in his commentary on the Brahma Sutra, refutes the Buddhist school of subjective idealism by saying that the world is empirically real. The idea of the false appearance of the world is intended to disclose its entirely dependent status, that is, it is not real per se. Brahman as real per se as cause of the origin, sustenance, and destruction of the world points to the formulation of the idea of being as timeless as the very presupposition of the temporal. There are two types of definition of Brahman as cause of the world in the Advaita Vedanta texts: one is *tatasha-laksana,* the accidental or modal definition; the other is *svarupa-laksana,* or the nonrelational definition. The modal definition indicates Brahman as the ground of the experienced world as it appears to be. But the Advaita-Vedanta advocates a nonrelational definition of Brahman as *sat-cit-ananda swarupa* (being–consciousness–bliss). The temporal world as effect is not ontologically real, but Brahman as its foundation is self-existent. In Advaita-Vedanta, Brahman is characterized as nontemporal, nonspatial, and noncausal. Time, space, and causality are all categories of the empirical world. These categories presuppose pluralities that are the products of our ignorance or *avidya.* It is because we are veiled with ignorance that we experience this plural world. Brahman transcends these categories and is the timeless Reality. Thus Brahman is beyond the spatiotemporal sequence of multiple events and things.

Sri Harsa, an ardent follower of Adaita Vedanta, raises the question whether such time distinctions as past, present, and future are integral or not integral to time as such. If these distinctions are integral to time as such, then the notion of the unity of time has to be given up. On the other hand, if one upholds the unity of time as essential and the differences of time-forms as inherent in it as its threefold nature, then the designations of past, present, and future could be made at random for want of a strict basis for such usages. This is to say that one cannot accept the differences of time-forms as integral to one time, either. But if it is said that it is due to the sun's motion that time divisions arise, Sri Harsa also finds that to be equally untenable. He holds that the solar motion cannot account for the determinations of the different time forms, since it is used as the common criterion for the divisions of all three time forms—past, present, and future. It is said that the same qualifying factor—the solar motion that distinguishes the past day from the present and also distinguishes the present day from the future—is not a basis for valid argumentation. In this way Sri Harsa rejects the reality of time.

Not only Sri Harsa but also Citsukha, another great exponent of Advaita Vedanta, in his important work *Tattvapradipika,* has discussed the problem of time thoroughly. While refuting the existence of time, Citsukha argues that neither perception nor inference can establish the reality of time. The ontological reality of a substance can be established through perception only if the substance in question can be said to be perceived by vision or touch. But as time is without form and is intangible, sense perception cannot be the source of knowledge. Time cannot be perceived even though the mind works only in association with the external senses. It cannot even be inferred in the absence of perceptual data.

Again it is possible to point to the existence of such mental states as happiness or sadness, which are known through introspection and need not be first known through sense perceptions. Could the existence of time be established in a similar way? But Citsukha rules out this possibility, as it is possible only for facts that are subjective, but time as an objective category of existence cannot be thus established.

Time cannot be inferred as the substratum of the notions of priority and posteriority, succession and simultaneity, quickness and slowness, as these notions are not associated always and in all places. It may be argued by the Naiyayikas that the entity that establishes relations between the solar vibration and worldly objects is called time. But Citsukha replies that all-conscious self is the cause of the manifestation of time in things and events; therefore it is unnecessary to assume the existence of a further entity called time. The notions of priority and posteriority are associated with a larger or smaller quantity of solar vibrations. So here also it is not necessary to admit time as a separate category.

Concluding Remarks

In conclusion, it may be noted that the Brahmanical tradition expresses its conception of being in its radical form in the Vedanta system, rejecting the pluralistic model. The system advocates a philosophy of nondualism and focuses on the reality of the unchanging eternal Brahman as the one and only Reality. The concept of time plays a phenomenal role without any ontological reality.

Debika Saha

See also Becoming and Being; Change; Eternity; Hinduism, Nyaya-Vaisesika; Hinduism, Samkhya-Yoga; Idealism; Materialism; Metaphysics; Ontology; Time, Measurements of

Further Readings

Balslev, A. N. (1999). *A study of time in Indian philosophy.* New Delhi: Munshiram Manoharlal Publishers.

Jha, G. (1942). *Purva-Mimamsa and its sources.* Banaras, India: Hindu University.

Mandal, K. K. (1981). *A comparative study of the concepts of space and time in Indian thought* (2nd ed.). Patna, India: A. Mandal.

Radhakrishnan, S. (Ed.). (1952). *History of philosophy: Eastern and Western.* London: Allen & Unwin.

Hinduism, Nyaya-Vaisesika

The Nyaya-Vaisesika schools of thought founded by Maharshi Gautama and Kanada, respectively, advocate a plural, realistic worldview. These schools focus on the reality of time as vital to their total conceptual framework. Their philosophical outlook regarding the role of time is distinctly different from that of other schools of the Indian tradition.

Time, in the context of the Nyaya-Vaisesika philosophy, has been studied in its various aspects. The question of its existence and how it is related to different ontological issues like causality, motion, and space are all highlighted in the Nyaya-Vaisesika system. This system believes in the theory of Creation. Kala, or Time, is considered as the eternal, unique, all-pervading background of the creative process. All events derive their chronological order through time. But time possesses no specific physical quality like color and thus cannot be an object of external perception. Neither is it perceivable internally, as the mind has no control over external or internal objects independently of a physical sense organ. But the question of its existence is arrived at by a series of inferences. The notions of priority (*paratva*) and posteriority (*aparatva*), of simultaneity (*yaugapadya*) and succession (*ayaugapadya*), and of quickness (*ksipratva*) and slowness (*ciratva*) constitute the grounds of inference for the existence of time.

It is a recognized fact that priority and posteriority are related with the movement of the sun. When using the term *now,* it is natural to refer to the motion of the sun above or below the horizon by so many degrees. But a pertinent question is raised by the Nyaya-Vaisesika philosopher: How can any object be related at all with the motion of the sun? It is not possible to establish any direct relation of inherence, as the motion of the sun inheres in the sun alone, and not between the object in question and the sun, which are far apart. There must be a connecting medium that joins the two and that is capable of transmitting the quality of one to the other. This fact leads to the inference of time. Regarding the question of whether time is perceived or inferred, there is a philosophical debate among the Indian realists. The main voice in denouncing the view of the Nyaya-Vaisesika is the Bhatta-Mimamsaka school. In reply to the Nyaya-Vaisesika view that time cannot be said to be perceived as it has no sensible qualities such as color and form, the Bhatta-Mimamsakas maintain that sensible qualities are not the criteria of perceptibility. However, they do acknowledge that time as such is never an object of perception, though it is always perceived as a qualification of sensible objects. It is for this reason events are perceived as slow or quick, which involves a direct reference to time. The Nyaya-Vaisesika philosophers answer that a directly perceived time would point to only a limited, divided time, which is not absolute time but conventional temporal time. Sridhara in his *Nyaya-Kandali* and Jayata Bhatta in his *Nyaya-Manjari* take up the issue in a brilliant manner. According to them, time cannot be established as objects of ordinary perception, as time does not possess any finite dimension.

There are certain typical terminologies in every Indian philosophical system that are unique within their field; the Nyaya-Vaisesika system is no exception. Besides normal perception, extraordinary perceptions are also accepted by this school. One of the extraordinary perceptions is known as *Jnanalaksana*. This is the type of perception where the perceived object is given to the senses through a previous knowledge of it. For example, when someone says, "I see the fragrant sandalwood." Here one visualizes fragrance due to a prior knowledge of it from past experience. Similarly, the perception of "the present pot" is composed of two elements. "The pot" is an object of ordinary perception, whereas the time element indicated by the word *present* is derived from previous prior knowledge of time, resulting in the extraordinary perception of "the present pot."

So the sense perception of time as a qualifying element of the object is analyzed by the Nyaya-Vaisesika philosopher as based on the previous inferential knowledge of time. Moreover, the Nyaya-Vaisesika system believes that time must be of unlimited magnitude as it has to determine the priority and posteriority of all finite substances of the world. In other words, it must be a ubiquitous substance. Time is also conceived as *nimitta karana* or the instrumental cause of all objects of the world. This causation also leads to the point that time is eternal.

Kala (time) is treated in the Nyaya-Vaisesika system as the substratum of motion. The statement "I am at present writing" clearly points out that time is the substratum of objective motion. Not only is time the substratum of objective motion, it is the cause of the origination, maintenance, and destruction of all objects of the world.

Time and Causality

In Nyaya-Vaisesika literature, the role of time comes to the forefront in discussions of causality. For any causal operation the idea of absolute time is accepted as a necessary presupposition. The distinction between the eternal and the contingent is clearly mentioned in their writings. An object that is ever-present cannot be amenable to creation or destruction. The contingent is defined as that which does not exist prior to its creation and ceases to exist after its destruction. An object like *akasa* (i.e., ether) is never nonexistent whereas an absolute nonentity like a hare's horn is ever nonexistent. Any causal operation is necessarily an event in time. No event is conceivable without time as its *adhara* or receptacle. According to Nyaya-Vaisesika philosophy, to deny time an objective reality is to face a static universe where there is no room for any change or movement.

The theory of causality known as *asat karyavada* presupposes time in the Nyaya-Vaisesika system. The theory is so called because the effect is conceived as *asat,* that is, nonexistent prior to the causal operation. Cause is defined as that which is an invariable and necessary antecedent to an event. Here, the idea of antecedence has an immediate temporal reference. The idea of time always follows when it is said that the effect succeeds the cause.

Another characteristic of time is that, though time is a *dravya (*substance) it does not presuppose any substratum for its existence, as it is something undivided and eternal. Time is *svatantra,* or independently real. As time is all-pervasive, it has no form. The main argument that the Nyaya-Vaisesika proposes is that time, being a necessary condition of all movement and change, must itself be free from general attributes.

Divisions of Time

But here a question arises: If time itself is free from general attributes, are divisions of time real? The Nyaya-Vaisesika does accept the conventional time divisions. Generally, time is divided into past, present, and future. This division does not affect the inherent nature of time. These conventional time divisions can be explained with the help of limiting adjuncts, which are of finite duration. It is only with relation to events that time takes on these distinctions. Saying that something is happening refers to an event that has already begun but has not yet ended. Similarly, the past is the time related to an event that completed its cause of action, and the future is related to an event that has yet to begin. It is only the actions that are labeled as past, present, and future. Real time is never affected by these *upadhis,* or external adjuncts, namely, different solar motions.

This conception of absolute time in the Nyaya-Vaisesika system has been criticized by all the schools of Indian philosophy. Here is the view of one of the major systems: The Advaita Vedanta school maintains that this argument is not plausible because all the three divisions of time are related in the same way with the same solar motion. For example, a particular day is understood as the present with reference to a particular solar motion. But it must be admitted that the same solar motion is responsible for past and future days. The day referred to above is understood as present on the day itself, as past on the days that follow, and as future on coming days. Here the three time determinations, namely present, past, and future, have the same conditioning factor, namely, solar motion.

The Nyaya-Vaisesika answer is that the above position has come about due to the absence of certain necessary qualifications regarding relationship. When the time of an event is in "actual" relationship to solar motion we cognize it as present. A thing is cognized as past when the particular relationship "has been" and "is no more," and when the relationship in question "will be" and "is not yet," it is recognized as future. But the vedantin does not accept this position and says this argument is merely tautologous. The terms *actual, has been,* and *will be* are synonyms of present, past, and future, respectively.

In answer to his opponent, the Nyaya-Vaisesika suggests a modified definition of time division. The time that is conditioned by a particular action is present in respect to that action alone and not in relation to other actions.

In fact, the criticisms that the opponent offers are applicable only to the time division of the Nyaya-Vaisesika system. But time division is not inherent in the nature of time; hence it does not at all affect time-in-itself. Thus the criticisms do not really affect the reality of absolute time. These time divisions belong only to the events that are in time. The Nyaya-Vaisesika does not agree that the time series is the "schema" of the understanding and is formed by the conceptual fusion of discrete movements. The reason behind this view is the following: It is not possible to encounter the objective existence of a momentary entity. "The jar exists for many moments." This perceptual judgment cannot prove the objective existence of moment. It is a common experience shared by us all that a moment is supposed to vanish just after its contact with the sense organs; it cannot synchronize with perceptual judgment. A question, therefore, arises: Is not the use of the term *moment* superfluous? The Nyaya-Vaisesika system maintains that it is not superfluous, it is part of the whole cognition procedure. Moreover, every cognition presupposes a determinant datum, hence a particular datum in this case should be pointed out. It is said that the datum in this case is a particular motion and the pre-nonexistence of disjunction caused by it as the determining factor of motion. Each of the moments covers a definite duration; hence they cannot separately be the datum. These two, taken together, form the datum of cognition.

Moment, Time, and Space

In the *Prasastapadabhasyam,* one of the major authentic books of the Nyaya-Vaisesika system, the unique character of time is brought out in relation to space. Time has only one form of mensuration. The point is elaborated by saying that the temporal order of events is such that it does not allow for reversibility, whereas the spatial order does allow that. Thus, in the realistic framework of Nyaya-Vaisesika, another question crops up: How are they related? It is said that every cognition acquires them at the same time; hence cognition itself is the connecting link. The moment itself is the datum of such cognition. Therefore the concept of moment arrives indirectly in the framework of cognition. A moment is the point of time that refers to the final phase of cause and the initial phase of effect. Vallabha, a famous commentator, in one of his books defines moment as that intervening span of time that comes between the completion of the totality of caused conditions and the production of effect. This discussion reflects the realistic attitude of the Nyaya-Vaisesika system. These two—space and time—are characterized as *niravayava* (noncomposite), *avibhajya* (indivisible), and *vibhu* (ubiquitous). All objects are in space and time, but space and time cannot be said to be contained in anything.

This traditional view of absolute time is questioned by the later school of the Nyaya-Vaisesika system. Raghunath Siromoni, one of the famous philosophers of the Nabya-Nyaya system, challenged the entire conceptual framework of the pluralistic metaphysics of Maharshi Gautama. In his book *Padarthatattvanirupanam,* he criticized the traditional understanding of time. He does not find enough justification for accepting these two all-pervasive substances that require adjuncts in order to account for spatial and temporal divisions. He wants to identify space and time with God, who is also characterized as an all-pervading substance. Regarding time, he gives up the notion of absolute time and introduces a new category called *ksana* (moment). But he rejects the notion of moment in relation to motion as inadequate. Instead he sets up a new category consisting of things that are not motions but that share the universal repeatable property of momentariness.

This version of Raghunatha Siromani was not approved, however, by the later adherents of the school. In fact, the idea of absolute time is integral to the whole fabric of Nyaya-Vaisesika thought as all the concepts are woven together against the background of this particular concept; that is, absolute time. Therefore, in the Nyaya-Vaisesika system, time is a reality per se, the very presupposition of the reality of change.

Debika Saha

See also Causality; Cognition; Eternity; Hinduism, Mimamsa-Vedanta; Hinduism, Samkhya-Yoga; Materialism; Metaphysics; Perception; Time, Absolute

Further Readings

Bhadhuri Sadananda. (1947). *Studies in the Nyaya-Vaisesika metaphysics* (Series 5). Poona, India: Bhandarkar Oriental Research Institute.

Chatterjee, S. C. (1939). *The Nyaya theory of knowledge.* Calcutta, India: University of Calcutta.

Jha, G. (1916). *Padarthadharmasangraha of Prasastapada: With the Nyayakandali of Sridhara.* (English Translation). Beneras, India: E. J. Lazarus.

Niyogi Balslev, A. (1999). *A study of time in Indian philosophy.* New Delhi: Munshiram Manoharlal Publishers.

Hinduism, Samkhya-Yoga

The Samkhya-Yoga system is one of the oldest Brahmanical traditions of India. Founded by Maharshi Kapil and Maharshi Patanjali, respectively, these two schools share a basic ontological structure, with some subtle differences in their treatments of time.

The Samkhya system rests on a dualistic metaphysics, tracing the whole course of the universe to an interplay of two ultimate principles—*Purusa* and *Prakriti.* The dichotomy of matter and consciousness is expressed by these two terms; Purusa is the unchanging principle of consciousness, whereas Prakriti is the ever-changing principle of matter. The Yoga system shares this metaphysical dualism of Samkhya but whereas the latter is atheistic, the former is theistic. Both of them, however, deny the Nyaya-Vaisesika view of absolute time.

Time, Causation, and Change

The concept of time in the Samkhya-Yoga system can be grasped only in the framework of their metaphysical thought, along with their theory of causation termed as *Satkaryavada.* This theory explains the relation between Purusa and Prakriti in a unique way. Everything that is manifest is dependent on a cause. This causal dependence shows the contingent character of the objects. It is not possible to posit any entity without a cause. In the Samkhya system the understanding of the manifest as caused leads ultimately to the postulation of Prakiti as the unmanifest, uncaused principle. Prakriti is dynamic; it is matter that evolves ceaselessly. It is the formal, material, and instrumental cause of the world. This Prakriti consists of three qualities, or *gunas: sattva,* as something illuminating; *rajas,* as the active component; and *tamas,* as the restraining forces. These three gunas, through mutual cooperation, create this objective world.

The *Samkhya-Karika* of Isvarakrisna contains a detailed discussion regarding the change and origination of the 25 categories, but what is interesting is that nowhere is time recognized as a separate category of existence (*tattva).* In fact, time is taken as an aspect of concrete becoming. The Samkhya system does not recognize any conception of time as independent of change. Change is not understood in abstraction, but as a concrete becoming.

The Samkhya recognizes that the principle of change is ultimate, and so this principle cannot be derived from any fixed principle. The heterogeneous categories of creation with all its varied aspects presuppose always a primordial movement that remains even in the state of cosmic dissolution. It is because of the interplay of the gunas (qualities) that Prakriti is always in motion. In his *Samkhya Karika,* Vacaspati Mistra, the famous commentator, remarks on this ever-changing nature of Prakriti. There are two types of manifestations of Prakriti, *Sadrisaparinama* (homogeneous manifestation) and *Visadrisaparinama* (heterogeneous manifestation). Though no unique object arises from the homogeneous manifestations of the gunas, as they do not mix with one another, yet the process of self-production that is sattva giving rise to sattva, raja giving rise to raja, and so on, continues. The gunas never remain unmodified, even for a moment, as the very characteristic of the gunas is dynamicity. Creation of varied objects is possible due to the heterogeneous movements of Prakriti. This unceasing, ever-active nature of Prakriti points to the principle of change. And this principle of change is nothing but time. Some scholars, such as Madhavacharya in his commentary on *Parasara Samhita,* have characterized Prakriti as the very personification of time.

Here it may be asked whether the process of change is enough to account for time-experience. The Samkhya replies in the positive. Time-experience is totally dependent on the duality of Purusa (consciousness) and Prakriti (matter).

This system rejects the idea of time as a receptacle, advocated by the Nyaya-Vaisesika philosophers. Here the process of becoming as a movement from the potential to the actual is identical with the causal process. The notion of empty time is rejected as merely a thought construction. In other words, the reality of change does not necessarily imply a conception of time apart from the changing material.

In *Samkhya Karika,* Vacaspati Misra observes that it is not necessary to postulate an absolute time for the explanation of action, solar motion, and so on. The temporal phases can be explained with reference to the creative movements of Prakriti.

The concept of concrete becoming is primary. In the state of cosmic dissolution, Prakriti is to be taken not only as a principle of unconscious matter but also as the principle of time itself in its transcendental aspect. In the conception of dynamic Prakriti, the Samkhya system combines both time and matter in the same principle.

Vijnanabhiksu, a noted Samkhya commentator of the 16th century, advocates a different view. In his *Samkhya Pravacana Bhasya,* he maintains that time is nothing apart from the ubiquitous ether or akasa, which is an evaluate of Prakriti. Limited space and time are ether or akasa itself perceived as space and time by limiting adjuncts. The same limiting adjuncts, which are said to account for time-divisions, can do so with reference to akasa, making it unnecessary to postulate time as a separate ubiquitous substance called time. Aniruddha, another noted Samkhya commentator, in his *Samkhya-Sutra Vritti,* also advocates that limited time and limited space are really ether (akasa) conditioned by upadhis (limiting adjuncts) and hence are included in the unified entity of the ether.

In fact, when Vijnanabhikshu consigns the status of space and time to the level of Prakriti itself, he is merely pushing the realistic dualism of the Samkhya to its logical limit. In the Samkhya system, Prakriti is taken as the rootless root of all, and this is the reason for including everything, even time, as part of Nature or Prakriti itself.

In the *Yoga-Sutra* of Patanjali, time is seen as instant. The Yoga school shares the basic ontological structure of the Samkhya. The Yoga system develops its specific stand on the reality of the instant (*ksana*) and the merely subjective construction of sequence (*krama*).

"Sequence" or krama is the temporal succession of forms of the same object. This sequence is broken up into infinitely short instants (ksana). If the flow of time were absolutely continuous, no change could ever happen. But at each moment in time, a subtle, imperceptible change takes place; this imperceptible change is perceptible only to the Yogin, and it is the accumulated effect of these minute changes of which common people become aware. This theory has its modern parallel in the conception of time not only as objective and relative but also as a continuous phenomenon.

The Yoga-Sutra focuses on the three modes of immanent change as the *dharma parinama, lakshana parinama,* and *avastha-parinama*. The Yoga system, like Samkhya, holds that change is incessant in the dynamic Prakriti—the ultimate substance, or *dharma*. When the change is perceptible as a charge of *guna* (quality) in an object, it is called *dharma-parinama. Laksana parinama* directly involves the notion of temporal phases (past, present, and future). The potential is the future state, the manifested is the present, and what has happened is the past phase of the thing. *Avasta-parinama* is that aspect of change that deals with the notion of new and old. This can be explained with an example. An earthen jug is made from a lump of clay. The change of quality through the different stages of the processing of the clay constitutes its dharma-parinama. When it is said that the clay that is at present transformed into a jug was in its past only a lump, it refers to the laksana-parinama. This jug, whether new or old, is known as *avastha-parinama.* The clay remains the same, though the shape changes. This theory of change of the yoga system coheres perfectly with the Samkhya Yoga metaphysical framework. The point that emerges here is that the main substance (*dharmin*) remains the same throughout the three stages of past, present, and future, and the temporal changes are ascribed to the external aspects or qualities of the substance. How does this change in time occur? This is answered by the third type of change, that of the *avastha* (condition) of a thing. Time is a succession of individual moments that imperceptibly alter the condition of the jug; this is the well-known process of decay or aging.

If we substitute consciousness for clay in the above example, we find that emergence and restriction are the forms or dharma of consciousness, each being connected with the three segments of time—past, present, and future—and experiencing its own growth and decay.

The concept of instant (ksana) plays a very important role in this system. As discussed earlier, the concept of time is explained as instant here. The *Yoga Bhasya,* a notable commentary on the *Yoga-Sutra* by Vyasa, holds that the whole universe undergoes change in a single moment. It is said that just as the atom is the minimal position of matter, so the moment is the minimal duration taken by an atom to change its position.

In the Yoga metaphysical structure, a discrete view of time is advocated, over against the concept of time as unitary and as an independent category of existence. This system holds that the idea of time as instant is objectively real, but the idea of time as duration, (e.g., day, month, year) is a mental construct. These are ideal representations. In the *Yoga-Bhasya,* the idea of the reality of instant is recognized. In fact, the idea of time as a continuum or as a substance is unreal for yoga. Time is *vastu-sunya* (unreal) as a substance but time as instant is real (*vastu-patita*). According to the Yoga system, the idea of sequence can be formed only when two moments exist simultaneously. But in reality, two moments cannot and do not occur other than successively. What we experience is always the present, because the past (earlier) and the future (later) moments have no objective reality. In the *Yoga-Sutra,* Vyasa clearly states that the moment is real, and that the idea of a unitary objective time, whether as a collection of moments or as an objective series, is a subjective representation.

Being and Becoming

The idea of time as instant does not hold true of being. In this system, being is not instantaneous. As it was remarked earlier, the substance or being remains the same, persisting through the changes. In the Yoga system, the concept of becoming presupposes the substratum of Prakriti that continues and supports the process of evolution. Not only that, in the Yoga system, the root nature of consciousness is unchanging and unchangeable. The Yoga system recognizes the self as timeless.

Language

From the perspective of philosophy of language, the concept of time plays a distinctive role in the Yoga system. Patanjali in his *Mahabhasya* points out that time is the basis for the tense distinctions of verbs. Here a very pertinent question arises: What accounts for the tense distinctions of verbs? Despite the same verbal root, a word may be used in various ways in the sense of past, present, and future. An analysis of the nature of verbs is always associated with the concept of time. In the *Mahabhasya* of Patanjali one comes across the idea of time as that in association with which bodies grow and decay. Furthermore, the concepts of day and night are described as possible due to the movement of the sun in connection with time.

From the above discussion, it becomes clear that though the Samkhya-Yoga systems share a basic common metaphysical structure, their treatments of the concept of time are not similar. Both of them reject the concept of absolute time, yet in dealing with time, the Samkhya system accepts Prakriti as time personified, whereas the yoga philosophy explicitly advocates a discrete view of time.

Following Professor K. C. Bhattacharya, an eminent Indian philosopher, an explanation of the above fact may be given. It is true that in both the systems time is not admitted as a separate *tattva,* or category. Time in both is concrete becoming, and this becoming is not an event in time. Here becoming, or *Parinama,* may be understood as the cause turning up its own limitation or as the limited effect having got manifested. In the former view, the real objective fact is the act of the cause, its act of production, the succession of cause and effect being only a retrospective construction. In the latter view, the real fact is the antecedence of the cause to the effect, the prior becoming of the effect, but the causal act as the initial moment of this becoming is but an abstraction. Therefore to Yoga that presents the former conception, time is real as the causal act, the initial moment of this becoming. To Samkhya, the effect being preexistent in the cause is never turned up, so that the time relation of sequence alone is real time.

In conclusion, it may be said in the Samkhya-Yoga system the notion of time is beautifully illustrated through Nature, or Prakriti, in its undifferentiated, transcendental state and its differentiated, multiform condition. The reality of time is the reality of the ever self-modifying primary substance.

Debika Saha

See also Becoming and Being; Causality; Change; Consciousness; Duration; Hinduism, Mimamsa-Vedanta; Hinduism, Nyaya-Vaisesika; Materialism; Metaphysics; Ontology

Further Readings

Bhattacharya, K. C. (1956). *Studies in philosophy* (Vol. 1). Calcutta: Motilal Books.

Dasgupta S. N. (1974). *Yoga philosophy.* Delhi, India: Motilal Banarasidas.

Feuerstein, G. (1989). *The yoga-sutra of Patañjali: A new translation and commentary.* Rochester, VT: Inner Traditions.

Sinha, B. M. (1983). *Time and temporality in Samkhya-yoga and Abhidharma Buddhism.* New Delhi: Munshiram Manoharlal.

Histories, Alternative

The literary category of alternative histories is also known as alternate histories, uchronias, allohistories, or counterfactual histories. The last term is often used for serious studies from a historical perspective. Historians run experiments of a sort in complex areas such as economic history by imagining all events that shape an outcome are static except for one change. For example, consider a counterfactual study in which Calvin

Coolidge and a conservatively controlled and business-favoring Congress did not lead the way to a huge difference in wealth between the very rich and the middle class during the 1920s. Economic historians believe this was one major factor that led to overspeculation and then a Depression. In this situation, would the Great Depression have occurred, and if it did not, what major changes would this cause? Would Roosevelt have been elected in 1932?

Besides historical counterfactuals, a good deal of alternative history falls into the fiction genre, and in particular, science fiction. These stories begin with the premise "What If" some single significant event in history either did not happen or happened differently and then go on to explore possible developments. This genre is found in many different languages besides English.

Examples of alternative history appeared in Western literature as early as 1836 with the publication of Louis-Napoléon Geoffroy-Chateau's *Napoléon et la conquête du monde, 1812–1832, Histoire de la monarchie universelle.* This novel tells the story of Napoleon crushing all his enemies and ending as emperor of the whole world. Far earlier in time, Herodotus, in the 5th century BCE, looked at the consequences had the Persians defeated the Greeks at the Battle of Marathon in 490 BCE. Livy's *Ab Urbe Condita* (history of Rome, c. 29 BCE) is considered to have some alternative history aspects.

There were sporadic additional writings now considered to be alternative history during the 19th and early 20th centuries. Examples include a story by Edward Everett Hale in the March 1881 *Harpers* titled "Hands Off." This tale imagined Joseph was not sold into slavery in Egypt, leading to an eventual conquest of the Mediterranean by the Phoenicians.

In 1899, Edmund Lawrence published *It May Happen Yet: A Tale of Bonaparte's Invasion of England.* H. G. Wells's *A Modern Utopia* (1905) falls into one of the subgenres of alternative history, the parallel or alternative Earth plot. In this work, the point of divergence from actual history is the complete skipping of the Dark Ages. In 1926 Charles Petrie published "If: A Jacobite Fantasy," in the *Weekly Westminster,* exploring the idea the Hanoverians fled from Bonnie Prince Charlie in 1745 and the Stuarts were restored to the throne.

More stories and books appeared during the 1920s and mid-1930s. In December 1939, a short story by L. Sprague de Camp titled "Lest Darkness Fall" appeared in the magazine *Unknown.* This story, later published as a novel, is generally credited with the beginning of alternative history as a distinct part of science fiction. "Lest Darkness Fall" involves an archaeologist, Martin Padway, who, while visiting the Pantheon in Rome in 1938, is suddenly transported to the 6th century BCE. There Padway recreates some 20th-century inventions and eventually succeeds in averting the Dark Ages. Although the plot is similar to Mark Twain's *A Connecticut Yankee in King Arthur's Court* (1889), what distinguishes the two is Twain's focus on social inequities and de Camp's exacting historical accuracy in his details. An alternate candidate for this honor is the 1934 short story "Sidewise in Time" by Murray Leinster. However, Harry Turtledove, who has written a number of alternative history novels, as well as some other authors, credits de Camp with getting him interested in this genre.

In the past 20 years there has been a dramatic upsurge in alternative history, not only in novels and short stories but also in all forms of entertainment media. A brief list would include *Timestalkers* (1987), *Sliding Doors* (1998), the *Quantum Leap* television series (1989–1993), *Time Cop* (1994), and *Fatherland* (1994).

An idea that is at the heart of much of alternative history is the "butterfly effect." This is a concept connected with chaos theory and was described by Edmund Lorenz in a 1972 talk titled "Predictability: Does the Flap of a Butterfly's Wings in Brazil Set Off a Tornado in Texas?" A traveler into the past may alter one tiny thing, perhaps just by his or presence alone, which leads to significant changes in the future. This was the basis of one of the most popular classics of the genre, Jack Finney's *Time and Again* (1970), in which a present-day New Yorker joins a secret government project and travels back to 1880s New York. By preventing one chance meeting between two people in the past, the entire project in the future never happens.

One of the largest publishing areas of alternative history is Nazism, the Third Reich, and the Second World War. Gathering interest since the 1970s, this subarea has sparked more novels, short stories, films, television shows, plays, and even comic books than any other topic in alternative history. There have been at least 50 novels written with plots ranging from the Nazis winning World War II to something happening to prevent Hitler from ever coming to power. One of the best known is Philip K. Dick's *The Man in the High Castle* (1962) in which the Axis powers won World War II. More recently, Philip Roth's novel *The Plot Against America* (2004) is based on the famous aviator and America-first isolationist Charles Lindbergh defeating Franklin D. Roosevelt in the 1940 election, leading to America's neutrality in the war against Hitler's Nazi Germany.

The increasing popularity of alternative history, particularly in the popular culture, may owe something to an increase in imagination on the part of filmmakers, disenchantment with the current social and political events in everyday life, and a wish for alternatives. The late-20th-century proliferation of alternative histories was made possible in part by developments in atomic physics. Quantum mechanics, and in particular the Heisenberg uncertainty principle, contradicts age-old beliefs in absolute determinism—the doctrine that all future developments in the whole universe, from the largest galaxy to the smallest particle, are predetermined. If true, this would mean history could never change.

Present-day physics, however, generally accepts a less deterministic view of the cosmos. In the past half-century or so, as physicists and mathematicians attempt to link classical and quantum physics with approaches such as string theory, the possible existence of parallel universes is being explored. Parallel or alternate universe concepts are explored in a number of science fiction novels that may or may not be linked to alternative histories. For example, novels in which the South won the Civil War may predicate an alternative universe in which this is true. Other alternate universe stories with no historical basis involve simple differences such as Jack Finney's *The Woodrow Wilson Dime,* in which the simple slip between parallel universes of a dime with Wilson's image on it causes the protagonist to move into a significantly different, but in some ways similar life.

Charles R. Anderson

See also Eternal Recurrence; Experiments, Thought; Multiverses; Novels, Time in; Sin, Original; Progress; Time and Universes; Worlds, Possible;

Further Readings

Hellekson, K. (2001). *The alternate history: Reconfiguring historical time.* Kent, OH: Kent State University Press.

Nedelkovich, A. B. (1994). *British and American science fiction novels 1950–1980 with the theme of alternative history.* Belgrade: University of Belgrade.

Rosenfeld, G. D. (2005). *The world Hitler never made: Alternate history and the memory of Nazism.* New York: Cambridge University Press.

History, End of

The end of history usually does not mean the end of time. In fact, it means that history has a definite goal in mind, one it is attempting to attain or one it has already reached. These expectations placed on human development depict an image of a meaningful history and comply, in an academic sense, with the school of thought we attribute to the philosophy of history. Classically speaking, when we view history from a philosophical perspective, we don't perceive things as just singular occurrences. We consider them in their historical development. Who determines the course of history? Where do the laws that advance history actually come from? Can the goal of history be judged as positive or negative? All these questions imply how diverse the range of opinions is in regard to this matter. Yet, at the same time, it is possible to identify some of the criteria that are characteristic of end-time thinking: First, people commonly contemplate the end of history during periods of change, times that give them reason to think about the present and the future, because they are either afraid of the unknown or hoping for better times. Second, a primary prerequisite for believing that history has a certain goal that it is heading toward is based on the conception that occurrences are part of a progressive process. Third, this historical process must, however, be understood as human-made; the goal of history must be attainable within the life of human beings and it should not be reserved only for those of divine stature.

Historical Process

There is a basic difference between the way ancient and modern historians view the idea of progress. In early antiquity, history was generally seen as a decline, as the never-ending distancing from the golden ages of mythic times. So, in that sense, the historical process is firmly in divine hands, if it is of any significance at all: History is initiated by the gods and is therefore principally beyond human influence.

According to ancient thought, time flows constantly, without being directed, in the stream of eternal sameness. Certainly, during the course of antiquity, a cyclical picture of history is developed that has been documented in the cyclical theories dealing with transitional political policies. But change occurs essentially along the known paths of human existence. Compared with the anthropological constants that characterize humankind, social and cultural factors are of no particular significance. This even applies to a thinker like Heraclitus (c. 535–475 BCE), whose philosophy centers around the cosmic idea of becoming and passing away. But this thought has nothing to do with progress; change will not necessarily produce any improvements, so it is nothing to place your hopes on. That is also a reason why there are no relevant drafts of the future from that period of time. History is fundamentally the rendition of stories that illustrate human existence—as exemplified by Thucydides (460–c. 396 BCE) in his study on the Peloponnesian War.

Not until Judaism appears on the scene does a new awareness of time evolve: The belief in a future Messiah becomes a historic expectation that defines life itself. The anticipation of a redeemer gives an extraordinary meaning to the future and a structure to the historical process that has a redeemer as its goal. Consequently it is possible to imagine an end of history, even though this development is not historically manmade. Christianity's development is similar: Although world history is divided into a time before and a time after the birth of Christ, historical appreciation remains focused on the Second Coming. Particularly in times of crisis, the promise of redemption has rekindled the specter of doomsday and transformed the fear of Judgment Day into the hope that all misery will come to an end. So it's no wonder that throughout history believers have tried to accelerate salvific history. A vivid illustration of that is offered in the so-called Paupers' Crusade of 1096. But the popular doomsday calculations can also be seen in that connection, because they include the wish to make the Redeemer's Second Coming predictable. The Catholic Church has always eyed these number games with suspicion, in part because they spark a discussion about the expiration date of their own reign. Augustine (354–430) clearly rejected doomsday calculations: First, this knowledge is reserved for God. Second, however, there could not be a qualitative improvement of humanity, historically speaking, because, according to Augustine, Original Sin is the reason why humankind is never purely good or bad; it will always remain in that tense relationship where it depends on redemption. In a similar way, Martin Luther also rejected the thought of humankind actively promoting the Second Coming.

Nevertheless, this belief still finds support within the Christian community, and, in the course of time, it has been partly responsible for the evolution of two complementary structures: While the wish continues to grow that Christ's Second Coming should be "prepared" within the worldly community, the meaning of Original Sin has been losing its significance. The transition is recognizable, for example, in Joachim von Fiore (1130–1202): Joachim differentiates among three realms, those of the Father, the Son and the Holy Ghost, and accordingly teaches that the third realm is immanent, born from the simple strength of monastic contemplation without divine assistance. These teachings are an early example of the budding secularization of doomsday expectations that gained further momentum during the Renaissance. During this era, the vision of history changes drastically. History no longer serves as a voice of divine revelation. It takes on its own significance: History becomes a forum of humankind's ascent to its own Creator who endows it with his divine image, thus distinguishing humankind and setting it apart. With humankind's increasing (self-)confidence, which also includes a worldly portion of truth and goodness, it develops a willingness to accept evil as a worldly matter for religious reasons, as did Thomas Müntzer (1486/1490–1525). According to Müntzer, the teachings of original sin begin to fade, and the battle between good and evil that was carried out within humanity itself now becomes a battle of good people versus evil people. That is why Müntzer felt obligated to "purge" the Christian community of the false-believers, in order to herald the Kingdom of God.

Meaningful History

Human beings make history. This understanding of history becomes more and more widely accepted until it is universally acknowledged in the French Revolution. During the revolution, history itself becomes the subject. Time draws a line. It becomes the modern age, leaving the ancient regime behind. Contrary to prior experience, traditions no longer have any intrinsic value of their own. They are outdated; the past is actually seen as the past. People are no longer embedded in existing structures. There are now unforeseen possibilities, and the future appears to be open and manageable. In antiquity it was the anthropological constants that determined thinking; now it is social circumstances. Conditions that are hostile to freedom and contradict the ideals of equality are removed by means of revolution and reform. The end of history now refers to a situation where human capabilities are optimally developed and established by people themselves.

For Immanuel Kant (1724–1804) this is a regulative idea that shows lawmaking reformers which way to go; for other representatives of German Idealism, for example Johann Gottlieb Fichte (1762–1814), this demand sounds "more final." But it was especially the early socialist currents of the 18th and early 19th centuries that portrayed a happy end of history with their utopias; among them were names like Charles Fourier (1772–1837), Henri de Saint-Simon (1760–1825), and Wilhelm Weitling (1808–1871). They all shared a belief in the power of the Enlightenment and the goal of making the system of political dominance and economic exploitation superfluous.

August Comte (1798–1857), one of the founding fathers of French sociology, developed one of the most mature programs of this nature: Like many of his socialist comrades-in-arms, Comte was inspired by the innovative capabilities of science and technology and regarded the social sciences as the foundation for a controlled "reconstruction" of society, quite similar to the way the natural sciences controlled nature. To him, progress is no longer a question of faith or hope but one of positive knowledge, "positive" in the sense of real, useful, and precise knowledge.

Comte based his Law of Three Stages on this belief, claiming that knowledge first passes through a theologically fictional stage, then a metaphysically abstract stage before finally reaching a scientifically positive state formed by a spirit of order and progress. As soon as it is possible to subject the social changes to an intellectual authority, consisting of the most capable scientists, happiness on Earth will be assured. An earthly paradise under the political leadership of the intellectual elite sounds like a "positivistic" Plato—and it is no wonder that Karl Marx (1819–1883) rejected this and other programs as idealistic.

According to Marx, it was naïve to believe that the effective powers of capitalism could be replaced by humanistic reason. Marx was convinced that the only way bourgeois society could be overcome was through its own contradictions. For instance, Marx's well-known quote about capitalism digging its own grave says that the bourgeois relations of production themselves will reproduce the class struggle between capital and labor without initializing the instruments of compensation. Therefore, this conflict, according to Marx's analysis, has an antagonistic structure: More and more workers will be enslaved by economic necessity and forced to carry their own skin to market, while more and more capital will be amassed in the hands of very few who will become richer and richer. It is this law of development for history itself that determines the course of affairs, no matter what the players want to do or should do. So the end of a certain history is predetermined. In this case, it is the history of bourgeois society.

End of Modern Society?

As is commonly known, bourgeois society not only failed to come to an end, it also successfully outlived its rival political systems in the context of the East–West conflict. The collapse of communist rule in the Soviet Union in 1989/1990 enabled the spread of liberalism in Central and Eastern Europe and inspired the hope of a "new world order," supported by a consensus of the community of states and based on human rights and human dignity. This optimism is reflected in the analysis published by American political scientist Francis Fukuyama titled *End of History,* first as an essay in 1989 where it was tagged with a question mark, and then as a book in 1992. Fukuyama claims that political reason has reached its goal, because liberal democracy has succeeded in becoming the adequate form of government for people in comparison with other political systems. Significant occurrences should not be excluded, but they will not alter the basic situation that—seen from a universally historical perspective—political development must result in a marriage between democracy and the market economy. There are no other alternatives.

Fukuyama bases his historical considerations on an interpretation of G. W. F. Hegel by Alexandre Kojève (1902–1968). In Kojève's version of Hegel's *Phenomenology of Spirit,* the end of history is reached when the contradictions that had previously existed in the various struggles for recognition are resolved and shared by everyone. Contrary to Marx, Kojève specifically assigns capitalism the competence not only to spread affluence and global standards of values and rights but also to balance the inequalities of the market and to redistribute prosperity. He envisions a state of universal freedom and the successful emancipation from all pressures for modern society.

Kojève's interpretation, which is especially influential in French philosophy, should not be understood as a true-to-the-original reconstruction of Hegel's philosophy. Hegel (1770–1831) himself does not assume that the dialectical logic of the struggle for recognition will be overcome. The state may restrain the struggle between individuals, but the intergovernmental world remains in its natural state and thus in the paradigm of the struggles for recognition. It has always been this point of view that others have used to accuse Hegel of having glorified the nation-state. For Hegel, however, it is more a matter of the plurality of concrete life forms. The Age of Enlightenment's universal demand should not seduce us into overlooking the fact that particular "national characters" have lives of their own regarding specific political communities; in Hegel's opinion, that would be an example of apolitical thinking denying itself the insight into the bourgeois era's cultural bondage. The tendencies of bourgeois society to expand into a world community is based on the success of the economy's division of labor. But it is Hegel's conviction that "no state can be established" on the interplay of diverse egoistic interests, calculated economic decision making, and formal lawmaking alone.

From the perspective of Hegel's philosophy of freedom, there is no end in sight for history, either. In Hegel's opinion, freedom and consciousness have a dialectic relationship: History advances in an awareness of freedom when its consciousness becomes conscious of itself and propagates itself as self-consciousness, as in the case of the French Revolution, which marked a decisive breakthrough toward general and political freedom. Yet this new understanding of freedom also introduces new demands that Hegel discusses in the context of the Jacobin terror. In view of the demands of the modern globalized world, Hegel would hardly speak of the end of history. Instead he would speak of the need to understand the ambivalences of freedom. This not only requires that the processes that brought about a lasting impulse for integration following the end of the East–West conflict in Europe are taken into consideration. It also requires that the "opposing movements" of regionalizing systems of order are understood, movements that stir up new conflicts and transform old systems. So it remains to be seen whether the effective cultural diversity, for example, between Islam and the West, will be consolidated in a new systematic rivalry, a "Clash of Civilization" (S. Huntington). And the future of liberal democracy is just as uncertain, considering that the majority of nations will hardly accept it as the universal and ultimate goal of history.

This "realistic" point of view of an uncertain future has also led, among other things, to a greater theoretical humility within political philosophy and the theories of international relations. On the one hand, it has promoted historico-philosophic reflections on end time that are connected to postmodern and post historical concepts. Even Kojève is ambivalent about his envisioned final stage of history: In the general state of happiness, man's "negativity" fades, Kojève claims, and with it his will to overcome himself, his ability to transcend his own nature. This view also absorbs Friedrich Nietzsche's (1844–1900) thoughts on the "last man," who tries to numb the pointlessness of his existence by satisfying his "little desires." One of Nietzsche's central thoughts consists in enlightening the world about the end of all illusions. Human reason set forth to retrace Christianity's promise of truth and morality; but, according to Nietzsche, it found—in the truest sense of the word—nothing. Consequently, man's own self-enlightenment had to end in the "death of God," making man responsible for the meaning of his own life. In Nietzsche's opinion, it is a task only the strongest individuals are able to cope with.

Postmodernism celebrates this disillusionment—in the words of Jean-François Lyotard (1924–1998)—as the "end of the great tales." It opens the world to a pluralistic diversity of views and attitudes that also allow criticism of the outdated ideas of a self-dependent subject. According to the views of postmodern theorists, it doesn't have as much to do with the end of history as with the end of the totality of every historical interpretation based upon reason. They don't see the open future as uncertain. They understand it as a form of liberation, opening the world to the chance of new ideas. Specifically, this belief in the power of innovation, particularly in the areas of the arts and culture, is branded by the post-histoire representatives as an illusion. Not diversity but simplicity characterizes the personality of the modern age. Yet this hectic business, as Arnold Gehlen (1904–1976) claimed, cannot deceive us from seeing that it is essentially just cultural redundancy. Only remakes and recycling, but no real progress anymore, neither in the arts nor in other social areas. The post-histoire view says that history has come to its end, because society has lost the strength to set new goals.

By reviewing the history of philosophy (of history) and considering the various schools of thought, it seems that any reflections on the end of history are a question of mood that can be compared to a theory of colors: ranging from hopeless black to gloomy gray to a happy colorfulness and a confident rosy-ness. So the course of history is, to quite a relevant extent, a question of what people themselves are willing to risk.

Oliver W. Lembcke

See also Augustine of Hippo, Saint; Clock, Doomsday; Comte, Auguste; End-Time, Beliefs in; Enlightenment, Age of; Fichte, Johann Gottlieb; Gehlen, Arnold; Hegel, Georg Wilhelm Friedrich; Heraclitus; Kant, Immanuel; Luther, Martin; Marx, Karl; Nietzsche, Friedrich; Postmodernism; Teilhard de Chardin, Pierre; Thucydides; Time, End of; Universe, End of; Zeitgeist

Further Readings

Cohn, N. (1970). *The pursuit of the millennium: Revolutionary millenarians and mystical anarchists of the Middle Ages*. Paladin: London.

Fukuyama, F. (1991). *The end of history and the last man*. New York: The Free Press.

Kojève, A. (1980). *Introduction to the reading of Hegel: Lectures on the phenomenology of spirit* (A. Bloom, Ed., J. H. Nichols, Trans.). Ithaca, NY: Cornell University Press.

Koselleck, R. (2004). *Futures past: On the semantics of historical time* (K. Tribe, Trans.). New York: Columbia University Press.

Lyotard, J.-F. (1984): *The postmodern condition. A report on knowledge* (G. Bennington & B. Massumi, Trans.). Minneapolis: University of Minnesota Press.

Niethammer, L. (1992). *Posthistoire: Has history come to an end?* (P. Camilier, Trans.). Verso: London.

Scholem, G. (1995). *The messianic idea in Judaism and other essays on Jewish spirituality.* New York: Schocken Books.

Hitler, Adolf (1889–1945)

German dictator Adolf Hitler (born Adolf Schicklgruber) was the leader of the Nazi party and Führer of the Third Reich of Germany from 1934 to 1945. He and his National Socialist movement were one of several nationalistic and racist mass movements that arose from the political and economic problems that followed World War I. Hitler and his followers were responsible for many of the events that led to World War II, most of which shaped the latter 20th century. His promotion of racial supremacist doctrines and anti-Semitism culminated in the Holocaust, the systematic murder of more than 6 million Jewish civilians. Consequently, Hitler left a tragic and indelible mark on recent human history.

With the outbreak of war in 1914, Hitler volunteered for action in the German army. He fought on Germany's Western front for 4 years. Injured and gassed, Hitler won the highly respected Iron Cross. After the German defeat, he became convinced that his country was not defeated on the battlefield but was stabbed in the back by traitors, Jews, and Marxists who sabotaged Germany with the Treaty of Versailles, by which the victorious Allied powers inflicted humiliation and ruinous reparation payments on a defeated nation.

After the war, Hitler attended a German Workers' Party meeting, joined, and became one of the party's best speakers. The party was one of many political groups formed after Germany's defeat that called for national unity and promoted anti-Semitism. These militant and nationalistic parties were similar to those fascist parties in Italy and Spain that were radical, anti-liberal, anti-Marxist, and authoritarian. When Hitler became leader of the party in 1921, it was renamed the National Socialist German Workers' Party (the official name of the Nazi party).

Runaway inflation and the French occupation of the Ruhr Valley contributed to the growth of the Nazi party in Germany. Hitler hoped to end the Ruhr occupation by staging the "Beer Hall" Putsch of November 8–9, 1923, to march against the government in Berlin. The attempt failed and Hitler was tried for treason and sentenced to prison. During his imprisonment, he dictated *Mein Kampf* (1925), an autobiographical account of his life and political philosophy in which he described Germany's need to re-arm, become self-sufficient, suppress Marxism, and rid itself of the Jewish minority.

The conditions of the Great Depression were especially severe in Germany during the postwar period of the Weimar Republic; widespread poverty and public demoralization aided the growth of the Nazi party to the point that, in January 1933, President Hindenburg called Hitler to be chancellor of a coalition government. Hitler consolidated his power by persuading the government to suspend the constitution and to grant him emergency powers. At the death of President Hindenburg in August 1934, Hitler merged the offices of Chancellor and President to become the single leader of both the Nazi party and the Third Reich. Consequently, Germany became a one-party state as other political parties were banned and the unions were destroyed.

Hitler began massive rearmament and a building program to ready Germany for war. This stimulated the German economy, making him a popular leader. He included a propaganda campaign promoting German nationalism, stressing themes from the 19th century that focused on military losses to the French and called for a return to the glories of the Prussian state.

His power secured in Germany, Hitler took advantage of the appeasement policies of the French and English governments. Germany walked out of the Geneva Disarmament Conference and withdrew from the League of Nations. Hitler militarized the Rhineland in 1936, contrary to the disarmament clauses of the Treaty of Versailles. Next, Austria was annexed to Germany in the 1938 Anschluss, followed by the annexation of the Sudetenland of Czechoslovakia with the 1938 Munich Agreement. These annexations led Hitler to be named *Time* magazine's Man of the Year.

On September 1, 1939, Hitler's armies invaded Poland. Alarmed at Germany's full occupation of Czechoslovakia, a violation of the Munich Agreement, France and Great Britain honored their agreement to keep Poland independent and declared war against Germany. By 1940, Hitler had gained control of Norway and Denmark. Next, he focused on France, Holland, and Belgium. Only Great Britain, in the Battle of Britain, repelled German advances.

Hitler invaded Russia on June 22, 1941. The Soviets held the Germans at Stalingrad in 1943. After the United States declared war on Germany and the Allied efforts intensified, the German army lost momentum and the tide of war began to turn against Germany. Hitler gradually withdrew from public view and ignored advice from his military generals. He also intensified his execution of Jewish people in conquered territories; Jewish ghettos and villages were emptied and survivors sent to concentration camps for extermination. But a series of Allied victories continued to drive back the German armies, and an invasion of Germany became inevitable. As Soviet troops converged on Berlin, Hitler escaped to an underground bunker and committed suicide on April 30, 1945. Germany surrendered in May.

Hitler's dream of a greater Germany existed a little over 12 years and caused the death of approximately 50 million people globally. It took a coalition of world powers to defeat the German military in a war that lasted nearly 6 years. To prevent future conflicts, the Allies formed the United Nations, whose first act was to ratify the creation of the new Jewish state of Israel, in response to the Holocaust.

The legacy of Hitler's actions continued for nearly half a century as a weakened Europe became a battlefront in the Cold War between the Soviet Union and the United States. Germany itself was divided in half; though defeated, both sides of Germany were coveted by the superpowers for military support. To some degree it was the political instability in postwar nations that allowed anticolonial movements in Asia and Africa to form independent states, and the resistance to these movements led in turn to conflicts such as the Vietnam War. Former German territories in central Europe, liberated by the Soviets at the end of the war, had Communist regimes installed. The Soviet occupation plus the memory of the failed Munich Agreement made political appeasement unattractive as a foreign policy; it helped to establish the policy of communist containment by the United States that lasted until the reunification of Germany in 1990 and the dissolution of the Soviet Union in 1991.

Laura Sare

See also Judaism; Marx, Karl; Stalin, Joseph

Further Readings

Bullock, A. (1964). *Hitler: A study in tyranny* (Rev. ed.). New York: Harper & Row.

Fest, J. C. (2002). *Hitler* (R. Winston & C. Winston, Trans.). New York: Harcourt Brace Jovanovich.

Hitler, A. (1943). *Mein Kampf* (R. Manheim, Trans.). Boston: Houghton Mifflin.

Shirer, W. L. (1990). *Rise and fall of the third Reich.* New York: Simon & Schuster/Touchstone.

Toland, J. (1991). *Adolf Hitler: The definitive biography.* New York: Anchor.

Homer

Homer is the conventional name of the supposed unitary author of the famous Greek epics *Iliad* and *Odyssey* that were composed shortly after written language came into use again in the first half of the 8th century BCE. The *Iliad* dates to the second half of the 8th century BCE and is the oldest written literature in the West that has come down to us. The *Odyssey* seems to have been written slightly later, possibly by a different author. Marking the end of a long oral tradition, both poems show characteristics of oral improvisation, as in the use of formulaic phrases typical of extempore epic traditions, including the repetition of entire verses. At the same time the poet is held in highest esteem because of his ingenious and creative composition.

There is not a single contemporary document about Homer's life, person, and time, since the first sources from the 7th and 6th centuries mentioning him do not seem to know an official calendar and refer to him merely as a poet of past times. The question of authorship, date, and transmission, the so-called Homeric question, was discussed by modern scholars for about 200 years. Whereas F. A. Wolf (1795) and his school of "Analysis" tried to identify different poets emphasizing the inconsistencies in both epics, the "Unitarians" put stress on their artistic unity. Since the 20th century, the mechanisms and effects of oral transmission, as well as the poetic and aesthetic quality of the poems, have been the focuses of attention.

In both the *Iliad* and the *Odyssey* time is referred to in a highly elaborate way. Times of the year and the day are expressed by verbal pictures; for example, the morning is frequently described by the appearance of the rosy-fingered goddess Dawn (Eos) and by a variety of terms, such as the frequent use of *etos* for a certain year and *eniautos* for the general course of a year with its regular natural phenomena that recur every 12 months. The meaning of some of these terms is still under discussion: looking *prosso kai opisso* is usually translated as looking "forward and backward," that is, "into the future and into the past," although it seems to mean looking "forward and beyond" at times. In this latter case, one anticipates the near future and the more distant future that hides behind the immediate future.

Modern scholarship has proved wrong H. Fränkel's theory of Homer's indifference toward time and Th. Zielinski's opinion that Homer was not fully able to describe parallel plots. Scholars have underlined the difference between the time of narrating and the narrated time (the described actions do not happen as fast or as slowly as the narration goes on) as well as the fine technique of looking back and forward that creates a complex view of time instead of a simple chronological account of the events. Thus both poems consist of a selection of scenes essential for the plot, necessarily focusing on certain periods of time within the set time span. For instance, the plot of the *Iliad,* whose theme is the anger of Achilles, extends over 51 days within the 10th year of war between the Achaeans and Trojans. It does not include the end of the war, because Achilles' anger had ended before the conquest of Troy. The events of only 15 days and 5 nights are described in detail, while those of the remaining days are merely mentioned (e.g., 9 days of plague, absence of the gods for 11 days, Achilles' ill-treatment of the corpse of Hector for 11 days). Aristotle praised Homer for concentrating on the plot in a way that would befit tragic writers, by leaving out all scenes that would need to be included from a historical point of view but that are not an essential part of the plot, which evolves from the characters of the protagonists and their interaction with the gods according to Zeus' plan.

Anja Heilmann

See also Herodotus; Hesiod; Mythology; Presocratic Age; Thucydides

Further Readings

Morris, I., & Powell, B. (1997). *A new companion to Homer.* Leiden, New York, & Köln: Brill.

Hominid–Pongid Split

During the past 2 centuries, curious scientists have laid the foundation for answering the question of human origins using advances in technology. Fossil evidence and genetic studies have made this quest possible. Patient accumulation of evidence has led to gradual acceptance by the general public of the conclusion that our species has evolved, during 5 million years, from an ancestor in common with the four great apes in the remote past.

Aristotle, considered the founder of biology, was the first to effectively place animals in a specific order of taxonomy. By organizing species into common groups, he established a foundation for understanding the similarities among life forms on this planet. Even so, he taught the eternal fixity of all species.

Linnaeus, the father of modern taxonomy, took the science of classification to the next level. A species is seen as a group of individuals that share enough biological similarities that they can interbreed with one another successfully. The primate order, which was formed about 70 million years ago, is divided into two suborders: Prosimii and Anthropoidea. Being hominoids, humans and pongids (apes) are placed into the same taxonomic family due to their biological similarities.

Linnaeus's writings were available in the century before Darwin's *On the Origin of Species* (1859). If it were not for Linnaeus's work in biological classification, it would not been possible to speculate on how some species die off and new species are formed. This was later explained by Darwin with his theory of evolution. Darwin realized that species are not in a static state, since everything is in a dynamic process that results in constant change. With the uses of relative dating techniques, Darwin came to the conclusion that fossils in rock strata demonstrate a continuous organic evolution that led to a species' survival or extinction.

Advances in radiometric techniques have allowed scientists to date fossil evidence more accurately. The modern technology of chronometric dating, through the use of radioactive decay, has greatly strengthened the hypothesis that our species has evolved from a common ancestor close to the four living great apes (orangutans, gorillas, chimpanzees, and bonobos). Darwin argued that our evolution took place in Africa. Scientists realized that, to find the truth about our evolutionary past, they had to gather empirical evidence to solve the mysteries of our origin and history. For more than a century, they have searched for the so-called missing link between the great apes and humans.

The first major discovery that established our descent from a common ancestor with the apes was made in Africa, and known as the "Zinj" skull. This unearthing in 1959 by Mary D. Leakey shed light on the hypothesis that our species is more similar to the great apes than had been thought. Several decades ago, anthropologists thought that the split between fossil hominids and fossil apes had occurred during the Miocene epoch, about 12 million years ago. However, more recent hominid species found in southeast Africa are also pongid-like. This evidence from the Pliocene, about 5 to 7 million years ago, determines that our split from the pongids was more recent than had been thought.

During the Miocene, hominoids emerged in many varieties. Before the end of the following Pliocene epoch around 3 million years ago (mya), the environment had changed; the tropical jungles of Africa had become scattered woodlands and open savannas. This change directly resulted in the split between early hominid-like hominoids and pongid-like hominoids. Based on fossil evidence, this split from Pliocene pongid-like hominoids happened roughly 6 mya. The species that were able to adapt to living a terrestrial life survived to form our more recent ancestors. Bipedality is the true separation between the fossil apes and more human-like forms. Many other specializations like tool-making, articulate speech, and a far more complex brain where all later developments during the past 3 million years.

An early ancestor that was successful in this transition from quadrapedal movement to bipedality is known as *Australopithecus afarensis;* the features of *afarensis* are from the neck up chimpanzee-like and from the waist down human-like. The discovery of *afarensis* was only the beginning; scientists are still trying to uncover more clues from our distant past. Interpreting the evidence in order to determine the evolutionary advantage for becoming bipedal continues.

Owen C. Lovejoy, an anthropologist and an expert in anatomy, was the person whom Donald C. Johanson trusted in studying his discoveries at Hadar. Lovejoy has been an influential contributor to the understanding of our past; he believes that our evolution was based on a social advantage that leads to our survival. Hominids created an evolved breeding strategy that enabled humans to raise fewer children, but also allowed them to focus on the success of a limited number of offspring. Lovejoy believes that hominids' opportunity for success revolved around living in large monogamous groups. This is supported by the secondary characteristics that have formed to create the modern human; these phenotypes control the amount of competition between males. In the animal kingdom, an obvious way for species to determine if a female is in heat is to observe the inflammation of sex organs and the growth of breasts. These characteristics are clear signs that lead males to fighting, which would lead to the disbanding of groups. In hominids, it is difficult to make this distinction when a woman is not pregnant. Many criticize this theory of a monogamous relationship, because it goes against Darwin's evolutionary logic. Without the most dominant males passing on their genes to multiple partners, how would hominids survive? Lovejoy answers this argument with the theory that by males appealing to a singular mate, using their time during the day to gather food for not just themselves but also their partner, they allow the females to spend all their time raising the offspring. This allows for a successful passing on of their genes. Another major distinction between the pongids and hominids is that we evolved from being simply insectivores or vegetarians to being primarily omnivores; this allowed for a broad diet that provided a better opportunity for survival in an environment where grasslands where slowly replacing forests in Africa. Through cooperation, *afarensis, Homo habilis, and Homo erectus* allowed humans the opportunity to exist. The creation of a more complex brain came later in the development of *Homo sapiens sapiens*.

From close genetic similarities and observations of human and pongid social behavior, many scientists now recognize that, as mentioned earlier, the split between the hominids and pongids did not occur in the Miocene epoch, but more recently in the Pliocene. In recent decades, biologists have come to the conclusion that our species is more similar to the great apes than had been imagined even by Darwin.

Ryan J. Trubits

See also Aristotle; Darwin, Charles; Evolution, Organic; Fossil Record; Fossils, Interpretations of; Fossils and Artifacts; Haeckel, Ernst; Huxley, Thomas Henry; Olduvai Gorge; Scopes "Monkey Trial" of 1925

Further Readings

Birx, H. J. (1988). *Human evolution.* Springfield, IL: Charles C Thomas.

Foley, R. A., & Lewin, R. (2004).*Principles of human evolution.* New York: Wiley.

Johanson, D. C. (1994). *Ancestors: In Search of human origins.* New York: Villard.

Hourglass

The hourglass, also known as the sandglass, is a timekeeping instrument that has been used for centuries. The sandglass is constructed using two conic reservoirs that are joined at their apexes by a small hole. One reservoir is filled with a finite volume of sand that flows into the bottom reservoir over a set duration of time. When the sand has run completely from the top reservoir through the small opening, the previously determined time period can be recorded and the timepiece inverted to begin running again. The hourglass has been made in various time denominations ranging from 30 seconds to longer than an hour.

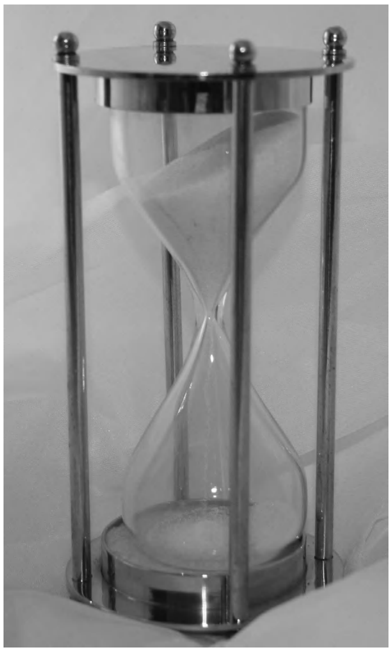
History

The actual date of the hourglass's emergence cannot be definitely placed. There are, however, many theories as to when the hourglass emerged as a common timekeeping instrument. The most significant clues to the invention of the hourglass deal with the dates of portrayals and the emergence of the technology needed to create the glass to make the reservoirs. No record exists of the sandglass's original form, so researchers have to work with the modern hourglass shape. Items were made from glass as far back as 2500 BCE, but the art of glass-blowing was not perfected until around 70 BCE.

The earliest definite depiction of an hourglass dates to between 1337 and 1339 CE. This depiction can be found in an Italian fresco on the walls of Palazzo Pubblico in Siena and was painted by Ambrogio Lorenzetti. Another early depiction of an hourglass can be found at the Mattei Palace in Rome. The palace contains a Greek bas-relief depicting Morpheus, the god of time, holding an hourglass. German artist Albrecht Dürer (1471–1528) profiles the hourglass prominently in many of his artistic works. The sandglass holds a prominent place in all three of his most famous copper engravings. *Knight, Death, and the Devil* (1513), *St. Jerome in His Study* (1514), and *Melancholia I* (1514) depict the hourglass just to the left of the central character. The first textual reference can be found in the Receipt of Thomas de Statesham, which dates to around 1345. This receipt references Thomas's acquisition of 12 hourglasses ("*pro xii orologiis vitreis*") in Flanders. The second textual reference dates to slightly after this, in 1380, and can be found in a furniture inventory of King Charles V of France: "*ung grant orloge de mer, de deux, grans fiolles plains de sablon en ung grant estuy de boys garny d'archal*" (a large sea clock with two large phials filled with sand, in a large wooden brass-bound case). The hourglass also finds reference in classical literature, specifically in the works of William Shakespeare. Specifically, Henry V (Act 1 Scene I) refers to an hourglass in the opening Chorus.

One theory credits the invention of the hourglass to an 8th-century monk of Chartres named Luitprand, but most historians believe that if there is any truth to this theory it would find credence as a reinvention or an improvement on the ancient sandglass after the Dark Ages. Many historians believe the hourglass came into use about the same time as, or slightly after, the clepsydra (water clock). Since both timekeepers use the same basic principle, emergence during the same approximate time period could be likely. For a long time no distinctions were made between the two, and they were simply called *horlogues,* leaving only context to determine which of the two was being described. This theory places the invention of the hourglass at around the 3rd century BCE in the Egyptian city of Alexandria. The sand for the hourglass would have been more accessible in regions with drier climates. In countries such as Egypt, water would have been scarce and not a resource that could be needlessly wasted. The more probable date of emergence coincides with the inception of sea travel, as the technology would aid in nautical navigation.

The hourglass has many advantages over the clepsydra. Sand, unlike water, flows at a consistent pace when pressure is applied from above. For this reason, sandglasses kept a more consistent and steady time. Moreover, unlike water, the sand would not freeze or evaporate, so no replacement filler was ever needed. Most high-quality sandglasses did not actually use sand, however, but finely crushed eggshells. The eggshells provided a smoother flow than sand and therefore provided a more accurate method of keeping time.



Several factors contribute to an hourglass's ability to accurately measure time. The type and quality of sand is important, and it must have a rate of flow that does not fluctuate.
Source: Patricia E. Green/Morguefile.

Ancient Variations

The hourglass has had many different variations since its invention. Although the hourglass and sandglass have become synonymous in modern meaning, ancient variations of the hourglass used different fillers as the timepiece evolved. Some ancient variations used mercury instead of sand. These variations required an extremely fine hole between the reservoirs to keep the mercury from flowing too quickly. Another mercury variation used a small bubble of mercury inside a narrow tube containing air. The resistance from the internal air pressure allowed the mercury to fall slowly through the tube and therefore allowed the measurement of a useful time period.

Since the original form of the hourglass is not known, it would be fair to consider the clepsydra and early sand clock (*clepsammia*) among the very early forms of the hourglass. Both of these early timepieces use a set amount of water or sand, respectively, and measured time by the volume of water and sand in a bottom reservoir, but could not be reset without refilling the top.

Ancient and Modern Uses

The hourglass found use in various places throughout history. The most notable of these is in the field of nautical navigation. In the early era of sea travel, it was crucial for ancient mariners to know the speed of their ship in order to know their location at sea. The hourglass provided a timepiece that would remain stable and reliable even in turbulent weather. Thirty-second sandglasses were used to calculate speed. Tying a rope to a heavy piece of wood and throwing the wood overboard behind the ship calculated speed. The wood created resistance with the water and dragged the rope out behind the boat. The rope would have knots tied 47-foot, 4-inch intervals so that each knot that ran through the fingers of the navigator in the 30-second time period indicated one nautical mile in an hour.

Sandglasses were also used as timers for all sorts of activities. They became the first industrial timers for early factories. *Das Feuerwerkpuck* (1450), a German essay on manufacturing, contains an illustration of a stamping mill being timed by an hourglass. Both politicians and clergy also used the sandglass as speech timers. The hourglass was introduced into the church during the 16th century as a tool to restrain preachers from speaking too long. The hourglass also served as a symbol during olden funerals that the sands of life had run out. In today's era, the sandglass has all but disappeared as a timer except for use in kitchens as the common 3-minute-egg timer.

Matthew A. Heselton

See also Archaeology; Clocks, Atomic; Clocks, Mechanical; Sundials; Time, Measurements of; Timepieces

Further Readings

Balmer, R. T. (1978, October). The operation of sand clocks and their medieval development. *Technology and Culture, 19*(4), 615–632.

Bruton, E. (1979). *The history of clocks and watches.* New York: Rizzoli International.

Cunynghame, H. H. (1970). *Time and clock: A description of ancient and modern methods of measuring time.* Detroit, MI: Singing Tree Press.

Macey, S. L. (1980). *Clocks and the cosmos: Time in Western life and thought.* Hamden, CT: Archon.

Humanism

While the word *humanism* is recent, the idea of humanism is one of the oldest and most transnational worldviews in human history. Most worldviews are defined in terms of the distinctive beliefs they hold, but the principal feature of humanism is not so much its core articles of belief, but the method by which inquiry into the world is undertaken.

The American philosopher Paul Kurtz provided what is perhaps the simplest understanding of humanism when he defined it in terms of its four constituent features. First and foremost, humanism is a method of inquiry; second, it presents a cosmic worldview; third, it offers a set of ethical recommendations for the individual's life stance; and, fourth, humanism expresses a number of social and political ideals. It is important to note the order in which these characteristics have been listed. Indeed, this order is a result of the seriousness with which humanism takes cosmic and evolutionary time. Number 4 is the least important of them, not because social and political ideals are unimportant, but because the nature and orientation of those ideals have been more susceptible to change over time and between continents. Numbers 2 and 3 are more important because the details of the worldview and the ethical recommendations have greater commonality over time and across cultures.

But the most important single characteristic of humanism is the one that is most impervious to the passage of time. The most constant defining feature of humanism is that it is a method of inquiry. From the Carvakas and Ajivikas in ancient India, from Kongfuzi and Wang Chong in China, from Thales and the Greek thinkers, through the Renaissance to the Enlightenment and on to the 21st century, humanism is best understood as a method of inquiry. The *conclusions* of that inquiry may change between cultures and between centuries, but the *method* of inquiry has remained essentially the same.

Symptomatic of the uniqueness of humanism is that for most of its life it has functioned very well without the word. Humanism as a *concept* has its origins in ancient India, China, and Greece—each one arising independently—but the actual *word* was not coined until 1808, in Germany. To make things more complicated, *humanist* existed as a word long before *humanism,* originating in the Renaissance, although traceable to the Roman word *humanitas*. But as humanism is defined principally by its method rather than by its conclusions, the lack of a word to act as a catch-all for those conclusions is a trivial issue.

Other philosophers, while agreeing that the method of inquiry remains the single paramount feature, have tried to articulate some general idea of what humanist philosophy would actually subscribe to. The best thought-out was by the American philosopher Corliss Lamont (1902–1995). In an influential account of the philosophy of humanism, one that went through several editions, Lamont outlined what he called the 10 central propositions of humanist philosophy.

1. Humanism believes in a naturalistic metaphysics or attitude toward the universe that considers all forms of the supernatural as myth.

2. Humanism believes that humankind is an evolutionary product of the nature of which we are a part; it has no survival after death.
3. Having its ultimate faith in humanity, humanism believes that human beings possess the power of solving their own problems, through reliance primarily upon reason and scientific method applied with courage and vision.
4. Humanism believes that all humans possess genuine freedom of creative choice and action, and are, within certain objective limits, the masters of their own destiny.
5. Humanism believes in grounding all human values in this-earthly experiences and relationships, and it holds as its highest goal this-worldly happiness, freedom, and progress—economic, cultural, and ethical—for all humankind.
6. Humanism believes that the individual attains the good life by harmoniously combining personal satisfactions and continuous self-development with significant work and other activities that contribute to the welfare of the community.
7. Humanism believes in the widest possible development of art and awareness of beauty, including the appreciation of nature's loveliness and splendor, so that the aesthetic experience may become a pervasive reality in the life of man.
8. Humanism believes in a worldwide democracy, peace, and a high standard of living on the foundations of a flourishing world order.
9. Humanism believes in the complete social implementation of reason and scientific method; and thereby in the use of democratic procedures, including full freedom of expression and civil liberties, throughout all areas of economic, political, and cultural life.
10. Humanism, in accordance with scientific method, believes in the unending questioning of basic assumptions and convictions, including its own.

The 10th proposition is significant. As with Kurtz's preference for seeing humanism as a method of inquiry, Lamont is clear that humanism is just as rigorous in questioning its own presuppositions as those of any other system. We may quibble over this or that point in Lamont's list, but the 10th proposition helps ensure the need for ongoing inquiry as the core humanist process.

Another account of humanism, by the philosopher Mario Bunge, seems at first sight to come from a different perspective than that of Kurtz or Lamont, but in the end it is the similarities that are more significant. Bunge speaks of humanism as involving concern for the lot of humanity. This concern he spells out in what he calls the seven theses of humanism, which go in this order:

1. *cosmological thesis:* whatever exists is either natural or manmade;
2. *anthropological thesis:* the common features of humanity are more significant than the differences;
3. *axiological thesis:* there are some basic human values, like well-being, honesty, loyalty, solidarity, fairness, security, peace, and knowledge, and these are worth working, even fighting, for;
4. *epistemological thesis:* it is possible to find out the truth about the world and ourselves with the help of experience, reason, imagination, and criticism;
5. *moral thesis:* we should seek salvation in this life through work and thought;
6. *social thesis:* liberty, equality, solidarity, and expertise in the management of the commonwealth;
7. *political thesis:* while allowing freedom of and from religious worship we should work toward the attainment or maintenance of a secular state.

Bunge is an advocate of what he calls *systemism,* which postulates that every thing and every idea is a system or a component of another system. In this way, the first thesis covers the broadest territory, and provides the foundation for the other theses. Looking at it another way, the theses run from the hard sciences through to the social sciences. Interestingly, in the first thesis, which addresses the individual human being, Bunge says what Kurtz also says, namely, the importance of the method of inquiry. From the point of view of time, the focus of inquiry for this encyclopedia, the crucial point of Bunge's systemism is that it proceeds from sectors in which time operates on a macro scale, to sectors operating on much more limited time scales, well within the human ability to grasp.

Humanism in the Ancient World

Humanism is a collective name that can be given to some of the oldest and most transcultural worldviews on Earth, beginning quite independently in India, China, and Greece. Looking to India first, humanist elements can be found in four of the six classic schools of thought (*darshana*) that make up classical Indian philosophy: the Samkhya, Mimamsa, Yoga, and Vaisesika. They either doubted the existence of any God or gods, or valued the acquisition of knowledge of the world as a worthwhile end in itself, or saw harmonious living within the world as freed from illusion as possible, as a worthwhile goal.

The oldest of the Indian *darshanas* is the Samkhya school, which was mentioned first in the 4th century BCE, although it had probably been flourishing for a century or so by then. The earliest known Samkhya work is the *Samkhya Karika,* written by Iswara Krishna about 200 CE. Samkhya thinking developed an elaborate metaphysics that was, broadly speaking, atheistic, recognizing only two ultimate realities: *purusa* (sentience) and *praktri* (matter). *Praktri* is uncaused, eternal, and in a state of constant evolution. It is composed of three essential substances: essence, energy, and inertia. Cosmic history began with these elements being in total equilibrium. Evolution began with the arrival of *purusa,* and is the principle for which evolution continues. *Purusa* is itself entirely uncreated and is neither God nor some sort of prime mover, although some strands of Samkhya thinking tend to promote *purusa* as a variation of universal spirit. It would be a mistake, however, to equate this notion of a universal spirit with God in the Western sense. What divided Samkhya thinkers was whether the notion of God was capable of any proof, or whether it was a mistaken belief. The Samkhya system advocated liberation from the bondage of *praktri* by knowledge, a liberation best equated with philosophical wisdom.

Standing alongside the classical Indian darshanas was the materialist school of thought known as the Carvakas, traceable to the 6th century BCE. Carvaka philosophy shared with other Indian schools the belief that the universe is interdependent and subject to perpetual evolution. But at that point they parted company, holding instead a range of unorthodox beliefs: that sacred literature should be regarded as false; that there is no deity, immortal soul, or afterlife; that karma is inoperative and illusory and matter is the fundamental element; and that only direct perception, and no religious injunctions, can give us true knowledge. The aim in life is to get the maximum amount of pleasure from it. This had various interpretations, from unalloyed hedonism to an altruistic service for other people on the principle that this will maximize one's own happiness as well as that of others. It will be seen that the humanist variants in Indian thought involved to no small extent a differing view of time, being more linear and embedded in nature.

Other Indian movements of a broadly humanist orientation in India include the Ajivikas and the Sumaniya, about which little is now known. The Ajivikas flourished between the 6th and 3rd centuries BCE, and their influence can be traced for more than 1,500 years. Like some early Jains and Buddhists, the Ajivikas went about naked to indicate their contempt for worldly goods. In the main, they upheld a principle of nonaction, denying that merit accrued from virtuous activity or demerit from wicked activity. Coupled with this was a thoroughgoing determinism and skepticism regarding karma and any sort of afterlife.

Humanist elements can be seen in some elements of contemporary Hinduism. For instance, the Rahda Soami group, which is engaged in building a magnificent temple in Agra, not far from the Taj Mahal, is broadly humanistic in outlook. They disavow caste barriers and undue emphasis on ritual and ceremony, and encourage secular and honest living.

In contrast to India, the humanist strand in China became the principal strand of thought. This is largely, though by no means exclusively, due to the influence of Kongfuzi (551–479 BCE), who is known in West by his Latinized name, Confucius. Chinese humanism is placed squarely in temporal time. Confucius's genius involved transforming the naturalism and humanism latent in Chinese thinking into the strongest forces in Chinese thought down to this day. He said that maintaining a distance from spiritual beings was a sign of wisdom; he expressed no opinion on the fate of souls, and never encouraged prayer.

Confucius realigned the concept of *junzi* (*chun-tzu* in old spelling), which had traditionally meant "son of the ruler" into "superior man," with the effect that nobility was no longer a matter of blood or birth, but of character. This was a very radical departure from the customary Chinese thinking preceding him. Along with this, he radically transformed the notion of *jen* from meaning kindliness to the more general "man of the golden rule," or perfect *junzi. Jen* was expressed in terms of *chung* and *shu,* or conscientiousness and altruism. Confucius spoke of the doctrine of the mean, which essentially meant doing things "just right," which in turn meant doing things in harmony with the Dao.

The clearest articulation of Confucian values was given in *The Great Learning,* the classical work of Confucian ethics. Originally part of a large Confucian work called the *Book of Rites, The Great Learning* was later extracted from it and made a standalone Confucian work. It was probably not written by Confucius himself, but by Zengzi (a disciple) or Zi Si (Confucius's grandson). The reference to great learning is to distinguish it from small learning, which children are in need of. The power of *The Great Learning* is that it encapsulates the Confucian educational, moral, and political program in a simple format. First are the Three Ways, or Three Aims: clear character; loving the people; and abiding in the highest good. These Ways are achieved by the Eight Steps: the investigation of things; extension of knowledge; sincerity of the will; rectification of the mind; cultivation of the personal life; regulation of the family; national order; and world peace.

The Three Ways and the Eight Steps encapsulate the Confucian emphasis upon reforming one's character and building social cohesion and the intimate links between the two notions. Another development of what could be called humanist thinking was developed by Mengzi (371–c. 289 BCE), known in the West as Mencius. The Great Morale (*Han Jan Chih Ch'i*) involved the morale of the individual who identifies with the universe. There are two ways of cultivating the Great Morale: understanding the Dao, or the way of principle that leads to the elevation of mind; and the accumulation of human-heartedness, or the constant doing of what one ought to do because one is a citizen of the universe. Through the constant accumulation of understanding of the Dao and cultivation of human-heartedness, the Great Morale will gradually develop within oneself. Mengzi also believed the Great Morale was achievable by everyone, because we all have the same nature, one that, at heart, is good. It is important to see how both processes begin with the individual, working on the basic premise that one can play no useful role in society if one's own personality and family are in disorder. At no point is there any reference to any supernatural order or command morality. Like the Indian humanist systems, Chinese humanism is located within natural time and subject to natural rhythms. It also has important points in common with Mario Bunge's systemism.

In Greece, humanism can be traced back to the philosophers known as the Presocratics; that is, philosophers active before Socrates. Many historians and philosophers have had reason to admire the general attitude of the Presocratics, even if their actual opinions are of less value than the attitudes that underlie them. Bertrand Russell praised them for not only having an open, scientific attitude of inquiry but for their creativity and imagination. In fact, most of the basic categories of philosophy began with them. The first of them was Thales (c. 624–548 BCE), the man credited as being the father of philosophy. Thales' claim to fame rests on being the first person to try to explain the world not in terms of myths, but by observation of the world as he actually saw it. Where Homer attributed the origin of all things to the God Oceanus, Thales taught that water was the prime element in all things.

One of the core foundational concepts of humanism as articulated in Greece was the notion of *Paideia*. The term comes from classical Greek philosophy and is derived from the Greek word *pais* or *paides,* which, translated literally, means "boy," but in its broader meaning can be defined as "education for responsible citizenship." It was understood by the Greeks that this sort of education was an effective democracy. *Paideia* had four characteristics: it offered a unified and systematic account of human knowledge; it provided a technique of reading and disputation based upon mastery of language and intellectual precision; it worked on the assumption that the human personality can be improved by education; and it valued the qualities of persuasion and leadership as important for the vital task of taking part in public affairs. The ideals of Paideia were given their best voice by Socrates who, during the trial for his life, declared that the unexamined life is not worth living. These ideals were imitated by the Romans, from whose language the Latin word *humanitas* comes.

The humanist tradition of Greek thought received a check in the philosophy of Plato, and never fully recovered. Several Hellenistic movements, in particular Epicureanism and Stoicism, reflected important elements of humanist thought, but all had been effectively countered or crushed by Platonism and then by Christianity.

Renaissance Humanism

The collapse of the Roman Empire was followed by what might still justifiably be called the Dark Ages. In these long centuries of faith and ignorance, the spirit of inquiry was almost lost in the West. It revived only with the Renaissance. In its broader sense, the Renaissance began with the life of Petrarch (1304–1374) and ended with the death by execution of Giordano Bruno for heresy in 1600, with the most productive years of the Renaissance being the century before the sack of Rome in 1527.

Medieval thinking had been dominated by cultural pessimism: weariness with this world, and a suspicion, derived mainly from Saint Augustine, that human affairs are inevitably tainted with corruption and selfishness. Renaissance thinking, by contrast, was positive and optimistic. While Renaissance humanism differed on many points, it was pretty unanimous in its condemnation of the monastic life with all its implications of defeatism and withdrawing from one's civic duties.

Humanist thought in the Renaissance is also responsible for some very basic units of periodization of history as developed in the West. The very notion of "Renaissance" came from the idea that this age was the first to rediscover and fully appreciate the cultural grandeur of the ancient world. What happened in between then and now was slightingly dubbed the Middle Ages—those ages of interest only insofar as they stood between the glories of antiquity and the glories of today. We still speak of the Middle Ages, and they have retained in popular imagination the gloomy picture drawn of them by the Renaissance humanists.

The thinkers of the Renaissance saw themselves as the scourge of medieval dogma and the pioneers of a new cultural and intellectual orientation centering on the majesty of the ancient world. The new style of thinking was stimulated by the rediscovery of ancient thinkers, in particular Lucretius, Cicero, and Plato. The Renaissance humanists were optimistic about the power of culture to effect positive social change. At its least helpful, what can be called Renaissance humanism encouraged too backward-looking a stance. The tremendous enthusiasm for the ancient scholars deteriorated into a conservative climate where simple quotation of an ancient authority was sufficient to bring a dispute to an end. Only after the sack of Rome in 1527 did this optimism decline and a return to contemplation and an escape from the world once more became a discernable trend in Renaissance thought.

Very few Renaissance thinkers were atheists: almost all were theists, the majority of them remained Christians, though of heterodox sympathies. Belief in personal immortality came to be questioned, and the understanding of God changed: God was something that could be understood through our learning. Indeed, learning was a deeply pious activity, in that learning about nature meant, ipso facto, learning about God. The influence of antiquity inevitably meant a renewed interest in the pre-Christian ideas of the ancients. Few people declared an overt preference for the pagan ideas, and a rather sophistical justification for interest in the subject developed. The triumph of Christianity, so this argument went, had expunged the danger in paganism, so there now would be little harm in studying it.

The Renaissance was a period of significant historical and scriptural research. For instance, Lorenzo Valla (1405–1457) was responsible for exposing the fraud known as the Donation of

Constantine, upon which the papal claims to own its large territories in Italy was based. Valla also wrote *Dialogue on Freewill,* a frankly skeptical work that is a very sympathetic account of Epicurus. Valla was influential in teaching people the need to read scriptures with a skeptical frame of mind. This religious scholarship of Renaissance scholars was usually undertaken with a mind to reform religion and purge it of its recent and harmful additions. This drive led directly to developing some of the first ideas since the ancient world of religious toleration. This trend came to an end only when the religious reformer Savonarola was burned at the stake in 1498.

Contemporary Humanism

The humanism of both the ancient world and the Renaissance were stifled by religious reaction. It slowly rose again to the surface in the 18th and 19th centuries for a complex array of reasons. The Renaissance and Reformation had broken forever the monolithic idea of a single Christian belief that covered the known world, excepting only a few heathens around the periphery. The discoveries of other civilizations by European explorers also showed that people could live quite happily without Christianity. This, along with greater knowledge of the civilizations of India and China, from which Europe might learn, had dramatic consequences for the monoculturalism of Christian Europe. The Enlightenment in Europe (roughly, the years between the 1680s and the 1780s) was characterized in part by the taking to heart of this realization.

It was during these changes in perception that the word *humanism* was coined, in 1808. Friedrich Immanuel Niethammer (1766–1848) was a German educational reformer who wanted to develop an educational philosophy avoiding the excesses of the Roman Catholic reactionaries and the radicals of his day, known as the Philanthropinists. Niethammer posited humanism as combining the respect for tradition stressed by the conservatives with the innovative education of the whole child, as advocated by the reformers. Niethammer was a close friend of the philosopher George Wilhelm Friedrich Hegel (1770–1831) and it was from him that subsequent writers, thinkers, and reformers took up the idea of humanism and adapted it to their purposes. By the 1870s humanism was known and used in the English-speaking world. It retained its general use as a catch-all idea for the values of the Renaissance or of the classical world until about the end of the 19th century when the philosopher F. C. S. Schiller (1864–1937) took the word up as the title for his brand of subjectivist pragmatism. From there, American religious progressives took humanism up as the word to denote a brand of nonsupernatural religion as personal commitment in the context of a common humanity. This position came to be known as religious humanism.

It was only after the Second World War that humanism became the most widely used word among secularists, rationalists, and freethinkers. Chief articulators of this kind of secular humanism were Corliss Lamont in the United States, referred to earlier; M. N. Roy (1887–1954) in India; and Hector Hawton (1901–1975) and H. J. Blackham in the United Kingdom. Religious humanists and secular humanists do not differ so much in what they believe. Both groupings are fundamentally naturalistic and reject supernaturalist interpretations of religion. They are also generally opposed to ecclesiastical authority being exercised in society and see science as having constructive contributions to make in science, philosophy, and society. Where they differ is more in their general perceptions of what religion is and what their response to it should be.

Returning to Paul Kurtz's outline of humanism, we can trace the changes in two of the points and the continuities in others. Item 2, the cosmic worldview, has become more modest and less geocentric, as required by developments in astronomy and cosmology. Item 4, the political ideals, has become inclusive of more groups than earlier humanisms would have endorsed. Toleration of slavery in ancient Greece and the widespread misogyny found in Confucianism and Greek thinking no longer play a part in humanist thinking.

In contrast to these changes, item 3, the ethical ideals, has remained fundamentally the same. The values identified by Solon, Pericles, Confucius, the Carvakas, or the Epicureans still resonate today. Enjoyment of the moment, resistance to the transcendental temptation, love of nature, impatience with display, imperviousness to materialism, respect for learning, civic values, and family responsibility; all were recommended by the ancient humanists and all find enthusiastic support among their contemporary successors.

But it is the first item of Kurtz's outline that has remained the most constant. The endorsements of skeptical, open-minded inquiry given by Socrates, Wang Chong, and the Ajivika thinker Upaka find direct parallels in the work of Bertrand Russell, Albert Einstein, and all the other humanist philosophers and scientists who have shaped the modern world. Humanism is first and foremost a method of inquiry, and it is the conclusions of that inquiry that furnish us with our ideas and beliefs. Humanists have always rejected static formulas of thought, or bowing to arguments from authority, or accepting command moralities. In contrast to systems that are founded on acceptance of bodies of thought, humanism assumes that as knowledge comes from humans, it is bound to include some element of error and therefore will be in need of revision as our learning grows. In this way, contemporary humanism can reject the anthropocentric conceit of the Renaissance humanists, the hedonism of the Carvakas, the humorlessness of the Stoics, and still honor their role in the long stream of humanist thought. And as our scientific and philosophic knowledge grows, doubtless some important features of 21st-century humanism will be replaced. But the primacy of humanism as a method of inquiry will remain.

Humanism and Time

We can conclude this general account of humanism by returning to its philosophy of time. Humanist outlooks differ from supernaturalist outlooks in many important ways, and these differences have important implications for their respective beliefs about time. In the centuries before the Copernican revolution, classical Western religions posited a geocentric universe that was both very young and very small and that revolved around one's own religious heartland and was geared to one's own needs. This viewpoint became untenable after the 17th century, along with the conceptions of time that attended it. The outlooks that have developed since then, including the humanist ones, have accepted the need for a cosmic perspective, which involves recognizing the relative unimportance of our galaxy, our planet, our species, and ourselves in the wider scheme of things. Baruch de Spinoza spoke in these terms when he extolled the virtue of *sub specie aeternitatis,* or "under the aspect of eternity." This cosmic perspective has been reiterated from humanist viewpoints by people as diverse as George Santayana, H. G. Wells, Bertrand Russell, Steven Weinberg, and Richard Dawkins. It is also similar to Mencius's idea of the Great Morale, mentioned above.

The next major shift in perception came as a result of the breakthroughs in geology and biology in the 19th century; in particular, Charles Darwin's articulation of natural selection as the means by which evolution takes place. Evolution has demonstrated that human beings must extend their newfound cosmic modesty to the animal kingdom. Ernst Mayr determined four basic beliefs central to theism that were overthrown by evolutionary thinking: belief in a constant world; belief in a created world; belief in a world created by a wise and benign creator; and belief in the unique position of humanity in that creation. Each of these beliefs required a radically different notion of time than is compatible with a scientific account. Once again, this involved a serious recalculation of our understanding of time and the relative position of humanity to time. The ongoing dialogue between evolutionary theory and humanist thinking is testimony to this dynamic relationship.

Finally, the falling away of generally accepted externally imposed goals and purposes in life has stimulated among many humanist thinkers an appreciation of living each moment fully and joyfully. Here some of the more religiously and poetically inclined humanists have helped provide the language necessary to appreciate and savor each moment for the joy it can bring, if only we can look openly at it. This has involved some very creative and significant new understandings of what something like "life eternal" can mean.

Bill Cooke

See also Bruno, Giordano; Christianity; Confucianism; Darwin, Charles; Einstein, Albert; Ethics; Farber, Marvin; Hinduism, Samkhya-Yoga; Marx, Karl; Materialism; Presocratic Age; Russell, Bertrand;

Sagan, Carl; Santayana, George; Spinoza, Baruch de; Values and Time; Wells, H. G.

Further Readings

Bullock, A. (1985). *The humanist tradition in the West.* London & New York: Thames & Hudson.
Bunge, M. (2001). *Philosophy in crisis.* Amherst, NY: Prometheus.
Chan, W.-T. (1973). *A source book in Chinese philosophy.* Princeton, NJ: Princeton University Press.
Cooke, B. (2006). *Dictionary of atheism, skepticism, and humanism.* Amherst, NY: Prometheus.
Fowler, J. (1999). *Humanism: Beliefs and practices.* Brighton, UK: Sussex Academic Press.
Fung, Y.-L. (1960). *A short history of Chinese philosophy.* New York: Macmillan.
Goicoechea, D., Luik, J., & Madigan, T. (1991). *The question of humanism: Challenges and possibilities.* Amherst, NY: Prometheus.
Hawton, H. (1963). *The humanist revolution.* London: Pemberton.
Hiorth, F. (1996). *Introduction to humanism.* Pune, India: Indian Secular Society.
Kurtz, P. (1986). *The transcendental temptation: A critique of religion and the paranormal.* Amherst, NY: Prometheus.
Kurtz, P. (1989). *Eupraxophy: Living without religion.* Amherst, NY: Prometheus.
Lamont, C. (1965). *The philosophy of humanism.* New York: Frederick Ungar.
Mayr, E. (1993). *One long argument: Charles Darwin and the genesis of modern evolutionary thought.* London: Penguin.
Riepe, D. (1961). *The naturalistic tradition in Indian thought.* Seattle: University of Washington Press.
Thrower, J. (1980). *The alternative tradition: A study of unbelief in the ancient world.* The Hague, The Netherlands:: Mouton.
Walter, N. (1997). *Humanism: What's in the word.* London: RPA.
Wilbur, J. B., & Allen, H. J. (1979). *The worlds of the early Greek philosophers.* Amherst, NY: Prometheus.

Hume, David (1711–1776)

David Hume, a Scottish moral philosopher, historian, and public economist, is considered among history's most important British men of letters. A major representative of British Empiricism, Hume influenced generations of thinkers, in particular Immanuel Kant, John Stuart Mill, Adam Smith, David Ricardo, and Friedrich August von Hayek. His writings on perception, causality, history, time, morality, and economics prepared the ground for many important subsequent philosophical and economic schools, for example, Utilitarianism, Rationalism, and the Austrian liberal economic school of the 20th century.

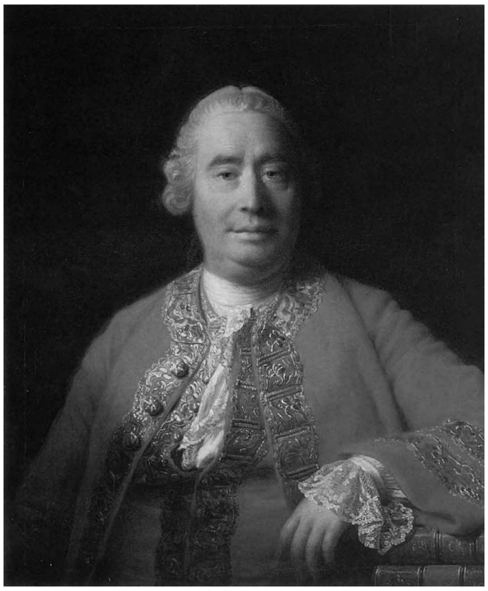
Life and Work

Hume was born into a noble albeit no longer prosperous family in Edinburgh on April 26, 1711. After the death of his father in 1713 he grew up with his two elder siblings under the care of his mother at Ninewells in the Scottish lowlands.

At the young age of 12 he followed his older brother to Edinburgh University. There he first studied mathematics; later on, he studied law but never completed the degree. Soon Hume turned his concentration to the great ancient philosophers, especially Cicero and Seneca. Beyond them he read the major contemporary British writers like Joseph Butler, John Locke, and George Berkeley; he admired them as fathers of moral science that was based on an experimental approach.

In 1734, after several years of intense reading, he felt sick and exhausted. In an effort to recover his health through a change of habits, Hume relocated to Bristol to take up work for a sugar importer. Because this way of life did not suit him at all, he quickly decided to resign and, still in the year 1734, took up his former studies again—but this time in France. Declining to accept gainful employment forced him to live a very modest life for years.

In France he stayed mainly in La Flèche, where roughly a century before Descartes had received his education in the Jesuit College, which still existed in Hume's time. There he read the continental philosophers' works and soon gained back his mental strength. Between 1734 and 1737 Hume composed his initial work, *Treatise of Human Nature*. To finalize the editing and for the sake of managing the book's release he moved to London. The first two volumes—*Of the Understanding* and *Of the Passions* were finally published in 1739.



Portrait of David Hume by Allan Ramsey, 1776. Hume was one of the greatest philosophers in Western history, as well as an accomplished historian and economist.

Eventually the third volume, *Of Morals,* appeared. *The Treatise* included Hume's attempt to introduce a "science of human nature."

But the *Treatise's* tepid reception and miserable sales left Hume disappointed since his ambition from his youngest age onward had been to become a reputable man of letters. Having experienced this frustration, he returned to Ninewells to carry on his studies. In 1741/1742, Hume published his *Essays Moral and Political.* In contrast to the previous work, this one met with wide success.

In search of a stable income and space for further free development, Hume applied in 1745 for a vacant chair of Ethics in Edinburgh. But the "murmur among the zealots" about Hume's alleged skepticism and atheism as voiced in the *Treatise* gave rise to successful opposition against his appointment. For the same reason he failed again 6 years later in Glasgow in his second and final effort to obtain a professorship.

After several short engagements, he followed the call of General James St. Clair—a cousin of his—in 1746 to accompany him as a secretary on a campaign against France, and 2 years later on a diplomatic mission to Vienna and Turin. During his absence his *Philosophical Essays Concerning Human Understanding*—today denoted as his first *Inquiry*—were published; these were succeeded by *Inquiry Concerning the Principles of Morals* and his major work as political economist, *Political Discourses.* The latter attracted international attention.

In 1752 Hume began engagement as Librarian to the Advocates' Faculty in Edinburgh. His primary benefit was being able to pursue his independent studies, allowing him to elaborate and release his six-volume *History of England,* which, again, met with great success. His belief in the necessity of historical classification of current issues and his view on history as immeasurably valuable "collections of experiments" motivated this body of work. In 1757 his *Four Dissertations* were published.

Fortune led him to Paris again, this time (1763) as secretary to the English ambassador. He enjoyed his opportunities to associate with noble Parisian society, with its stimulating and convivial salons. Returning to Britain in the company of Jean-Jacques Rousseau, with whom he shared a brief friendship, Hume soon became undersecretary of state. As a newly prosperous man, he retired to Edinburgh in the late 1760s.

David Hume died in Edinburgh on August 25, 1776, after having spent some years of comfortable life. His most controversial literary work, *Dialogues Concerning Natural Religion,* was published posthumously in 1779.

Moral Philosophy and Method

Hume emphatically distinguished "ought from is"—in today's scientific language to speak from normative versus positive analysis.

Along with Berkeley and Locke, Hume is regarded an important representative of British Empiricism; Hume's theory of knowledge follows the distinction of the perceptions (sensations vs. reflections) of the human mind into impressions and ideas; according to Hume, any idea, however elaborate, is based on a bundle of simple impressions. Hume therefore stated that any theory not empirically based must be rejected categorically. He presented the copy principle (that simple ideas come from simple impressions of the outside world) and thought about the principles of natural connections of ideas in mind—the process of association. These findings had implications for his judgments of the status of the outside world and free will.

Hume bewailed the primacy of passions over sanity in human behavior, causing him to state, "Mankind are so much the same, in all times and places, that history informs us of nothing new or strange. . . ." Some authors took this as an indication of Hume's disregard of time and history; others believed he grasped the understanding of history and reason being central to philosophical advance.

Hume challenged the widespread unconscious supposition of causality between two events closely following another in time. Historically constant conjunction of two events should not be misunderstood as a proof of natural coincidence through causation and must not lead to the firm expectation of conjunct occurrence in the future.

Hume described the custom and habit of induction based on humankind's natural tendency to form expectations of a general circumstance out of single observations of incidents—that is to say, inductive generalizable deductions. He denied that this way of generalizing in order to build expectations for the future was rational, because he did not detect the slightest evidence to confirm such generalization or to believe in even the prospectively constant conjunction as a form of stationary behavior over time. On the contrary, there may occur significant inconsistencies between past and future events. Some traces of parallelism to John Stuart Mill's thought may be discerned here.

Hume doubted the moral rationalists' (in particular Locke's) and the "selfish schools" (e.g., Thomas Hobbes's) behavioral assumptions and thought about the origins of humankind's natural sympathy (benevolence) and morality. Hume tended to be a skeptic, especially in regard to religion.

Political Economy

Beyond his philosophical and historical thoughts, Hume made relevant contributions to the new science of economics. By means of progressive empirical inquiries, he disproved the theories of the strong contemporary school of mercantilists who believed in the achievements of protectionism. Hume spoke in favor of free trade and more dynamic currency regimes and hereby set a cornerstone of classical economics; in this respect he strongly influenced his close friend and later famous economist Adam Smith, as well as constituting a source of Ricardo's monetary theory. Furthermore, he was convinced that in the absence of economic freedom any real political freedom would be unreachable, an idea that later inspired Hayek and others.

Matthias S. Hauser

See also Berkeley, George; Causality; Ethics; Kant, Immanuel; Morality; Rousseau, Jean-Jacques

Further Readings

Mossner, E. C. (1954). *The life of David Hume.* London: Nelson.

Stewart, J. B. (1992). *Opinion and reform in Hume's political philosophy.* Princeton, NJ: Princeton University Press.

Stroud, B. (1977). *Hume.* London: Routledge.

Husserl, Edmund (1859–1938)

Edmund Husserl, a German philosopher, was the founder of the phenomenological tradition. He studied mathematics, science, and philosophy in Leipzig, Berlin, and Vienna. In Vienna (1881–1882) he studied with Franz Brentano, who inspired him to establish the phenomenological method, which later became one of the most important philosophical movements in 20th-century continental Europe, influencing among others Martin Heidegger, Jean-Paul Sartre, and Maurice Merleau-Ponty. Husserl taught at Halle, Göttingen, and Freiburg. Before he turned his interest to the development of phenomenology, he worked on the philosophical foundations of mathematics (*Philosophy of Arithmetic,* 1891). In this connection, his discussion with Gottlob Frege, who established analytical philosophy, was important.

Husserl's concept of time was initially inspired by what Brentano had taught in Vienna. Two crucial insights of Brentano became the foundation of Husserl's phenomenology: First, the psychic contents of an experiencing consciousness can be the subject of an unmediated inner perception; and, second, consciousness is always related to something by intention, meaning that there is no consciousness without an intended object. In short, the phenomenal "givenness" of psychic contents and "intentionality" as an irreducible structure of consciousness form the starting points of phenomenology. Time is the system that orders the contents of consciousness first of all, giving rise to before-and-after relations and making the past experiences qua memory accessible to the subject. This means that past experiences become recognizable as one's own experiences; thus, time is a function of self-identity. Until this point, Husserl's notion of time remains quite Kantian.

The Problem of Subjectivity

Specific to Husserl's time theory is the problem of a subjectivity that constitutes time but is also related to an original temporally distributed flow of experiences. That means consciousness constitutes time and is itself temporal. In order to explain this, Husserl introduces the "absolute consciousness," a unifying transcendental function of consciousness that is in itself atemporal. This theoretical construct is contentious not only among his interpreters but also for himself because it cannot become the subject of phenomenological analyses. Phenomenology as Husserl has developed it is a philosophy of description in a strictly scientific sense. The goal of philosophy should be the precise description of how things appear to us. It is not about how things are in themselves, but rather how we apprehend them. Our experience is a source of apodictic truths for Husserl. But the individual contents of consciousness do not belong to these truths; it is the way or the structure in which they are given that can be an apodictic truth. The Kantian distinction between the thing-in-itself and how it appears is to be found in *Logical Investigations* (1900–1901), but in his analyses of time Husserl gave up that sharp distinction. The thing-in-itself is then defined as the identity that can be intuited through manifold apprehensions or perspectives of it. Therefore it no longer belongs to the realm of transcendent things if transcendent is understood as being beyond the reach of our recognition.

The analyses concerning time-consciousness are fundamental to Husserl's phenomenology because time is not an object like other objects; it is rather the way in which objects are given to and apprehended by consciousness. That is why time is so fundamental to phenomenology, and its analysis stretches over the whole period of Husserl's investigations. He focuses on subjective time, the time-consciousness and not on an objective "world-time." In general it can be said that phenomenology is always concerned with how things appear to a consciousness. The question of how things are in themselves misses the point that there is no object without a subject. This does not mean that Husserl is an idealist. He thinks that the attempt to describe something while leaving out the condition that it must be described by someone cannot be a sufficient description and, therefore, cannot be true. Husserl distinguishes two perspectives: the "natural attitude" and the "phenomenological attitude." The former is the perspective we adopt in everyday life, in which we naturally believe in the existence of the world. In the latter, the philosopher suspends all convictions and intentions that belong to the "natural attitude," especially convictions about existence. This suspension is called *phenomenological epoché,* and is gained by a reductive method that leads through different levels back to pure intention. Intention is the way in which a consciousness is directed toward an object. There are many ways in which an object can be given to a consciousness (in perception, imagination, representation, etc.). In order to describe the nature of these modes, Husserl uses variation, the so-called eidetic variation, which is a method of distinguishing between contingent and necessary features of the intention. Intentionality is the subjective structure of consciousness, which apprehends an object. In an analysis, a distinction is made between the *noema* (object of consciousness) and the *noesis* (corresponding mental activity). They can be analyzed separately, but they are not reducible to one another.

Consciousness and Time

The central question concerning time is how temporal objectivity can be constituted by a temporal consciousness. Analogous to this question, the phenomenological analysis splits at first into two subjects: the temporal object (e.g., a melody) and time-consciousness (the succession of now-moments and their becoming more and more past and the anticipation of the impressions yet to come). The constitution of a temporal object, an object that endures identical to itself over time, needs time. That means the time the consciousness takes to constitute a temporal object needs to be just as long as the object endures. While the intuited identity of the object appears as an integral whole, the object is in fact given only in successive perspectives or temporal parts. Husserl takes a melody as an example of how time-consciousness constitutes such a temporal object. He asks why we not only hear the successive tones while listening to a melody, but also grasp them as a whole. His explanation is that time-consciousness is not only consciousness of the present moment ("primal impression"), but rather encompasses moments already past ("retention" or "primary memory") and anticipates others still in the future ("protention"). The now-point is fundamental as a source of the present since consciousness is defined as a continually flowing stream of contents, but the present moment is ideal only in the sense that it has no duration. It is a kind of border between the past and the future. The temporal field, the duration of the present composed of past, primal impression, and anticipation, is necessary for the connection of the different tones and the recognition of the melody. The succession of primal impressions causes the backward-shift of the former primal impressions, and, therefore, the temporal field of what is recognized as present is continually changing. The function of "secondary memory," which is distinguished from retention, is to keep all continually changing apprehensions in mind, so that the whole continuum of the temporal phases of the melody can be apprehended as a whole. The content of this secondary memory is not present, but remembered or, as Husserl puts it in *On the Phenomenology of the Consciousness of Internal Time* (1893–1917), the "re-presented present." This kind of memory is also distinguished from what is commonly called memory, the reproduction of an impression in the mind. Time-consciousness is clearly distinguished from and not reducible to any other kind of mediated consciousness like imagination, sign-reading, or consciousness of pictorial images; it is a consciousness sui generis since it apprehends something as present that is not present as a whole, but that is held in consciousness as if it were present as a whole; therefore, it does not reproduce its contents as, for example, imagination does.

Time-consciousness not only accompanies the constitutions of temporal objects of these specific kinds, such as melodies. It is a type of consciousness that is always at work and necessary for all kinds of object-constitution. For example, if we look at a house, we do not see it as a whole, although we intend it as a whole. In fact, what is given is a manifold of perspectives on that house, which we mentally synthesize. At no stage of this perception is the sum total of perspectives ever given; there is always something absent, but we apprehend the absent perspectives simultaneously with the present ones. Perception of an object is always a process of synthesizing different perspectives or sense data; therefore it is spread over a certain period of time. The perception of things exhibits the same necessary temporal structure as the perception of objects that are distributed only in time, like melodies. The problem is to clarify how a consciousness, whose contents are successively and that means temporally distributed, can constitute enduring temporal objects and an objective time.

How Time Is Constituted

Husserl attempted to describe the constitution of time in countless manuscripts. As with all phenomenological analyses, he tries to elaborate the structures and processes that are at work in every act of consciousness but that do not appear in the normal course of objective events within the natural attitude. The constitution of time has three different stages. The first is constitution of the objects or things in objective time; they are constituted in the duration of the present by apprehension of past, present, and future together. The second stage is the basis for the first, the object-constituting sense data or the manifold impressions in their wholeness within a so-called pre-empirical or prephenomenal time. This time is called prephenomenal because its succession is not apprehended. The third and most fundamental stage is the wholeness of the "absolute time-constituting flow of consciousness." All these stages represent forms of reflective acts of consciousness that constitute different kinds of objectivity, such as temporal objects, objective time (i.e., measured time), and personal experiences as objects of consciousness. The problem with this model and that Husserl himself was aware of is that of constitution via reflexivity. This concept may lead to a vicious circle: If the constituting reflexivity is not itself atemporal (which is also problematic), it would need to be constituted at a higher-level reflexivity or consciousness, and so on.

Time-consciousness consists according to Husserl of two different but inseparably united kinds of intentionality: The first one he calls "transverse intentionality" (*Querintentionalität*), which has the function of keeping the past phases of an experience in mind in order to preserve its duration and objective identity. This intention is directed onto the duration and process of the experience. The second kind of intentionality is called "horizontal intentionality" (*Längsintentionalität*) and, this being the fundamental function, it is directed to the whole continuum of the inner flow of time. It functions as self-reflection, or in other words, *the retention of retention*. This intentionality is the necessary condition of possibility for an awareness of time-consciousness, which Husserl calls "absolute consciousness." The contentious question is whether this transcendental form of consciousness is to be understood as temporal or not. If it is understood as temporal, the theory ends up in a vicious circle because the transcendental instance itself would have to be constituted by something, and so on. Husserl tends to define it as nontemporal, thus avoiding this vicious circle. But having just shown that objectivity depends on temporality, how can it be consciousness if it is not temporal? If the absolute consciousness were not temporal, it would not be consciousness of something. Husserl saw this problem in his constitutional theory and did not settle the question definitely.

Later Analyses

In his later manuscripts, which are not yet available in translation, the *Bernauer Manuskripte über das Zeitbewußtsein* (1917/1918) and *Späte Texte über Zeitkonstituition* (1929–1934), he constantly revised his theory. There Husserl shifts the emphasis of his thought from analyses of the inner time-consciousness to its intersubjective conditions. He follows the idea of a universal time-structure, which is the necessary condition for both history and the human life-world (*Lebenswelt*). With the new topic he develops a new method. The former analyses were dedicated to the intentional structure. They described the static relationship between subject and appearances of objects, which he called static phenomenology. Later on he searched for a way in which phenomenology could also explore the conditions for the dynamic process of the flow of consciousness and the constitution of objects. This next step he called genetic phenomenology. The later manuscripts on time exhibit this new direction, as, for example, in his *Die Welt der lebendigen Gegenwart und die Konstitution der ausserleiblichen Umwelt* (1931), in which Husserl follows the thought of constitution beyond the subject into the life-world. With the ontology of the life-world, Husserl examines both the meaning of and necessary conditions for history more closely. From *Ideas,* in which Husserl maintained that the possibility for objective experience lies purely in the subject, in the transcendental function of consciousness, it was a long way until his later work *Cartesian Meditations,* in which he speaks of transcendental intersubjectivity. This shift from idealism to ontology of the life-world was accompanied by the analyses of time. The phenomenology of time therefore is one of the most important topics on the way to a phenomenological philosophy.

Husserl's Legacy

Among Husserl's students were Martin Heidegger and Maurice Merleau-Ponty, who also worked on the problem of time. His influence extended beyond these prominent students, though. He influenced Rudolf Carnap's theory of logical empiricism; Marvin Farber, who introduced Husserl's phenomenology to the United States; Roman Ingarden, who focused on phenomenological aesthetics; Jean-Paul Sartre and Emmanuel Levinas, two of the most important phenomenologists in France; and Edith Stein. Husserl was also a source of inspiration to Jacques Derrida, the analytic phenomenologist Hubert Dreyfus, and many phenomenological philosophers in Germany and North America.

Yvonne Foerster

See also Consciousness; Derrida, Jacques; Farber, Marvin; Frege, Gottlob; Heidegger, Martin; Idealism; Intuition; Merleau-Ponty, Maurice; Metaphysics; Ontology; Time, Phenomenology of; Time, Subjective Flow of

Further Readings

Bell, D. (1999). *Husserl.* London: Routledge.

Bernet, R., Welton, D., & Zavota, G. (Eds.). (2005). *Edmund Husserl: Critical assessments of leading philosophers.* London: Routledge.

Brough, J. (2004). Husserl's phenomenology of time-consciousness. In D. Moran & L. E. Embree (Eds.), *Phenomenology: Critical concepts in philosophy* (pp. 56–89). London: Routledge. (Original work published 1928)

Husserl, E. (1973). *Cartesian meditations* (D. Cairns, Trans.). The Hague, The Netherlands: Nijhoff.

Husserl, E. (1980). On the phenomenology of the consciousness of internal time (1893–1917). In R. Bernet (Ed.), *Edmund Husserl: Collected Works, Vol. IV* (J. B. Barnett, Trans.). Dordrecht, The Netherlands: Kluwer Academic.

Husserl, E. (1982). *Ideas pertaining to a pure phenomenology and to a phenomenological philosophy* (F. Kersten, Trans.). The Hague, The Netherlands: Nijhoff.

Smith, B., & Smith, D. W. (Eds.). (1995). *The Cambridge companion to Husserl.* Cambridge, UK: Cambridge University Press.

Hutton, James (1726–1797)

James Hutton was a Scottish geologist, chemist, and naturalist noted for formulating the uniformitarianist doctrine and the Plutonist school of thought. After short careers in law and medicine at the University of Edinburgh, he followed his interest in chemistry and the nascent science of geology. He analyzed metamorphic and igneous rocks at Glen Tilt in the Cairngorm Mountains in the Scottish Highlands and layers of sedimentary rock at Siccar Point on the Berwickshire coast, east of Edinburgh. After these studies, he noted that the origins of sedimentary and igneous rocks are different and formulated theories on the earth's origin that paved the way for modern geological science.

Hutton began a dispute with the popular Neptunist school, which suggested that all rocks developed by precipitating out of a single great flood. After studying the Devonian Old Red Sandstone along Scotland's coast, he realized sedimentary rocks originated not from a single flood but a series of successive floods. He established what became known as Hutton's Unconformity. Hutton reasoned that there must have been several cycles of depositing sedimentary layers, with each cycle involving deposition on the seabed, uplift and erosion, and new deposition on the seabed. He suggested that the stratigraphic record clearly indicated gradual geomorphologic processes throughout the earth's history.

Moreover, Hutton found granite penetrating metamorphic schists at Glen Tilt. This indicated that the granite had been molten in the past, suggesting that granite formed from the cooling of molten rock and not precipitation out of water. The suggestion that plutonic and volcanic activity were the sources of rocks on the surface of the earth replaced Abraham Werner's Neptunism theory, which claimed that rocks had originated from a great flood and were basically sedimentary in origin.

Hutton concluded that the history of Earth can be explained by observing the geological forces now at work. This is the basis of uniformitarianism, the doctrine that assumes that the natural processes of the past are the same as those that can be observed operating in the present: "the present is the key to the past." The theory of uniformity is one of the most basic principles of modern geology. It contrasts with catastrophism, which states that Earth's surface features originated suddenly, through catastrophic geological processes (e.g., the biblical flood) that were radically different from current processes. Because of these hypotheses, Hutton was accused of atheism and poor logic, especially by Richard Kirwan, an Irish scientist who supported the catastrophist theory. Note, however, that many catastrophic events (e.g., earthquakes, glaciations, hurricanes, tsunamis, volcanic eruptions, meteoritic impacts, etc.) are perfectly compatible with uniformitarianism.

In 1795, Hutton summarized his views in a major work, *The Theory of the Earth,* where he affirmed: "Earth is very old and present-day geological structures formed slowly by processes observable today, such as erosion and deposition." Hutton's theory was first presented at meetings of the Royal Society of Edinburgh in 1785, and published in Volume I of the *Transactions of the Royal Society of Edinburgh,* 1788. Two years before his death, Hutton published *The Theory of the Earth* in two volumes, consisting of the 1788 version of his theory with slight additions. In this work, Hutton compiled material on various subjects previously published, such as the origin of granite. His ideas influenced Charles Lyell's principles of geology, which in turn influenced Charles Darwin's theories of adaptive evolution.

Ignacio Arenillas

See also Chronostratigraphy; Catastrophism; Erosion; Geological Column; Geologic Timescale; Geology; Lyell, Charles; Paleontology; Plate Tectonics; Sedimentation; Uniformitarianism; Wegener, Alfred

Further Readings

Bailey, E. B. (1967). *James Hutton: The founder of modern geology.* New York: Elsevier.

Baxter, S. (2004). *Ages in chaos: James Hutton and the true age of the world.* New York: Forges Books.

Repcheck, J. (1987). *The man who found time: James Hutton and the discovery of the earth's antiquity.* London & Cambridge, MA: Simon & Schuster.

Huxley, Thomas Henry (1825–1895)

Within a short time of its 1859 publication, Charles Darwin's *On the Origin of Species by Means of Natural Selection* evoked a wide variety of reactions. Many of his readers enthusiastically embraced natural selection as the elusive mechanism that explained the process of evolution, while others recoiled from Darwinian naturalism, which seemed to obviate divine involvement and purpose. Responses came from all quarters—scientists, philosophers, theologians—and the concept of evolution soon made its way into almost every academic discipline. Because of his temperament and bad health, Darwin shunned the limelight, especially public confrontation. Thomas Henry Huxley, one of Darwin's closest friends and confidants, entered the debate about evolution with a more combative spirit and quickly earned the nickname "Darwin's Bulldog." No epithet was given more deservedly. Though he did not agree with every aspect of Darwinism, Huxley advanced the arguments that related to evolution—its tempo and mode—through his knowledge of comparative anatomy and paleontology. In Charles Lyell and the writings of other geologists, he and his peers found the long stretches of geological—or evolutionary—time needed to produce the vast, fascinating array of extinct and living species. As Huxley conducted research on several broad fronts, he promoted an agenda of change and made a significant impact in science, education, and society at large.

Thomas Henry Huxley (usually referred to as T. H. Huxley) was born in 1825 in Ealing, a small village west of London, and grew up under humble circumstances. Like Dickens, Huxley obtained most of his early education through voracious and wide reading. After a medical apprenticeship, he received a scholarship to study medicine at Charing Cross Hospital (London). Huxley gave special attention to anatomy and physiology and completed this preparation in 1845. In a manner that has some parallels with Charles Darwin's experience on the *Beagle,* Huxley entered the Royal Navy as an assistant surgeon on the *HMS Rattlesnake,* which sailed to Melanesia and surveyed Australia's coast. On a cruise that lasted nearly 4 years (1846–1850), he—also taking on the duties of amateur naturalist—observed a wide range of wildlife and human cultures. While on this journey, Huxley sent detailed studies of invertebrates back home and, upon returning to England, was elected a Fellow of the Royal Society. In 1854, he left the navy and became a lecturer in Natural History at the School of Mines, in London, where he launched his lifelong study of and writing about various topics in comparative anatomy, paleontology, and related disciplines. Over the next 4 decades, T. H. Huxley held many positions in educational and scientific organizations and institutions (including the Anthropological Institute and the British Museum); he also accepted a number of government appointments that drew upon his expertise. Huxley won many awards and promoted scientific research (especially in the lecture hall and laboratory) and publications (and helped start the journal *Nature*). Throughout his career, he identified enemies (scientists, churchmen, and politicians) and attacked them vigorously through the spoken and written word. Along the way, Huxley, known in his intimate circles as "Hal," was devoted to his family, loyal to his scientific colleagues, and committed to improving the situation of the working class.

As was true for many scientists of his era, T. H. Huxley was interested in—and later obsessed with—the lively discussion concerning evolution, even before Darwin published *On the Origin of Species*. Many participants in this dialogue influenced Huxley, one way or the other, at some point in his own intellectual development (e.g., Chambers, Cuvier, Etienne Geoffrey Saint-Hilaire, Haeckel, Hooker, Lamarck, Lyell, Marsh, Spencer). K. E. von Baer, the father of embryology, helped Huxley bring order to his biological worldview through the study of fixed types. Even though he became Darwin's ardent defender and champion, Huxley never fully accepted his friend's fundamental claim that the slow process of natural selection could transform one species to another. Huxley, the scientist, insisted that he needed experimental proof that this mechanism could produce such a powerful transmutation. He also thought that Darwin restricted himself too much by insisting on gradual changes, since Huxley believed that changes could occur "by jumps" (*per saltum*). (Though based on considerably less data, this debate anticipated in some ways the modern discussion concerning "punctuated equilibrium," itself a form of natural selection.)

Although he argued with scientist and churchman alike, Huxley saved some of his most potent venom for the church. He rejected any form of special creation and insisted that a logical, scientific approach would not allow any sort of divine involvement or plan (as held by Adam Sedgwick, Louis Agassiz, Asa Gray, and many others). As a student and admirer of Hume, Huxley's rational, scientific naturalism—supported by his self-professed "agnosticism" (a term usually attributed to him, though others defined it differently)—brought mixed reactions from Rome and the Anglican Establishment. Huxley successfully devoted himself to the task of deflating the church's power and influence in certain aspects of British society, including the universities (Oxford and Cambridge, in particular) and scientific education and research. Indeed, one of the most famous events in the history of science took place at Oxford's Museum of Natural History in the summer of 1860, when Darwin's Bulldog briefly debated Bishop Samuel Wilberforce about evolution. Much (though not all) of Huxley's (and Darwin's) disdain for Richard Owen, a leading comparative anatomist and paleontologist at the British Museum, resulted from the latter's stubborn reference to a divine plan—what some might call intelligent design today.

Whatever course the 1860 Huxley–Wilberforce debate took—and accounts vary a bit—it is clear that sparks flew with reference to the subject of human descent from apes. This subject remained pivotal for T. H. Huxley, as evident in the 1863 publication of what many regard as his most important book, *Evidence as to Man's Place in Nature*. In this same year, Charles Lyell published a volume on this topic, *The Geological Evidence of the Antiquity of Man*. Both Huxley and Darwin counted on Lyell's earlier discussion of "geological time" (though Lord Kelvin objected to Lyell's uniformitarianism) but, of course, nobody in that era had access to the inventory of fossil specimens known today—much less the modern science of genetics. Huxley's study antedated Darwin's 1871 book, *The Descent of Man and Selection in Relation to Sex*, though the former writer said little about the causes of change. Huxley defeated Owen in a debate concerning human and gorilla brain anatomy and insisted, as he did in his encounter with Wilberforce, that the ape's human descendants should feel no shame because of their common ancestors. He held this view at a time when Europeans had limited knowledge of the gorilla. Nevertheless, from Huxley's perspective, human beings were part of the animal kingdom and shared a "pedigree of prodigious length," and the frontispiece in *Man's Place in Nature* (which depicts a human skeleton followed by a gorilla, chimpanzee, orangutan, and gibbon) secured its place in the iconography of science. For Huxley, and his contemporaries, whose outlook was formed, in part, by the place they occupied in the British Empire, the "savages" who lived in remote corners of that empire served as more recent, albeit stone-age, specimens in the same human family tree.

Huxley's study of paleontology led him to accept the transmutation of species, though he did not believe that Darwin's gradualism was reflected in the fossil record. Darwin also recognized this weakness in his argument. The *Archaeopteryx* and *Compsognathus* fossils offered intriguing illustrations of the transition from reptiles to birds, and other aspects of the fossil record helped Darwin and Huxley identify similarities and delineate the continuity between species. Othniel C. Marsh, paleontologist at Yale's Peabody Museum, introduced Huxley to *Hesperornis,* another bird fossil that fueled the latter's speculation about dinosaur–bird evolution. Huxley's knowledge of fossils (including other dinosaurs) and a close reading of Ernst Haeckel's two volumes on *Morphologie* allowed him to see family trees—a genetic connection between the past and the present. T. H. Huxley found special significance in his proposed sequence of horse fossils, also contained in the Peabody collection.

In his 1859 letter to Charles Darwin, Huxley expressed his willingness "to go to the stake" (figuratively speaking by their day!) in support of evolution. He remained loyal to his good friend and continued to promote the cause after Darwin's death, in 1882. Indeed, Huxley's entire career reflects the curiosity and tenacity that allowed him to achieve greatness from such a humble start in life. For Darwin's Bulldog, even the piece of chalk (formed from the remains of countless microorganisms) that a carpenter carried in his pocket reflected the earth's antiquity; his enthusiasm for learning about that past provides a good example even today.

Gerald L. Mattingly

See also Darwin, Charles; Design, Intelligent; Evolution, Organic; Haeckel, Ernst; Lyell, Charles; Saltationism and Gradualism; Scopes "Monkey Trial" of 1925

Further Readings

Barr, A. P. (Ed.). (1997). *Thomas Henry Huxley's place in science and letters: Centenary essays.* Athens: University of Georgia Press.

Desmond, A. (1997). *Huxley: From devil's disciple to evolution's high priest.* Reading, MA: Addison-Wesley.

Di Gregorio, M. A. (1984). *T. H. Huxley's place in natural science.* New Haven, CT: Yale University Press.

Huxley, T. H. (1863). *Evidence as to man's place in nature.* London: William & Norgate.

Huxley, T. H. (1970). *Collected essays (1893–1894)* (9 vols., Reprinted ed.). New York: Georg Olms Verlag.

Lyons, S. L. (1999). *Thomas Henry Huxley: The evolution of a scientist.* Amherst, NY: Prometheus.

Weiss, K. M. (2004). Thomas Henry Huxley (1825–1895) puts us in our place. *Journal of Experimental Zoology, 302B,* 196–206.

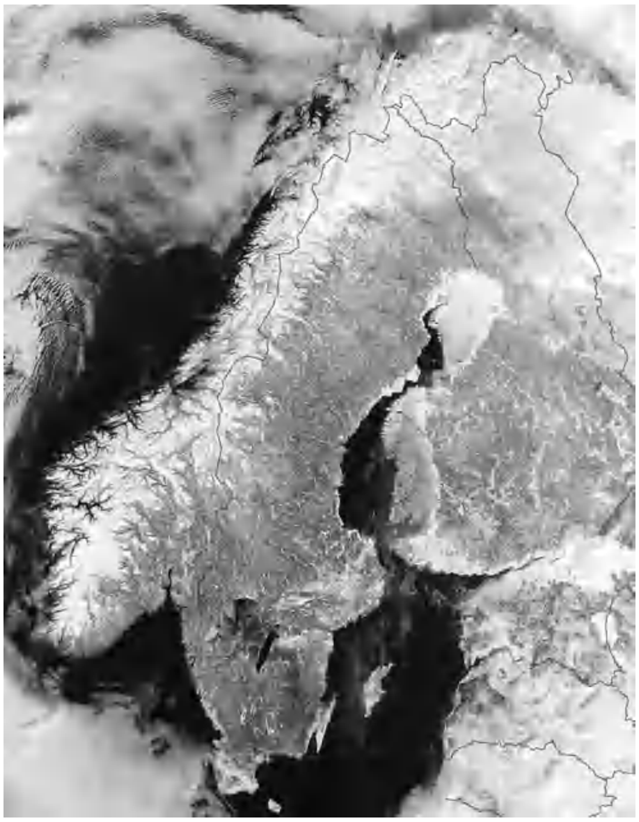
White, P. (2002). *Thomas Huxley: Making the "Man of science."* New York: Cambridge University Press.

I

Ice Ages

The most recent ice age can be considered the last million years of geologic time—the Cenozoic era, the latter part of which comprises the Pleistocene and Holocene epochs, which include the most recent ice age. There is evidence, however, that other ice ages occurred much earlier in time, although their existence and extent are more difficult to determine. Evidence of ancient climate change, which covers a range in temperatures from tropic to arctic, is mostly found with fossil evidence. For example, a reef complex and marine invertebrates tend to indicate a tropical area, while mastodon fossils show a cold environment. Thus, knowledge about the ice ages depends to some extent on the study of fossils.

At present, we know of six ice ages. The oldest two known occurred during the Precambrian era, more than 570 million years ago; one of these may have extended into the early Cambrian era. The next oldest ice age occurred during the Permian period and had a time span of about 55 million years, beginning about 280 million years ago. The next ice age came in the early Cretaceous period and another in late Cretaceous, but both were rather limited in extent. The span of time between the early and late Cretaceous ice ages is about 71 million years, beginning about 136 million years before the present (BP). The present ice age began about 1 million years ago, and because glaciers still exist but are receding, *it* can be considered an interglacial stage, presuming another glacial stage is forthcoming.



The Scandinavian Peninsula is a landscape that was largely shaped by glaciers over the last ice age. The moderate resolution imaging spectroradiometer (MODIS) instrument aboard NASA's Terra satellite captured this image of the Scandinavian Peninsula on February 19, 2003. Along the left side of the peninsula one can see the jagged inlets (fjords) lining Norway's coast. Many of these fjords are well over 2,000 feet (610 meters) deep and were carved out by extremely heavy, thick glaciers that formed during the last ice age.

Source: Jacques Descloitres, MODIS Rapid Response Team, NASA/GSFC.

The ice ages of the Cryptozoic eon might be difficult to imagine, but glacial till or tillite with a thickness of more than 500 feet has been identified, as have areas with grooved, striated, and faceted boulders, dating from middle Huronian time during the Proterozoic era in Canada, north of the present Great Lakes, extending more than 1000 miles in diameter. Also, ancient tillites have been found in Manitoba, eastern Greenland, and northern Utah, where layers of tillite with other formations have a thickness greater than 12,000 feet and could be a part of the Cambrian. This type of ice age evidence is also found in southwest Africa, as well as the Transvaal, the Katanga, Griqualand, and South Africa. In Australia, the Flinders Range shows tillite more than 600 feet thick. Ancient tillites are also found in northeast China, and northwestern and eastern India, dating from the end of the Proterozoic. With only tillite to show the location of the glaciation, and without fossil evidence from the Precambrian, it is impossible to estimate the time periods for these occurrences, except that these ice ages, with perhaps others not yet known, occurred approximately from 500 million to 2 billion years BP. So, at least two ice ages are presumed to have occurred in the Precambrian eras.

The ice age of the Permian period was mostly in the southern hemisphere. Primarily consisting of ice sheets, the glaciers covered a large part of southern Africa, portions of Nigeria, Uganda, and the southern tip of Madagascar. Three small portions in India, three areas in Australia, and six sections of South America were also covered with glacial ice. These areas show striated, grooved, and polished rock, with adjacent tillite formations sometimes greater than 100 feet in thickness. These locations appear to have been glaciated repeatedly, all moving in a northerly direction lying within 20° to 35° of the equator. It is likely that these land masses were much farther south than they are at the present time, giving rise to the acknowledgment of continental drift. That is, ice sheets in areas of India and Nigeria that are now north of the equator were well south of the equator in Permian times. Fossils formed during the Permian have been found near the glaciated areas. Especially noted were the small, hardy tongue ferns, *Glossopteris* and *Gangamopteris,* surviving the increasingly harsh climate. These fossils tend to confirm the specific time of the Permian ice age.

The ice age during the Cretaceous period, again, was mostly in the southern hemisphere during Aptian time or in the Late Cretaceous. This is when the dinosaurs ceased to exist, during the Laramide disturbance. Thus, the end of the Mesozoic era and the beginning of the Cenozoic era, about 70 million years BP, is adequately marked. It is noted that the plateau of eastern Australia was ice-capped, with glaciers flowing toward the west into the sea. Icebergs also calved into an inland sea to the east.

During the Cenozoic era, the most recent and well-known ice age occurred. The Pleistocene epoch had four ice ages, or in some accounts, one great ice age with four separate ice advances separated by interglacial stages. Using North American terminology, beginning with the Nebraskan stage about 1 million years ago and lasting about 100,000 years, global warming, or the Aftonian interglacial stage, was about 200,000 years in length. Then, the Kansan stage of glaciation began and lasted for about 100,000 years, followed by the Yarmouth interglacial stage, which lasted for 310,000 years. The Illinoian stage was only about 100,000 years in length, but it appears to have the greatest ice coverage of the four advances during the Pleistocene. The Sangamon interglacial stage was about 135,000 years long; this was the shortest of the three interglacial stages. The Wisconsin stage began about 55,000 years ago and ended a mere 11,000 years ago with the advent of the present interglacial stage, which is known as the Holocene epoch. It is known that the Wisconsin glacial stage had four distinct ice advances and recessions, making a complex landscape across the Midwest of the United States with the same being true in Europe and Siberia.

It is generally accepted that during the last million years or so, crustal movement has been poleward in the northern hemisphere, and that the continents whose shapes and location we know today were different long ago. These are all, of course, geological concerns involving time. Also to be considered are meteorological concerns, which involve the cyclical changes in temperature of land, sea, and atmosphere. At present there is a warming trend that began an estimated 11,000 years ago. It is questioned whether we are at the end of the ice ages or merely between two glacial ice advances. If the global atmospheric temperature decreased a mere 5° C, another ice advance would be likely to begin. How long is this warming trend to last? How has humankind affected this warming trend? What effect will it have if we are still in the Pleistocene ice age or at the end of it? There are more questions than answers. Perhaps significant, however, is that the occurrences of the six known ice ages are spaced closer in time toward the present.

Approximately 4,500 to 5,000 years ago, ice covered all of Minnesota; it had been receding from Iowa since about 2,800 years earlier, although ice had reached as far south as northern Missouri. Today the last vestige of this ice is the arctic polar ice cap, which is continuing to recede. As the ice receded, vegetation and wildlife followed, with aborigines migrating northward from the southern climes. So it is today with nations looking for environmental resources where the ice is melting. Since the shortest known interglacial stage is the Sangamon, which lasted 135,000 years and ended 55,000 years ago, it can be expected that a phase of global warming is just beginning and will be here for tens of thousand of years more, whether affected or not by the activities of humankind.

Richard A. Stephenson

See also Cretaceous; Erosion; Geology; Glaciers; Pangea; Wegener, Alfred

Further Readings

Ausich, W., & Lane, N. G. (1999). *Life of the past* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Chernicoff, S., & Whitney, D. (2007). *Geology* (4th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Martini, I. P., Brookfield, M. E., & Sadura, S. (2001). *Principles of glacial geomorphology and geology*. Upper Saddle River, NJ: Prentice Hall.

Weiner, J. (1986). *Planet earth*. Toronto, ON, Canada: Bantam Books.

Idealism

The term *idealism* refers to any philosophical system or thesis that emphasizes the mental (idea) or the notion of very high or preeminent value (ideal). Because minds evaluate, it is possible to imagine a deep relationship between these two very different criteria. There are some connections, but clarity demands that they be understood separately. Only the emphasis on the mental yields a distinctly idealist conception of time.

When emphasizing value, *ideal, idealistic,* and *idealize* serve many functions. For example, norms and goals are often called ideals. On that basis, some moral attitudes such as optimism, commitment, and cheerfulness are deemed idealism, as in "the idealism of youth." Similarly, in international relations, idealism refers to a policy or posture obligating a state to promote higher aims among nations, such as peace, justice, cooperation, open borders, or democracy, while *practical* idealism refers to a position between that kind of idealism and what is known as *realism,* which refers to a state's selfishness in international affairs.

A second line of usage takes off from the fact that whatever would fully satisfy a desire is called ideal. Hence, in aesthetics, idealism has to do with representing things as we would like them to be (idealized) rather than as they are. With a little pejorative shading here, *idealist* calls out a vice. Thus, in ethics, the idealist is one whose standards are unrealistically high, or who is too confident about the virtue of a person or line of action, or perhaps altruistic to a fault. A system of ethics might be called idealistic if it sacrifices too much for the sake of a particular principle; or if it elevates any aspect of moral life too high, for example, sympathy at the expense of autonomy, but especially the spiritual or rational at the expense of the sensual or immediate; or if it believes too much in the goodness, or perfectibility, of human nature; or if it overestimates the moral efficacy of a line of causation, such as instruction, role models, prayer, meditation, sobriety, free markets, self-denial, the individual, the mass, the ego, the id, or rationality. Slightly more pejorative shading renders the idealist an idle dreamer of utopias, or an impractical adherent of some perfect, best, or ultimate in some domain. At the deepest levels of pejoration, *ideal* gives way to *idea,* in the sense of imaginary, and the idealist is primarily a fantasist.

Philosophy and Idealism

When the emphasis falls on mind, rather than value, there are both broad and narrow uses.

Most broadly, idealism is the negative of naturalism, materialism, or realism. Both *naturalism* (which abjures supernatural explanations) and *materialism* (which asserts that reality is ultimately physical) relegate the mental to a nonbasic, nonfundamental ontological status. Idealists do the reverse. Realism holds that the world exists independently of thoughts about it. Idealists typically deny some or all of that. However, there are systems of idealism that grant a good deal of realism, and so the most common and broadest ways of thinking about idealism treat it as the negative either of materialism or naturalism, or both.

For Karl Marx, it is the negative of materialism. If materialism is built upon the particular, the describable, and the sensuous, idealism stresses the universal, the indescribable, and the supersensuous. Where materialism posits the mechanistic, idealism introduces the teleological, and where it abjures evaluation, idealism inserts appraisals. Taken in this way, idealism includes all theses and systems that ultimately ground reality in the animate or the mental, whether taken as idea, mind, will, ego, nous, logos, word, text, absolute, God, life force, or earth turtle. Every kind of theism in which something animate is the source, ground, or essence of nature is idealism. Every account of causation that introduces teleology is idealism. Every ascription of a value to the essence of things is idealism. In this sense, the history of philosophy is very much a history of idealism, if only because it has been rare for thinkers to adhere to strict materialism and to forgo teleological and normative language in their descriptions of the world. When they have deviated into materialism, many have settled on a dualistic view in which it inevitably became all but impossible to allow the material equal footing with the ideal, making them realists who maintain a form of idealism.

Such views are often called *realistic idealism,* which refers to any doctrine that recognizes the existence of nonmental, nonideal entities but relegates them to a subordinate status as compared to the ideal. Theistic schools of this sort allow some category of nonmental existence independent of the divine mind but also hold that the divine created it, perfected it, controls it, or is coeternal with it. Nontheistic schools include Plato's system, in which timeless, disembodied ideas are organically united in the idea of the Good. Insofar as the world of particular things is downgraded into a mere imitation of these transcendent universals, Plato's system is an instance of realistic idealism. Another example is psychological idealism, which is the doctrine that ideas or judgments cause thoughts or behaviors. Like Plato's system, this doctrine is understood as denying either naturalism or materialism, or both, but not realism.

Epistemological idealism is the view that all entities other than minds are exclusively noetic objects, meaning that they have no reality apart from being perceived or thought by a mind. Edmund Husserl attempted to systematically think through a hypothetically couched form of epistemological idealism. In his phenomenology, the essences of objects, including the self, the other, time, and causation, are methodically treated *as if* they were exclusively noetic, apart from any other status they might actually have. A nonhypothetical system is found in George Berkeley's doctrine of immaterialism, where to be is to be perceived, and all that exists must be either perceiver or perception. Another is the transcendental idealism of Immanuel Kant, in which knowledge is wholly a product of the logical self or of transcendental unity of apperception.

In the existentialism of Martin Heidegger, learning is giving oneself to oneself. In postmodernism, there is nothing outside the text, and there are signifiers but no signified, both of which directly imply that our minds can encounter only thought. Semantic idealism is the thesis that our descriptions refer only to ideas rather than to things, so that, for example, the tautology, "When I speak of my right hand, it is my right hand of which I speak" is false, and instead, "When I speak of my right hand, it is an idea of my right hand of which I speak" is true. The implausibility of semantic idealism has been a frequent challenge to forms of epistemological and psychological idealism that rely on or imply it.

In its narrowest senses, *idealism* is variously qualified so as to sort and organize metaphysical outlooks. For example, impersonalistic idealism grounds the world in unconscious, spontaneous mental energy, whether as life force, precognitive urge, or primordial will. Personalistic idealism, also known as personalism, grounds the world in a self-conscious or purposive principle, such as nous, logos, or ego. The relationship between the mental world ground and individual, finite minds is crucial.

Monistic idealism holds that each finite mind is a mode, aspect, or projection of the One. Pluralistic idealism grants varying degrees of freedom, autonomy, privacy, uniqueness, and causal independence to the thoughts and acts of finite minds. With regard to their means of accounting for the natural world, schools of idealism are either subjective or objective. *Subjective idealism* holds that the natural world is a projection of our minds and appears to imply solipsism. *Objective idealism* identifies the natural world with the thoughts or acts of the world ground. Given these distinctions, Arthur Schopenhauer's philosophy, which grounds the world in blind will and affirms that every lion is one lion, can be understood as an impersonalistic, monistic, objective idealism. Schopenhauer's primary influence, the Vedic philosophy, which teaches that the finite self is a moment of the impersonal *Brahman,* is also an impersonalistic, monistic, objective idealism.

Schopenhauer's antipode, G. W. F. Hegel's philosophy, which treats thought as the ground of the world, freedom as the condition of thought, and self-consciousness as the condition of freedom, obviously grounds the world in a self-conscious principle, and it is thus a personalistic, pluralistic, objective idealism. Henri Bergson's philosophy of *elan vitale* is an impersonalistic, pluralistic, objective idealism, a status it shares with Friedrich Nietzsche's philosophy of will to power.

George Berkeley's immaterialism is often described as "subjective idealism," but that cannot be the case as the term is defined here. Berkeley denies only matter in nature, not nature's independence from finite minds. Objects in nature turn out to be exclusively noetic in his system, but they are not projections of our minds, but rather thoughts perceived in the mind of God, a view echoing prior work by Arthur Collier and John Norris. Because objects in nature are accounted for in terms of the acts of God's mind, rather than the acts of finite minds, Berkeley is an objective idealist with a personalistic world ground and a pluralistic outlook on finite minds.

A version of subjective idealism is found in the "windowless monads" of Gottfried Leibniz, which perceive the real world by perceiving only themselves. A more recent example is the decidedly antirealist school of postmodernism. Given its denial that our minds can encounter anything other than thought, the question becomes whose thought, our own or that of another, is encountered in the objects of nature. The postmodernist cannot offer us an encounter with the thoughts or acts of an independent world ground, because that would mean encountering the signified rather than the signifier. With the only route to objective idealism thus blocked, the postmodern idealist must be a subjective idealist for whom the natural world is a mental projection conditioned by our backgrounds and differences. Because these backgrounds and differences condition the world, postmodernism is an impersonalistic, notably monistic, subjective idealism, in which an unmistakable degree of monism among finite minds is achieved through the notion of impersonal, collective construction of reality—to be is to signify as a group member.

In the philosophy of mind, *hylozoism,* the view that matter is alive, and *hylopathism,* the view that matter is sentient, or that whatever is ontologically more basic than consciousness, such as neurons and their building blocks, already contain the essentials of consciousness, are impersonalistic idealist views. Alfred North Whitehead's *panexperientialism,* which holds that the fundamental constituents of reality are experiences, is somewhat more personalistic than these, as is *panpsychism,* which attributes mind to matter. *Panentheism,* which holds that the One both transcends and is imminent in the universe, and *pantheism,* which identifies the natural world with the One, are yet more personalistic. The *occasionalism* of Nicholas Malebranch, in which natural causation is an illusion and God is the sole cause of all events, including all human acts and cognitions, is an example of a highly monistic causal pantheism, the omnisufficiency of a personal One, in the philosophy of mind.

Time and Idealism

Because idealist thinking is found in all ages and languages, the term *idealism* is frequently restricted so as to sort schools according to historical criteria, for example, as 19th century, modern, or ancient idealism; German or British; Vedic or Buddhist; philosophical or religious. By the same token, there is no single idealist attitude pertaining to time. History's various gods and goddesses of time, such as Chronos, Aion, Kali, and the figure of Father

Time, express personalistic views, while a World Tree and a World Snake express impersonalistic views. Personalistic creationism in this area has often stumbled over the fact that the notion of a creator of time looks incoherent, because a creator of time must change from a state of not creating time to a state of creating time, and thus time must exist (as the medium of change) before it is created.

In philosophy, there has been one characteristically idealist thesis about time, known as the *ideality of time* thesis, which holds that time is not to be found outside of mind, or that it is exclusively noetic, or phenomenal, a view expressed as early as Antiphon the Sophist. Plotinus held it as well. Its modern proponents, in their various ways, include Leibniz, Baruch Spinoza, and most of the school of 19th century German idealists, including Schopenhauer, Hegel, Johann Fichte, and Friedrich Schelling. Kant held that space and time were necessary, a priori preconditions of understanding. The external world is necessarily represented in space and time, while the inner world of thought is necessarily represented temporally. In both cases, time is empirically real but transcendentally ideal, meaning that it is an actual datum of experience, though we can have no reliable conception of it outside of experience. In contrast, Nietzsche probably denied the ideality of time in favor of a real eternal return. More recently, many of the existentialists who were inspired by Husserl's work entertained phenomenological versions of the ideality of time, including Heidegger and Karl Jaspers. In the school of British Idealism, F. H. Bradley and J. M. E. McTaggart embraced the ideality of time thesis. The latter famously argued for the unreality of time and produced a system that was so pluralistic that there was no God or One in it. Instead, McTaggart grounded the world in the thoughts of a community of immortal spirits.

Belief in the ideality of time has often been held as a consequence of the belief that all things are ideal, but it has also occurred, for example in Kant and McTaggart, that belief in the ideality of time thesis has been the basis on which a more general idealism was erected and justified.

Idealism's Critics

Critics of idealism have been many, beginning at least with Aristotle. The most notable German critics are Kant and Nietzsche. Kant argued against all forms of thought, including all forms of idealism, that move beyond the limits of categorical experience to predicate the thing in itself. Nietzsche suggests that Kant's transcendental idealism is based in the faulty argument that a priori synthetic truths are possible by virtue of a faculty, and he describes Hegelian idealism and Kantian skepticism as delaying tactics employed in a largely theological struggle to prevent the emergence of a naturalistic world view.

In Britain, G. E. Moore and Bertrand Russell led a revolt against the breed of Hegelian idealism that was then dominant in English philosophy. It was the seminal event in the birth of the school now known as analytic philosophy.

Bryan Finken

See also Berkeley, George; Hegel, Georg Wilhelm Friedrich; Kant, Immanuel; Marx, Karl; Materialism; McTaggart, John M. E.; Nietzsche, Friedrich; Plato; Schopenhauer, Arthur; Solipsism; Whitehead, Alfred North

Further Readings

Ameriks, K. (Ed.). (2001). *The Cambridge companion to German idealism.* Cambridge, UK: Cambridge University Press.

Ewing, A. C. (1934). *Idealism: A critical survey.* London: Methuen.

Foster, J. (1982). *The case for idealism.* London: Routledge.

Franks, P. (2005). *All or nothing: Systematicity, transcendental arguments, and skepticism in German idealism.* Cambridge, MA: Harvard University Press.

Muirhead, J. (1931). *The platonic tradition in Anglo-Saxon philosophy: Studies in the history of idealism in England and America.* London: Allen and Unwin.

Neujahr, P. J. (1995). *Kant's idealism.* Macon, GA: Mercer University Press.

Stove, D. (1991). *The Plato cult and other philosophical follies.* London: Blackwell.

Ides of March

In the complex world of the Roman calendar, each month had a day called its *ides*. In March, May, July, and October, the ides fell on the 15th of the month. In the remaining months, the ides fell on the 13th. Ides comes from the word *iduare,* which means, "to divide" and literally signified the division of a month into two equal parts. The Roman calendar divided each month into *kalends, nones,* and *ides,* each celebrated in their own ways, indicating lunar events, and serving as a calendar for the common citizens. The ides was a day traditionally marked for ritual offerings and sacrifices.

Religious and political leaders kept calendars private and were often adjusting the length and structure to remain in sync with the lunar and seasonal changes. In the Roman and Julian calendars, the term *ides* was commonly used, equivalent to using such modern terms as *next week, today, tomorrow,* or *yesterday.*

The ides of March took on a whole new meaning in the year 44 BCE. It was on this day that Julius Caesar, emperor of Rome, was assassinated by a group of nobles in the Roman Senate. William Shakespeare captured this historic assassination in his play *Julius Caesar.* In Act One, Scene Two, a soothsayer proclaims a warning to Caesar in the infamous line, "Beware the ides of March."

After the Julian calendar, inspired by Julius Caesar, displaced the Roman calendar in 46 BCE, the term *ides* was used only colloquially to denote the middle of the month. Those living under the traditional Roman calendar most accurately interpreted the ides as the 15th of the month. With the passing of time, the expression "beware the ides of March" came to signify the prediction of doom, much like the aura of superstition that associates bad luck with Friday the 13th.

Debra Lucas

See also Caesar, Gaius Julius; Calendar, Gregorian; Calendar, Julian; Calendar, Roman; Rome, Ancient

Further Readings

Evans, G. B. (1974). *The Riverside Shakespeare.* Boston: Houghton Mifflin.

Feeney, D. C. (2007). *Caesar's calendar: Ancient time and the beginnings of history.* Berkeley: University of California Press.

Michels, A. K. (1967). *The calendar of the Roman Republic.* Princeton, NJ: Princeton University Press.

Immortality, Personal

Personal immortality is best understood as the belief in the actual survival beyond physical death of the core element of our personality or consciousness—often called the soul—for an indefinite period. The primary assumption of this belief is that the core element of consciousness, or soul, is entirely distinct from our body, and so can be removed from it on the body's death with no compromise in quality or essence. The consequences of belief in personal immortality on one's view of time are profound and involve a comprehensive rejection of temporality. It is also considered of fundamental importance in the development of religion.

Beginnings

It seems apparent that some of our predecessors' earliest speculations revolved around death and its consequences. The existence of burial sites among Neanderthals from 60,000 years ago and early *Homo sapiens* from about 35,000 years ago suggest that death was believed to be a transitional state. The practice in primal societies of killing off aging people was due, in part, to the supposition that their bodies, not being yet decrepit, would be useful to them in the afterlife. And the mutilation or eating of enemies was done with the same view in mind; the destruction of their bodies so as to cripple their ability to exact revenge from beyond the grave.

Similar views carried on in the early civilizations. The Egyptians, for instance, held high store on immortality, but their extraordinary efforts to preserve the physical body with processes like mummification suggest they could not conceive of immortality without a physical body. The coronation of the pharaoh was held to coincide with either the rising of the Nile in the early summer or receding of the waters in autumn when the fertilized fields were ready to be sown. As part of the coronation the pharaoh would reenact the deeds of Osiris, who represented the life-giving waters of the Nile. Beliefs about Osiris embodied the cycle of birth, death, and rebirth around which Egyptian life revolved. And from this cycle came the promise of immortality, which for many centuries was the preserve only of the pharaohs but eventually became available to anyone who could afford the expensive rites and observances.

Asian Traditions

Indian notions of immortality resonate to a different beat, bound up as they are with the idea of rebirth. It is one thing for the soul to survive death, but immortality is another thing altogether. The Vedas spoke simply of an afterlife presided over by the god Yama, but ideas of rebirth developed later. In what has become understood as the quintessential Hindu view, the soul will undergo an almost countless number of rebirths and, along the way, gradually rid itself of the life-clinging vices of greed, hate, and delusion. The final aim in Hinduism is *Moksa,* or liberation. Here and only here is true immortality achieved, but at the cost of having shed all traces of existence apart from the universal whole into which it has merged. Much the same is true of the Buddhist notion of *nibbana,* or in Sanskrit, *nirvana.*

In China, Confucianists and Taoists alike shared the Indians' suspicion of the egotism thought to underlie a desire to live forever, but they had no thought of rebirth, thinking instead that we have but one life to live. One tradition of thought expressed this well by speaking of the "three establishments." Instead of yearning for immortality in heaven, they advised we focus more on being remembered well here on earth, which could be done in any of these three ways: *establish virtue* to be remembered as an upright and honest person; *establish achievement* to be remembered by what one achieved in life; and *establish words* to be remembered by any written legacy one may have left. The Asian traditions, then, do not value personal immortality. In fact, their core insight is to rid oneself of the delusions that would presuppose such a goal to be worthwhile.

The Middle East and Judeo-Christian Traditions

As long as the physical body was bound up with the afterlife, as in Egypt, thinking on personal immortality could only go so far. It was the Persian sage Zoroaster who is credited as the first to associate personal immortality with the beliefs and actions of one's life. As part of a rebellion against the polytheism of the Persia of his day, Zarathustra posited a universe characterized by a cosmic struggle between good and evil. The good was exemplified by Ohrmazd and the evil by Ahriman. While Ahriman owed his existence to God, he had of his own free will chosen the evil path. Zarathustra taught that human beings can also choose to follow the righteous or the evil path and that our immortal destiny depends on the decisions we make.

As is now widely recognized, Jewish, and later Christian, religious concepts owe a heavy debt to Zoroastrianism. Jewish eschatology was primarily concerned with the fate of the nation, but the collapse of the Jewish nation and the Jews' exposure to Zoroastrian beliefs while in exile in Babylonia in the 6th century BCE introduced new ideas of personal immortality linked to the passionate belief in the justice of God. It is likely that the development of personal horoscopes in Babylonia in the 5th century BCE was due to the influence of Persian doctrines of personal immortality.

Until the exposure to Persian ideas on personal immortality, there was little discussion in the Jewish tradition of what happens after death beyond mention of a dim underworld called Sheol, to which all departed go, whether righteous or wicked. *Sheol* originally referred simply to the collective graves of the tribe. Sheol was a sad place where the soul wanders aimlessly, an enfeebled remnant of the living person. After the Persian ideas became available, some evidence exists that views developed to include the possibility of intervention from Sheol into worldly affairs. These ideas were resisted by the more learned sections of society, and more skeptical ideas became prevalent.

The other important influence on Jewish thought on immortality was Platonism. Before Plato, little attention had been given to a life after death. The funeral oration of Pericles, for example, makes no mention of an afterlife for those who had fallen in defense of Athens. Popular notions of Hades were much like Sheol: dark, gloomy, and unwelcoming. So when, in the *Phaedo,* Plato argued for personal immortality as experienced by an immortal soul, he was going against the grain of Greek thinking.

As a result of these different influences, it is hardly surprising that Jewish thinking on immortality was not consistent. On the one hand it was believed that at the end of time the soul would be reunited once again with the body and that the righteous and the wicked would receive rewards or punishments accordingly. But alongside this was the idea that the soul, being immortal, survived bodily demise and received its punishment or reward immediately upon death. And then there is the eloquently phrased skepticism of any sort of afterlife, as expressed in Ecclesiastes (9: 3–10).

For first century Judaism, then, the question of immortality was hotly contested, with the Sadducees arguing against it on the grounds that such an idea has little or no scriptural warrant. Against them stood the Pharisees, who were less traditional and more influenced by the Greeks in this respect, and their case won in the end. The influence of the later Greek thinkers, with their notions of an immortal soul for which the body was simply the vessel, can be seen in the thought of Philo of Alexandria (c. 20 BCE–c. 50 CE).

Christian teaching on immortality inherited some of the ambiguities of Judaism, but Saint. Paul's strong commitment to personal immortality smothered them. Saint Paul was quite clear about the central role immortality had in his theology. "And if Christ be not risen, then is our preaching vain, and your faith is also vain. . . . If in this life only we have hope in Christ, we are of all men the most miserable." (1 Cor 15:14, 19) His strong interpretation of immortality was followed up by Saint Augustine (354–430 CE), whose works were vastly influential in establishing Christian dogma for more than 1,000 years.

But even in Saint Paul there was a certain ambiguity. It is not certain, for instance, that eternal life can be understood straightforwardly as surviving beyond death. Elsewhere Paul speaks of our mortality being clothed with immortality, but once again this is as likely to refer to the eternal life of salvation with no suggestion of personal survival. This more sophisticated argument has not found favor among the vast majority of Christian believers, who continue to believe in their own personal immortality.

It is true, however, that there are two quite different conceptions of immortality in the early church, neither of which was clearly articulated. On the one hand, the belief that with the Second Coming of Christ all the dead will be resurrected requires that they lie dormant until then. But on the other hand, there is the belief that our souls depart from our bodies on death and immediately go to whichever point of repose is allocated to them. In the early years of the church, this distinction did not matter a great deal, because the return of Christ was believed to be imminent. But as time passed and Christ did not return as expected, the problem of this intermediate period between death and resurrection took on a greater urgency, particularly as the promise of immortality constituted its principal point of difference with other religions and with paganism.

Renaissance and Modernity

The importance of the idea to the Christian appeal notwithstanding, major areas of confusion remained for centuries to come. The individuality of the soul—an idea essential to the notion of personal immortality—only became established dogma at the fifth Lateran Council of 1513. But Pope Leo X's effort to enshrine belief in immortality was indication that it was under attack. In the general spirit of inquiry that characterizes the Renaissance, belief in personal immortality was one of the first supernaturalist nostrums to be queried. Of particular interest here is Pietro Pomponazzi's (1462–1525) *On the Immortality of the Soul*. Published only 3 years after Leo's edict, Pomponazzi's treatise looked at the discrepancies between Aristotle's view of the soul and that of official Catholic teaching. In particular, it explored the difficulties in reconciling the status of the perished soul in the twilight zone between death and resurrection. It ended up saying that personal immortality could not be established by reason and could only be believed as an article of faith. His work was publicly burned and he narrowly escaped more serious persecution.

Over the next centuries, thinking on immortality diversified a great deal. Immanuel Kant (1724–1804) devoted much energy to placing immortality as a postulate of the moral law, but almost completely ignored any description of what immortality might be like. A landmark in thinking on personal immortality came from Ludwig Feuerbach

(1804–1872), who was one of the first to articulate a contemporary understanding of immortality. In *Thoughts on Death and Immortality* (1830), Feuerbach argued that the ancient world conceived of immortality as achieved through identification with the state and the people, and it felt no consequent need to denigrate the limitations of a life lived in the here and now. But the specifically personal immortality before a personal transcendent God was a relatively recent development of Christianity, this not having been the main understanding of immortality during the Middle Ages. But, he argued, in the face of the "double nothing" of living people without essences and essences without meaning, the traditional dualism of Christian dogma was no longer viable. God, by this way of thinking, became an alien "other," outside the framework of human love. Instead, the earlier notions of immortality as a social memory and as part of a larger community were now returning to their rightful position.

In the wake of Feuerbach, a variety of naturalistic accounts have been offered. Following on from the ancient Indians and Chinese, 19th and 20th century freethinkers were suspicious of the motives that underlie the popularity of the idea of personal immortality. Nowhere was this more forcefully put than by the American pragmatist thinker William James, who wrote, "The pivot round which the religious life, as we have traced it, revolves, is the interest of the individual in his private personal destiny. Religion, in short is a monumental chapter of human egotism." Many freethinkers of the time thought the same. For example, George Anderson (1824–1915), an English businessman and philanthropist, wrote a poem called "Immortality," which was published in the *Agnostic Annual* in 1897. Anderson understood well the attraction behind claims of personal immortality: "So man's weak vanity was touched and flattered,/And thus he listened to the wondrous tale,/That all creation might be whelmed and shattered,/While He o'er death itself would prevail."

Several attempts were made in the 19th century to reconcile belief in immortality with the naturalistic worldview, the most influential of which was the phenomenon of spiritualism, which attracted considerable support between the 1850s and the 1920s. Through séances run by mediums, it was widely believed that contact could be made with the deceased. The more devoted spiritualists were convinced that they had achieved a major scientific breakthrough. Personal immortality was no longer a matter of faith or dogma, but of testable fact. The last great wave of interest in spiritualism happened during the First World War, as grieving family members sought to establish contact with loved ones killed in the fighting. But spiritualism declined after the war, as greater scrutiny of the mediums' practices revealed them to be tricks that magicians could reproduce or even simple fraud.

Other thinkers tried to avoid the question of whether personal immortality is actually true or not. For instance the pragmatist philosopher F. C. S. Schiller (1864–1937) acknowledged that dogmas about immortality were accepted because they were what people want to believe. But he specifically sidestepped the question of whether personal immortality was true and confined himself solely to the value of the belief on a person's conduct and well-being. He went further when he insisted that the ethical argument for immortality remains independent from whatever science may discover. This style of thinking has remained influential among religious progressives.

The most thorough critique of personal immortality from the 20th century was *The Illusion of Immortality* (1935) by Corliss Lamont (1902–1995), an American philosopher who studied under John Dewey. This work went through three editions and remained in print for 40 years. Lamont was not unsympathetic to the motivation behind the wish for immortality, but it was clear to him that immortality was incompatible with a naturalistic account of things. This said, he did more than simply deny the traditional conception of immortality; he also broadened the range of ways we could think about immortality, which involved many more perspectives than simply personal immortality, which relied upon a heavy dualism. Lamont identified *ideal immortality,* or the eternal moment that Spinoza and Santayana spoke of; *material immortality,* where the material that makes us up is subsumed after death back into nature; *historical immortality,* or the simple fact of our existence in time; *biological immortality,* or our continued existence through our children; and *social immortality,* or survival through the memory of our achievements.

An interesting development over the past half century has been an increase in interest in the beliefs of the general citizen on matters such as this. For example, the World Values Survey, which polled people in 74 societies around the world between 1981 and 2001, found a general decrease in belief in personal immortality as societies become more prosperous, although with an interesting anomaly. In agrarian societies, belief was measured at 55%, in industrial societies at 44%, and in postindustrial societies at 49%. The slight rise of reported belief in personal immortality in postindustrial societies may be accounted for by the inclusion of the United States, where the figures are out of alignment with all other postindustrial nations, with its growth of various "new age" spiritualities. Interestingly, this was the only anomaly in an otherwise even decline in all recognized forms of religious belief and expression from agrarian to postindustrial societies.

More recently a wide range of Christian thinkers have reconciled themselves with the naturalistic account of the world and have abandoned the more supernaturalistic interpretations of personal immortality. Many have developed variations of Lamont's ideal immortality to reposition the argument. These, along with the more naturalistic interpretations, mean that immortality has a wider range of interpretations now than at any time in history. In general, however, personal immortality has given way to variations of the nonpersonal immortalities Lamont and others have outlined. And in so doing, time has been handed back its absolute dominion.

Bill Cooke

See also Aquinas, Saint Thomas; Augustine of Hippo, Saint; Christianity; Feuerbach, Ludwig; Judaism; Kant, Immanuel; Plato; Egypt, Ancient

Further Readings

Anderson, G. (1897). Immortality. In C. A. Watts, (Ed.), *The agnostic annual* (pp. 47–48). London: Watts.

James, W. (1908). *The varieties of religious experience.* London: Longmans, Green.

Lamont, C. (1959). *The illusion of immortality.* New York: Philosophical Library.

Norris, P., & Inglehart, R. (2004). *Sacred and secular: Religion and politics worldwide.* Cambridge, UK: Cambridge University Press.

Schiller, F. C. S. (1912). *Humanism: Philosophical essays.* London: Macmillan.

Whitrow, G. J. (1988). *Time in history.* Oxford, UK: Oxford University Press.

Incubation

Incubation refers to the amount of time required in a developmental period. It stems from the Latin root *incubare,* which means to lie upon. This correlates with the term's most common use today, avian incubation. However incubation can also be applied to chemistry, microbiology, medicine, and even ritual.

Avian incubation denotes the time when the parent birds, usually female, sit upon their eggs. The body heat from the parent provides warmth to the growing eggs and maintains a consistent environment, providing constant humidity, shade, and temperature. Some species of bird, such as megapodes, incubate their eggs by burying them, with the eggs receiving warmth from geothermal heat and organic breakdown of vegetable matter. The incubation period varies from species to species, ranging from only 11 days up to 85 days. Some species may also begin incubating at different times of development to either stagger the brood's growth or create a simultaneous hatching.

In chemistry and biochemistry, incubation is the period of time and set of conditions required to maintain a chemical reaction. These condition constants can include temperature, pressure, concentration of reactants and products, and the presence and concentration of a catalyst. By utilizing the proper chemical incubation period, chemists are able to synthesize the highest yield of products in the shortest time.

In medicine, or more specifically pathology, incubation is the amount of time before a patient begins showing symptoms after a pathogen or disease-causing bacterium enters the body. This is often also referred to as the latency period. This incubation period varies for each disease and can range from a few minutes to several years. Generally the incubation period in children is shorter than the incubation period in adults.

Because these diseases are caused by pathogenic organisms, a valuable tool for diagnosing these illness are cultures, including blood, stool, urine, and sputum cultures. These cultured samples are actually grown in optimal conditions in machines called incubators, which can range in size from small tabletop units to those as large as rooms. These microbiological incubators can be programmed to simulate highly specific conditions, including carbon dioxide and oxygen levels, humidity, and temperature. Most incubators are programmed to simulate the internal environment in a human, because pathogenic bacteria usually experience optimal growth in these surroundings.

Another form of medical incubation is done in neonatal intensive care units (NICUs). Here, newborns in critical condition are placed in incubators, which are essentially large open warming units. These provide a constant temperature and oxygen level and a relatively clean environment. More advanced incubators may feature monitoring equipment and pressure capabilities, which help keep premature infants' airways from collapsing. However, this technology has its drawbacks, as newborns in the NICU often experience high noise and light levels, reduced physical contact with humans, and separation from their parents.

In a less scientific sense than the other definitions, incubation may also be applied to the mystical practice of sleeping in a sacred or divine area in hopes of achieving a spiritual enlightenment, whether it be through a dream, vision, experience, or cure. In ancient times, this practice was very common, especially for followers of the Greek deity Asclepius, the demigod of healing and medicine. Several present-day Christian sects and Greek Orthodox monasteries still practice this method of incubation today.

Christopher D. Czaplicki

See also Chemistry; Medicine, History of; Thanatochemistry

Further Readings

Bergtold, W. H. (1917). *A study of the incubation period of birds: What determines their length*. Denver, CO: Kendrick-Bellamy.

Hamilton, M. (2006). *Incubation: The cure of disease in pagan temples and Christian churches*. Whitefish, MT: Kessinger.

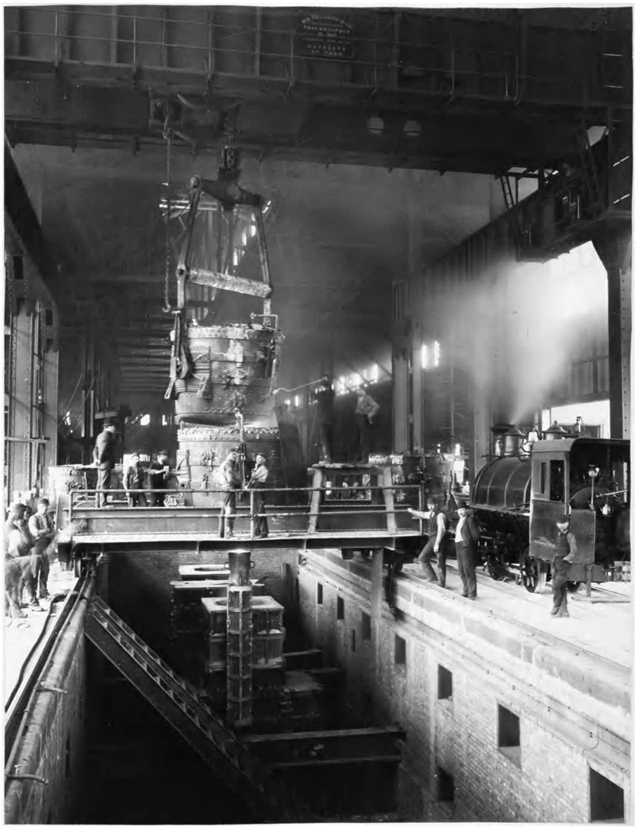
Industrial Revolution

The Industrial Revolution was a period in modern history when the production of goods by hand was gradually converted to methods of manufacture using large machines and assembly lines. This shift is seen by many historians as the force chiefly responsible for the birth of the modern era and for the ongoing phenomenon of globalization that emerged in the 19th century and now continues into the 21st.

The Industrial Revolution began in Great Britain. In 1650 the population of England was approximately 10 million, of which 90% earned a livelihood through farming of one kind or another. In 1821, Thomas Malthus wrote *Principles of Political Economy,* in which he discussed the concern that a lack of moral restraint by the British working class might lead to unchecked population growth. This behavior on the part of some people would create a fall in production, and the world would face a famine. Malthus gave a very gloomy prediction that worldwide mass starvation would eventually occur. In just 200 years, 1650 to 1850, the English population soared to more than 30 million, with less than 20% at work in fields, barns, and granaries. During this time England experienced the first Industrial Revolution, as entrepreneurs and capitalists began procuring the natural resources and labor power to produce goods for profit on a scale hitherto unknown.

The Industrial Revolution succeeded the longstanding agrarian age, which had begun millennia before when much of humankind developed agriculture and gave up nomadic lifestyles. Agrarian societies allowed people to escape from dependence on food sources over which they had no control. In such societies people produced surpluses that could be used to feed new classes of non–food-producers. At the same time, these societies required increasing amounts of land, which led to conflicts over territory. The need to store and defend food supplies and to house non–food-producers resulted in the growth of villages and small cities. Agrarian societies developed extensive division of labor and interdependence.

In *Principles of Political Economy and Taxation,* economist David Ricardo furthered the explanation for the changes that were occurring during the



Homestead Steel Works, *by B. L. H. Dabbs, 1893–1895. Workers watch as a foundry ladle prepares to pour molten iron into ingot molds at Carnegie Steel Company's Homestead Steel Works.*

Industrial Revolution. Ricardo explained the notion of cooperation as a consequence of prosperity in his theory of comparative advantage. Ricardo concerned himself with explaining the factors that caused growth in an agrarian economy. At the time, modern science and technology had not been applied to agriculture, and capital tools such as hoes and plows were of relatively minor importance as productivity inputs. Ricardo argued that the average productivity of labor would eventually decrease. This decrease in productivity would lead to falling wages for workers.

The Industrial Revolution in the simplest terms can be described as the advent of a decline in household production. It started in Britain for several reasons. The increased population provided labor for factories and markets. Britain had a rich supply of raw materials. Britain had many small shop owners that knew how to run a business. The change in production was an economic one, yet over time it became a political one as well as a social one.

Political Thoughts on the Industrial Revolution

The first Industrial Revolution was the impetus that led to the science of political economy. A new way of thinking was needed to explain and justify the social conditions. This began as philosophers in Europe struggled with the fundamental problem of how the individual pursuit of self-interest would lead to the highest social good. According to Arild Saether, theology and the power of the universal church as an explanation for human behaviors were replaced by new theories independent of church doctrines. There was a new distinction between positive and natural laws. Natural law was the manifestation of divine law. This law was revealed through nature based on reason. On the other hand, humankind created the concept of positive law. People needed to create laws to secure peace. New laws were required, because in a natural state everyone has the same equal and unlimited right to everything. With the advent of the Industrial Revolution, social structures changed and continued to develop specialized production of material goods. A continued propagation of the natural law would have resulted in a war of all men against all men, and self-destruction would have resulted. Hence, it was necessary for people to seek an agreement of cooperation and common wealth with each other. Works were written to explain positive laws. Such positive law acquired dominance in the 18th century and was firmly established in the 19th century.

The origins of the early teachings of political science are widely agreed upon. The Industrial Revolution had created a wealthy class of industrial capitalists who had to pay workers at least enough to live on. England at that time had a living wage that depended greatly on food prices. Ricardo advocated trade between countries. Consequently, the Corn Laws were passed. The Corn Laws placed tariffs on grain imports and created export subsidies that kept food prices high and increased the wages that capitalists had to pay. The basis of David Ricardo's theory, accepted in Parliament, was that specialization and free trade were beneficial to all trading partners. Adam

Smith and Ricardo had successfully explained the need and advantages for material cooperation and the acceptance of economic inequalities.

Adam Smith, a Scottish philosopher, wrote *The Wealth of Nations* in 1776; the book was widely accepted as a blueprint for economic activity and has been called the "bible of capitalism." Smith's teaching underscored the way humans reconciled self with others during the first Industrial Revolution. Smith discussed the division of labor as a consequence of social prosperity and people's desire to barter and exchange one thing for another. He explained how people managed to coexist by offering goods and services for sale in quantities that satisfied each other's private wants. Smith described how the invisible hand of the marketplace led to a cooperation that provided productivity and distribution that met the needs of society, and he argued that people would act in their own self-interest to provide goods and services of the greatest possible value. That in turn would allow for one to trade a good or service of a proportional value for another that one otherwise would not be able to receive. Those who produced the best would thrive, while those who provided the wrong good or provided an inferior good would lose out. Smith explained how the Industrial Revolution shaped what became known as the free market.

The free market paradigm provided an incentive for productivity and trade and provided a rationale for people to accept the idea of economic inequalities. Smith in essence justified the unequal distribution of wealth, arguing that in the long run everyone would gain. This notion of inequality was not new to the human race, but the free market explanation was an extension of the new concept of positive law. At the time of Smith's publication, England's Industrial Revolution saw the new manufacturing technologies, the development of more efficient forms of transportation, and the increase in productivity of agriculture that led to a massive movement from the countryside to the city. People in search of work migrated from rural areas to crowded cities and toiled long hours.

In 1875, Karl Marx completed work on the book *Capital* (*Das Kapital*). Marx's treatise developed an alternative understanding of the value of human labor. Marx's work served as an intellectual basis for a different vision of society, one that originated in class conflict, a struggle between labor resources and owners of capital. The labor theory of value, according to Marx, was the value of any commodity that resulted from the labor needed to produce the commodity. Labor provided more value in a day than it was paid. Capital owners were able to extract a profit when labor was used for the production of commodities. This notion proved to be a basis of the controversy as to how cooperation among humans over material value was organized. The philosophy of Marx pointed to the inevitably antiprogressive results of the economic and social inequality that the Industrial Revolution produced. Marx's view of progress was not supportive of the Industrial Revolution and the decline of family production. His philosophy was not based on incentives for people to be productive in order to get their needs and wants met. Marx's work in the field of political economy promoted an egalitarian economic and social structure, unlike the theories of other political economists, which were concerned with explaining the Industrial Revolution.

These three scholars—Smith, Ricardo, and Marx—are considered the progenitors of modern economics; in due course their ideas were exported across the Atlantic and promoted in the United States.

The Industrial Revolution in the United States

The Industrial Revolution that began in the mid-19th century in the United States must have seemed to others to have come out of nowhere. Europe had been the undisputed economic and technological leader in the world until, suddenly, the United States appeared in the vanguard. By 1926, the United States was producing about 45% of the world's industrial output, including 80% of the world's automobiles and 50% of its steel, electricity, and crude oil. America's experience of the Industrial Revolution had a decisive effect on the role of human resources in the economy and on social conditions for the American family. The Industrial Revolution in the United States thus mirrored Europe, as production changed from the manufacture of goods in small workshops to making goods with machines in factories.

The Industrial Revolution in the United States placed the family squarely in the capitalist mode of production, a fact well documented by the stories of urban working-class families' struggles to survive the Industrial Revolution. Changes in social relationships in the workplace and in households as a result of the Industrial Revolution have been viewed as both progressive and antiprogressive. The limits of capital's extensive mode of consuming labor in the first phase of industrialization, it has been argued, created a false consciousness among urban working-class families. The forces inducing conversion to a more intensive regime of separate spheres between work and home in the latter half of the 19th century were crystallized. Changing forms of family occurred as a result of the Industrial Revolution, as modern industry created the social construction of the "male breadwinner wage."

Thus, the economic structure of modern industry led to significant changes for American families. Prior to the industrial revolution, families had been largely self-sufficient work units. Fathers and mothers worked side by side, and children joined in the work as soon as they were able. Almost all of the values and skills needed for life were learned in the family setting. A sense of self-worth came naturally as did a sense of one's place in society.

The Industrial Revolution and the growth of cities changed all that. Fathers left home to work for money wages, and real wages rose quickly. Many families left their small farms and moved to the city. Children became more of an economic liability and less of an economic asset as they became unable to contribute to family maintenance. During the Industrial Revolution, work changed from requiring physical strength to requiring the ability to manipulate factory machinery, and what adults did was separate from children. This prompted the social need to limit the size of the family during the early years of the 20th century. The modern image of the family consisting of mother at home, a father at work, and children playing at home was born during the Industrial Revolution. Some scholars see the current crisis in family life as a long-term effect of the Industrial Revolution, one that poses a serious challenge for the 21st century.

In the United States as elsewhere, the Industrial Revolution greatly enhanced the economic fortunes of the middle classes and brought economic and social improvement for many people owing to the increase in earned wages. The lower classes, however, gained far less economically and socially. As the nation advanced, it failed to build adequate support systems for families in which both parents were employed. Indeed, the United States has not put national policies in place to provide for children's needs, as many European countries have done. Much of the energy behind popular demands for political change arises from the perception that the socioeconomic system that resulted from the Industrial Revolution and its aftermath has expanded social inequalities. As some economists and sociologists have pointed out, economic power in the 21st century has remained concentrated in the hands of those who own and control the means of production.

Marianne Partee

See also Economics; Evolution, Cultural; Fossil Fuels; Global Warming; Marx, Karl; Technology Assessment; Timetables; White, Leslie A.

Further Readings

Adam, L. (1965). *Agricultural depression and farm relief in England 1813–1852.* New York: A. M. Kelly.

Buchholz, T. G. (1989). *New ideas from dead economists.* New York: Plume Books.

Malthus, T. (1821). *Principles of political economy.* Boston: Wells and Lilly.

Marsh, R., & Tucker, M. (1992). *Thinking for a living.* New York: Basic Books.

Marx, K., & Engels, F. (1982). *Collected works.* New York: International.

Pfeffer, R. (1979). *Working for capitalism.* New York: Columbia University Press.

Reich, R. (1992). *The work of nations.* New York: Vintage Books.

Smith, A. (1937). *The wealth of nations.* New York: Random House. (Original work published 1776)

Wirth, A. G. (1992). *Education and work for the year 2000: Choices we face.* San Francisco: Jossey-Bass.

Infinity

Infinity refers to that which has no end. Inherently filled with paradoxes and contradictions, it is a concept found in math, science, and philosophy, and it can refer to time, space, and numbers.

Mathematical Infinity

Infinite Sets

In mathematics, infinity is not a number itself but a construct to refer to a sequence of numbers with no ending. The common symbol for infinity, ∞, was introduced into mathematical literature by the English mathematician John Wallis in the 17th century. Positive integers are an example of a set of infinite numbers, because there is no last number. For any number that one can consider, there is always a higher one.

Nineteenth century mathematician Georg Cantor stated that a collection is infinite if some of the parts are as big as the whole. This can seem to create paradoxes. For example, if one has an infinite number of objects, he or she can add or remove objects from the group and still have the same quantity. In the above example, positive integers make up an infinite series, but so do a set of just positive *even* integers. The second set comprises only a part of the first set, which would appear to make it only half as large. But in both cases, a larger number always follows, so they are both infinite.

Aristotle described two ways of looking at an infinite series. In actual infinity, one conceives of the series as completed. In potential infinity the series is never completed, but it is considered infinite because a next item in the series is always possible.

Other Uses of Infinity in Mathematics

The concept of infinity was introduced into geometry in the 17th century by Gérard Desargues. He developed projective geometry, in which "infinity" is the point where two parallel lines meet, a concept that was already being used in art.

In the algebraic function $y = 1/x$, y approaches infinity as x approaches zero. The expression y could never actually be infinity, since x could never be zero, because an expression of division by zero has no meaning in algebra. However, the smaller that x gets, the more times it could be divided into 1.

Paradoxes of Infinity

The Greek philosopher Zeno of Elea wrote of the dichotomy paradox. In order to travel a certain distance, we would first need to travel half of the total distance. In turn, before we reach that point, we must first have gotten halfway there (1/4 of the total distance), and so on. The distance we would need to travel first becomes infinitely smaller, so that it is impossible even to get started—for every distance to travel, there is always a smaller distance to travel first. These circumstances obviously would not have the same result in a real-life occurrence. However, the paradox demonstrates the idea of a distance being infinitely divisible. In other words, there are an infinite number of fractions between zero and 1 (or any two numbers).

The same idea is demonstrated in Zeno's paradox of Achilles and the tortoise. In the story, Achilles, a swift runner, races the slow tortoise but allows him a head start of 100 feet. If we imagine that each racer is going at a constant speed (one fast, one slow), then after some period of time, Achilles would have reached 100 feet—the tortoise's starting point. But by that time, the tortoise would have advanced a further distance. By the time Achilles catches up to the new point, the tortoise would have gone still farther. Zeno states the paradox: Achilles would never catch up to the tortoise, because the more distance he travels, the further ahead the tortoise is. To catch up to the tortoise in the story, Achilles would need to complete an infinite number of actions. Aristotle responded to this paradox by using the ideas of actual and potential infinity. Like the dichotomy paradox, this paradox assumes an actual infinity of points between Achilles and the tortoise.

Neither of these paradoxes would happen in a real-life occurrence, because a person can travel a given distance without having to take account of each point between the start and finish. Therefore, the traveler would be able to reach the destination, and Achilles would catch up to (and surpass) the tortoise in a finite time.

Bertrand Russell described the Tristram Shandy paradox, which is based on the title character of the novel by Laurence Sterne. In the novel, Shandy attempts to write his autobiography but finds that it takes him 2 years to write about the first 2 days of his life. Shandy complained that he would never be able to complete the writing, because the more he wrote, the more material there would be to write about. Russell suggested that if Shandy lived for an infinite number of years, then every day of his life would eventually be written about.

The paradox lies in the fact that there would never come a day when Shandy could finish the book, because with each day of writing, he became a year farther away from his goal.

Infinity of Time

Time and the Universe

In some schools of thought, time is inextricably linked to the universe itself. Thus, many theories dealing with the infinity of time are actually referring to the infinity of the universe. Saint Augustine wrote that time exists only within the created universe, with God existing outside of time in the "eternal present." While science theorizes that the universe began with the big bang, we cannot know if time began at this point as well or if there was time before there was a universe. According to some theories, the universe will end with a big crunch, but again, it is unknown if time would end at that point as well. Richard Tolman, in his oscillatory universe theory, hypothesized that the universe is in an infinite cycle of big bangs followed by big crunches.

An Infinite Past

The possibilities of an infinite past or infinite future have been discussed by philosophers for millennia. In 1692, English theologian and scholar Richard Bentley rejected the idea of an infinite past while accepting the idea of an infinite future. He wrote that the revolution of the earth, occurring in the present, could continue into infinity, because the future was inexhaustible. However, an infinite number of revolutions in the past was not possible, because each revolution would have once been part of the present and therefore finite. Immanuel Kant also rejected an infinite past, saying that an infinity cannot be completed, and if the past were infinite, we would never have arrived at the present moment.

Modern Perspectives

Debate about various aspects of infinity has continued into the 20th and 21st centuries. Albert Einstein wrote that our universe was finite but had no boundaries. Physicist Stephen Hawking built upon this idea, proposing that time and space together were finite but boundless (similar to the surface of the earth) and therefore had no beginning.

Galileo stated that infinity, by its very nature, was incomprehensible to human minds. Nevertheless, it is likely that infinity, with its possibilities and paradoxes, will continue to be a source of theory and discussion.

Jaclyn McKewan

See also Aquinas, Saint Thomas; Augustine of Hippo, Saint; Bruno, Giordano; Eternity; Gödel, Kurt; Kant, Immanuel; Russell, Bertrand; Zeno of Elea

Further Readings

Clegg, B. (2003). *A brief history of infinity.* London: Robinson.

Craig, W. L. (1978). Whitrow and Popper on the impossibility of an infinite past. *The British Journal for the Philosophy of Science, 30,* 165–170.

Lavine, S. (1998). *Understanding the infinite.* Cambridge, MA: Harvard University Press.

Whitrow, G. J. (1980). *The natural philosophy of time.* New York: Oxford University Press.

Information

The theory of information is fundamental to a rational understanding of the temporal fabric of our world. The principal reason for this is that information and time cannot be separated reasonably—a fact that will become evident from a short consideration of how we know about time and information. Only if information produces effects on objects whose changes in time are measurable physically is there a chance to test hypotheses about information objectively. Time, again, is measurable by a physical system only on condition that this system has information about its internal changes. To measure time, information about change is necessary, and to measure information, change in time is necessary.

Motivated by concrete problems of empirical research and engineering, the theory of information is steadily developing into a coherent system of mathematical models describing the complex abstract structure of information. On the one hand, information is an entity difficult to grasp, because the interactions between its syntactic, semantic, and pragmatic components constitute a complex structure. On the other hand, information is something supposed to exist almost everywhere: Its abstract features are claimed to be discernible in the most different kinds of systems such as quantum entanglements, cells, humans, computers, and societies.

The need for a unified theory of information is, thus, felt at nearly all frontiers of science. Quantum physicists are discussing whether an interpretation of their experimental data in terms of information could resolve some of the paradoxes that haunt their understanding of the subatomic world. Cosmologists are calculating the information content of black holes. Geneticists are describing the hereditary substance as containing information that is decoded in cells by means of the genetic code. Evolutionary biologists are assuming that the most important steps in the history of life on earth consisted in establishing increasingly efficient ways of information processing. Neurophysiologists are talking about the brain as the most complex information processor known to us. Computer scientists are constructing and programming machines that process information more and more intelligently without being continuously assisted by humans. Communication engineers are building information networks that connect human brains to computers in a new kind of symbiosis. Economists are proposing mathematical theories of economic behavior based on the distribution of information among people who buy and sell goods in a market. Sociologists are characterizing developed countries as information societies in a globalized world.

If we do not want to get lost in the jungle of information concepts used in different sciences, and if we want to make the relation between time and information clear, we are well advised to orient ourselves with the help of a rough classification of the manifold aspects of information and to distinguish its syntactic, semantic, and pragmatic components. The scientific disciplines of syntax, semantics, and pragmatics are known to anyone who studies language or other sign systems. In short, *syntax* is the study of signs in their relation to other signs; *semantics* is the study of signs in relation to their conceptual and referential meaning; *pragmatics* is the study of signs in relation to the agents using them. That all three disciplines are also of utmost importance for an information theorist should not come as a surprise, because sign systems basically are means of transmitting information. Each sign is, as it were, a package of information: a syntactic unit that transports a meaning from a sender to a receiver.

This entry presents some fundamental characteristics of the syntactic components of information and reflects on the relation between syntactic and semantic features of information. The reason for restricting ourselves to these topics is that the general semantics and pragmatics of information still constitute a mostly uncharted continent. To explore it further, not only sophisticated mathematical models but also new concepts for analyzing the close relation between time and information will have to be developed.

Syntactic Features of Information in Shannon's Communication Theory

Syntactic features of information are described by a variety of mathematical models. The most important one resulted from Claude E. Shannon's understanding of communication as transmission of information. Shannon (1916–2001), researching on communication systems first as an engineer at the Bell Laboratories and then as a professor at the Massachusetts Institute of Technology, has rightly been called "the father of information theory." The scheme of a general communication system he introduced in his classic paper, *A Mathematical Theory of Communication* (1948), still is the basis for most research in information theory.

According to Shannon, a general communication system consists of five components: an information source, a transmitter, a channel, a receiver, and a destination. The information source generates a message that is to be transmitted over the channel to the destination. Then the transmitter encodes the message in a signal that is suited for being transmitted via the channel. In the channel, there normally exists a certain probability that noise distorts the signal. The receiver decodes the transmitted and possibly distorted signal. Finally, the message is delivered to the destination. This general communication system can easily be exemplified by telephony. A person (the information source) speaks into a telephone (the transmitter) that encodes sound waves in a sequence of analog or digital signals. These signals are transmitted via fiberglass cables, air, satellites, or other channels. The physical structure of the medium of transmission, atmospherics, defective electronic devices, jamming stations, and other noise sources might distort the signal. A telephone at the other end of the channel (the receiver) decodes the transmitted signals in sound waves that some person (the destination) can hear.

Shannon introduced the general communication system in order to solve two main problems of information transmission. First, how many signals do we minimally need on average to encode a message of given length generated by an information source? Second, how fast can we reliably transmit an encoded message over a noisy channel? Both problems ask for principal spatial and temporal limits of communication, or in other words, for minimum code lengths and maximum transmission rates. To answer these questions, Shannon defined an information-theoretical analogue to entropy, the statistical measure of disorder in a thermodynamic system.

Omitting formal technicalities, Shannon's crucial idea goes as follows. For any message that is generated by an information source, the information content of the message is equal to the amount of uncertainty that the destination of the message loses on its receipt. The less probable the receipt of a message is, the more information it carries to the destination. Shannon's measure of the entropy of an information source, in short: Shannon entropy quantifies the average information content of a message generated by an information source.

Shannon's noiseless, or source, coding theorem shows that the entropy of an information source provides us with a lower boundary on the average length of signals that encode messages of the information source and are transmitted over a noiseless channel. If the length of these messages goes to infinity, the minimum expected signal length per message symbol goes to the entropy of the information source. Shannon entropy defines, thus, in terms of signal length, what a sender can optimally achieve in encoding messages.

In his noisy, or channel, coding theorem, Shannon proves the counterintuitive result that messages can always be sent with arbitrarily low, and even zero, error probability over a noisy channel—on condition that the rate (measured in information units per channel use) at which the message is transmitted does not exceed an upper limit specific to the particular channel. This upper limit is called *channel capacity* and can be quantified by an ingenious use of Shannon entropy. If we subtract from the entropy of the information source the conditional entropy of the information source given the messages that are received by the destination, we get the mutual information of the information source and the destination. *Mutual information* measures how much the uncertainty about which message has been generated by the information source is reduced when we know the message the destination has received. If the channel is noiseless, its capacity is equal to the Shannon entropy of the information source. The noisier the channel is, the more signals we must transmit additionally in order to correct the transmission errors. The maximum mutual information of an information source and a destination equals the capacity of the channel that connects both. That a sender who wants to transmit a message reliably tries to achieve channel capacity, regardless of how noisy the channel is, seems to be a vain endeavor, because any correction signal is subjected to distortion, too. Yet Shannon could show that for any noisy channel, there do exist codes by means of which a sender can transmit messages with arbitrarily small error at rates not above channel capacity—alas, he did not find a general procedure by which we could construct such codes, and up to now no information theorist has been able to perform this feat.

Shannon's coding theorems prove, with mathematical exactness, principal physical limits of information transmission. His channel coding theorem shows that if we want to reliably transmit a message over a noisy channel—and any realistic channel is noisy—we must respect the channel capacity as an upper limit on the transmission rate of our message. If we want to be sure that another person receives our message in its original form, we must take the properties of the medium of transmission into account and make the encoding of the message as redundant as necessary. To make an encoding redundant means to make it longer than required by the noiseless coding theorem. It means that we need more time to transmit a message over a noisy channel than over a noiseless one. Shannon's information theory implies, thus, an economics of information transmission: Given the goal of reliable information transmission and knowing the noise in a channel, we must respect a spatial lower limit on the length of encodings and a temporal upper limit on their transmission rate.

Shannon entropy measures only a syntactic property of information, more precisely: a mathematical property of statistical distributions of messages. Its definition does not explicitly involve semantic or pragmatic aspects of information. Whether a transmitted message is completely nonsensical or very meaningful for its destination, Shannon entropy takes into account just the probability that a message is generated by an information source. Since Shannon published his mathematical theory of communication, further statistical measures of syntactic aspects of information have been defined. For example, the theory of *identification entropy,* developed by the German mathematicians Rudolf Ahlswede and Gunter Dueck at the end of the 1980s, refers to Shannon's general communication system yet introduces a decisive pragmatic difference as regards the purpose of communication. In Ahlswede and Dueck's scenario, the information source and the destination are not interested in the reliable transmission of all messages that the information source can generate. The destination just wants to be sure as fast as possible that one particular message has been sent, which might have been encoded in different signals by the sender. It is the situation of someone who has bet money on a horse and only wants to know exactly whether this horse has won the race. Such a relaxation in the goal of communication allows an enormous increase in the speed of information transmission.

Semantic Features of Information in Shannon's Communication Theory

The semantic and pragmatic features of information are much more difficult to formalize than its syntactic features. Some approaches to semantic aspects of information try, therefore, first to identify syntactic properties of signals that may be correlated to the fact that these signals have a meaning for both the information source and the destination. When we speak about meaning, sense, reference, and other semantic concepts in an information-theoretical context, we do not suppose that information sources and destinations have complex psychological qualities like those of human beings. Access to semantic aspects of information is, thus, not restricted to self-reflective agents who associate, with signs, mental representations as designations and who refer consciously to objects in the real world as denotations. In this sense, "the semantic component of information" just means that at least a set of messages and a set of signals are interrelated by means of a convention.

A code, as a system of conventional rules that allow encoding and decoding, is the minimum semantic structure *par excellence.* It is normally not possible to infer which message is related to which signal, and vice versa, if we know only the elements of both sets (i.e., the messages and the signals), and the natural laws that constrain the encoding of messages in signals and the decoding of signals in messages. Thus, the most characteristic feature of the semantics of information is the conventional nature, or contingency, of the relation between messages and signals.

From this perspective, Shannon's theory of communication as information transmission does say a lot about semantics implicitly, because it is also a theory of the encoding of messages in signals and the decoding of signals in messages. Shannon's coding theorems express information-theoretical limits on the syntax of signals if the latter semantically represent messages under pragmatic constraints on the compressibility of encodings and on the reliability of transmissions.

Let us now focus our discussion on the channel coding theorem and the measure of mutual information. The higher the channel capacity—that is, the higher the maximum mutual information of an information source and a destination—the more is known about the statistical properties of the information source given the destination, and vice versa. We can express, for each channel, the information transmission distance between a given information source and a given destination in terms of time minimally needed by the fastest receiver for interpreting transmitted signals correctly as syntactic units that represent other syntactic units, namely messages. The noisier the channel between sender and receiver is, the less certain the semantic relation between a received signal and a transmitted message is for the receiver. Because the most general pragmatic function of communication is, for Shannon, the loss of uncertainty, the gain of uncertainty due to noisy channels must be counteracted by the use of longer signals. Then the actual rate of information transmission over the channel decreases and the transmission time increases. The more effort has to go into making a signal a reliable representation of a message, the longer the receiver needs to infer the transmitted message from a received signal.

Conclusion

We started our investigation into the relation of time and information by observing two very general facts: To measure time, information about change is necessary; and to measure information, change in time is necessary. We ended up describing an important example of the latter fact in semantics: The less certain the semantic content of a signal is, the more time is required to receive further signals needed for getting to know the message. Shannon's theory of communication contains, thus, a quantitative insight into the context dependence of information: Interpreting signals is a process that must obey temporal constraints depending on the media used for information transmission. In-depth analysis of the semantic, and also the pragmatic, features of information will arguably need more insight into the interdependence of time and information.

Stefan Artmann

See also DNA; Entropy; Logical Depth; Maxwell's Demon; Quantum Mechanics

Further Readings

Arndt, C. (2001). *Information measures: Information and its description in science and engineering.* New York: Springer.

Cover, T. M., & Thomas, J. A. (1991). *Elements of information theory.* New York: Wiley.

Pierce, J. R. (1980). *An introduction to information theory: Symbols, signals, and noise* (2nd ed., rev.). New York: Dover.

Shannon, C. E., & Weaver, W. (1998). *The mathematical theory of communication.* Urbana: University of Illinois Press. (Original work published 1949)

Von Baeyer, H. C. (2003). *Information: The new language of science.* London: Weidenfeld & Nicolson.

Intuition

Intuition is a concept with a number of meanings. It derives from the Latin *in-tueri:* knowing from within, that is, by contemplation. Intuition is a mode of perceiving objects, concepts, and ideas through direct apperception, as when people refer to having had an insight or illumination. In modern psychological approaches to various processes of judgment, intuition, in contrast with analytical thought, is described as a fast and instant thought process that does not demand mental effort, is not necessarily conscious, and allows neither description nor explanation. One illustration is constituted by heuristic processes, which are a type of unexplained rules of thumb that allow us to make various judgments, including perceptual judgments, rapidly. Another common description of intuition is "just having a hunch."

Intuition and time are related in both directions: On one hand, we can examine the role of intuition in the processes that lead to time perception and perception of duration, while on the other, we can observe the role of time in intuitive processes themselves.

Time is a key dimension to which every living creature must relate in order to adapt to its environment. Nevertheless, in the absence of any specifically defined perceptual apparatus for duration perception, on one hand, and, on the other, of any specific stimulus that represents temporal duration, the question arises of how time apperception occurs. Though this question is relevant in relation to any living creature, it is especially so to human beings due to their awareness of time. This is why philosophers have always wondered about the nature of time and about how the sense and consciousness of time and duration emerge.

An early example of this can be found in Saint Augustine of Hippo (354–430), who deals with the question of time in the sixth book of his *Confessions*. He argues that, when not asked about the nature of time, he knew the nature of time; however, when asked to explain, he was unable to explain. His text suggests that time is a type of primary experience that we cannot explain. That is to say, time is not experienced as the product of higher-order cognitive activity. Indeed, some major philosophers share a notion of time as a primary intuitive concept.

Immanuel Kant (1724–1804) held that time and space are two major intuitions of the human mind. He rejected doctrines like Gottfried Leibniz's, according to which experience is characterized by an inherent rationality. Kant argued that time and space are a priori categories necessary for human experience to occur. As such, he thought time and space to be enabling conditions of the human mode of experience. Time is not a real feature of things-in-themselves but rather a structure of the knowing mind.

Henri Bergson (1859–1941) rejected Kantian idealism but still associated time with intuition. He distinguished between an intuitive and an analytical mode of thinking. Intuition, for Bergson, yields metaphysical knowledge of reality as time, change, and creative evolution, which is certain knowledge. Reason, on the other hand, does not render absolute knowledge about reality but only relative knowledge about the material objects of science and experience. If reality is in flux—that is, not static—then for Bergson it is intuition that gives us this awareness of time and change as creative evolution.

Modern psychological theories have been dealing with the question of whether intuition forms the substrate of perception on the whole and of time perception in particular. But while most of them consider sensory input from the external environment a key component in a person's image of the world, some acknowledge that this sensory component is not sufficient. One example is the *constructive perception* approach (e.g., that of Jerome Bruner). *Gestalt psychology* (J. P. Kotter, Kurt Koffka, Max Wertheimer) holds that perception does not consist of a direct reflection of physical features of external reality. The perceptual system imposes organizing principles (*gestalt rules*) on the incoming stimuli, and these eventually determine the resulting image in the human brain. These organizing principles could be considered a priori, intuitive rules.

Developmental cognitive research, to which Jean Piaget (1896—1980) was a crucial contributor, has dedicated much attention to the development of the ability to grasp time in its various respects, e.g., the ability to understand the sequential nature of the time in which external phenomena occur. According to Piaget's findings, the ability to grasp time evolves in stages and gradually. A case in point is the development of the ability to integrate information according to the sequence and order in time of phenomena or actions. Children below age 12, it was found, are affected by intuitive thinking when making judgments about time, and this causes misperceptions. Abstract thought and logical reasoning evolve only in the formal operations stage, between ages 12 and 16. The ability to fully grasp time concepts matures only at a relatively late stage, and this testifies to the complexity of time perception. On the basis of this research, Piaget concluded that human understanding of time is not intuitive and depends on the acquisition of complex mental abilities.

Contemporary models of psychological time, too, consider the experience of time as the product of a cognitive process based on elaboration and integration of various types of information. This, it should be noted, does not necessarily clash with the Kantian approach: It could be that the concept of time as such—rather than the experience of duration—is intuitive and a priori.

Modern psychological approaches to cognitive processes and judgment consider intuition as a mode of thinking with unique features, which is unlike analytical thinking. This distinction refers to time as one of its parameters. First, intuitive thinking is very rapid, in contrast to analytical thinking. Second, intuitive thinking relies on past experience and on tacit knowledge (H. A. Simon), that is, on accumulated information that has been encoded in the memory over time.

Daniel Kahneman and Shane Frederick (2002) suggested that judgment can be achieved in two manners. The first is by means of a rapid intuitive, associative, and automatic process that demands no mental effort—this is also known as System 1. Alternatively it can result from a slower process that requires mental effort and that is controlled by rules and laws: System 2. Intuitive errors, accordingly, occur under two conditions: System 1 errs (usually due to applying past experience that is not relevant to the judgment in question) while System 2 fails to get activated in order to correct the error. Intuitive thinking, it must be noted, can produce effective and adaptive judgments if it is based on relevant experience, as happens in the case of expertise in the field of judgment. It is not easy to remove bias in the case of intuitive errors. Many perceptual illusions are the result of the activation of intuitive heuristics: Mere awareness of this does not suffice to avoid the perceptual illusion. Time illusions, too, which are expressed in erroneous experience of the clock duration of various events, are the result of heuristic intuitive thinking. Thus, for instance, in the case of the “filled time illusion,” a time interval “filled” with stimuli and events is perceived as longer than a time interval identical in duration but “empty” in terms of stimuli and events (see also Time, Illusion of).

In part, time affects heuristic thinking as it does due to organizational processes in the memory that occur involuntarily in the course of time. As a result, a person is not always aware of the correct order of events in objective time, so that it may occur that later information may be perceived as—or combined with—earlier information. This may be reflected in intuitive biases like false memories or hindsight bias.

Often errors in eyewitness evidence are actually in part the result of such processes. And so we observe that the very dependency of intuition on the accumulation over time of information in the memory may cause intuitive bias regarding the dimension of time itself.

Dan Zakay

See also Augustine of Hippo, Saint; Bergson, Henri; Consciousness; Kant, Immanuel; Memory

Further Readings

Al-Azm, S. J. (1967). *Kant's theory of time.* New York: Philosophical Library.

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin., & D. Kahneman (Eds.), *Heuristics and biases* (pp. 49–81). New York: Cambridge University Press.

Lacey, A. R. (1989). *Bergson.* London: Routledge.

Islam

The religion of Islam originated in 622 CE, inspired and guided by the teachings of Muhammad ibn Abdullah, who lived in Mecca, Arabia, and who (in the Islamic belief tradition) received revealed truths directly from God and recorded them in the holy text called the Qur’an. As a religion, Islam has its roots in the same Middle Eastern monotheistic faith as Judaism and Christianity, and they share many of the same beliefs, practices, and sacred texts. Followers of all of these Abrahamic religions believe themselves to be descended down through time from the first man (Adam) and to have been chosen as God’s special people through a covenant made between God and the Hebrew patriarch Abraham in about 1800 BCE. However, while Judaism teaches that the Messiah has not yet been born, and Christians believe that Jesus Christ was the divine Messiah, followers of Islam believe that Christ and Muhammad were both prophets of God in the tradition of Abraham, Moses, Samuel, and others but were not themselves divine.

Muslims believe that Muhammad was the last messenger or prophet sent by God to restore his people to the original, uncorrupted version of the Abrahamic faith. Muslims (“those who submit to God”) therefore seek to return to the earliest and purest forms of worshipping God through the constant practice of the five pillars of Islam: professing faith, fasting, prayer, alms giving, and making the *hajj* pilgrimage to Mecca. The word *Islam* means “submission,” and Muslims seek to demonstrate their obedience to God’s will in all aspects of daily living, holding the teachings of the Qur’an to be a literal and uncorrupted version of God’s laws, in contrast to the practices and texts of Judaism and Christianity, which have been distorted and corrupted by the long passage of time since the covenant was made between Abraham and God. In contrast to what they believe about the Qur'an, Muslims consider all earlier holy texts of the Abrahamic tradition (the Old and New Testaments) to be only partially "revealed" versions of God's will, because they were not recorded directly by the Hebrew and Christian prophets themselves but were embellished and altered by the followers and descendants of those prophets.

Time is also an important criterion in determining the *Sunni* (the "trodden path") practices that Muslims use to regulate religious practice and beliefs: *Sunnah* are defined as those religious actions and practices that Muhammad introduced during the 23 years of his ministry and that were subsequently passed down as tradition to subsequent generations by his closest companions. Adhering to tradition, by ensuring that religious holy days are observed at the correct times and for the correct durations of time, is therefore an extremely important aspect of Islamic culture. And, the Islamic world has evolved intricate and highly formalized ways of marking the passage of time and the timing of religious observances and holy days or months through use of a lunisolar calendar.

Origins of Life

The Islamic version of the origins of life and humanity has many parallels with Judaic and Christian beliefs. For Muslims, the creation of the universe is proof of the all-encompassing and absolute power of Allah (God). Allah is the beginning and end of all things, and the universe itself is an expression of his will, subject to his laws. For Muslims, the creation story derives from the Qur'an, which describes the division of the heavens and earth by Allah (God) from one solid mass into their present states over six long stages of time (not literal days as in the Judaic or Christian versions of the creation myth). Allah next created all of the living creatures and vegetation that inhabit the earth and sky, as well as the angels and heavenly bodies. Last, Allah used clay, earth, sand, and water to make and breathe life into the first man (Adam).

By breathing his own spirit into Adam, God distinguished him from the animals and endowed him with the ability to think and freely choose to submit to Allah or not, as well as to use his intelligence to seek to understand the workings of God in the rest of Creation. After Allah took Adam to live with him in paradise, Allah also created the first woman (Eve, or Haw) from Adam's side, and placed the two humans in a beautiful garden in paradise, forbidding them to eat the fruit of a certain tree. Ibis, an evil jinn (a disobedient angel, or Satan), tempted Adam and Eve to disobey God and eat the fruit of that tree. When they did, God cast them out of paradise and sent them to live on earth. In Islamic belief, all human beings are descended from Adam and Eve.

End of Time

As with the other Abrahamic religions, Islam depicts the end of time as a period of great disruption and trouble. This period will directly precede the Second Coming of the Messiah, who will bring an end to evil and suffering and will establish a new era of the kingdom of God. The Qur'an does not provide specific details about the end of time (Allah will not reveal these until that time arrives), but it does describe many signs that will signal its imminent arrival. The signs associated with the end of time will include such dramatic environmental events as drought, flood, the falling of the stars, and the cleaving of the heavens. As well, the earth will be purified of nonbelievers, either through mass conversion or by death. Most of humanity will have begun to worship the *Dajjal* or Antichrist, who opposes God's law and is aided by two leaders (Gog and Magog) who head nations opposed to God. The Dajjal will be ultimately defeated by the *Mahdi* ("the guided one"), a great leader descended from Muhammad who will become the final Muslim caliph. He will unify all of the various sects within Islam and will lead Muslims to a period of great prosperity and equality.

The prophet Jesus Christ will return to earth to aid the Mahdi in establishing Islam as the one true religion and to help defeat all of the unbelievers. He will then live on for 44 years until he dies and is buried next to the prophet Muhammad. Christ's death and burial will be followed by the resurrection of all humankind in preparation for the final judgment day. The sequence of events leading up to the judgment day will include a first trumpet blast, which will crush the mountains and kill all living creatures on earth (including the angels); a second trumpet blast, which will mark the resurrection of all humans; the descent of Allah to earth in order to pass judgment on all humans; the passing of thousands of years while humanity awaits judgment; and the final judgment or division by Allah of humankind according to whether or not their good deeds have outweighed their bad deeds during their lifetimes. Those who have submitted to Allah's will and followed his commands will enter paradise and then be placed to the right of his throne; those who rebelled against Allah by practicing evil ways will be placed to the left of his throne and condemned to live in hell for all time.

Helen Theresa Salmon

See also Adam, Creation of; Calendar, Islamic; Qur'an; Time, End of

Further Readings

Aslan, R. (2006). *No God but God: The origins, evolution, and future of Islam.* New York: Random House.

Denny, F. M. (2006). *An introduction to Islam.* Upper Saddle River, NJ: Pearson Prentice Hall.

Grieve, P. (2006). *A brief guide to Islam: History, faith and politics.* New York: Carroll and Graf.

Neusner, J. (Ed.). (2006). *Religious foundations of western civilization: Judaism, Christianity, and Islam.* Nashville, TN: Abingdon Press.

Riddell, P. G., & Cotterell, P. (2003). *Islam in context: Past, present, and future.* Grand Rapids, MI: Baker Academic.

J

Jainism

Jainism is a non-Brahmanical philosophical tradition of India. Enriched by the deep insights of 24 spiritual gurus or *tirthankaras,* from Risabha (the first) to Mahavira (the last), Jainism has its own distinctive flavor that distinguishes this philosophy from others. To understand the concept of time in Jainism, it is necessary to have an overall idea of the metaphysical system of the Jainas. Jainas believe in a many-sided view of reality, known as *anekantavada,* or the theory of pluralism. This concept of reality can accommodate identity and difference, permanence and change. There are two main important terms in Jaina philosophy, *dravya* and *astikaya,* which pervade Jaina writings. The concept of *kala* (time) is to be understood in terms of these two concepts.

Umasvati, a famous Jaina philosopher, defines *dravya* or substance as that which possesses qualities and modes. Substance is always characterized by qualities and modes. Jainism offers six substances as ultimately real, and time is one among them. They are *jiva* (the soul), *pudgala* (the matter), *dharma* (the principle of motion), *adharma* (the principal of rest), *akasa* (space) and *kala* (time).

Amongst the six substances, five are known as *astikaya,* a term which, negatively speaking, helps to understand the concept of time. In the *Dravya-Samgraha,* a famous book of the Jainas written by Nemichandra, the term *astikaya* is explained in the following way: This term consists of two parts, *asti,* meaning "to exist" and *kaya,* meaning "body." Therefore this term refers to those five substances that exist and occupy space. The term *kaya* also technically is to be understood as consisting of many indivisible particles (*pradesa*). So, five out of the six substances apart from time can be characterized as astikayas. This notion of indivisible particles points to the fact that the Jainas believe in the general atomic conception of the universe. The five substances are called astikaya (extended) because the particles of which they are made are not separate. This is also the reason why time is not classified as an extended substance, even though it has existence.

According to Jaina philosophy, time is real, as it possesses origination, decay, and permanence, the characteristics of all real things. Time is as real as the five others, as it is the accompanying cause or condition of the modification of substances. This reality of things is explained by the Jaina philosophers by recognizing the two aspects of things, *parjaya* (the mode) and *dravya* (the substance). The former is the series of temporary modes with coming and going, and the latter is the core thing that remains constant. Time as a real substance possesses all these states. The above can be explained by taking an example from our everyday life. When a man clenches his fingers into a fist, then this phenomenon—clenching of the fingers—occurs (origination), and the previous state of the fingers necessarily is at end (decay), yet so far as the fingers are concerned, they continue to be substantially the same (permanence).

In the famous Jaina text entitled *Pancastikayasara,* the atomic conception of time is discussed. The

This 15th-century Jain temple at Ranakpur represents a culmination of Jaina temple building in western India.
Source: Tonis Valing/iStockphoto.

characteristics of time atoms are such that each atom is distinct and can never be mixed with other time atoms. This is the reason for advocating the theory that time has one *pradesa* only, or in other words, the time atoms can never be combined. And this also leads to the point that the time atoms can only constitute a unidimensional series that is unilateral. In Jaina terminology, this is known as *urdha-pracaya* (unilateral) as opposed to the *tiryak-pracaya*—a multidimensional series or horizontal extension. All other substances except time possess extensions in both these dimensions. As kala (time) consists of infinite *samaya* (instants), it possesses only unilateral extension. This unilateral extension of kala points to the fact that the world is constantly progressing with the help of time.

The Jainas held that there are two kinds of kala, *vyavahara kala* (conventional time) and *niscayakala* (transcendental time). Vyavahara kala is also known as samaya in Jaina philosophy. In our daily life we use the concepts of moments, hours, and days to indicate the beginning and end of a particular event. This conventional or practical time is indicated by modification, activity, distance, and proximity. The Jainas describe modification as the self-variation in a thing without a change in its substance. Activity is caused by the movement of a body. Distance and proximity are to be understood here in relation to time. In our everyday life we label a thing as new or old by observing its state of modification. On watching the sunrise in the east, we say we have the daybreak, and so we gather the ideas of midday, evening, and night by observing the movements of the heavenly bodies. A thing under actual observation is said to be proximate in time, otherwise it is distant in time. In this way, the external objects indicate and refer to the conventional or empirical time denoted by moments, hours, and days, as we call them.

In the Jaina literature, *pancatikaya-sara,* the conventional or empirical time periods, are discussed elaborately. The minutest unit of kala is *samaya.* This unit is defined as a period of time taken by an *anu* (atom) in traversing to its consecutive anu. *Vyavahara kala,* or conventional time, consists of infinite samaya. The time undertaken by an adult person in inhaling and exhaling is termed a *prana.* Seven pranas make one *stoka.* Seven stokas compose one *lava.* Thirty-eight and one-half lavas form one *nali.* Then comes *muhurta,* which is equal to two nalis. Thirty muhurtas form one *divaratra* (day and night). Fifteen divaratras form one *paksa.* One month comprises two paksas. Two months equal a *ritu* (season). Three ritus make one *ayana.* A year is formed by two ayanas. These divisions and subdivisions of time are linked to the different units of measurement pertaining to *vyavahara-kala* or conventional time.

The above divisions are dependent on some external factors, such as the motions of the heavenly bodies. But in addition to the motions of the heavenly bodies, vyavahara kala or conventional time is dependent on niscayakala, or transcendental time, for the determination of its measure. This niscayakala is variously designated as *paramarthkala* or *dravyakala. Vartana,* or continuance, is the main characteristic of niscayakala. Brahmadeva, a commentator on Jainism, holds that vartana is the accompanying cause of the modifications of things, like the stone beneath a potter's wheel or like fire in the matter of studying in winter. This vartana is the characteristic of real time. The stone underneath the potter's wheel does not directly impart motion to the wheel, but still the stone is indispensable in the matter of the movement of the wheel. Similarly, fire is not directly responsible for one's study, but study is impossible in winter without fire for heat and light. The case of time is comparable.

Therefore the changes that can be observed in things point to something more than those changes and the changing things. Every change is accompanied by a definite point of time, called samaya, or conventional time, while the continuing reality underlying this conventional time is the dravyakala, or transcendental time. The transcendental time is conceived as having both a beginning and an end. This point brings an important feature of the Jaina understanding of time. The samaya, or instants arranged unilaterally, are conceived of as permanent—beginningless and endless. This is indicative of the fact that the transcendental time can never be made an object of sense perception. But one can arrive at knowledge by inference. Another characteristic is that time is *amurta* or formless; in this respect it is similar to the concept of soul. Time or kala is described as *niskriya,* or devoid of activity, and it is different from soul, which is *sakriya* or active.

The Jaina conception of transcendental time is to be contrasted to the idea of time as appearance. In fact the concept of time plays a very important role in the pluralistic metaphysics of the Jaina system. Nothing can be conceived in this universe without time.

Jainism with its realistic viewpoint of thinking accepts the reality of change, which in turn indicates the reality of time. It is not possible to deny the reality of time, as every change involving birth, growth, and decay happens within the framework of time.

Thus time is confined within the limits of *lokakasa,* or the space that is occupied by other substances; the *aloka,* which is beyond this, has not time within it. But as aloka is a substance, it must have modifications also. Now how are these modifications possible in the aloka, signifying void which has no time within it? This point is stated in the following way. Aloka, although it is beyond the loka, is still a part of the akasa, or space. Time being within the akasa, it brings about modifications in any part of it, just as a pleasant object coming in contact with a particular part of a body causes pleasant feeling all over the body, or a potter's stick moves the whole wheel by striking at a particular point of the pot. Innumerable and partless atoms of time fill the lokakasa. In Alokakasa there is absence of matter, and so there is absence of *kalanus,* or instants.

Anu is the smallest part of a substance, and when these anus are combined inseparably, the substance constituted of them is an extended substance. The five substances—jiva, pudgala, akasa, dharma, and adharma, are extended substances, because their smallest constituents are mixed together, and they remain inseparably combined with one another. But the case is different with time. Time has also minute kalanus, or instants, but these anus or ultimate particles are not capable of mixing up with one another. Therefore, these ultimate particles remain always separate. It is for this reason that Jaina thinkers compare time substance with a heap of jewels. The jewels embedded in a garland remain separate; similarly these anus do not form a kaya; that is, they do not aggregate as the other five substances do. In addition, each kalanu occupies only one pradesa , or space point. Therefore, it does not possess an aggregate or volume space point comparable to that portion of space that is obstructed by an anu or atom. These time atoms are imperceptible, formless, and inactive. Thus they have no extension, but they possess existence.

There is again another principle of classification, on the basis of which substances are classified as conscious or unconscious. Following this line, jiva alone is singled out as conscious, and all other substances, including time, are labeled as insentient.

In conclusion, it may be pointed out that the Jainas make change the essential character of all reality, which is intelligible only in terms of time. Jaina thought, with its law of pluralism accompanied by time as a constant variable, stands unique among the philosophical traditions of India.

Debika Saha

See also Christianity; God and Time; Hinduism, Mimamsa-Vedanta; Hinduism, Nyaya-Vaisesika; Hinduism, Samkhya-Yoga

Further Readings

Mandal, K. K. (1968). *A comparative study of the concept of time and space in Indian thought.* Varanasi, India: Chowkhamba Sanskrit Series.

Mukherjee, S. (1944). The Jaina philosophy of non-absolutism. Calcutta: Bharati Jaina Parisad.

Potter, K. H. (Ed.). (1970). *The encyclopedia of Indian philosophies* (Vols. 1–2). Delhi: Motilal Banarsidas.

Rao Venkateswara, R. (2004). *The concept of time in ancient India.* Delhi: Bharatiya Kala Prakashan.

Tatiya, N. M. (1951). *Studies in Jaina philosophy,* Banares, India: Jain Cultural Research Society.

JANUS

In Roman mythology, Janus was the god of doorways and of transitions in time. He was depicted as a double-faced head with the two faces looking in opposite directions. As the god of transitions, Janus was deeply associated with the notion of time.

Janus was one of the most ancient gods worshipped by the Romans. Unlike many other Roman gods, Janus has no Greek counterpart. The Romans invoked Janus at the beginning of each month, as well as at the new year. They prayed to Janus during important events such as birth, marriage, and harvest time. To the Romans, Janus signified transitions such as from primitive society to civilization, childhood to adulthood, and especially from war to peace and vice versa. The Romans built numerous temples in honor of Janus, and the name January for the 1st month of the year is a modern vestige of the deity.

As the god of beginnings, the Romans believed that Janus predated even Jupiter, the primary Roman god. According to tradition, Janus was the first king of Latium. His rule witnessed a golden age in which laws, coinage, and agriculture were introduced. The Romans believed that Janus had protected Rome from the legendary attack by the Sabines. In memory of this protection, the Romans left the gates of Janus's temples open when Rome was at war and closed them during times of peace. In addition to temples, Rome also had many gateways called *jani* (the plural form of *janus*) which often bore the symbol of Janus. The most important janus was the Janus Geminus located in Rome. It had a gateway at each end through which the Roman legions would parade before departing for war. The coins of the Roman Republic also carried the double-faced image of Janus. The Roman Empire later often depicted Janus with four faces looking in opposite directions, known as Janus quadifrons. Two of these faces were often bearded and the others shaven.

Janus was known as the inventor of religion, festivals, temples, and coins. The Romans held him in very high esteem as the custodian of the universe. In this role, he transcended many other gods in importance. Janus was present in all aspects of time: beginnings and endings, sunrise and sunset, the progression of life, and during rites of passage. He was invoked on a wide variety of important occasions in Roman cultural life.

In the Roman religion, Janus was believed to have come from Thessaly in Greece. He was invited to rule Latium with Camese. The two became the parents of the god Tiberinus, who was the Roman river god. The Tiber River in Rome is his namesake. Janus was also the father of Fontus, the Roman god of springs. Worship of the god Janus in effect ceased with the decline of the Roman religion. Janus is often cited in popular culture in connection with personalities or ideas that have two opposing sides.

James P. Bonanno

See also Calendar, Roman; Rome, Ancient

Further Readings

Beard, M., North, J., & Price, S. (1998). *Religions of Rome.* New York: Cambridge University Press.

Dumezil, G. (1966). *Archaic Roman religion.* (P. Krapp, Trans.). Chicago: University of Chicago Press.

Turcan, R. (2001). *The gods of ancient Rome: Religion in everyday life from archaic to imperial times.* New York: Routledge.

JASPERS, KARL (1883–1969)

Karl Theodor Jaspers was a German existential philosopher whose initial profession had been psychiatry. In later life he attained an international reputation owing to his highly publicized statements as a political philosopher in postwar Germany and received several honorary doctorates and prestigious awards honoring his philosophical work for peace, freedom, and humanity.

Jaspers was born into a middle-class family in Oldenburg, northern Germany, on February 23, 1883. The liberal democratic mindset in his family deeply shaped his way of thinking. Jaspers first studied law, but partly owing to pulmonary disease contracted in his youth, he switched to the study of medicine. Due to his illness Jaspers was forced to live a calm and retiring life. Notwithstanding, he passed his exams in Heidelberg with distinction. In 1910 he married the nurse Gertrud Mayer, daughter of a Jewish merchant and sister of his fellow student Ernst Mayer.

Jaspers received his medical degree in 1908. He obtained his second doctorate from the philosophy faculty of Heidelberg University for his book *General Psychopathology,* still considered an important psychological work today. Beginning around 1910 Jaspers gradually had moved toward philosophy—mainly inspired by his readings of Baruch Spinoza, Immanuel Kant, Georg W. F. Hegel, Friedrich Nietzsche, and Søren Kierkegaard. His first predominantly philosophical book was *Psychology of World Views* (1919). By 1922 he had became full professor of philosophy in Heidelberg University.

In 1909 Jaspers made the acquaintance of Max Weber, one of the most important liberals, economists, and sociologists of prewar Germany. Weber was to play a guiding role in Jaspers's personal and academic development. During the same period Jaspers also met Ernst Bloch, Georg Lukács, Friedrich Naumann, and Georg Simmel.

Jaspers dissociated from the neo-Kantian philosophy that prevailed at this time and was one the first researchers who fought with insistence for a widening of the scope of philosophical sciences. Jaspers's main work is chastely titled *Philosophy* (1932) (*Philosophical World Orientation, The Illumination of Existence, Metaphysics*). Some further prewar works are *Man in the Modern Age* (1931), *Reason and Existence* (1935), and *Philosophy of Existence* (1938). Jaspers investigated the influences of borderline situations on the human being's attitudes and described a transcendental theory of the encompassing (*das Umgreifende*). Jaspers's attitude toward religion, however, was critical, and he did not consider it essential to philosophy.

Jaspers became deeply involved in the history of philosophy, which he understood as a facet of existential philosophy. He was among the first to think of history beyond the notion of a path of time or a path of ideas. Thus, when considering the heritage of the great philosophers, he replaces the link through time with the link through reason. One could say Jaspers widened the dimensions of history and time by ignoring their strict chronological order and interpretation.

Jaspers also dealt with Friedrich Nietzsche's thoughts about the eternal return or recurrence of time and the necessary overcoming of weakness and nihilism through such recurrence. Jaspers esteemed Nietzsche's work, although he disagreed with some parts of Nietzsche's legacy, particularly in Nietzsche's interpretations of the existence and role of transcendence. Furthermore, Jaspers was opposed to any thinking of the concept of the superior man.

Another outstanding person in his life was Martin Heidegger, with whom he shared an intense discourse. Nonetheless they quite frankly took very opposite philosophical positions. Jointly they are considered the most important representatives of German existential philosophy—clearly demarcated from Jean-Paul Sartre's existentialism. Their relationship abruptly ended the day Heidegger declared his accordance with the aims of Hitler. More satisfying was Jaspers's lifelong friendship with his former student, the political philosopher Hannah Arendt.

As a consequence of Jaspers's marriage to a Jewish woman and his declining to collaborate with the Nazi regime, he was subjected to certain restrictions, including the prohibition to teach and to publish. After the end of the war, however, with his reputation intact, he was among the well-regarded academics who helped to refound Heidelberg University, but in 1948 he chose to relocate to the University of Basel in Switzerland out of his dissatisfaction with the political and academic developments in postwar Germany.

Induced by his experiences during the Nazi tyranny, Jaspers had become an increasingly politically thinking person and fought against the quick rehabilitation of former Nazi collaborators like Heidegger. His well-known and controversial book

The Question of German Guilt appeared shortly after the war's end (1946). Jaspers assumed the role of a strong advocate for freedom and purer democracy. Some explicitly humanistic works, such as *The Atom Bomb and the Future of Mankind* (1961), followed. At this stage he pronounced the importance of an enlightened and educated bourgeoisie to the stability of democratically ruled societies.

Jaspers's circumscribed influence in modern philosophical theory, especially outside the German sphere, is partly due to the fact that more famous philosophers such as Heidegger and Theodor W. Adorno did not take issue with the greater part of his perceptions and ideas.

Karl Jaspers became a Swiss citizen in 1967. He died in Basel on February 26, 1969.

Matthias S. Hauser

See also Hegel, Georg Wilhelm Friedrich; Heidegger, Martin; Kant, Immanuel; Morality; Nietzsche, Friedrich; Space and Time; Weber, Max

Further Readings

Ehrlich, L. (1975). *Karl Jaspers: Philosophy as faith.* Amherst: University of Massachusetts Press.

Josephus, Flavius (27–100 CE)

Flavius Josephus, a Jewish native of Jerusalem and later a Roman citizen, achieved lasting significance for his writings about Judaism and the Roman Empire (*The Jewish War, Antiquities of the Jews, Against Apion,* and *The Life of Josephus*). His own life and writings illustrate the 1st century clash of the Jewish and Greco-Roman worlds.

Although his historical works follow the methods of Greek historians like Thucydides, Josephus communicated the Jewish tradition of ancient history and the beginnings of time to the Greco-Roman world. As with Jewish histories in general, his observations of the passage of history emphasize a linear progression of connected events driven by divine providence. Though Josephus showed great interest in the accurate record of factual history, his ordering of events focused on the quality and readability of the story, often to the sacrifice of exact chronology.

Born to an aristocratic family within the Jewish priesthood, Josephus rose to prominence as a Pharisee and political leader in Judea, later receiving a military command during the Judean revolt. Josephus had been convinced of Rome's glory and power since he visited the empire's capital at age 26, and his own writings indicate that he felt neither convicted about the cause for revolt nor confident of any sort of victory for the Jews. Josephus was defeated and captured by the Romans at Jotapata in 67 CE, but he quickly made a powerful acquaintance with Emperor-to-be Vespasian by predicting his rise to power. Vespasian later secured Josephus's freedom and his Roman citizenship and provided for him in Rome with a residence and pension. Once he was in Rome, Josephus began his writing. Little else is known about the latter part of his life.

Major Works

In Rome, Josephus wrote *The Jewish War,* a commissioned account of the Judean revolt and the destruction of Jerusalem, which received imperial endorsement from Vespasian. For this task Josephus drew upon his own experiences in the war, Roman military records, and his many contacts. Josephus was politically sensitive in his handling of the conflict, generally pointing all blame toward the Judeans who had stirred up the revolt.

In his next undertaking, *Antiquities of the Jews,* Josephus composed his own version of Jewish history for explanation to the Greco-Roman world, covering a span of some 5,000 years. As an appendix to this account, he attached *The Life of Josephus,* a short autobiography that focused on his ambiguous role in the Judean revolt. *Antiquities* was based on the Hebrew scriptures as well as other rabbinic sources and traditions, but it also contains interpretations and inferences that were uniquely his. When dating events, he often used Jewish reckoning alongside that of other civilizations such as Egypt or Rome. As in *Genesis,* in *Antiquities,* time was said to begin with the 7-day divine Creation of the world, which became the model for a 7-day week. Josephus also recorded the origins of the feasts and celebrations that make up the Jewish year.

In his last work, *Against Apion,* Josephus defended his own accounts of Jewish history and offered an apology for the Jewish religion. Against Roman accusations that Judaism was a young and unimportant religion, Josephus argued that Judaism was in fact quite ancient and possessed a rich antiquity equal to that of the Greeks and Romans. In this work, Josephus sharply criticizes Greek histories initially but then uses them to help validate many aspects of Jewish history. Throughout his writing he confirmed his belief that God guided the events of history and that all things happened at the time appointed them by God.

Adam L. Bean

See also Creation, Myths of; Judaism; Philo Judaeus; Thucydides

Further Readings

Cohen, S. J. D. (2002). *Josephus in Galilee and Rome.* Boston: Brill.

Fieldman, L. H., & Hata, G. (Eds.). (1987). *Josephus, Judaism, and Christianity.* Detroit, MI: Wayne State University Press.

Hadas-Lebel, M. (1993). *Flavius Josephus* (R. Miller, Trans.). New York: Macmillan.

Josephus, F. (1999). *New complete works of Josephus* (W. Whiston, Trans.; P. Maier, Comm.). Grand Rapids, MI: Kregel.

Joyce, James (1882–1941)

James Joyce, widely regarded as the most important novelist of the 20th century, was born in Dublin to a family of modest means and was educated at Belvedere College, Dublin. He began his writing career within the then-dominant mode of literary naturalism but soon outgrew those conventions and produced, over several decades, a remarkably original body of work that, for sheer inventiveness and virtuosity of prose style, gained him international acclaim. Joyce's novels virtually defined modernism in literature, influenced several generations of writers, and continue to exert a fascination for serious readers.

The early work *Dubliners,* a collection of penetratingly observant short stories, was followed by the autobiographical novel *Portrait of the Artist as a Young Man,* which introduced experimental techniques that Joyce later explored fully in the radically innovative novel *Ulysses.* Finding the atmosphere of Ireland to be stiflingly parochial and repressive, Joyce resolved to live as an expatriate in order to maintain fidelity to his vocation as an artist. Composed in Paris, Trieste, and Zurich, where Joyce and his wife Nora had taken up successive residences after leaving Ireland, the novel *Ulysses* was completed in 1921. This book, Joyce's masterpiece, focuses on the lives of several residents of Dublin whose paths intersect over the course of a single day. In planning *Ulysses* Joyce took enormous pains to follow a rigorous outline that, beneath the surface of the novel, incorporates detailed parallels between the day's events and the major episodes of the *Odyssey,* a classical Greek epic work attributed to the poet Homer. Published in France, Joyce's novel was immediately recognized for its masterful use of the technique that became known as *stream of consciousness.* This literary tool, afterward widely imitated, became a mainstay in modernist literature, using a constant flow of subjective observations, reactions to events, reflections, and ideas as they pass through a character's mind, providing a uniquely intimate view of a character's mentality. Most famously, the final chapter of *Ulysses,* commonly referred to as Molly Bloom's soliloquy, is a lengthy, labyrinthine, richly associative interior monologue composed of only three sentences. As if to remind his readers that time presses on even at the close of a story, Joyce allows for the final lines of the novel to linger on a slight and momentary notion.

Owing to chronic poverty and the pressures of family, specifically the deteriorating mental health of his daughter, Lucia, Joyce found himself exhausted upon completing *Ulysses.* After a year's hiatus he began writing again in 1923. A work in progress that would eventually become *Finnegans Wake* occupied Joyce for more than 6 years and involved the use of narrative techniques and multilingual word play that left even the highly inventive idiom of *Ulysses* far behind. A complex amalgam of myths and folktales, archetypal themes, and timeless stories told in a unique style of language filled with puns, wordplay, and allusions to events that span world history, the novel posits the idea that history is not linear but cyclical and is bound to repeat. In this Joyce echoes the philosopher Friedrich Nietzsche's idea of eternal recurrence; in this way the *Wake* opens onto a vista that embraces all of human endeavor, encompassing past, present, and future. The final passage of the book ends in midsentence, continuing with the first phrase on the first page, thereby manifesting the very cyclical nature that Joyce came to see as a fundamental not only to the act of storytelling but also to the universe itself.

In the last decade of his life, internationally famous and with his literary reputation secure, Joyce became nearly blind, undergoing a series of eye operations that were only partially successful and were complicated by alcoholism. He died in Zurich in 1941 following surgery for a stomach ulcer.

Christian Austin

See also Homer; Mann, Thomas; Nietzsche, Friedrich; Novels, Time in; Proust, Marcel

Further Readings

Ellmann, R. (1982). *James Joyce: A biography* (Rev. ed.). New York: Oxford University Press.

Joyce, J. (1967). *A portrait of the artist as a young man.* New York: Viking Compass. (Original work published 1917)

Joyce, J. (1976). *Finnegans wake.* New York: Viking Penguin. (Original work published 1939)

Joyce, J. (2003). *Ulysses.* Ann Arbor, MI: Borders Classics. (Original work published 1922)

JUDAISM

Judaism is the religious, ethnic, and cultural heritage derived from the ancient people of Israel and the Hebrew scriptures. While the practice of Judaism is centered around the books of the Hebrew Bible, and among those primarily the five books of the Torah, its developed form, often referred to as a civilization, represents the accumulation of custom and tradition over centuries of thought and writing.

Intriguingly, many of the most central aspects of Judaism are connected to unique ways of measuring time and marking its passage. Judaism follows a nuanced calendar that prioritizes the cycles of the moon over the revolution of the earth around the sun. Within this calendar, the Jewish year is given distinct color and texture by numerous holidays and festivals that make up the liturgical schedule for worship. Through this continuous liturgical cycle that celebrates milestones of national and historical significance, Judaism captures both the cyclical and linear elements of time. Each year moves forward into history but also repeats the same journey as those before it—for example, the complete reading of the Torah, the celebration of special days like Pesach, Shavuot, or Sukkoth, and the blast of the *shofar* to greet the new year on Rosh Hashanah. Throughout its long history, Judaism has also contributed significantly to the discussion and philosophy of time. The ancient Hebrews solidified their religious and cultural identity in part by their beliefs concerning the beginning of time and the creator God who moved it forward through history. Centuries later, medieval Jewish thinkers grappled with influential philosophies of time originating outside their tradition and tested their compatibility with Jewish theology. In the European Age of Enlightenment, with the relaxation of strictures forbidding Jews from participating in civic culture, Jewish thinkers and philosophers engaged more freely in dialogue and debate with their Christian counterparts. Today, as full participants in secular society, observant Jews still preserve ancient customs revolving around the Jewish calendar and religious year.

Jewish Calendars and Chronology

Throughout most of its history, Judaism has used a calendar based primarily on a lunar year with necessary intercalations made to avoid excessive divergence from the solar year. This year is divided into twelve lunar months: Nisan, Iyyar, Sivan, Tammuz, Av, Elul, Tishri, Heshvan, Kislev, Tevet, Shevat, and Adar. In leap years, an extra intercalary month called Adar II is added. The names of these Jewish months closely resemble Babylonian month names, a probable result of the 6th century BCE exile of the Hebrew people in Babylon.

Each month begins at the new moon, or *molad* ("birth" in Hebrew). Since the average lunar month is approximately 29.5 days, the Jewish months alternate between 30 and 29 days in length. This results in a typical year of around 354 days and a leap year of around 384 days. The present system of leap years is based on a 19-year cycle in which the 3rd, 6th, 8th, 11th, 14th, 17th, and 19th years are intercalated with a 13th month. Originally, the commencement of new months and insertion of leap months were physically observed rather than calculated. New moons were observed and announced to Jewish communities by the religious leadership, and leap months were inserted when it was observed that the calendar and festival cycle were deviating too much from the agricultural season. In the 4th century CE, patriarch Hillel II formulated a new mathematical foundation for the calendar that introduced the 19-year cycle of leap years and diminished the need for physical observation. His calendar method was refined for the remainder of the 1st millennium and has remained essentially unchanged since that time.

For Judaism, the day begins and ends at dusk, rather than midnight. Thus, the Sabbath begins at sundown on Friday of the secular calendar and ends 24 hours later. For the reckoning of times for daily prayers and observances, 24 uneven hours (proportionate divisions of the daytime and the night) are used, while 24 even hours are used for most other purposes. Rather than minutes and seconds, Jewish custom divides the hour into 1080 *halakim,* which equal about 3.5 seconds each.

A potentially confusing aspect of the Jewish calendar is the starting point of a new year. Originally, Nisan corresponded to the "1st month," as was the case in the Babylonian ordering of the months. Likewise, it is between Adar and Nisan that the leap month Adar II is inserted. Despite this fact, the 1st day of Tishri is actually considered the start of the new year, called Rosh Hashanah, approximately corresponding with the autumnal equinox. Though Rosh Hashanah is the 1st day of the month of Tishri, it does not always occur on the day of the *molad.* In the interest of avoiding certain scenarios, such as Yom Kippur being a Friday or Sunday, Rosh Hashanah is sometimes delayed by one or two days. Because of this, the year always begins on a Monday, Tuesday, Thursday, or Saturday. An individual year is succinctly described by three facts that determine liturgical schedules: the day of the week of Rosh Hashanah, the number of days in the year (353, 354, or 355 for regular years; 383, 384, or 385 for leap years), and the day of the week on which Passover begins.

Standard Jewish chronology numbers the years from the supposed date of the Creation of the world, sometimes indicated by the abbreviation AM for *anno mundi,* "year of the world." Though various calculations have been made by Jews and Christians based on biblical genealogies and histories, Jewish dating accepts the conclusion attributed to 2nd century rabbi José ben Halafta that the Creation occurred in the year 3761 BCE. By this chronology, the year 5768 corresponds with 2007–2008 CE.

While the calendar system described above reflects the mainstream of Jewish tradition throughout its history, there have been dissidents. Most noteworthy is a group of solar calendars described in the 2nd century BCE book of *Jubilees* and in multiple versions of the book of *Enoch.* The main calendar of this type was distinctively solar, describing the year as 364 days or exactly 52 weeks. These calendars are generally regarded as sectarian within the Judaism of their time, and there is little evidence to determine the extent of their observance. Materials referring to such calendars have been discovered at Qumran, but references to other systems make it unclear exactly what calendar the Qumran sect observed. Clearly, the 364-day calendar would drift from the actual 365.5-day solar year at a steady pace, but no intercalation method is mentioned in literature connected to these calendars, a fact that causes some to doubt their sustained observance.

The Sabbath

Throughout history, a primary distinguishing characteristic of Judaism has been the observance of the Sabbath (or Shabbat), a day of rest observed on the seventh and final day of each week. The Sabbath has been central to Jewish identity since ancient Israel, and it figures prominently throughout the Hebrew Bible. Biblical passages connect the institution of the Sabbath with God's 7-day Creation of the world, the Israelite wanderings in the wilderness, and the Decalogue. Prophetic texts sternly rebuke neglect of the Sabbath in Israel, while later rabbinic writers further delineate what would be acceptable and unacceptable on the Sabbath. Jews observe the Sabbath (which actually runs from Friday evening until Saturday evening) as a time of relaxation, prayer, and worship. Food is prepared ahead of time, and most activities classified as "work" are prohibited. Most of the Sabbath is spent together by families at home, but synagogue services are typically held on Saturday morning.

While the concept of a 7-day week is taken for granted in modern culture, in the ancient world it was a cultural novelty of Judaism. Because it does not directly follow any natural phenomenon (as days, months, and years all do), the week is one of the more puzzling chronological developments in human civilization. While the Jewish week appears to have been a unique development, there are interesting parallels from the ancient Near East, such as Assyrian "unlucky days," which occurred on the 7th, 14th, 19th , 21st, and 28th days of the month (the 19th is understood to equal seven cycles of seven from the start of the previous month). The 7-day week in its modern form is a combination of the Sabbath-based week of Judaism and the Roman planetary week, which emerged around the turn of the common era. A further development was a Christian adoption of the 1st day of the week, Sunday, as its day of worship and rest after the day of Jesus' resurrection, contributing to the development of the 2-day weekend now widely observed.

Jewish Holidays

The Jewish year is given shape by a number of festivals and holidays that are central to Jewish religious life. These observances provide a liturgical cycle of worship, a continuous revolution that commemorates annual occurrences and special events from Jewish history. Because of the original uncertainty or delayed information concerning the fixing of new years and months, especially for diaspora Judaism, a second day was added to most festival days, a convention that is still maintained despite more precise methods of calculation.

Of special importance for Judaism are the 3-week-long pilgrimage festivals (Passover, Shavuot, and Sukkoth), which are each tied both to events from the biblical history of Israel and to agricultural seasons. Passover (or Pesach), beginning on Nisan 15, is connected with the Israelite exodus from Egypt and the beginning of the spring harvest. The most widely celebrated Jewish holiday, Passover, is commemorated with a special seder meal. Shavuot (the Feast of Weeks or Pentecost) follows Passover by 7 weeks and celebrates the giving of the Torah at Mount Sinai, as well as the end of the barley harvest and the beginning of the wheat harvest. On the 15th of Tishri, Sukkoth (the Feast of Booths or Tabernacles) recalls the Israelite wilderness wandering and celebrates the ingathering of grain from the fields into barns. Observers of Sukkoth construct a *sukkah,* a simple booth, in which they are to dwell during the 7 days of the festival.

In addition to the three central festivals, many other special days mark the Jewish year. As explained above, Rosh Hashanah ("head of the year") occurs at the beginning of Tishri, in autumn. The Jewish new year is ushered in with the blasts of a *shofar,* a ram's horn, and marked with a day of introspection and special synagogue worship. Shortly after the start of the new year on Tishri 10, Jews observe Yom Kippur, the Day of Atonement. This is the most somber of Jewish holidays, marked by fasting, abstinence from work, and lengthy synagogue services of confession and repentance. Other significant occasions include Shemini Atzeret ("assembly of the eighth day") and Simhat Torah ("joy of the Torah"). These immediately follow the 7 days of Sukkoth in Tishri, and Simhat Torah marks the completion of the annual cycle of readings through the Torah, the first five books of the Hebrew Bible. Purim is a celebration of Jewish survival from Persian oppression, revealed in the book of Esther, and is held on Adar 14 or Adar II 14 in leap years. Hanukkah, the Festival of Lights or of Dedication, is well known for its proximity to the Christian Christmas holiday and commemorates the miraculous burning of a menorah lamp for 8 days at the rededication of the Jerusalem temple in the 2nd century BCE. This holiday is celebrated for 8 days, beginning on Kislev 25 with the lighting of candles in a menorah.

Time in Jewish Thought and Literature

Though the ancient people of the Hebrews do not seem to have developed any extensive philosophies of time, among ancient civilizations they were pioneers of the concept of historical identity. In some sense, the entire development of the Hebrew Bible and subsequent Jewish tradition centered around the conviction that historical events that made up the progression of time had meaning and purpose. It was the activity of humanity (guided by the hand of God) that made up history or time for the ancient Hebrews rather than purely abstract measurements or theories. Modern scholarship does assert that the Hebrew scriptures are not "historical" in the modern sense; they represent a mixing of mythology, historical reality, and theological-historical interpretation. Still, it is precisely through these mediums that they communicated the narratives that formed the Hebrew identity and gave meaning to the progression of time. This begins with the very first passage of the Hebrew Bible, which asserts that time began with the Creation of "the heavens and the earth" by God. This affirmation became, for both Jewish and Christian thinkers, a frequent point of contrast with Greek philosophies, which often argued for the eternality of matter and a cyclical nature of history.

In addition to prescribing a beginning of time at Creation, the ancient Hebrews developed beliefs concerning the end or consummation of time, generally classified as "eschatology." The seeds of Jewish eschatology are present even in the Torah, as the concept of Israel as God's chosen people becomes fully developed, but it is the prophetic writings that contain the bulk of Jewish eschatological language. As the course of Israelite history grew darker and the prophets struggled with what they considered unfaithfulness to God among the Israelites, the focus turned increasingly toward concepts of future divine judgment. Terms such as "that day" and "the day of the Lord" became common indicators of a coming time when God would intervene on a universal scale, judging all peoples and setting right the injustices of the world. Within this realm of thought, the concepts of a messiah and of life after death developed and grew, particularly in late prophetic and intertestamental literature. Increasingly, the hope of resolution of injustice in the world was pushed to a future time, when all people would be resurrected and face judgment.

By the medieval period, many Jewish philosophers interacted with classical Greek traditions about the subject of time. Moses Maimonides accepted a primarily Aristotelian concept of time, in which time was an "accident" of the motion of physical bodies. Hasdai Crescas, on the other hand, rejected the Aristotelian conception and connected time to the consciousness of the mind, not motion, a concept more akin to that of Plotinus. For these and other philosophers, numerous questions of God's relationship to time became pressing: Does God exist within time or outside of it? Was there time before Creation? If so, what was God doing during that time? Can "eternity" be understood in the normal sense of time? Such questions were discussed among Jewish thinkers as well as theologians of the Christian and Islamic traditions with diverse and varying answers. For both monotheistic faiths, the philosophical questions of time, eternity, and cosmogony have been a constant component of theological discussion.

Judaism in the modern world is very diverse and difficult to characterize as a whole. For many, Judaism is more a cultural than religious identifier. Despite this, observing time by the traditional calendar and customs of Judaism remains a central aspect of faith for many. Keeping the sabbath is fundamental to being a Torah observer, and the Jewish calendar system is still the framework of worship. The richness of Jewish customs regarding time and their persistence throughout history, even in the face of modern secular assimilation, testifies to the remarkable character of Judaism as a religious, cultural, and ethnic entity that has preserved a genuinely unique identity.

Adam L. Bean

See also Adam, Creation of; Bible and Time; Creation, Myths of; Genesis, Book of; Moses; Noah

Further Readings

Beckwith, R. T. (1996). *Calendar and chronology, Jewish and Christian: Biblical, intertestamental and Patristic studies.* Leiden, The Netherlands: Brill.

Beckwith, R. T. (2005). *Calendar, chronology and worship: Studies in ancient Judaism and early Christianity.* Leiden, The Netherlands: Brill.

Brin, G. (2001). *The concept of time in the Bible and the Dead Sea Scrolls.* Leiden, The Netherlands: Brill.

Richards, E. G. (1999). *Mapping time: The calendar and its history.* Oxford, UK: Oxford University Press.

Skolnik, F., & Berenbaum, M. (Eds.). (2006). *Encyclopedia Judaica.* New York: Macmillan Reference.

Steel, D. (2000). *Marking time: The epic quest to invent the perfect calendar.* New York: Wiley.

Stern, S. (2001). *Calendar and community: A history of the Jewish calendar, second century BCE—tenth century CE.* Oxford, UK: Oxford University Press.

Stern, S. (2003). The rabbinic concept of time from late antiquity to the Middle Ages. In G. Jaritz & G. Moreno-Riano (Eds.), *Time and eternity: The medieval discourse* (pp. 129–146). Turnhout, Belgium: Brepols.

Talmon, S. (2005). What's in a calendar? Calendar conformity, calendar controversy, and calendar reform in ancient and medieval Judaism. In R. L. Troxel, K. G. Friebel, & D. R. Magary (Eds.), *Seeking out the wisdom of the ancients* (pp. 451–460). Winona Lake, IN: Eisenbrauns.

Wacholder, B. Z. (1976). *Essays on Jewish chronology and chronography.* New York: KTAV.

Zerubavel, E. (1985). *The seven day circle: The history and meaning of the week.* New York: The Free Press.

K

KABBALAH

Kabbalah, derived from the Hebrew root meaning "to receive," is the name given to a Jewish mystical tradition that originated around 100 BCE. Owing to variations in transliteration from the Hebrew, it is sometimes rendered as Kabalah, Qabalah, or Qabbalah. The name Kabbalah is attributed to the scholar Isaac the Blind (c. 1160–1236), sometimes called the Father of Kabbalah, although the practice of Kabbalah predates him. As a form of Jewish mysticism, it is primarily concerned with directly experiencing God through meditation, spiritual exercises, or interpretations of scripture (particularly the Torah) and other writings. Kabbalah has both a traditional and a distinct beginning.

Traditionally Kabbalah is believed to date from the relationship between Adam and God. According to the first three chapters of Genesis, Adam enjoyed a unique experience with God: Adam conversed directly with God without any mediation from another person or text. He was able to know God face-to-face. This is the kernel of mysticism in general and Kabbalah specifically: to know God directly.

Viewed this way, many persons from the *Tanakh* (Hebrew Bible; in Christianity, the Old Testament) are viewed as having kabbalistic experiences. According to Jewish teaching, the events in the book of Genesis occurred prior to God giving the Law of Moses. Within Genesis, people speak with God directly. While Genesis makes no mention of the type of relationship between Melchizedek and God, Melchizedek (Gen 14: 18–20) is mentioned as a priest of God prior to the establishment of the Torah (Law). Therefore (the reasoning goes), because there was no mediation, Melchizedek must have had a direct experience with God. Abraham spoke directly with God (Gen 12–22) as did Moses (Exodus through Deuteronomy).

In other books of the Tanakh, prophets are mentioned as having direct experiences with God. This is important for understanding Kabbalah, because the prophets had experiences with God after the Law of Moses was given. To a Kabbalist, therefore, the Law of Moses does not stand between a follower of God and God, such as in the role of a mediator, but instead the Law of Moses becomes a gateway into communication with God.

Kabbalah has a distinct beginning that can be traced to a wealth of Jewish mystical literature from the period 100 BCE to 1000 CE. Over time, the literature and understanding of Kabbalah increased. Yet the central Kabbalah text is the *Sefer ha-Zohar* (Book of Splendor), which is usually given simply as Zohar. The Zohar contains commentary and stories. Its preeminence among Kabbalah is borne out by the number of commentaries that have been written about the Zohar. This book is attributed to Simeon bar Yohai (2nd century CE), although the first record of the book is from the 13th century in Spain as the work of Moses ben Shem Tov de Leon (1240–1305). He either edited the writings of Simeon bar Yohai or based his work on Simeon; in either case the work originated with Simeon and was completed by Moses de Leon.

Soon after the Zohar, *Ma-arekhet ha-Elohut* (The Order of God) appeared, which attempted to systematically explain Kabbalah doctrine. In addition, *Sefer ha-Bahir* (Book of Light) was another early Kabbalah text that explained the *sefirot* (the emanations of God).

A central tenet of Kabbalah is the tree of life. This symbol contains a diagram (sometimes represented as a tree) with ten sefirot (emanations): sovereignty, foundation, endurance, majesty, beauty, loving kindness, judgment, wisdom, understanding, and the crown. The sefirot exhibit different aspects of God. They are to be viewed as a unit and individually. As a unit, these represent the way that God communicates or interacts with the world. Individually, these are steps along which the kabbalist works or progresses in an attempt to draw closer to God.

Prominent teachers of Kabbalah include Moses Cordovero (1552–1570), who wrote *Tamar Devorah* (Palm Tree of Deborah), which explains Kabbalah, and *Or Yaqar* (Precious Light), which is a commentary on the Zohar. Isaiah ben Abraham ha-Levi Horowitz (1565–1630) wrote *Shenei Luhot ha-Berit* (Two Tablets of the Covenant). Isaac the Blind (c. 1160–1235) is believed to have written the *Sefer ha-Bahir* (Book of the Brightness). Over time, texts and commentaries on Kabbalah have been written and collected, and interest in the texts has increased both within and outside Judaism.

Similar to other mystical traditions, Kabbalah considers time and space as mundane realities. Within the spiritual realm, therefore, concepts such as time, space, and place are nonexistent. Understanding God entails understanding his actions apart from time; God's qualities exist beyond time and cannot be limited or perceived by temporal constraints. This in itself tends to restrict interest in Kabbalah to truly serious adherents, because practitioners must remove themselves from the physicalness of their surroundings in their efforts to fully understand God.

Among Jewish religious groups, the Kabbalah greatly influenced the ultraorthodox Hasidim. This influence can be seen in the Hasidic theology of working toward a union with God and in their concept of *devekut* (from the Hebrew for "cleaving," the cleansing or preparation of prayer and mediation toward God).

In understanding the intent toward the Torah of Kabbalah, the teaching of Bahya ben Asher is instructive. He held to four different interpretations of scripture: the literal, the homiletic (preaching), the moral, and the mystical. The Kabbalah is not solely interested in the mystical meaning of scripture, yet it is concerned with utilizing the former three while focusing on the mystical. For the kabbalist, the Torah does not solely teach people about God and how to live before God; instead it starts with those and brings the person into communication with God.

Kabbalah texts can be difficult to understand, many being written in esoteric language. Additionally, some kabbalists in the past believed that no one under the age of 40 should practice Kabbalah. Kabbalah was understood to be reserved for those willing to devote themselves to a mystical relationship with God.

Recently, more accessible forms of Kabbalah have become popularized and are currently practiced by people from various backgrounds, both Jewish and gentile. Kabbalah centers can be found in major cities worldwide, and a number of Web sites offer instruction and guidance in teachings that are based on elements of the kabbalistic traditions.

Mark Nickens

See also Bible and Time; Genesis, Book of; Judaism; Moses; Mysticism

Further Readings

Carmody, D. L., & Carmody, J. T. (1996). *Mysticism: Holiness east and west.* New York: Oxford University Press.

Epstein, P. (1978). *Kabbalah: The way of the Jewish mystic.* Boston: Shambhala.

Scholem, G. (Ed.). (1995). *Zohar: The book of splendor: Basic readings from the Kabbalah.* New York: Schocken Books.

Kafka, Franz (1883–1924)

Franz Kafka, among the most highly acclaimed writers of the 20th century, was a Jewish

Czechoslovakian who wrote allegorical stories in the German language. As literary critics have pointed out, Kafka's meticulously constructed tales seem to defy categorization, containing elements of the comedic and satirical as well as the tragic. He has been described as a realist, an absurdist, a Marxist, a sociologist, an existentialist, and a comedic theologian. Now widely considered the paradigmatic artist of his time, Kafka developed a personal idiom of expression that imposed a unique literary order on the disorder of the emerging modern world and gave universal form to his own personal nightmares and obsessions. Many later writers have acknowledged Kafka's influence, including Jorge Luis Borges, Milan Kundera, Gabriel García Márquez, Carlos Fuentes, and Salman Rushdie.

A striking aspect of Kafka's work is in its uncanny foreshadowing of the nightmare of bureaucratic control and mechanized murder that, more than a decade after Kafka's premature death from tuberculosis, would take shape as the Holocaust. In his novels *The Trial* and *The Castle,* both published posthumously, the central characters undergo persecution by petty officials: Joseph K. is anonymously accused of a crime whose nature remains unspecified; his attempts to clear himself only draw him deeper and deeper into a labyrinthine legal system that ultimately issues a death sentence carried out in an impersonal and humiliating manner. The protagonist of *The Castle,* who is identified only by the initial "K.," is repeatedly thwarted by a succession of bureaucrats and office holders in his efforts to gain access to the forbidding, enigmatic structure and ultimate source of power that dominates the town where the story is set.

A sense of oppression and anxiety characterizes much of Kafka's literary output. In the novella *The Metamorphosis,* which was published during Kafka's lifetime and received considerable acclaim, the main character, Gregor Samsa, a traveling salesman and the primary breadwinner for his mother, father, and sister, awakens one morning to find himself transformed into a giant insect. His efforts to confront the reality of this existential nightmare are described in such a way as to convey the dark humor as well as the horror of his situation.

Other acclaimed stories include "The Judgment," "In the Penal Colony," "A Country Doctor," and "A Hunger Artist," as well as the unfinished novel *Amerika,* the first chapter of which is the acclaimed story "The Stoker."

Kafka was born in the cosmopolitan city of Prague, Bohemia, which is now part of the Czech Republic. His father Hermann, a businessman, was physically imposing, overbearing, unsympathetic, and intimidating, and their relationship, always difficult, grew more strained as the years passed. The primordial theme of father-son conflict would emerge in Kafka's writing again and again in the form of confrontations with remote and sometimes hostile authority figures. Kafka refused to work in the family business, intent instead on a university education. After several years of changing majors at Ferdinand-Karls University in Prague, he went on to earn a doctoral degree in law.

As a student Kafka made acquaintances with other intellectuals and aspiring artists. He befriended Max Brod, a lifelong friend and confidant, to whom he would later entrust his literary estate. Throughout Kafka's life, he would continually battle bouts of physical, emotional, and mental exhaustion and would seek rest and treatment at sanatoriums. His first sanatorium stay occurred before he finished his law degree in 1905. In 1906, just after graduation, the pressures of family, professional, and scholarly pursuits overcame him, and again he sought the refuge of the sanatorium.

Two years after graduation, he took employment as an attorney with the Worker's Accident Insurance Institute for the Kingdom of Bohemia, where he worked diligently until shortly before his death. While in this employment, Kafka wrote several articles on the prevention of industrial accidents. In 1909, he published his first stories, excerpts from an abandoned novel, *Description of a Struggle,* in the journal *Hyperion.*

Kafka's complex inner life and his ambivalence concerning intimate relationships caused him to break off several affairs and marital engagements. As a young man, he would confess to his friend Brod that he was unsuitable for marriage and that he could never love a woman if she returned that affection.

Kafka obtained an early retirement from his long-term employer, and in 1922 he wrote "Investigations of a Dog'" and *The Castle.* By this time his health was seriously affected by the chronic tuberculosis that would eventually take his life. He lived transiently between sanatoriums and his sisters' homes. In 1922, he befriended a woman named Dora Dymant, with whom he lived briefly and to whom he eventually proposed marriage. Early in 1924, however, increasingly ill and near death, he traveled back to Prague, where he lived briefly with his parents and wrote "Josephine the Singer." He died on June 3 in a sanatorium near Vienna.

Although Kafka had directed Brod, his literary estate executor and lifelong friend, to destroy all his unfinished manuscripts, Brod salvaged the unfinished manuscripts instead. In the1920s three novels were posthumously published, and in 1931 a collection of incomplete tales was printed, together establishing Kafka as a 20th century literary master who, against the background of a decaying empire, had prophetically glimpsed the outlines of the world that was soon to come and had responded with a sense of dread and foreboding.

Debra Lucas

See also Dreams; Existentialism; Novels, Time in

Further Readings

Brod, M. (1947). *Franz Kafka* (G. H. Roberts & R. Winston, Trans.). New York: Schocken.

Kafka, F. (1948). *The penal colony: Stories and short pieces* (W. Muir & E. Muir, Trans.). New York: Schocken.

Kafka, F. (1995). *The trial* (W. Muir & E. Muir, Trans.). New York: Schocken. (Original work published 1925)

Sokel, W. (2002). *The myth of power and the self: Essays on Franz Kafka*. Detroit, MI: Wayne State University Press.

Kant, Immanuel (1724–1804)

Immanuel Kant, like Plato and Aristotle, counts as one of the most influential philosophers of all time. He developed a new theory of time and space that combined insights from rationalism and empiricism. In his practical philosophy he developed a completely new approach, which makes Kant one of the most distinguished scholars of the European Enlightenment.

Kant was born in Königsberg (formerly East Prussia, since 1945 renamed Kaliningrad, Russia) on April 22, 1724, as the son of a saddler. He was brought up in the spirit of Pietism, a Lutheran movement that focused on love, which is realized through duty and good deeds. He never left Königsberg. It was there where he went to school and attended university, where he received permission to teach as a university lecturer (*Privatdozent*) in 1755, and again where he was appointed full professor of logic and metaphysics in 1770 after declining an offer from Jena in 1769. He held this position for the rest of his life and died on February 12, 1804.

The tone of the German intellectual landscape in which Kant started his work was largely set by the so-called "school philosophy" of Leibniz and Wolff, a thoroughgoing form of rationalism. Wolff, continuing Leibniz's work, believed that every truth of reason could be deduced from the principles of noncontradiction and sufficient reason. When Kant encountered Hume's empiricist philosophy, he felt awakened from his dogmatic slumbers. In 1770 he consolidated many of the intellectual gains he had made during the 1750s and 1760s in his Latin inaugural dissertation (*Habilitationsschrift*). He introduced an important new theory about the epistemology and metaphysics of time (and space). His fundamental new philosophical insight, which he later elaborated in his famous work *Critique of Pure Reason,* goes as follows:

> 1. The idea of time does not arise from the senses but is presupposed by the senses. . . . 5. Time is not something objective and real (*tempus non est obiectivum aliquid et reale*); it is neither an accident, nor a substance, nor a relation; it is the subjective condition, necessary because of the nature of human mind, of coordinating everything that we experience (*quaelibet sensibilia*) by a certain law, and is a pure intuition. For we coordinate substances and accidents alike, as well according to simultaneity as to succession, only through the concept of time.

The same holds for space, which he maintains is also neither objective nor real. Kant combines

Hume's empiricist point of view with the rationalistic assumption of an ordered universe. Hume believes that with sense-knowledge, the given consists of impressions and sensations, and, for this reason, we can only discover post hoc a succession in time without causal relation. Rationalists assume that there is a fundamental causal connection between events (a post hoc principle of sufficient reason). Kant explains that time and space, as our subjective forms of intuition, are the reason why we have the experience of causal connections without holding that these causal connections are real in an absolute sense. But they are real to us, because all human beings have the same experience, which results from the notion that all human beings have the same subjective forms of intuition; that is, of time and space. Kant's position on time and space is of great philosophical interest. For example, Einstein's theory of relativity shows that it is not possible for us to have absolute time or space, so it seems to be true that our experiences are just of appearances and do not tell the whole story.

In his *Critique of Pure Reason* (1781/1787) Kant developed these important insights to encompass all the categories used in thought. However, Kant admits that this work does not describe the whole system but instead is the blueprint for a new transcendental philosophy, thereby destroying the metaphysics of the past. Kant's central idea is to argue that the unity of consciousness, the so-called transcendental unity of apperception, categorizes all of the sensations according to the forms of intuition (time and space) and the forms of intellect; that is, the pure concepts (categories). This explains why there are universal and necessary laws for every being with consciousness and intellect, in other words, for every human being. Kant calls this knowledge synthetic a priori, because it is necessary and universal, on the one hand, but is not inferable through the analysis of concepts, on the other. From that follows that "things" that are not explicable in space and time, for example, God or an immortal soul (if they exist), cannot be assessed by human beings without leading to an endless series of irresolvable disputes. The previous system of metaphysics is now null and void. As a result, we cannot derive ethical conclusions from theological (or metaphysical) "knowledge" of the good. We are left without a solid foundation for a consequentialist account of ethical reasoning.

Kant proposes an alternative theory of practical reasoning that can be found in *Fundamental Principles of Metaphysics* (1785), *Critique of Practical Reason* (1788), *The Metaphysics of Morals* (1797), and numerous sections of other works. He assumes that only a will that acts for the sake of duty and not for the sake of inclination is a morally good will. The will is good when, for the sake of duty, it follows the fundamental commandment he calls the "categorical imperative," a principle of action that is a universal moral law. All rational beings endowed with freedom, regardless of their particular interests and social background, have to adopt this principle. Kant formulates it in the *Groundwork for the Metaphysics of Morals* in four different ways. The most famous formulation is as follows: "Act only according to the maxim (the determining motive of the will) through which you can at the same time will that it become a universal law." By *universal law* Kant means that this principle does not allow for exceptions, in contrast to the laws of nature. Another formulation of the categorical imperative demands the impartial respect of humanity in every human being: "Treat humanity . . . never simply as a means, but always at the same time as an end." Here Kant introduces the concept of human dignity, which remains among the most discussed of all ethical concepts.

In his third critique, the *Critique of Judgement,* Kant tries to unite theoretical and practical reason. Nature can be understood as a determinate system only under the regulative idea of being a system serving an ultimate end. This idea is regulative because it helps us to understand nature according to our capacities of reason. Consequently, we do not know whether nature serves an ultimate end at all; instead we are just left to postulate it.

Many aspects of Kant's theoretical and practical philosophy have been questioned, in particular his assumption of synthetic a priori propositions and his ethics of the categorical imperative. His theory of time and space, however, will likely remain a cornerstone of philosophical thought for generations to come.

Nikolaus J. Knoepffler

See also Ethics; Hume, David; Intuition; Metaphysics; Morality; Space; Space and Time; Time, Perspectives of

Further Readings

Guyer, P. (Ed.). (2006). *The Cambridge companion to Kant and modern philosophy.* Cambridge, UK: Cambridge University Press.

Kant, I. (1992ff). *The Cambridge edition of the works of Immanuel Kant* (P. Guyer & A. W. Wood, Eds.). Cambridge, UK: Cambridge University Press.

Kühn, M. (2001). *Kant: A biography.* Cambridge, UK: Cambridge University Press.

Kierkegaard, Søren Aabye (1813–1855)

Søren Aabye Kierkegaard was a Danish literary author, philosopher, and theologian whose work has had an abiding influence on philosophy, especially existentialism and postmodernism in the 20th century. His wide-ranging thought focuses largely on points where theological explication of the Christian faith and philosophical investigation of concrete human existence intersect and inform one another. Throughout his authorship, Kierkegaard proposed different understandings of existential (and theological) human temporality—how the human individual dwells and relates to himself or herself and the eternal order in the midst of time.

For Kierkegaard, time itself is a fluid and infinite succession of discrete points that are passing by. This succession is one of ceaseless quantity that spreads out extensively. Temporality, taken as signifying the temporal domain, is characterized in Kierkegaard's work as a realm of plurality (difference) and becoming (movement). This becoming is not a necessary one. All finite, temporal actuality for Kierkegaard is contingent; it could have been another way if another possibility had been actualized. (It is for this reason that human understanding or knowledge of events in time, in history, involves an irreducible uncertainty due to the contingent status of its objects.) In the midst of this fleeting impermanence, any given moment in time—from the perspective of time alone—is an infinite vanishing, a nothing. Considering time as such, there is no present and thus no past or future. There is only the infinite succession. The differentiation and distinction into present, past, and future only arises in the relation of time to another order—to the eternal.

The temporal, for Kierkegaard, is understood in contradistinction and dialectical relation to the eternal. Generally, the eternal is presented as an eternal present—a present in full in which the relative succession of time is annulled. (For Kierkegaard, in a sense, the present is eternal before it is temporal.) "The eternal," while it is used in various ways throughout Kierkegaard's authorship, refers more specifically to the transcendent God and that which has to do with one's relation to him (such as one's moral ideals and one's future life beyond death). Kierkegaard presents God as the source of ethical-religious stability in human existence that, in himself, transcends the temporal order (see below). As opposed to the ancient Greek intellectual conception (in Kierkegaard's estimation) of eternity in the form of abstract ideas, Kierkegaard affirms the Judeo-Christian "eternal" of a personal creator God who transcends history and yet actively relates to it—in its origin (creation), its progression (guiding and interacting), and its consummation. It is the divine eternal that makes time into something like unified narrative.

Following the Judeo-Christian understanding, Kierkegaard understands the eternal God as creating the temporal-finite order out of nothing. This created temporal realm is that of "existence"—of what has come to be in contingent finite-historical becoming, for the temporal realm as a whole, as freely created by God, could have been otherwise. In Kierkegaard's writings, existence is primarily discussed as the realm of ethical coming-to-be, of human existence and self-becoming.

The existing human being, for Kierkegaard, is a synthesis of the temporal and the eternal. The human at once dwells in time and relates to the eternal in *the moment*—a point in the succession of time at which an individual comes into contact with something of an order other than the finite-temporal. The moment is where the "present" of the eternal relates to time (where there is no present as such) in human consciousness. In the moment, time is meaningful (is more than mere succession) inasmuch as it relates to a transcendent order. It is only now that temporality—in terms of present, past, or future—is truly posited.

In Kierkegaard's anthropology, the existing human self is an identity that is actively produced in and through time. Human living and temporality are understood in terms of *repetition*—the project of trying to make of one's life something of the eternal, the stable, the abiding. For Kierkegaard, "aesthetic" repetition, the attempt to make pleasurable experiences permanent, fails because of the discontinuous and contingent nature of time. In ethical-religious repetition, however, one attempts to forge an identity through the discontinuity and becoming of time. In moral commitment, one seeks to establish a continuity over time—a continuity of temporal moments relating to the eternal—in which one becomes a self by relating to the eternal, ultimately to God. Here the unity of the self comes to be in the midst of the instability of time relative to something stable transcending time. The willing of one thing (God, the good, the eternal) in the midst of the plurality of one's temporal life makes one into one—into one thing—into a self.

The problem in establishing this self as a continuity over time is that of sin, of moral failure. When one considers the moral task of repetition along with the possibility of freedom, one encounters a psychological state of *anxiety* regarding the possibility of sin, of moral failure. Anxiety, for Kierkegaard, specifically relates to dwelling in time. For anxiety has to do with the human spirit's awareness of itself as free, as being able to actualize various non-necessary possibilities in the future—namely with the possibility of moral failure. Anxiety has to do with the tension in the synthesis of the self between our dwelling in time as finite beings and our "spiritual" relating of our finite lives to the eternal. Our freedom to act (in relation to the eternal, rightly or wrongly) and our responsibility for our actions incites anxiety over the very real possibility of failure—a kind of dizziness of freedom. In such a failure, one fails to relate to God and to relate to one's self as a dependent being-in-relation to God—not wanting to be what one is, failing to be a self.

Kierkegaard, as a kind of Christian theologian, affirms the *incarnation* of the eternal God in the historical person of Jesus Christ. In Jesus Christ, the incarnate God-man, there inheres a paradoxical unity of the eternal and the temporal, the divine and the human. The eternal entered into time in order both to save humanity by reconciling individuals to the eternal as a gift and to provide a prototype of the eternal moral character of God in a human life. The human individual comes into contact with this event of the eternal in time *in the moment* of Christian salvation. As at once a supreme if not archetypical instance of the ethical moment (see above) and an analogue of the incarnation, the moment of Christian salvation is a moment in time that has eternal significance. Kierkegaard observes that in this intensive moment of relating to Christ in salvation inheres the paradox that something eternal (one's eternal salvation) can be decided in time. Kierkegaard writes that it is quite understandable that this is something that does not "make sense" in the order of temporality alone—that a moment can be more than merely one moment among moments. In the moment of the possibility of one's salvation, one meets the moment of the incarnation with faith or offense. In *faith,* one believes and accepts that in Christ the eternal to which one has failed to attain a proper and consistent relationship in one's temporal life has come into time and given itself to one as a gift. In this moment of receiving the gift of salvation, there is a *contemporaneity* with Christ—for, in the moment of faith, the moment of the incarnate Christ's being in history is "present" to one. Through the gift of Christ and the example of his life, one can attain an identity that is not a mere aggregate of equivocal points of time in succession—one can become a self in relation to God.

Christopher Ben Simpson

See also Becoming and Being; Christianity; Eternity; Existentialism; God and Time

Further Readings

Evans, C. S. (1983). *Kierkegaard's* Fragments *and* Postscript*: The religious philosophy of Johannes Climacus.* Atlantic Heights, NJ: Humanities Press.

Kierkegaard, S. A. (1980). *The concept of anxiety* (R. Thomte, Trans.). Princeton, NJ: Princeton University Press. (Original work published 1844)

Kierkegaard, S. A. (1985). *Philosophical fragments* and *Johannes Climacus* (H. V. Hong & E. H. Hong, Trans.). Princeton, NJ: Princeton University Press.

Knezević, Bozidar (1852–1905)

As a science-oriented philosopher and historian living in Yugoslavia during the emergence of Darwinism, Bozidar Knezević was greatly influenced by the theory of evolution. He extended Darwin's process view of life on earth to include the future of organic evolution on this planet within a cosmic perspective. Knezević's philosophy of time and evolution was presented in his two-volume work *The Principles of History* (1898–1901). His incredible vision was a mixture of facts, concepts, and rational speculations that embraced both the ascent and subsequent descent of life forms on earth (including our own species) over a vast period of time.

Knezević acknowledged the awesome immensity of this dynamic universe in terms of both time and space. He claimed that humankind is merely a fleeting aspect of cosmic reality. Focusing on our planet, he saw three major stages of material development: inorganic, organic, and psychic levels of evolution. Within this sweeping perspective, our species recently emerged on the earth. Like all other forms of life, Knezević maintained that humankind is subject to the same finite history of evolution and then devolution that will eventually engulf all species on this planet. He referred to this history as the semicircular model of cosmic reality in general and organic evolution on earth in particular. This geometrical scheme is an engaging approach to understanding and appreciating the vulnerability of life forms throughout time.

According to Knezević, the history of our planet has been a material evolution of organic forms from simplicity to ever-increasing complexity, from the first appearance of the earliest life forms and then the fishes, through amphibians and reptiles, to mammals and the recent emergence of humankind. In the future, he speculated that organic evolution will result in the disappearance of life forms: Humans will vanish first, this will be followed by the extinction of the other mammals, then reptiles and amphibians will vanish, and finally the fishes and simplest organisms will become extinct. As the last species to emerge in evolution, humankind will be the first form of life to disappear; our species is linked to the fatal destiny of the earth and this solar system. Likewise, the first life forms to appear on earth will be the last forms of life to vanish.

For present environmentalists, this semicircular model of organic evolution may be relevant to a meaningful degree. If our planet changes significantly, then it could be the fact that the more complex life forms will become extinct first, while the fishes and invertebrates will survive much longer, far beyond the duration of mammals, reptiles, and amphibians. Eventually, perhaps even bacteria and viruses will vanish from the earth.

For Knezević, time is both creative and destructive. Through evolution, time created the enormous diversity of organisms on this planet, as well as life forms and intelligent beings on other worlds. Through devolution, time will destroy all life among the galaxies. Knezević also envisioned all other planets, galaxies, and entire universes passing through such a semicircular history. Collectively, all these semicircular histories represent God as an infinite series of creations and destructions within the endless flux of cosmic reality. Only matter itself endures throughout time, while time creates and destroys all objects and events in a process that is both unending and beyond human comprehension.

H. James Birx

See also Cosmology, Cyclic; Darwin, Charles; Evolution, Organic; Extinction; Extinction and Evolution; Materialism; Spencer, Herbert; Time, Cyclical

Further Readings

Birx, H. J. (1982). Knezević and Teilhard de Chardin: Two visions of cosmic evolution. *Serbian Studies 1*(4), 53–63.

Knezević, B. (1980). *History: The anatomy of time (the final phase of sunlight)*. New York: Philosophical Library.

Kronos

See Cronus (Kronos)

Kropotkin, Peter (1842–1921)

Peter (Pytor) Alekeyevich Kropotkin, born in Moscow into the Russian aristocracy, was a geographer, revolutionary anarchist, libertarian communist, zoologist, anthropologist, economist, philosopher, and sociologist. His writings were published in several languages and widely discussed, exerting considerable influence, especially among political thinkers and activists of the period preceding the Russian Revolution of 1918.

In the course of his geographic work Kropotkin demonstrated that eastern Siberia was affected by post-Pliocene continental glaciations. As a result of his animal life studies, Kropotkin theorized that mutual aid was the key to understanding human evolution, contrary to the notion of the natural world as shaped entirely by ruthless competition. He suggested that science and morality must be united in the "revolutionary project." Education should be global and humanistic and should empower everyone equally. Children should learn not only in the classroom, but also in nature and in living communities. To him, education and science should be based upon mutual aid and serve as a revolutionary activism with which to transform the entire world. This was not only morally correct, but the only life worth living.

Evolution is influenced and shaped by adaptation to a changing environment and adverse circumstances. Among many animal societies, competition between individuals, though important, is secondary to intraspecies cooperation in the survival of the species. Adaptation to the environment and the struggle against adverse conditions lead to an evolutionary theme, resulting in individuals working in partnership to protect their offspring.

In the animal world, most animals live in societies. Kropotkin felt that the survival strategy of safety was a concept that needed closer examination. This was not just a struggle for existence but a protection from all natural conditions that any species may face. Each individual increases its chances by being a member of a group. Mutual protection allows certain individuals to attain old age and experience. Among humans, these collective groups allowed for the evolution of culture. In the earliest band societies, social institutions were highly developed. In later evolution of clans and tribes, these institutions were expanded to include larger groups. Chiefdoms and state societies shared mutual identities in groups so large that an individual did not know all members. The idea of common defense of a territory and the shared character of nationalism appeared in the growth of the group sharing a collective distinctiveness.

Solidarity gives the species as a whole a better opportunity to survive. Thus, supportive attention for the well-being of relationships of the group is selected for. The manipulative and sly individuals are cleansed from the pool of ancestors, and those most supportive of mutual social life are selected to survive. Along with this, safety in numbers allows for increased chances of survival. Cooperation increases chances of an intelligent response to a threat to the group or the offspring by a coordinated effort. Be it hunters in a pack or herbivores cooperating, these efforts develop social skills and an awareness of comrades. The needs of the progeny and for continued existence bring together groups for reproduction and protection of the young. Because of this, security of all individuals is enhanced through mutual aid.

Ethics are thus a part of natural evolution. The strongest section of social companionship, which is the attraction of all major religions, is learned through the observation of nature. As animal behavior becomes more complex, association becomes less instinctual and more learned. Conscious awareness of the needs of others becomes increasingly important to the survival of the group and all its members. Communication becomes central to sociability. Vocal communication, exchange of ideas, and replication all help to teach collected knowledge to other individuals. Being companionable is an adaptation to the environment, and struggle and friendliness are the main foundations of evolution.

Through cooperation, less energy is expended for gathering food or fighting off danger. Cooperation, observed Kropotkin, favors the evolution of intelligence. Moreover, social feelings are central to development of societies, justice is part of the natural world, and ethics have a biological origin. The struggle for survival most often has a collective origin.

Carrying capacity determines population density, not by the most favorable circumstances but by the most server-limiting factors. Competition between individuals adds little to the survival of the species. Species become extinct not because they kill each other off but because they fail to adapt to a changing environment. Intraspecies competition is secondary.

According to Kropotkin, peace and reciprocal support are the rule within the group. Because societies or bands were the first social organizations in human evolution, they are the origin of consciousness, the source of social conscience, the innovators of ethics, the originators of the best of religion, gods, and our humanity. The sharing of resources necessary for life precedes all other systems of distribution. Reciprocity is the foundation of our common identity; the community precedes the individual. The life of the community becomes the validation for the life of the individual. Self-sacrifice in all major truth-seeking or sacred systems is the source of the greatest joy for the individual.

Sympathy and self-sacrifice are positively vital to human shared advantage for improvement. Sense of suitability versus hard-heartedness is the starting point of human unity. Mutual aid everywhere can be seen as the dawn of the human spirit and the soul of our humanity. The quest for power is also part of the human condition. With intelligence, conscience needs to be learned. The will to power and the quest for wealth by individuals everywhere undermines community and solidarity. Democratic communism is replaced by a stratified society based upon coercion, exploitation, and oppression. Popular democratic uprisings are as old as class society.

Social instincts are based on the pleasure of companionship; the collaboration of others is the primary basis of ethics. Compassion is the starting point of public service. The public good is expressed in the dialogue of mutual aid. The guide to action is always moral self-control and reciprocal support.

Kropotkin begins by asking the origin and meaning of social ethics. To him, exploitation is caused by unacceptable wealth based upon the poverty of others and is intolerable. Poverty is the direct result of wealth. It is the poor who support the rich through their hard work. This planet has the capacity to feed, clothe, and house every human comfortably. But, the problem must be attacked. It is important to know what is possible and to understand the right thing to do. Where science and ethics come together is the realm of sociology (anthropology).

Freedom and necessity join, and agency becomes action founded upon information. Liberty, based upon knowledge of the essential principles of nature, is the source of sovereignty. Needs and determinism are the sources of free will; people have true choices only if they have the proper knowledge of how to act to lessen unexpected consequences.

In Kropotkin's view, ethics ultimately does lead to fulfillment, for satisfaction comes from the abandonment of exploitation and oppression. Harmony between the individual and the community is this instinct of sociality. Through imagination, we are able to feel what we have never experienced and identify with the joys and sorrows of others. This strengthens our individual identity by morally connecting us with others. Individual initiative grows out of belonging to a community. Each unique individual works together as part of a group to develop strategies for the welfare of all. This is the starting place for the expansion of the individual personality. Moral courage is the first step to overcome passivity—breaking with the narrow philosophies and religions of the past. Fulfillment comes through mutual aid and egalitarian self-restraint. Conversely, economic individualism and personal salvation are the bedrock of narcissism and existential isolation.

Michael Joseph Francisconi

See also Darwin, Charles; Ethics; Evolution, Organic; Humanism; Marx, Karl; Materialism; Morality

Further Readings

Kropotkin, P. (1967). *Memoirs of a revolutionist.* Gloucester, MA: Peter Smith.

Kropotkin, P. (1967). *Mutual aid.* Boston: Extending Horizons.

Kropotkin, P. (1968). *Ethics: Origin and development.* London: Benjamin Blom.

Kropotkin, P. (1968). *Fields, factories and workshops tomorrow.* London: Benjamin Blom.

Kropotkin, P. (1970). *Revolutionary pamphlets.* New York: Dover.

Kropotkin, P. (1989). *The conquest of bread.* Montreal, QC, Canada: Black Rose Books.
Woodcock, G. (1971). *The anarchist prince: Peter Kropotkin.* New York: Schocken.

K-T Boundary

The Cretaceous-Paleogene (K-Pg) boundary, dated about 65 million years ago, marks the base of the Paleogene period and consequently of the Cenozoic era. ("K" is traditionally used as an abbreviation for the Cretaceous period (from the German term *Kreide*) in order to avoid confusion with the abbreviation "C" of the Cenomanian epoch and the abbreviation "C-T" of the Cenomanian-Turonian boundary.) It is more popularly known as Cretaceous-Tertiary (K-T) boundary, but the term *Tertiary* has become informal and is not used in the geologic timescale. From the chronostratigraphic point of view, the K-T (or K-Pg) boundary was formally defined at the base of a dark clay bed at the El Kef stratotypic section (Tunisia). This bed is commonly called the *K-T boundary clay,* and its basal part is characterized by a millimeter-thick reddish layer, called *K-T airfall layer,* containing meteoritic impact evidence such as anomalous-concentrated iridium, siderophile trace elements in chondritic proportions, microdiamonds, nickel-rich spinels, shocked quartz, and altered microtektites.

The K-Pg or K-T boundary is widely known, because it represents one of the five major mass extinction events recorded in the earth's history, which affected the most famous paleontological group, the dinosaurs. However, the dinosaurs were not the only victims of this biotic catastrophe. It is considered that 75% to 80% of then extant species were extinguished; this included the total extinction of dinosaurs (*Tyrannosaurus, Triceratops,* and *Ankylosaurus* among others), plesiosaurs, mosasaurs, ichthyosaurs, primitive birds (*Enantiornithes, Hesperornithiformes*), ammonites, belemnites, rudists, and orbitoid foraminifers. Many other groups were severely affected, such as mammals (~80% extinguished), osteichthian fishes (~96%), nautiloids (~50%), gastropods (~80%), bivalves (~60%), brachiopods (~70%), scleractinian corals (~80%), thermospheric ostracods (~75%), planktic foraminifers (~96%), radiolarians (~85%) and calcareous nannofossils (~75%). Marsupial mammals became extinct except for those in Australia and South America. Remarkably, insects, amphibians, lepidosaurs (lizards, snakes, etc.), crocodilians, turtles, and insectivore mammals and birds were not very affected by the K-T extinction. Moreover, although their populations were initially decimated, many species of terrestrial plants and of marine phytoplankton (diatoms or dinoflagellates) also tended to survive, due surely to their capacity to form resistant cysts, spores, or seeds.

The K-T extinction was therefore selective, with a species' survival depending on its position in the food chains. In the open ocean, the food chain is and was based on the microscopic phytoplankton (unicellular algae), such as coccolitophorids (calcareous nannoplankton), dinoflagellates, or diatoms. The marine protozoons and animals at successively higher levels in this food chain (phytoplanktivorous and carnivorous) were very strongly affected (planktic foraminifers, ammonites, carnivorous fishes, and marine reptiles such as plesiosaurs, mosasaurs, and ichthyosaurs). However, those animals whose diet was suspensivorous or detritivorous—or those who lived on these—tended to survive, at least partially (e.g., benthic foraminifers and many bivalves, bryozoans, brachiopods, and fishes). In the terrestrial environment, the food chain is and was based on plants, so the herbivorous and carnivorous animals directly or indirectly dependent on this vegetation—all dinosaurs and many birds and mammals—became extinct. On the contrary, those terrestrial animals whose diet was detritivorous (e.g., insects), who were potentially scavengers (e.g., cocodilians, turtles) or insectivorous (ancestral mammals and many birds, amphibians and lepidosaurs) tended to survive.

The most widely accepted theory for explaining the K-T mass extinction event is the meteoritic impact theory proposed by Luis Alvarez (1968 Nobel Prize winner in physics), Walter Alvarez, Frank Asaro, and Helen Michels in 1980. They discovered a reddish-greenish sedimentary layer at Gubbio (Italy) that marked the boundary between Cretaceous and Tertiary sediments, and it contained an anomalous concentration of iridium—hundreds of times grater than normal. Iridium is extremely rare in the earth's crust but abundant in chondritic and iron meteorites. For this reason, Alvarez's team proposed that a collision with a large asteroid (about 10 kilometers in diameter) caused the K-T extinction event 65 million years ago and the deposition of the reddish-greenish layer or airfall layer at Gubbio. Almost at the same time that Alvarez's team proposed this collision, Jan Smit suggested the same theory after studying the Caravaca section (Spain), which was a more expanded and continuous section than that at Gubbio. He proved that the airfall layer coincides with the largest, most sudden planktic foraminiferal mass extinction in evolutionary history, suggesting a clear relation of cause and effect between the impact event and the K-T catastrophic mass extinction. Since then similar airfall layers have been found at sections worldwide, such as the El Kef section, suggesting the totality of the K-T event.

The discovery of the ~180-kilometer-diameter Chicxulub crater on the northern Yucatan Peninsula (Mexico) supported strongly the Alvarez group's theory, because such a crater was coincident in age with the K-T boundary and has just the size to have been formed by the predicted 10-kilometer-diameter meteorite. In addition, strange and thick K-T clastic sediments were discovered around the entire Gulf of Mexico, suggesting the destabilization of continental margins in the region as result of giant tsunamis and earthquakes generated from the impact point at Yucatan.

Most geologists and paleontologists agree with Alvarez's impact theory, although alternative scenarios have been suggested for explaining the K-T extinction. They include sea-level regressions, increases of the volcanic activity linked to the Deccan Traps (an extensive basalt province in India), or multiple causes, that is, all the aforementioned causes operating at the same time. However, these hypotheses have not been accepted by the geologic and paleontologic communities, because they would be more compatible with uncorroborated gradual extinction patterns occurring hundreds of thousands of years before and after the K-T boundary.

According to Alvarez's theory, the impact raised a vast dust cloud of fine ejecta in the atmosphere and triggered global firestorms due to the fall of incandescent melted fragments worldwide (tektites and microtektites). The dust and soot cloud generated a global atmospheric darkening, sudden climatic cooling and acid rain, a phenomenon known as "impact winter" (similar to a nuclear winter). The blockout of sunlight caused the cessation of all photosynthesis and the severe disruption of food chains, initiating the catastrophic mass extinction event at the K-T boundary. The dust and fine ejecta that covered the atmosphere after the Chicxulub impact were deposited slowly, probably over months or a few years, forming the K-T airfall layer worldwide.

Atmospheric carbon dioxide content increased rapidly as result of the emissions from the impact site and the widespread fires as well as the temporary cessation of photosynthesis and primary productivity. After the dust cloud settled, the high concentration of carbon dioxide initiated a greenhouse effect period that lasted about 10,000 or 15,000 years. The K-T boundary clay was deposited during this period of global decrease in primary productivity and of increased greenhouse effect after the impact winter. All postimpact paleoenvironmental aftermaths of longer term (decrease in primary productivity, low biodiversity, greenhouse effect, disruption in the water column stratification, etc.) have been recorded in the K-T boundary clay worldwide. Only the most cosmopolitan, generalist, and opportunistic species were able to survive the environmental damage of both the impact winter and greenhouse effect periods.

Terrestrial plants and marine phytoplankton, and consequently primary productivity, recovered progressively over thousands of years, reestablishing the food chains and decreasing the concentration of carbon dioxide in the atmosphere. Many niches remained vacant after the K-T mass extinction, so the opportunistic surviving species began to occupy them. Small and new marine and land species appeared in the earliest Tertiary, following a model of "explosive" adaptive radiation. For instance, mammals diversified, evolving from the small insectivorous mammals that had survived the K-T event and becoming dominant on land. Similar adaptive radiations occurred in other marine and terrestrial groups. Thanks to the K-T extinction of the dinosaurs, the mammal groups could diversify during the Tertiary, including those that formed the evolutionary lineage of the primates that culminated with the appearance of the species *Homo sapiens*.

Ignacio Arenillas

See also Chicxulub Crater; Cretaceous; Dinosaurs; Evolution, Organic; Extinction, Mass; Foraminifers; Fossil Record; Geologic Timescale; Geology; Nuclear Winter; Paleogene; Paleontology; Permian Extinction

Further Readings

Alvarez, L. W., Alvarez, W., Asaro, F., & Michel, H.V. (1980). Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science, 208,* 1095–1108.

Alvarez, W. (1997). *T. rex and the crater of doom.* Princeton, NJ: Princeton University Press.

Ryder, G., Fastowsky, D., & Gartner, S. (Eds.). (1996). *The Cretaceous-Tertiary event and other catastrophes in Earth history.* Geological Society of America Special Paper 307. Boulder, CO: Geological Society of America.

Smit, J., & Hertogen, J. (1980). An extraterrestrial event at the Cretaceous-Tertiary boundary. *Nature, 285,* 198–200.

Kuhn, Thomas S. (1922–1996)

Thomas S. Kuhn is recognized as one of the foremost historians of science to have emerged in the 20th century. He is credited with a controversial approach to understanding scientific development, one that emphasizes rare but significant revolutions that challenge and even overthrow traditional ways of observing the world. Such revolutions, he claimed, change our views so profoundly that it may be unreasonable to compare theories that originated in different times. It is unfair, for example, to judge the writings of Aristotle (384–322 BCE) according to the standards of proof required today, not only because Aristotle could not have been aware of the scientific discoveries since his time, but also because the ancient Greeks understood worldly phenomena according to a different set of guiding principles. The scientific revolutions of more than 2000 years have rendered our perspectives beyond comparison; Kuhn calls this the "incommensurability thesis."

Paradigm Shifts

Kuhn studied physics at Harvard before teaching the philosophy of science at a variety of schools (most recently Princeton and MIT). His book *The Structure of Scientific Revolutions* (1962) inspired intense controversy by calling attention to the limitations of accepted scientific methodology. Kuhn wrote that science, or rather scientists, proceed through time operating according to a collection of accepted theories. There are few challenges to these theories, because they are assumed to reveal truths about the world. Because the scientific method has already exhaustively tested such explanations, any new work by scientists is expected to conform to accepted laws and principles. Occasionally, however, the conventional knowledge base is unable to answer a particular problem, or worse, it is at odds with a new theory or observation. When a solution emerges that resolves such a crisis by overthrowing previously accepted elements of scientific knowledge, then what Kuhn calls a *revolution* has occurred.

The term *paradigm shift* originated with Kuhn's vision of a scientific revolution that interrupts the normal thought paradigm. The traditional view of science presumes continual progress as advancements contribute to an ever-growing base of knowledge. When theories are revised and formerly held principles abandoned, then science simply has witnessed a correction that brings us closer to an underlying truth. Kuhn rejected this traditional view. Instead, he claimed that there are long periods with negligible progress, what he called *normal science* (operating within conventional knowledge) that are occasionally punctuated by revolutions. There *is* monumental progress in science, Kuhn would claim, but only through the process of alternating eras: convention, revolution, convention, revolution, etc.

Scientists might pursue monumental innovations (e.g., inventions, discoveries, cures for diseases), but they are held back, Kuhn claimed, by the prevailing wisdom of the time. In other words, the tendency is to think *inside* the box. This urge for innovation, restrained by conventional thinking, Kuhn referred to as *the essential tension.* In his view, revolutions are not actively sought. Instead, changes in thinking occur as a matter of necessity when accepted principles are replaced by the new paradigm. Advancement has less to do with individual accomplishments than with new modes of thinking that are so profound that they render obsolete some aspect of the former status quo. If science consists of games or puzzles, then there are familiar rules under which we attempt to solve problems. A true paradigm shift introduces not just a new puzzle to be solved, but new directions for answering old questions. The new theory not only resolves some inadequacies of past thinking, but also launches a new set of problems and guidelines for proceeding. Kuhn was not suggesting that individuals strive to overthrow established consensus. Rather, he was describing a cycle of convention, crisis, revolution, and new convention.

Evolutionary Science

To Kuhn, this theory was not just for the history and evolution of frameworks in science; science itself is evolutionary. When science meets with the hostile environment of an unsolvable problem, adjustments are made to address the challenge. In the traditional view of science, competing theories battle against one another; through the trial and error of the scientific method, the strongest theory emerges victorious and progress is claimed. For Kuhn, however, the competition pits the existing body of scientific knowledge against conflicting ideas; challenges to the standard way of thinking are discredited by conventional scientists, because their operating principles are regarded as truths. If a sufficient number of scientists present the same new idea over time, or especially if a new idea successfully resolves a major problem that has plagued science for a very long time, then that new idea might be paradigm shifting.

In embracing the revolution, the evolutionary change is dramatic. Where traditional science would (reluctantly) accept new information as an addition to the growing body of knowledge, however, Kuhn emphasized that some old theories, instead, are discarded to make way for the new. In organic evolution, fins are replaced with limbs, not augmented by them; it is absurd to imagine a creature that collects and maintains every feature its ancestors have ever possessed (the platypus notwithstanding). To continue the analogy, Kuhn saw revolutionary science as changing significantly enough that appendages are no longer recognizable. Traditional science, like Darwin's original conception of evolution, envisioned a series of continual changes over time. To recognize biological evolution as a series of periodic responses to catastrophes, however, is more akin to Kuhn's vision: Scientific revolutions are reactions to intellectual crisis, but they are rare.

The conventional view of science, according to Kuhn, is mistakenly teleological; it presumes that scientific inquiry is progressing toward a particular goal. The principles originally developed through the observation of patterns in nature have been elevated to such esteem that they are taken as truths about the world or, in any case, as steps toward eventually knowing an objective and unchanging Truth. Just as evolutionary adjustments might be arbitrary, though, responding as they do to challenges posed by the external environment, in Kuhn's view scientific advancement is vulnerable to sociological influence. History has shown that political bias sometimes keeps science at bay: Followers of Copernicus were convicted of heresy for daring to support his theory of heliocentrism (e.g., Giordano Bruno was burned at the stake; Galileo Galilei was placed under house arrest). Indian astronomers as early as the 7th century BCE (and ancient Greeks 300 years later) had believed the earth to rotate around the sun, yet religious influence prevented acceptance for centuries. Like the Connecticut Yankee, regarded as a magician for his demonstrations in King Arthur's court, scientific knowledge is contingent upon a particular era in time.

Kuhn's view of the history of science recognizes that what passes for "knowledge" is subject to revision and conventional science restricted by its own parameters. The scientific timeline is neither static nor perpetually expanding as we endlessly acquire new knowledge. Paradigm shifts are so radical it is inappropriate to hold theories from one era to the standards of another. According to Kuhn, true scientific advancement replaces obsolete principles with new ways of thinking that revolutionize our view of the world.

Elisa Ruhl

See also Aquinas and Augustine; Aristotle and Plato; Bruno and Nicholas of Cusa; Copernicus, Nicolaus; Darwin and Aristotle; Einstein and Newton; Galilei, Galileo; Hegel and Kant; Nietzsche and Heraclitus

Further Readings

Fuller, S. (2000). *Thomas Kuhn: A philosophical history for our times.* Chicago: University of Chicago Press.

Horwich, P. (Ed.). (1993). *World changes: Thomas Kuhn and the nature of science.* Cambridge: MIT Press.

Kuhn, T. (1959). The essential tension: Tradition and innovation in scientific research. In E. C. Taylor (Ed.). *The third (1959) University of Utah Research Conference on the Identification of Scientific Talent* (pp. 162–174). Salt Lake City: University of Utah Press.

Kuhn, T. (1962). *The structure of scientific revolutions.* Chicago: University of Chicago Press.

L

La Brea Tar Pits

The La Brea Tar Pits, or Rancho La Brea, are a famous group of tar pits located in Hancock Park in the heart of downtown Los Angeles, California. This location contains one of the richest and best preserved assemblages of fossilized Pleistocene life in the world. The plant and animal remains found represent hundreds of species that populated southern California from almost 40,000 to 10,000 years ago. Rancho La Brea provides a wealth of information on life during the most recent ice age.

Tar pits form in places where crude oil seeps to the surface of the earth through cracks in the bedrock. A portion of the oil evaporates, leaving thick, viscous pools of asphalt behind. Local natives used this resource for thousands of years to waterproof baskets and canoes. As Caucasian settlers moved into the area, the tar was collected and used for roofing in the nearby town of Pueblo de Nuestra Señora la Reina de los Angeles.

A family named Hancock owned and worked a 4,400-acre ranch that encompassed the tar pits in the late 1800s and continued to mine the pits for tar to use as a sealant. Occasional bones unearthed were assumed to be those of cattle that strayed, got stuck in the tar, and perished. Eventually paleontologists heard about the bones and performed the first scientific excavation in 1901. Work intensified as the number of finds increased. From 1913 to 1915, digging at over 100 pits produced more than 1 million bones. In 1924, businessman G. Allan Hancock donated the 23-acre plot containing most of the tar pits to Los Angeles County. Early excavators tended to keep only the large, complete bones for museum display. When digging resumed in 1969, more care was taken in cleaning and analyzing over 40,000 additional specimens retrieved.

Tallying and cataloging the bone and plant remains provided insight into the activity around the tar pits so long ago. Wood, plant, and pollen remnants illustrate a cooler and wetter environment than exists today. The park is best known for the large mammals found in the pits, including mammoths, camels, sabertooth cats, dire wolves, and giant ground sloths, but many other species have been revealed. Since excavations at Rancho La Brea began, evidence of more than 650 species has been recovered: 231 vertebrates, 159 plants, and 234 invertebrates. More than 95% of the mammal bones found belong to only seven species. Four were carnivores: the dire wolf, the sabertooth cat, the coyote, and the North American lion, and three were herbivores: the ground sloth, the bison, and the western horse. The most common bones found are those of the dire wolves, with over 2,000 sabertooth cat specimens ranking second. Of the mammals found, 80% were predators, and 60% of the birds were birds of prey. These percentages reflect the exact opposite of what you would expect to find in the wild.

In a stable ecosystem, herbivores always outnumber carnivores by about 10 to 1. The leading theory to explain this discrepancy is called *entrapment.* Asphalt is very sticky, especially when it is warm. Only one inch of this tar can hold a horse or cow until it dies of starvation or exposure. In dry weather, dust can blow across the surface, making the ground appear solid. A trapped animal thrashing around trying to escape would attract the attention of many predators. In attacking the prey, some of the attackers would also get stuck, providing additional food for other carnivores. This cycle repeated for 30,000 years to create the accumulation seen at Rancho La Brea today. Although the collection seems to represent a huge number of animals, it averages out to one herbivore being trapped every decade, and several scavengers attempting to retrieve the meat and joining their prey.

Although thousands of individual animals have been found in La Brea, only one human skeleton has been discovered. The skull and partial skeleton of a Native American woman was recovered in 1914. She was in her early 20s when she appears to have been killed by a blow to the head. Her bones have been dated to about 9,000 years ago.

The La Brea Tar Pits provide a treasure trove of information about life during the late Pleistocene. While studying the bone collection reveals information about ancient food chains, the sophisticated chemical tests available today reveal a surprising amount of detail about how animals became trapped in the tar pits and what happened to them in their final hours of life. The Page Museum in Hancock Park opened in 1977 to house the heritage of over 1 million specimens recovered from the tar. The museum features more than 30 exhibits of reconstructed skeletons and robotic sculptures, a glass-walled working laboratory where visitors can watch the curators work, hands-on displays, films, and many wall murals. Rancho La Brea sheds light on a fascinating time period when glaciers last covered much of the hemisphere.

Jill M. Church

See also Dating Techniques; Extinction and Evolution; Fossil Record; Fossils, Interpretations of; Museums; Paleontology

Further Readings

Harris, J. M., & Jefferson, G. T. (1985). *Rancho La Brea: Treasures of the tar pits.* Los Angeles: Los Angeles County Museum.

Perkins, S. (2004). L.A.'s oldest tourist trap. *Science News, 165,* 56–58.

Stock, C., & Harris, J. M. (1992). *Rancho La Brea: A record of Pleistocene life in California.* Los Angeles: Los Angeles County Museum.

Laetoli Footprints

In 1976, a trail of fossilized hominid tracks was found in Laetoli, Tanzania. These footprints were determined to be at least 3.6 million years old, and some of the earliest evidence ever found to illustrate upright, bipedal walking in early hominids. Thanks to a chance series of events including a volcanic eruption, a light rainfall, and a second deposit of ash, scientists today can observe firsthand the preservation of a specific moment in prehistoric time.

Laetoli was first surveyed by anthropologists in 1935, when Louis S. B. Leakey and his wife Mary D. Leakey evaluated the area. They were excavating at Olduvai Gorge 2 days to the north when Maasai tribesmen told them there were many bones at Laetoli. The team investigated when the Olduvai season ended. After making a few scattered, fragmented finds, they left. Later, during the 1938–1939 season, a German team surveyed the Laetoli area. The Leakeys returned a couple of more times, with few results. In 1974, Mary Leakey found better preserved hominid remains, resulting in a more systematic evaluation of the area. One night in 1976, team member Andrew Hill was joking around with colleagues, throwing dried elephant dung in a mock battle. As Hill ducked to avoid a hit, he noted what appeared to be animal prints preserved in the exposed volcanic tuff. Further investigation revealed a trail of hominid footprints.

The majority of the Laetoli footprint site was excavated in 1978. The exposed trail is about 80 feet long. The prints are distinctively different in size and in two parallel tracks. Despite the size disparity, the strides are the same length, indicating that the two hominids were walking together and compensating to match their strides. Scientists have disagreed as to whether the tracks represent two or three individuals. The smaller prints in the westernmost trail have sharp, clear impressions. The larger prints are blurred and more indistinct. Some argue that a third hominid was walking in the prints made by the larger individual, while others claim the larger, heavier hominid was simply sliding more in the wet ash. The footprints are almost indistinguishable from those of modern humans except for their small size. They have a deep heel impression, a distinct arch, and push off from the toes at the end of the stride. The big toe is in line with the other toes like the toes of a modern human, rather than being an opposing toe like that of a chimpanzee.

Regardless of whether the prints were made by two or three hominids, the importance of this find cannot be overstated. It is, literally, rock-solid proof that early hominids were bipedal long before large brains evolved and stone tools were used. The only hominid fossils found at Laetoli belong to *Australopithecus afarensis,* indicating that individuals of this species made the trail. Despite years of searching, no stone tools have been found in the Laetoli beds, indicating for now that hominids had not yet developed into the toolmaking stage.

Study and debate about the Laetoli footprints is ongoing, but no one can deny the uniqueness of this find. Approximately 3.6 million years ago, the Laetoli area was savanna that supported a varied animal population. At the beginning of a rainy season, Sadiman, a volcano to the east, erupted. The shower of ash was not severe enough to drive the animals away. The season brought intermittent showers, turning the ash to a fine mud that the local fauna continued to walk through. Several times over the course of a few weeks additional light layers of ash covered the area. The scattered rains continued to make a mud that left distinct impressions. Finally a heavy ash fall buried the area deeply, protecting the Footprint Tuff from erosion. Over time, the ash cemented and became rock. Weathering eventually brought the Footprint Tuff layer to the surface again, giving modern man a unique view of a specific event in the life of early hominids. A brief moment in prehistoric time has been preserved.

Jill M. Church

See also Anthropology; Dating Techniques; Evolution, Organic; Fossils, Interpretations of; Olduvai Gorge; Paleontology

Further Readings

Hay, R. L., & Leakey, M. D. (1982). Fossil footprints of Laetoli. *Scientific American, 246,* 50–57.

Leakey, M. D., & Harris, J. M. (Eds.). (1987). *Laetoli: A Pliocene site in northern Tanzania.* Oxford, UK: Clarendon.

Stringer, C., & Andrews, P. (2005). *The complete world of human evolution.* New York: Thames & Hudson.

Lamarck, Jean-Baptiste de (1744–1829)

During the latter half of the 18th century, a handful of science-oriented enlightened thinkers took time and change seriously; they saw history in terms of process and progress. Jean-Baptiste de Lamarck extended this perspective to become the first serious evolutionist. He argued for the mutability of animal species over vast periods of time, in an age when most other naturalists still maintained the fixity of life forms on a planet held to be only several thousand years old. As an invertebrate paleontologist, he took the fossil record in the geological column as empirical evidence demonstrating the evolution of species, into life forms of increasing complexity and greater perfection, as seen in their preservation up through the rock strata. Lamarck presented this controversial view of organic history in his major work, *Zoological Philosophy* (1809).

Lamarck's evolutionary interpretation of life was in sharp contrast to the one offered by the contemporary vertebrate paleontologist Georges Cuvier, who held that the fossil record (with its gaps) represented a history of periodic creations and extinctions. Cuvier's vision suggested a series of divine creations, each special creation eventually followed by worldwide extinction due to a planetwide catastrophe. Thus, Cuvier was not an evolutionist. However, Lamarck saw the biological continuity of species (without any extinctions) throughout organic history. Because evolution challenged the entrenched beliefs in the biblical story of Creation in the Book of Genesis, with its 6 days of Creation, religious naturalists were not open to Lamarck's new worldview, despite those ongoing discoveries in geology and paleontology that clearly supported an ancient earth and the mutability of species on it, respectively.

Lamarck held that spontaneous generation would explain the sudden appearance of the first forms of life on earth. But, the fossil evidence to the contrary, he needed to account for the evolution of species over considerable time. Lamarck offered two explanatory mechanisms: the inheritance of acquired characteristics through use and disuse, and a form of vitalism that manifested itself only in complex animals. Lamarck's famous but now notorious example to demonstrate his first explanation involves the evolutionary history of the giraffe. He held that, eons ago, short-necked giraffes fed on the leaves of eye-level trees. Over time, these trees continuously became taller. Consequently, in order to reach and eat the ever-higher leaves, the giraffes needed to constantly stretch their necks. This acquired characteristic of a longer neck (due to continuous stretching) was inherited by the offspring over numerous generations. The ongoing accumulation of this useful and specific characteristic has resulted in the long-necked giraffe of modern times.

Furthermore, Lamarck speculated that complex animals with consciousness could actually will those characteristics (structures and functions) that they needed or desired in order to adapt to, and survive in, changing environments; he even thought that, through willing, new organs and behavior patterns could emerge over time. Not surprisingly, because of a lack of convincing experimental evidence, naturalists have not accepted as true Lamarck's two explanatory mechanisms for the evolution of life on this planet.

Concerning the origin of our own species, Lamarck boldly claimed that the human animal had emerged from an orangutan-like primate somewhere in Asia. Through slow evolution, he maintained, our human species gradually acquired those mental faculties and biological characteristics it has today. Moreover, Lamarck argued that humans differ from the living apes and monkeys merely in degree rather than in kind; the superiority of human reason is grounded in the larger and more complex brain of our species. However, the present fossil record points to Africa as the cradle of humankind. Even so, modern primatology does clearly demonstrate the striking similarities between the human animal and the great apes.

Lamarck died blind and poor, unaccepted and unappreciated by most of the naturalists of his time. Nevertheless, he was a significant link between the ideas of earlier natural philosophers, who held to the fixity of species, and those pivotal scientific writings of Charles Darwin that presented the mutability of life forms in terms of organic evolution by natural selection. In fact, Darwin's *On the Origin of Species* (1859) appeared exactly 50 years after the publication of Lamarck's *Philosophy of Zoology* (1809).

H. James Birx

See also Darwin, Charles; Evolution, Organic; Haeckel, Ernst; Huxley, Thomas Henry; Lysenko, Trofim D.; Spencer, Herbert

Further Readings

Birx, H. J. (1984). *Theories of evolution.* Springfield, IL: Charles C Thomas.

Lamarck, J.-B. (1984). *Zoological philosophy: An exposition with regard to the natural history of animals.* Chicago: University of Chicago Press. (Original work published 1809)

Packard, A. (1980). *Lamarck: The founder of evolution—His life and work.* North Stratford, NH: Ayer.

Language

> We look back at the thoughts of our predecessors, and find we can see only as far as language lets us see. We look forward in time, and find we can plan only through language. We look outward in space, and send symbols of communication along with our spacecraft, to explain who we are, in case there is anyone who wants to know. (David Crystal)

Among the most popular areas of study that involve explorations to characterize humankind is the study of language. Throughout history, individuals have been fascinated about how language works and even more by the unique characteristics of each language as well as the common ones among the languages of the world. The phonology of different languages is especially interesting to some researchers; others are intrigued by grammar and morphology that show similarities in structure among languages. Some find great satisfaction in studying expressions of idiom, metaphor, and humor; others look to how societies function and get along as they adjust their language use for communicating in specific environments (e.g., formal or casual). Whatever the intentions or goals of those who study language, that this field of endeavor has endured for thousands of years attests to the changing nature of language over time, wherein there is always something new on the horizon to try to understand.

Definitions of Language

Although there are some distinct characteristics that are used to identify languages (e.g., phonology, grammar), definitions of *language* and *languages* vary among scholars depending upon their particular curiosity and the questions for which they want to find answers. Joel Davis comments that there is somewhat of a dilemma for linguists to capture all of the characteristics into one definition. How does one describe language incorporating the terms of the language he or she uses? It is like defining a word by using that word in the definition. Thus, many researchers attempt to compare human languages in order to find common components and to identify differences, hoping such pursuits will add to the specificity of the term. Language definition is somewhat like trying to hit a slowly moving target, because there are many factors of language that gradually change as societies change. Abram de Swaan proposes that a language may be defined by the capacity of any two speakers to understand each other and incidentally notes that the variety and complexity of languages is such as to be comparable to that of life itself.

Studies about language can be separated from studies about the history of humankind only by an imaginary line that has to be crossed quite regularly. Definitions of language have to allow for distinctions that influence it from other areas of human evolution, such as the development of communities, trade, music, and art (in themselves kinds of language).

The Generative Nature of Language

If one were to converse with thoughtful individuals about their native tongues, one would probably find out that they agree that their own language is not static but rather is creative and permits new and adapted forms of words and expressions as the times require them. As societies and communities progress and as educational opportunities grow, so does the mother tongue. But, in some cases where there is little progress, languages become endangered and sometimes extinct. Technological terms, for example, not occurring in the first few decades of the 20th century are now part of many languages of the world: the word *computer,* for example, appears in French as *l'ordinateur,* in Japanese as *keisanki,* and in Maori as *rorohiko*. Contrastively, languages among hunter-gatherer tribes in Africa, as explained by Lenore Grenoble and Lindsay Whaley, are more threatened by extinction than those spoken by groups that are involved in socioeconomic reorganization and growth.

Spoken Language Over Time

Linguists recognize that amidst the intricate web of factors involved in language change, modifications in sounds and vocabulary seem to lead the other stages, particularly grammar, even though the total process may be extremely slow, occurring sometimes over centuries. John McWhorter discusses how the "erosion" of sounds over time leads to the development of new words, or even of new languages. Consider, for example, McWhorter's description of the movement from the Latin word for woman, *femina* (FEH-mee-nah) to *femme* (FAHM) in French. The accented syllable in the Latin word for woman remained, while the other two weak syllables eventually disappeared. Latin evolved into several new languages, including French, and although it is no longer a spoken language, Latin endures in written form.

Throughout human history, individuals have modified their indigenous languages and have created new words and expressions. For example, William Shakespeare (1564–1616) left an enduring influence on the English language with hundreds of words commonly used today that he created by using nouns as verbs, using verbs as adjectives, and adding prefixes and suffixes (e.g., *countless, bet, laughable, excitement, torture)*. Words are also coined or invented when there is a need for new ones. Among his many malapropisms, U.S. President Warren G. Harding's *normalcy* (for *normality*) continues in common American English usage today. Some novel words endure, and others disappear (e.g., *defidate,* to pollute, circa 1669; *yuppie,* attributed to Bob Greene of the *Chicago Tribune; guillotine,* renamed for Dr. Guillotine who urged the machine's use in the French Revolution).

Language Mixtures

Although the grammars of spoken languages are rather stable, bound by rules, and slow to change, they may be affected by the incorporation of new expressions, especially in those societies whose members may have come from nations with different mother tongues. Such is the case in the United States, considering the large waves of immigration from the mid-1800s to the 1920s. As first and second generation children of immigrants from Western Europe and Asia learned English, they adopted accommodation behaviors, or *interlanguage* for communicating appropriately in places in their communities when their English was not yet fluent (e.g., at the store, in mixed ethnic neighborhoods). An interlanguage is defined in one of two ways. It may be the way that one individual, still learning the language of a society different from one's own, creates novel terms or mixes terms between one's language and the target language. A Polish immigrant might say something like, "*Ja będę iść do marku*" ("I will go to the market"), substituting the English word, *market,* for the Polish word, *rynku,* but retaining the final letters from the Polish word.

A second characterization of interlanguage regards the reciprocal relationship in communication between two individuals with distinct mother tongues. In this case, each individual accommodates the other in clever verbal manipulations. The use of interlanguage may continue among speakers for considerable time, or it may eventually lose its utility once the speakers become fluent in a single new language. Larry Selinker provides an example of an Israeli who continued to produce English sentences of the type, *I bought downtown the postcard,* even as a fluent bilingual in Hebrew and English.

Quite often, when individuals become bilingual, they switch between the two languages in their attempts not only to be understood but also to clarify for themselves what they mean. This behavior, called *code switching,* has been studied extensively by sociolinguists for spoken language as well as written language where it also might occur. Over time, accommodations such as interlanguage and code switching influence the development of new words and expressions in the main target language.

A special case where factors such as code switching and interlanguage are especially helpful for understanding language growth is manual language, particularly sign language that is used by deaf communities. Of over 100 such sign languages used throughout the world, the most studied is American Sign Language (ASL). Because of the efforts of William C. Stokoe in the 1960s, ASL gained recognition as a true language. Researchers have since explored all facets of the language to support its identity. Sociolinguistic research into ASL continues into the 21st century to identify characteristics that are equivalent to those found in spoken languages. Besides the areas that concern formal linguistics (i.e., phonology, grammar, semantics, pragmatics), research is now replete with studies regarding code switching and pidginization. Research about social interactions within deaf communities and between deaf individuals and hearing individuals has been most fruitful.

Code switching and interlanguage are relatives to a language dynamic known as *diglossia.* This occurs when members of a community recognize that there are varieties of their mother tongue that have to be selected for particular situations, such as a more formal variety for the business world, or for worship or governmental meetings. These varieties may differ in grammar as well as word usage. Joshua Fishman explains that diglossia can also involve two distinct languages (e.g., Latin in some Roman Catholic Church services, but a native language outside of church).

Language varieties are special forms of language that endure within speech communities, and they may have taken a long time to establish (e.g., formal French and vernacular French). Often, a more formal variety is one that is used in written literature, while the less formal variety will never be used in writing. What is interesting about diglossia is the existence of two or more varieties of a language, side by side, that do not eventually mix. This is not the case, however, with pidgins and creoles.

Pidgins and Creoles

Pidgins are formed when individuals who speak two different languages create a means for immediate communication that involves the integration of characteristics of each of their languages. Most pidgins endure only as long as they are needed for a particular purpose, but some, such as *Tok Pisin* of Papua New Guinea, remain as a common vernacular. Historically, pidgins have developed throughout the world, with many used predominantly in areas where trade necessitated communication between European traders or colonizers and native people. These "half-languages," as John McWhorter calls them, can occur any time when conditions warrant it between speakers. Although pidgins do have limited rule systems, they do not qualify as natural languages even though some pidgins endure and are expanded over time so that they have all the typical characteristics of a true language.

In some societies, pidgin languages have undergone a process of change from one generation of speakers to the next so that they become the mother tongue, or more appropriately, a vernacular. These new languages are called *creoles,* taken from a Portuguese term that describes persons of European descent who were born and have lived in a colonial territory. The process by which a pidgin becomes a creole is known as *creolization.* It involves the stabilization of grammatical rules and vocabulary that allows for language generativity and novel use, similar to that in natural languages. McWhorter explains that that there can be varieties of a creole language, somewhat as on a continuum. Individuals may show flexibility for using a creole language in more than one variety depending upon the circumstances and needs of a particular communication.

More Evidence of Language Change

Another set of characteristics that are evidence of language change include dialects, jargon, slang, and colloquial expressions.

Dialects are forms of language that involve pronunciation, vocabulary, and grammar that differs from what is designated as the standard form of a language. The origins of dialects vary. The language, Icelandic, for example, began as a dialect branching from Proto-Germanic, the precursor of the Germanic line of languages in the Indo-European language tree. Sometimes dialects have developed within groups of individuals that live apart from a larger society; sometimes they have developed over time in a geographic region that has been influenced by the merging of linguistic elements from two or more varieties of languages. People of the Appalachian Mountains speak a dialect that was influenced by varieties of English from Scotland as well as England.

The term *dialect* may also be used as an equivalent term to describe a language. Many Chinese languages are called dialects (e.g., Oirat dialect, a Mongolian language), as are some creoles.

Dialects are many times erroneously identified solely by speech patterns. They are likewise mistaken in many instances as having to do with one's social status. Historically, Americans in the northern states have judged individuals from the south with significant bias due to their dialects. As access to communication media becomes more common, bringing people of all walks of life together on a daily basis, these biases are weakened in America.

Slang and jargon provide evidence that languages can change with the influence of individuals who might be assumed to have little or no effect upon how the majority will continue to speak (e.g., adolescents). Robert MacNeil and William Cran, recounting what they learned about Californian *surfer dude* speech from the writer George Plomarity, explain that it is not actually uncommon for slang expressions to take on formal use over time. For example, someone who works in a law office might comment that he is *caught inside,* meaning in a situation that cannot be avoided where a great amount of information and interactions are coming in all at once (just like waves of the ocean).

Language Adaptations and Language Continuance

Because one of the main goals of humans is to interact with other humans, it might seem obvious that language adaptation would be relatively common. And, individuals frequently do adapt their language to facilitate communication, sometimes creating pidgins or using interlanguage, for example. Over time, what started out as an adaptation may show novel and somewhat permanent changes within existing natural languages, or new languages such as creoles might evolve. Yet, considering the tendency of societies to grow and change, access to certain language forms might also be limited to specific groups of people within a community. Sociolinguists have documented barriers to communication in thriving as well as developing nations and societies in the world.

Abram de Swaan, a political sociologist of language, envisions the world as a complex language system, a galaxy constituted of a global constellation in which there are major star patterns determined by factors identified in social science theories (e.g., trade, economics). As do many sociolinguists, de Swaan points out that language can be used as a tool for isolation and for insulation of groups of people. It can be manipulated to keep individuals from participating in specific areas within a society as well as enabling individuals to bond with others. For example, literacy continues to be prohibited to women in certain societies. Contrastively, interlanguage or pidgins can open up communication between peoples with different indigenous languages for the sake of commerce.

In some nations it may take a concerted act of the leaders within a society to establish venues that will help to keep a native language viable and to generate new words and expressions that are necessary for communication in subjects and categories that may influence a nation's growth. It may be a matter of pride among the people themselves to try to maintain their native tongue. Fearful of the demise of their lingua franca, Ewe, the people of the small country of Togo took measures to develop terms such as those needed for technology and new forms of commerce. Once a French colony, the Togolese Republic uses French as an official language, but it strives deliberately to keep its indigenous tongue, Ewe, alive. There is also a considerable body of literature written in Ewe, and this is helpful for sustaining the language.

Written Language and Literacy Over Time

The provision of a written form of a spoken language tends to support the viability of that language. Although this is so, forms of written language and literacy have not always been available to all classes or groups of people in societies from the time of their invention. Literacy was used as a tool for economic and political power in ancient civilizations, and this continues even to the present. Fishman describes the nature of literacy as "a sociocultural phenomenon in its own right, thus subject to many of the same political and self-interest concerns which come into play when making a language/dialect decision."

Alice Joan Metge documents this situation in her history of the Maori of New Zealand. Up until the mid-1800s, most of the Maori had maintained their native tongue and had established a base of literature. Those in power at that time, however, developed language-planning goals insisting upon the use of English in the community and as the only language in schools. Children were punished for using the Maori language even into the 1960s. At the beginning of the 20th century, some 90% of Maori children knew their indigenous language, but by 1953–1958, this number had dropped to 26%. Families also contributed to this loss. They recognized opportunities for their children if they used English. Thus, instead of creating terminology for industry and commerce in the Maori language, communities used English words and spoke for the most part in English. In the early 1970s, the Maori Youth Movement was successful in convincing the government to support efforts to revive the Maori language. The Ministry of Education adjusted the school curricula for children, and courses were offered in Maori up through the university level. Maori became integrated in many venues in society. Now, Maori terms and expressions necessary for daily life have increased in number and are not treated as novel. In the 21st century, New Zealand continues to celebrate Maori Language Day and has week-long activities to encourage pride in the native tongue. Literature is thriving and programming in Maori is available on the Internet as well as on local television.

The situation of the Maori is not unique. Fishman explains that as communities strive to modernize, the development of literacy involves their statement of economic, political, social, and cultural power. The leadership elite who may have had exclusive command of literacy will not necessarily be satisfied to permit the common person the capability to acquire it and join them in acts of literacy. Yet, literacy, just like spoken language, is growing relatively rapidly in developing as well as established nations.

Considering literacy in Europe, Fishman cites research that indicates there were only six languages of literacy by the year 950 (i.e., Latin, Greek, Hebrew, Old Church Slavonic, Arabic, and Anglo-Saxon). At the beginning of the 20th century, there were 31; by 1937, 56. By the late 1980s in Western Europe only, there were 67 different languages used in schools and adult education to teach literacy. In all Europe by 1989 there were at least some 200 languages. Fishman estimates that in the 20th century alone, the languages of literacy in Europe increased sixfold. As of 2003, he sees the same kind of dramatic growth in countries in Africa and Asia.

It appears to make sense that a spoken language will survive if its speakers have access to that language in writing. As in the case of Maori, that may be true. There is another direction, however, that some languages take where they appear to be on the verge of extinction in spoken form. A literary tradition of the language may develop and survive beyond its conversational utility.

One language that falls into this group is Picard, a language recognized by Belgium as an indigenous language and acknowledged as a language by the European Bureau for Lesser Used Languages. Although it is very similar to French in many respects, France considers it separate from French, and as with other minority languages, does not particularly care to recognize Picard as a "good" language. Picard is spoken in an area near the English Channel, in a northern region of France and in southern Belgium. Linguist Julie Auger explains that by all appearances spoken Picard should be dying, because most of the speakers in larger towns are older individuals, and they do not seem to see the necessity for concerted transmission of the language to the young. In actuality, the French government has given very little support to groups such as the Picards.

On the other hand, Auger has observed that written Picard is, in her words, "varied and dynamic." There were hints of a literary tradition as far back as the 16th century, but it was in the latter half of the 19th century that there were significant numbers of written works in Picard. By the year 2000, literature and a new magazine were thriving, and these works were being read in print as well as on the Internet. In the final analysis, Auger is hopeful that the expanded literary tradition will continue to get readers more involved in Picard and that the French government may enable it to thrive as a spoken language by giving it recognition and support.

Human Languages and Artificial Languages

Early in the 20th century, with the growth of cognitive psychology, the idea of the generative nature of human language aroused the curiosity of scientists regarding the possibility of creating languages with computers that might mimic human languages. If this were possible, then perhaps the computer could act as a bridge among peoples with different spoken languages. The challenge was particularly provocative for individuals such as Marvin Minsky, who, in an important work titled *A Framework for Representing Knowledge,* proposed structures that stimulated thought regarding the duplication of human language in machines.

In order to function as human languages, artificial ones would have to have grammatical rules that a machine could apply at the level of a sentence, and the machine would have to be able to apply inferential reasoning to capture the real, singular meaning of ideas or the multiple meanings of ideas, expressions, and words. For example, how might a computer interpret words for emotions and feelings and distinguish between them as well as indicate variations by degree (e.g., love of a friend versus love of a picture)? How might it deal with the ambiguity that is so prevalent in human spoken languages (e.g., *Bill told John that he loved Mary)?* In other spoken languages, including English, how might a computer distinguish among polysemous words?

Since the 1970s, the field of artificial intelligence has provided several powerful paradigms that in the 21st century are often taken for granted. Minsky's ideas and those of others like himself regarding frames of knowledge have been translated in such schema and models as that of Vinton Cerf's Arpanet, a precursor of the Internet, as well as in scientific applications such as those of Ray Kurzweil, considered a second Albert Einstein by many. Among his myriad accomplishments, Kurzweil has become well known for his print-to-speech reading machine for the blind as well as for his work with voice activated word processing. Cerf, the vice president of Google since 2005, has been called the father of the Internet. He has had a special interest in the field of communication and deafness because he himself is hard of hearing and his wife, Sigrid, is deaf.

Developments in artificial intelligence have enabled mutual understandings among humans beyond that of their distinct spoken languages. These new means for communication are realized in the scientific world as well as in commerce and even in music, another area studied by Kurzweil. Such developments point to the potential for humans to use "invented" forms of language in ways that can add to the growth of civilization and to enable a convergence of knowledge and sharing of cultures among diverse societies around the world.

Patricia N. Chrosniak

See also Anthropology; Consciousness; Language, Evolution of; Languages, Tree of; Memory

Further Readings

Aboba, B. (1993). *The online user's encyclopedia.* New York: Addison-Wesley.

Bartlett, J. R. (1859). *Dictionary of Americanisms* (2nd ed.). Boston: Little, Brown.

Cooper, R. (Ed.). (1982). *Language spread: Studies in diffusion and social change.* Bloomington: Indiana University Press.

Coulmas, F. (Ed.). (1989). *Language adaptation.* New York: Cambridge University Press.

Crystal, D. (1997). *The Cambridge encyclopedia of language* (2nd ed.). New York: Cambridge University Press.

Davis, J. (1994). *Mother tongue: How humans create language.* New York: Carol.

de Swaan, A. (2001). *Words of the world.* Malden, MA: Blackwell.

Fishman, J. A., Hornberger, N. H., & Putz, M. (2006). *Language loyalty, language planning and language revitalization: Recent writings and reflections of Joshua A. Fishman.* Bristol, UK: Multilingual Matters.

Garry, J., & Rubino, C. (Eds.). (2001). *Facts about the world's languages.* New York: H. W. Wilson.

Grenoble, L. A., & Whaley, L. J. (Eds.). (1998). *Endangered languages: Current issues and future prospects.* New York: Cambridge University Press.

Joseph, B. D., DeStephano, J., Jacobs, N. G., & LeHiste, I. (Eds.). (2003). *When languages collide: Perspectives on language conflict, language competition, and language coexistence.* Columbus: The Ohio State University Press.

Kurzweil, R. (1999). *The age of spiritual machines: When computers exceed human intelligence.* New York: Viking Press.

Lucas, C. (Ed.). (1995). *Sociolinguistics in deaf communities.* Washington, DC: Gallaudet University Press.

McNeil, R., & Cran, W. (2005). *Do you speak American?* New York: Nan A. Talese.

McWhorter, J. (2001). *The power of Babel.* New York: Henry Holt.

Metge, A. J. (1976). *The Maoris of New Zealand: Rautahi* (2nd ed.). London: Routledge & Kegan Paul.

Minsky, M. (1975). A framework for representing knowledge. In P. H. Winston (Ed.), *The psychology of computer vision.* New York: McGraw-Hill.

Selinker, L. (1992). *Rediscovering interlanguage.* New York: Longman.

Language, Evolution of

The study of the origin and evolution of human language is an essential one to characterize what distinguishes humans from other species on earth. Yet this noble and challenging endeavor has been a source of much speculation as well as research as far back as 3,000 years ago. The search for answers to such questions as why language began and how it evolved has provided researchers with a particularly grand puzzle. In spite of recurring fascination about the topic, without sources of direct evidence it has been virtually impossible to verify many theories, to know precisely when language originated and what the first spoken language was like. At some points in modern history there has been great frustration about the directions of the search, and this even led to a moratorium on scientific investigations in 1866 that slowed down research until the late 20th century.

Shortly after the publication of Darwin's *On the Origin of Species,* ideas and speculations about language evolution were so rampant and frequently quite strange that the primary authority regarding language study, the Société de Linguistique de Paris, put a ban on all discussions about the origins of language. It was not until the last decade of the 20th century that renewed vigorous study emerged. Many believe that the presentation in 1990 of a research paper, *Natural Language and Natural Selection* by Steven Pinker and Paul Bloom, inspired the rapid spread of study into the 21st century.

Although one might assume that researchers in subfields aligned with linguistics would have long been in the forefront of the study of language origins and development, this has not necessarily been the case. Many of the most curious have been in fields such as psychology, anthropology, biology, neuroscience, computer science, and archaeology. At the beginning of the 21st century, a number of researchers, including Marc Hauser, Noam Chomsky, Morten Christensen, and Simon Kirby, called for interdisciplinary research to help define the faculty of language and subsequently posit some answers regarding its evolution. The complexity of the subject requires collaborative efforts among specialists from distinct fields who can deal with the important questions together that otherwise in isolation lead these specialists down a narrow tunnel, so to speak, where there appears to be little light at the end.

Defining Language

The term *language* may refer to one of several constructs (e.g., language of music, language of love, computer language, spoken language, body language). Language is a major component in the larger category of communication among humans as well as among nonhuman primates, birds, insects, and water mammals. Characterizing human language, Noam Chomsky wrote,

> The human faculty of language seems to be a true "species property," varying little among humans and without significant analogue elsewhere. . . . Furthermore, the faculty of language enters crucially into every aspect of human life, thought, and interaction. It is largely responsible for the fact that alone in the biological world, humans have a history, cultural evolution and diversity of any complexity and richness, even biological success in the technical sense that their numbers are huge. (Chomsky, 2000)

Studies of communication among species other than *Homo sapiens* have helped to develop a clearer understanding of the unique nature of human language. For example, scientists studying the dance of the bees have identified two characteristics of this signaling system—distance and direction—that help other bees find a source of nectar. In their dance, bees map distance and direction into particular angles and speeds, some greater and smaller, more or less. There is no variation, no modification, of this behavior otherwise.

Joseph Greenberg notes that language systems such as the dance of the bees are iconic. In other words, there is always a one-to-one correspondence between the purpose of alerting for nectar and the specific movements in the dance. Human language, by comparison, is a complex symbolic system with infinite possibilities for generating meaning. Grammar and syntax distinguish human language from the languages of other creatures. Thus, trying to identify the steps through which human language evolved is much more challenging than researching the dance of bees. The search for the origins of human language is a search for a generative and growing system of human exchange between minds and external events, as James Hurford puts it.

Origins and Evolution

The question of where and when the earliest language occurred requires studying the evolution of modern humans from their ancestors, the first hominids (i.e., beings within the taxonomic family, Hominidae). For explorations of human language evolution, it is necessary to consider two realizations of language, gestural language and spoken language.

Gesture

The majority of study regarding the evolution of language focuses upon verbal communication, but a second area of research provides many answers about human language, that is, gestural language. In the latter case, scientists may be concerned with the communicative function of gestures in themselves, or they may be concerned, as is Michael Corballis, with the evolutionary processes of gestural language to speech. He proposes that language emerged from manual gestures rather than from vocalization.

Although there is no documented evidence that early hominids used gestural language, Corballis provides a set of arguments supporting the practicality and effectiveness of gestural communication that may have been used as far back as 25 to 30 million years ago. For example, as an essentially spatial mode of communication, gesturing would provide a silent visual means to alert others about predators or to support the hunting of game.

Somewhere around 6 to 7 million years ago (mya), hominids and apes diverged into distinct groups. At that time, archeological findings indicate, both groups were assumed to have used simple gestures, and both probably vocalized for emotional needs. Hand signals for purposes other than just emotional release are believed to have been used by hominids designated as the genus *Australopithecus,* who are identified by two important characteristics: nonprojecting canine teeth and bipedal locomotion. Because they lacked dental defenses, they needed to develop some way of surviving. Thus, C. Loring Brace postulates that they must have created primitive cultures. This idea is backed up by the discovery of rudimentary stone tools from around 2.5 million years ago. Scientist Ralph Holloway, among others, comments that the early bases for language may have had roots at the time of tool creation and use. Hominids at this time would have had a reason to establish groups for hunting, scavenging, and cooperative living and thus have had a need to develop forms of communication within these groups. Because the hands were no longer needed for locomotion, they could be used for gestures and making tools. These activities could have stimulated the evolution of the brain and especially those parts of the brain necessary for speech.

It seems logical that the early *Homo erectus* would use hand signals and body gestures to communicate. Corballis notes that, given the fossil evidence, by 2 mya the gestures would have been fully syntactic and vocalizations would have been progressively increasing. By 100,000 years ago, early *Homo sapiens* would have used more speech than gestures, but gestures would still have been a characteristic of communication.

Theories about early communication gestures have been most affirmed by those who study manual languages such as American Sign (ASL) or any of the other modern sign languages used by deaf persons in countries other than the United States. Just as research about language evolution and gestures has been slow in developing, it was not until the 1960s that sign language research began to build with studies of the grammar of ASL. The growth of research was due to the work of William C. Stokoe, who provided the foundation for identifying sign languages as true, formally structured languages and not merely cryptic means for communication. Since his time, sign language research has included study within several areas of linguistics, including sociolinguistics and neurolinguistics.

In the field of sociolinguistics, researchers such as James Woodward have established a large body of knowledge of interlanguage communication, studying areas of the world where deaf persons use sign language within their own established communities and/or with hearing individuals. This research is similar to that regarding the development of pidgins and creoles in spoken languages.

What of gestural language among hearing, speaking individuals? Gestures supply visual–spatial support to conversations, enabling a speaker to use emphasis or to demonstrate information that otherwise might take a longer period of time to describe verbally. When there is little or no opportunity to speak, gestures can take on a form of syntax designating meaning. For example, individuals who try to communicate with someone who speaks a language other than their own use hand gestures accompanied by facial expressions and body language in an orderly fashion that parallels their spoken language.

Considering neurolinguistics, much has been learned from the last decade of the 20th century into the 21st regarding language function areas in the brain and sign language. For example, just as do hearing listeners of spoken language, deaf persons show increased activity in the left side of the brain for receptive communication in sign language. Both of the language-mediating areas of the brain, Broca's area and Wernicke's area, are activated when deaf signers watch sentences presented in ASL. Even so, deaf persons show more activity in the right side of the brain than do hearing persons. This has frequently been attributed to the fact that ASL has a distinct spatial component where facial, head, and body movements complement the hand signs.

Philip Lieberman explains that the hominid brain and hand evolved in a precise way that facilitated manual dexterity. He notes that studies in the 20th century comparing the brains of normal individuals to aphasics and those with mental retardation show that there is a link between speech and syntax and motor activity. If that is true, then it makes sense that as the human brain developed, and as the skull and throat developed in the earliest hominids, so too would the use of gestures have developed as well as the growth of spoken language.

Spoken Language

Scientists document that during the Late Pleistocene period that began around 130,000 years ago, brain size in hominids, classified as archaic *Homo sapiens,* had reached modern levels. The increased expansion of the brain is taken as a sign of brain reorganization for language. At the same time, another major indicator of the evolution of humans, the manufacture of tools, shows multiple traditions of stylistic differences across specific regions of the world to which these hominids had migrated. C. Loring Brace explains that these geographic areas are coincidental with the areas of the world that have been mapped for major language families. Thus, he posits that there may be a connection between the development of tools and the development of verbal communication in these geographic areas.

Fossils show that the necessary mouth and throat anatomy for speech were in place even 150,000 years ago. The structure of the human brain and the larynx have evolved so that humans are the only ones who have a low larynx that facilitates speech but that can also interfere with swallowing and be obstructed by food. With this kind of physical structure, it would seem that hominids of the middle Paleolithic era would necessarily cultivate vocalization. Yet, this is a quandary, because other evidence (e.g., hints from unearthed art, burial and living sites, and jewelry) would signal that verbal language did not appear until about 40,000 years ago. This time of social organization and growth is known as the Upper Paleolithic explosion. Most archaeologists would agree that at that time there must have been liberal use of language.

Some scientists believe that there was a sudden cultural shift; others believe the development of speech use was gradual. Just because the hominid anatomy was available for speech, the evolution of the neural pathways may not yet have been ready earlier in time, that is, before 50,000 to 40,000 years ago. Another missing piece of the puzzle is the fact that it is hard to infer without fossil evidence the ways that soft tissue was connected to the anatomy of the vocal tract.

Lieberman believes that speech should have been possible between 150,000 and 100,000 years ago, because there is evidence that the African hominid living during that time had a cranial structure identical to that of modern humans. The tongue was rooted in the throat and not restricted to the vocal cavity, and the larynx had descended. This kind of structure is necessary for rapid and complex speech, and there would be little reason to think that speech might not exist among these hominids. However, their vocal tracts were not completely formed, nor were their abdominal and thoracic muscles that, among modern humans, receive stimulation for speech through the thoracic region of the spinal cord.

Many scientists indicate that there is little evidence about the development of human culture that would support the argument for the necessity of speech before 50,000 years ago. Alternatively, some scientists, such as John Yellen and his colleagues, have discovered signs of a kind of trading network among the Katanda people of Africa, as well as barbed bone, obsidian, and stone used for spear points, and the use of pigments such as red ochre that can be dated between 80,000 and 90,000 years ago. Yellen and his colleagues explain that these archaeological traces may indicate the existence of early societies whose members had modern behavioral potential and hominids with anatomies that resembled those of modern humans. Thus, there may have to be a change regarding the target year estimate of 40,000 years ago for the emergence of speech.

Clues From Written Language

Observations of written language provide clues regarding the existence of grammar and syntax of spoken language as well as changes in these components that signal the difference between human language and that of other species.

Formal Written Language

There is some agreement among scholars that the oldest known formal written language was in use about 5,000 years ago and was probably Sumerian, an extinct isolate language that shows few characteristics common to any of the other spoken language families. There are over 30,000 preserved cuneiform writings in this language as well as evidence from remnants of Sumerian monuments. These show accounts of commerce and politics, culture, poetry, myths, and epics about the origins of civilization in the Fertile Crescent. As a spoken language, Sumerian must have existed prior to being put down in writing. It was spoken in Mesopotamia, in part of what is now modern Iraq, until 2,000 BCE and was supplanted by Akkadian, a Semitic language that like Sumerian is now extinct. The Akkadians, a nomadic people, lived peacefully among the Sumerians until the conquest by Sargon of Akkad, who insisted upon language assimilation. The geographic region continued to use Semitic languages through the time of the Babylonian empire, whose people spoke a dialect of Akkadian. Subsequently, another Semitic language, Aramaic, predominated in the region.

Informal Written Languages

Writing systems that are characterized as representations of informal language lack the consistent use of grammar or syntax. Informal written languages existed as far back as 30,000 years ago. Evidence is seen in cave and other drawings and engravings at burial sites and in artifacts such as jewelry. These forms are found in several key archaeological sites around the world. Although explorations have been made predominantly on the African continent and in the Near and Middle East, one land that has been a source of curiosity about language evolution is Australia. The Aborigines, living in Australia for perhaps 40,000 years or longer, are one people whose ancestors have left a pictorial record across the continent in carvings and paintings representing symbols of life around them, some of these over 23,000 years old. Many of the Aboriginal drawings are in geometric shapes, and they appear to be accounts of numbers of people and events within designated time frames.

It has been estimated that at one time there may have been over 500 spoken languages among 200 distinct groups of Aborigines. These languages show no clear connection to any of the other language families of the world and have been classified by anthropological linguists into 28 of their own families. Currently, in a population of some 400,000, there are fewer than 30,000 who speak one of the remaining 263 original languages. And, it has only been a little over 100 years since outsiders have helped the Aborigines establish a formal written language based upon the visual material that has survived and developed over the centuries. However, there is still much to be learned about these people to put one more piece in place in the puzzle of language evolution.

Language and Future Changes

Recent research in anthropological linguistics as well as genetic linguistics has supported our understandings of the origins, evolution, and current status of languages around the world. Coupled with studies by allied and growing fields such as computer science, biology, and neuroscience, the horizon appears bright, revealing ever more information about language change over time. Linguist Salikoko Mufwene remarks that there is a need for researchers to be open to a variety of alternative assumptions that might advance and enrich current and future thought about language evolution. He states,

> A language is more like a bacterial, Lamarckian species than like an organism. A subset of innovations/deviations in the communicative acts of individual speakers cumulate into the "invisible ecological hand" that produces evolution. . . . There are internal and external factors that bear on language evolution, but they apply concurrently in all cases of language evolution.

Given what is already known about the development of language in humans, it is highly probable that scientific explorations, especially by researchers of several fields collaborating, will continue to reveal subtle as well as vivid evolutionary processes that enable creative and distinct language use among all persons across the earth.

Patricia N. Chrosniak

See also Anthropology; Evolution, Cultural; Hammurabi, Codex of; Language; Languages, Tree of; Rosetta Stone

Further Readings

Asher, R. E., & Moseley, C. J. (Eds.). (2007). *Atlas of the world's languages* (2nd ed.). New York: Routledge.

Brace, C. L. (1995). *The stages of human evolution.* Englewood Cliffs, NJ: Prentice Hall.

Chomsky, N. (2000). *New horizons in the study of language and mind.* Cambridge, UK: Cambridge University Press.

Christiansen, M. H., & Waller, S. (2003). *Language evolution.* New York: Oxford University Press.

Corballis, M. C. (1999). The gestural origins of language. *American Scientist, 87,* 138–145.

Corballis, M. C. (2002). *From hand to mouth: The origins of language.* Princeton, NJ: Princeton University Press.

Crystal, D. (1997). *The Cambridge encyclopedia of language* (2nd ed.). New York: Cambridge University Press.

Greenberg, J. H. (1968). *Anthropological linguistics: An introduction.* New York: Random House.

Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science, 298,* 1569–1579.

Holden, C. (1998). No last word on language origins. *Science, 282,* 1455–1458.

Lieberman, P. (1998). *Eve spoke: Human language and human evolution.* New York: W. W. Norton.

Mufwene, S. S. (2001). *The ecology of language evolution.* New York: Cambridge University Press.

Stokoe, W. C. (2002). *Language in hand: Why sign came before speech.* Washington, DC: Gallaudet University Press.

Yellen, J. E., Brooks, A. S., Cornelissen, E., Mehlman, M. J., & Stewart, K. (1997). A Middle Stone Age worked bone industry from Katanda, Upper Semliki Valley, Zaire. *Science, 268,* 553–556.

Languages, Tree of

It is estimated that there are between 6,000 and 10,000 living languages in the world. Not all of these languages have been identified and not all have names; not all of these languages will survive in the 21st century. The languages that prevail have done so because of evolutionary processes over vast periods of time. These processes have been characterized and documented by scholars, and all identified languages have been represented using the metaphor of *language families* in schematics known as *language trees*.

Among human languages, there are spoken languages that are indigenous to a geographic area, those that are spoken in places other than the area of origin, and those that are called *official* languages as designated by an official body within a geographic community. There are creole and pidgin languages that developed from contact between two particularly different language-speaking groups, typically a result of trade between Europeans and peoples on other continents, such as Africa. There are language dialects that are sometimes designated as languages, as occurs in China. There are also gestural languages, such as sign languages used by deaf persons. Each sign language has a distinct grammar, syntax, and phonology according to the country in which it is used. It is estimated that there are at least 112 sign languages in the world.

There are many reasons for knowing about the organization and life of human languages. One reason is to support understanding of the history, the current dynamic, and the future of specific cultures and nations. Another is to assist in understanding the role that diversity plays among peoples in the world.

In 1993, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) embarked on a project to find out which languages were viable, endangered, close to extinction, and extinct. As a result of this process, classification schemes for the world's languages were modified, and maps were collected into an atlas that was in its second edition in 2001.

Besides the UNESCO project, the study of the origins of human languages has been especially fruitful from the last decade of the 20th century up

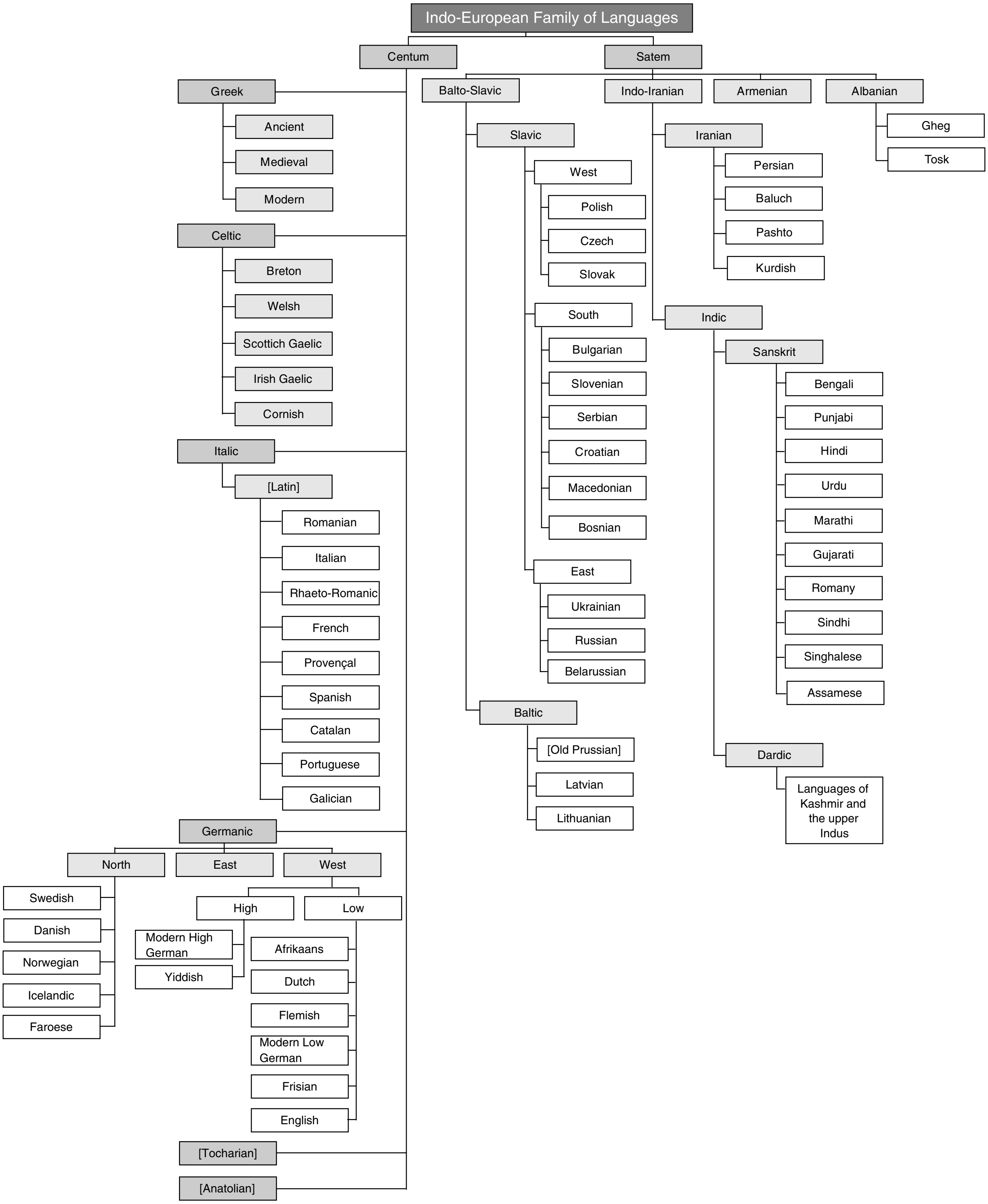


Figure 1 The Indo-European family of languages

to the present, and this research has helped to create schematics for the classification of languages into their particular families. Currently there are 94 different language families in the world whose member languages have been identified by a process called *genetic classification,* where linguists and philologists looked for similarities that showed descent from the same parent language.

Lyovin explains that languages are compared to one another especially for recurring sound correspondences between and among the words of languages that have roughly the same meaning and belong to the basic vocabulary. Each language can be further characterized in relation to other families, constituting distinct *language trees.* The schematic for these trees is usually reversed in a hierarchical format with the main, central family name at the top and the branches extending out systematically below it. For example, there are over 2.5 billion speakers of languages in the Indo-European family, the most studied of language families. This number constitutes 44.78% of the world's people. The Indo-European family tree is divided into two major components, the Centum languages (Western European) and the Satum (Eastern European and Asian). Subsequently, there are branches, such as West Slavic, that then are subdivided into the actual spoken languages of each branch.

Although the Indo-European language family predominates for number of speakers in the world, there are only 430 living languages in this tree. The Niger-Congo tree, however, is constituted of 1,495 living languages that are spoken by 6.26% of all the world's people. Six of the 94 language families account for about five-sixths of the world's population. Among the other 88 language families, there are *isolates:* individual languages with no known connections to any other group of languages. Gilyak, for example, is an isolate language spoken by about 1,000 people on Sakhalin Island and along the Amur River in East Asian Russia. Not every language that is spoken by few individuals is an isolate. Yukhagir is a separate language family of East Asian Russia that is spoken by only 120 people, mostly the elderly, and it is expected to become extinct once these speakers die.

As stated above, each language tree is composed of several subcategories, or *branches* of languages that share certain common characteristics. Languages in the same branch may or may not share commonalities of grammar and syntax, vocabulary and phonology. Some may use the same scripts and alphabets, while others show no similarity in this regard. For example, French and English have comparable alphabets, although French has diacritical marks not used in English. Russian uses a Cyrillic alphabet that has little resemblance to the variation of the Roman alphabet used for Polish. There are, however, words that sound quite similar in Russian and Polish, such as the word for *opportunity* (in Polish, *okazja [oh kahzh'yah];* in Russian, transliterated from Russian Cyrillic to English, *okaziya [oh kah zy'yah]*). Russian is an East Slavic language in the Indo-European family tree; Polish is a West Slavic language.

Some languages have an exact one-to-one correspondence between each letter of their alphabets and each sound in words; others have several sounds that are associated with the same letter or combination of letters. For example, in English /g/ can be "hard" or "soft" as in the words, *gorilla* and *cage.*

Languages vary in the number of consonants and vowels and how they are produced. There are tonal languages such as Chinese where words are pronounced with obligatory changes in pitch, or tones, to each stressed syllable. In Mandarin Chinese, the national language, a syllable might look like this example from Lyovin:

(C)(G)V (N or G) + Tone

where C represents a consonant, G a glide (nonsyllabic vowel), V a full vowel, and N a nasal consonant. There are 235 living languages in the Republic of China. Chinese is in the Sino-Tibetan language family; the languages of Myanmar and Thailand are also members of this family.

One of the oldest language families in Africa is the Khoisan. There are estimates that languages in this family existed some 60,000 years ago, which might place them beyond the commonly proposed time for the appearance of speech at 40,000 years ago. Khoisan languages are recognized by the incorporation of clicks in speaking; the grammars of the 22 languages are rather distinct. Most speakers are found in southwestern Africa around the Kalahari Desert regions, particularly in Botswana and Namibia. Some language scientists, such as Abram de Swaan, are concerned that the neglected study of such small language families as Khoisan might mean the eventual loss of information about the origins of language and the development of cultures prior to colonization by the Western world.

Patricia N. Chrosniak

See also Anthropology; Evolution, Cultural; Language; Language, Evolution of

Further Readings

Asher, R. E., & Moseley, R. E. (2007). *Atlas of the world's languages* (2nd ed.). New York: Routledge.

de Swaan, A. (2001). *Words of the world.* Malden, MA: Blackwell.

Gordon, R. G. (Ed.). (2005). *Ethnologue: Languages of the world.* (15th ed.). Dallas, TX: SIL International.

Lyovin, A. V. (1997). *An introduction to the languages of the world.* New York: Oxford University Press.

Wurm, S. A., & Heyward, I. (2001). *Atlas of the world's languages in danger of disappearing* (2nd ed.). Paris: UNESCO.

Laplace, Marquis Pierre-Simon de (1749–1827)

Marquis Pierre-Simon de Laplace, French mathematician and cosmologist, sought to explain the origin of the universe in terms of mathematics, physics, and philosophy. Although his conceptual reference for the temporal framework of the universe is not evident, other than under the general heading of orbital computations, Laplace's speculation within the nebular hypothesis poses a unique and interesting account for the origin of our solar system. Laplace was well known for his publications, *Systems of the World* (1796) and *Celestial Mechanics* (1825).

The existence of the solar system, with all the stars, planets, and comets, retains the appearance of regularity and stability. Laplace, with observations and mathematical computations, understood the governing factors and influence of both gravitation and motion among celestial objects. The vastness of our solar system, as evident by cometary orbits, was suggested as going beyond the then-known limits of our system. It was postulated that the solar system was a product of the expansion and contraction of a superheated sun whose atmosphere existed beyond the known planets. These newly formed planets possess similarities in directional rotation (including satellites), plane, and projection. Such commonalities were evidence of a common origin, albeit only a probable origin.

As for temporal facets of the known solar system, Laplace's concepts of time are held within the mechanical operations of a solar system in particular and the universe in general. The totality of time or age of the solar system or universe became secondary to operational understanding. Perhaps in Laplace's view, time measured within human consciousness becomes irrelevant when compared with the vastness and mechanistic system of the universe. Essentially, the birth of our solar system, like that of the universe, is indifferent to humankind's existence or to life in general.

It is rather interesting to note that before modern science and evolutionary theory, Laplace had mentioned, though briefly, that life may exist on other planets, or in his words, this is extremely probable. This assumption concerning the probability of the existence of life on other planets can be seen as a logical outcrop of the commonalities that are shared among the planets. This novel idea of extraterrestrial life is devoid of both human and divine interaction. Should life forms exist elsewhere in the universe, their existence becomes as irrelevant to our species as the universe is to human existence. The mechanistic nature of the universe, both in implementation and adjustments, becomes a set of interconnected subsystems in which individual life, assuming the existence of life on other planets, becomes insulated. Within Laplace's cosmology, there is no need for a divine essence that permeates the universe. Probability and mechanics replace the deity or force in both planetary and human existence.

In Laplace's substantial contributions, inferences regarding time become subtle statements without regard for theology and philosophy. The replacement of the Son with the Sun, as it were, has remarkable connotations for human existence and placement within nature. Laplace advised extreme caution to readers regarding his conjectures. Nevertheless, the materialistic explanation and justification seems to support this view. It is unknown if he held any theistic views before his death in 1827. However, the contradiction between science and traditional religious beliefs would surely become problematic. The concept of time as supported by science would be greater than human experience would allow. Timelessness or eternity would only be inferred as applying to the planets and the mechanical operations of solar systems and the universe.

David Alexander Lukaszek

See also Cosmogony; Kant, Immanuel; Nebular Hypothesis; Planets; Time, Planetary

Further Readings

Laplace, P.-S. (1966). *Celestial mechanics*. Bronx, NY: Chelsea. (Original work published 1825)

Laplace, P.-S. (1976). The system of the world. In M. Bartusiak (Ed.), *Archives of the universe*. New York: Vintage Books. (Original work published 1796)

Lascaux Cave

Lascaux Cave, like many archaeological sites, was discovered by chance. Four young boys stumbled across the cave in 1940 in southern France near the town of Montignac. Inside, these adventurers encountered what later researchers further explored and analyzed: a cavern filled with paintings and engravings on limestone walls depicting an array of images, which were determined to have been created millennia before. Today, Lascaux Cave's contents provide a glimpse of a people and a time in prehistory of which little else is known.

Lascaux is a multichambered cave extending approximately 250 meters in total length when considering all its areas. Chamber widths vary considerably so that the height of Lascaux's ceiling is equally diverse in size, going from less than one meter to several meters high, with variations in dimensions sometimes happening within a single chamber. As for when the cave was occupied, researchers conducted the dating of Lascaux's occupations through the use of multiple techniques including carbon-14 dating and the observance of animal species depicted in the wall art. The results of these tests have generated a range of corresponding dates, particularly between 18,000 and 16,000 years ago.

The actual paintings and engravings within the Lascaux Cave include a myriad of designs ranging from realistic and abstract images of animals to images and designs whose meaning remains undetermined. The images include horses, aurochs, bison, and felines. In addition to the wall art discovered in the Lascaux Cave, researchers discovered tools such as projectile points, miscellaneous flint tools used for engraving, and pottery sherds. As with other caves discovered in Europe with similar artwork, the paintings and engravings within the Lascaux Cave demonstrate the use of multiple techniques to generate images on stone. The materials used to generate colors for the wall art at Lascaux were predominately iron and manganese oxides.

Questions remain as to the importance and function of these images to their creators. Some researchers have postulated that the images were to serve as magical aids in hunting, perhaps in rituals; others have argued that the images were created as a form of decorative art. While answers to these questions remain elusive, interest in the images of Lascaux Cave remains strong. However, further investigation of the cave and its contents has been suspended and access has been restricted. This was considered necessary to protect the cave and its contents from continued deterioration caused by multiple contaminants that were destroying Lascaux's art. When and if access will be granted to researchers in the future remains to be seen. Fortunately, researchers have at least acquired a glimpse into the lives and activities of those who occupied and decorated Lascaux Cave, thereby providing us with some understanding of an era that remains relatively unknown.

Neil Patrick O'Donnell

See also Anthropology; Altamira Cave; Chauvet Cave; Evolution, Cultural; Olduvai Gorge

Further Readings

Aujoulat, N. (2005). *Lascaux: Movement, space, and time.* New York: Harry N. Abrams.

Tattersall, I., & Mowbray, K. (2006). Lascaux Cave. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (Vol. 4, pp. 1431–1432). Thousand Oaks, CA: Sage.

Last Judgment

The Last Judgment refers to an event that, according to religious tradition, will occur after the world has ended and God pronounces his final verdict on the human race. For Christians, the Last Judgment is the stage in which all people are judged according to their behavior when they were still alive. The righteous will receive their reward and will spend an eternity in fellowship with God; however, the evil will spend an eternity in hell, acknowledging they had the opportunity for heaven but chose otherwise.

Some Christians believe that there will be only one judgment, because one's soul is asleep or unconscious between its demise and the Last Judgment (a view held by the religious reformer Martin Luther and others). Most Christians believe, however, that souls are not asleep and that they receive their punishment or reward after death. This first judgment is called the *particular judgment,* and it is different from the Last Judgment, where individuals are sentenced for their belief or lack thereof. This acceptance regarding one's final judgment is considered dogma by Roman Catholic believers, but the Church feels that the Last Judgment is not an actual trial, because the individuals already deceased are either residing in heaven or hell or working off their sins in purgatory—all resulting from their particular judgment at the moment of their death. Protestant believers in millennialism regard the two judgments as describing separate events, one at the moment of death and one after the end of the world.

According to this belief, the Last Judgment will take place after the deceased have been resurrected and undergone a complete reunion of the body and soul, where their evil acts are judged and their eternal sentence will be known to all before their fate before the resurrection is continued. At that specific moment, the joys of heaven and the sorrows of hell will be evident, because everyone present will be able to feel both pleasure and pain. This scenario appears most directly in "the sheep and the goats" section in the Book of Matthew. This belief regarding the afterlife can also be found in the books of Daniel, Isaiah, and Revelation.

Christianity is not the only religion that deals with the end-times. In Islam, there is *Yawm al-Qīyāmah* (the day of the resurrection). At a time preordained by Allah but unknown to humanity (at a time when people least expect it), Allah will consent for the Qiyâmah to commence. The archangel Israfel, named "the caller" in the Qur'an, will puff mightily into his horn, and out will come a "blast of truth." This specific occasion can also be seen in Jewish eschatology, where it is called "the day of the blowing of the shofar," found in Ezekiel 33:6. The Qur'an states that the Qiyâmah will last 50,000 years. Some Islamic scholars believe that this period refers to the vastness of man's spiritual advancement (one day is equal to 50,000 years), or that the day may signify the final triumph of Truth in the world, from the time when revelation was first granted to man.

In the Qiyâmah as envisioned, *Alameen* (humanity, the jinn, and all other living beings) are gathered upon a vast, white plain under a blistering sun. Each is completely unclothed, uncircumcised, and standing so close together that some are submerged in their own sweat. The depth of one's submergence in sweat depends upon how good or pious one was. Those that practiced good *adab* (following good etiquette) by following the Five Pillars of Islam daily are considered *nadirah* (shining and radiant). However, the expressions of the disbelievers are called *basirah* (miserable and grimacing). Although they are all nude, anxiety and fear are so great that no one thinks to look at another's nakedness. The creatures wait to be brought before Allah for their judgment, but they are terrified. The prophets plea to Allah with the phrase "sallim, sallim," translated as, "Spare your followers, Oh God." Those that followed Muhammad while he was alive, but then left

Islam after his demise, are apostates and are engulfed in fire. The angels are afraid, as state several *hadiths* (actions and utterances the prophet made while on earth), because Allah is livid with anger, more so than before or after.

In the Hindu religion, *pralay* is the specific time when the earth will be completely annihilated. Garuda Purana is one of the *puranas* (means "belonging to ancient time" and is a genre in Sanskrit literature) that are part of the Hindu body of texts known as the *smriti*. This sacred text discusses in vivid detail precisely what to expect after someone dies, specifying the different torments one can expect for the evil committed while alive, including being scorched in hot, boiling oil and given to bloodsuckers as prey. Some Western theologians see this scenario as being comparable to the Christian idea of Judgment Day.

Garuda Purana are directions given by Lord Maha Vishnu to Sri Garuda (also known as the king of birds—a *vahana* of Lord Vishnu). This specific purana looks at a wide range of subjects, including cosmology, various remedies for sickness, language syntax, and information regarding jewelry. The Garuda Purana is deemed the most respected Vedic book discussing the Nine Pearls (the nine sacred gemstones), and the second half of the tome deals with life after death. The Hindus residing in northern India customarily read this purana as they cremate the bodies of their loved ones.

Cary Stacy Smith and Li-Ching Hung

See also Apocalypse; Bible and Time; Christianity; Eschatology; God and Time; Gospels; Immortality, Personal; Luther, Martin; Michelangelo Buonarroti; Nirvana; Parousia; Qur'an; Religions and Time; Revelation, Book of; Time, Sacred

Further Readings

Braaten, C. E. (2003). *The last things: Biblical and theological perspectives on eschatology.* Grand Rapids, MI: Eerdmans.

Schwarz, H. (2001). *Eschatology.* Grand Rapids, MI: Eerdmans.

Smith, J. I. (2006). *The Islamic understanding of death and resurrection.* London: Oxford University Press.

Upton, C. (2005). *Legends of the end: Prophecies of the end times, antichrist, apocalypse, and messiah.* Ghent and New York: Sophia Perennis et Universalis.

Latitude

For the purpose of finding an relative location on the earth's surface with precision, geographers have drawn certain circles to which the position of any point may be referred. The art of navigation may have begun approximately 6,000 to 8,000 years ago; eventually it became a science of vast importance, particularly during Europe's age of discovery, when knowing one's exact position at sea saved both ships and the lives of sailors. With longitude being determined by time, and latitude by the angle of the sun at noon, mariners were able to find their exact position.

The earth, not a perfect orb, is an oblate spheroid, as discovered by A. R. Clarke in 1866. It is known that the earth rotates on its polar axis, or a line between the north and south poles. From this axis great circles can be contrived, such as the equator or 0° latitude, which has a 90° angle to the axis, and divides the earth in half, making the equator the largest or great circle. With the equator at 0°, the north and south poles are at 90° north and south latitude, respectively, with various angles from the axis in between. Latitude, then, is a line or parallel on the earth's surface that runs east and west at various angles from the axis and measures distance north and south on the earth's surface. Thus, the only latitude being a great circle is the equator with all other latitudes being smaller circles.

But, a number of great circles can be drawn on the earth depending on the angle from the axis, such as longitude. Longitude is a line or meridian that runs north and south but measures distance east and west (see the entry on John Harrison in this encyclopedia). Using an accurate timepiece such as a ship's chronometer, longitude can be calculated, and using a sextant the latitude can be found so that an exact position on the earth's surface can be plotted. Depending upon the accuracy required, latitude and longitude are measured by degrees, minutes, and seconds of an angle. The distance between lines of longitude decreases as one proceeds from the equator to the poles or as latitude increases.

It was Pythagoras, around 529 BCE, who first advanced the concept of the earth being a sphere with a moon evolving around the sun along with five known planets at that time. Later, Eratosthenes, around 300 BCE, was the first to place parallels on a sphere, but he named them after places. He also calculated the earth's circumference very accurately for that time, using the distance between two latitudes in Egypt. It was Ptolemy who first wrote about latitude and longitude in his *Geographia,* about the time that Alexander the Great was expanding Greek civilization.

The tools of navigation are a chart, a chronometer, a compass, and a sextant. Probably the first tool was the chart. The first charts, perhaps appearing as early as 2,700 BCE, were quite inaccurate. But, as time passed and technology improved, charts have become very accurate, so that contemporary charts actually a margin of error of less than one tenth of 1%. For measuring latitudinal position, the common quadrant was invented. From this crude instrument the astrolabe developed, first appearing about the 3rd century BCE. The astrolabe, like the common quadrant, was a device to measure the angle of the sun and various stars from the zenith. It was a cumbersome procedure involving several mariners. Later, the cross-staff was developed, with which the visible horizon was used rather than the zenith. Then, the back-staff or sea quadrant was invented by John Davis in 1590. Finally, in 1730, John Hadley perfected the sextant that is still in use today, commonly to measure latitude at noon using the angle between the horizon and the sun.

Another important tool is the compass. Crude though it may have been at first, it certainly decreased the chance of being lost at sea or in the desert. Perhaps the first compasses came into use about around the 11th century and were used by Norsemen. But, it wasn't until almost the 20th century that an acceptable compass was developed by Lord Kelvin for the British Admiralty. An accurate timepiece for use at sea, the chronometer, was developed by John Harrison in the 18th century for measuring longitude; this was the last tool to be developed for accurate navigation at sea. Today, the global positioning system (GPS) is used to find accurate location or position.

Latitudes of significance, besides the equator and the poles, include the Arctic and Antarctic Circles at 67.5° north latitude and 67.5° south latitude, respectively, and the Tropic of Cancer and the Tropic of Capricorn at 23.5° north latitude and 23.5° south latitude, respectively. These smaller circles represent the relationship of the sun's illumination at the summer and winter solstices. During the vernal equinox and the autumnal equinox, the sun's rays are directly on the equator, but during the solstices the sun's direct rays are over the tropics of Cancer and Capricorn, while the poles are in either total darkness or sunshine. These relationships between the earth and the sun are directly related to our weather patterns, seasons, and climate.

Richard A. Stephenson

See also Astrolabes; Chronometry; Harrison, John; Presocratic Age; Timepieces

Further Readings

Bowditch, N. (2002). *American practical navigator.* Washington, DC: National Imagery and Mapping Agency. (Original work published 1802)

Christopherson, R. W. (2004). *Elemental geosystems* (4th ed.). Upper Saddle River, NJ: Prentice Hall.

Dunlap, G. D., & Shufeldt, H. H. (1972). *Dutton's navigation and piloting* (12th ed.). Annapolis, MD: Naval Institute Press.

LAW

Law is a cultural achievement of humankind. It is subject to an evolutionary process in which a sense of right and wrong is developed, and the legal system as the end of this evolution is connected and continuously adapted to the conditions of human existence within a complex framework of social interaction. Essentially the main function of law consists in judging and sanctioning human behavior according to the judicial code of legal/illegal. It is possible to differentiate systems of law from an historical point of view depending on whether this function is intended to uphold and continue past customs or to steer the future.

Ancient and medieval systems of law are structurally characterized by a strong connection between law, politics, and morals; a case in point is the historical trial against Socrates (469–399 BCE). The law of those eras is deeply rooted in social customs and traditions. It is not so much the will of the lawmaker that determines what is right. What is right is primarily established by the authority of the judge, often personified by rulers themselves, who legitimize the law through their decisions. His point of view is principally directed toward the past as a time when conditions were right. And their verdict must uphold this continuity—old law is good law.

According to Georg Wilhelm Friedrich Hegel (1770–1831), legal thinking changed with the "invention" of subjectivity during the eras of the Renaissance and the Reformation. Individuals came to be seen as subjects who make themselves the persons they are. No longer did the demands of the past determine the life of an individual. Instead, individuals came to be defined by the tasks they choose themselves and their dedication to fulfilling them. But the joy of being the creative sculptor of one's own biography, the "plastes et factor," as Pico della Mirandola (1463–1494) fittingly calls it in his *Oratio de Dignitate Hominis,* is joined by worries about the future, a future that is essentially open and uncertain. Consequently, even today, the main task of law is to steer the future.

Temporality of Law

It has been obvious since the Enlightenment, or beginning of the Modern Era, that differentiations are made between law, politics, and morals. Living an upright life has increasingly become a question of outwardly obeying laws with no particular regard to moral considerations. The difference between making and enforcing laws has been institutionally reinforced. In general, the judge's verdict has been given a legal framework and thus become much less dependent on the center of political power—due in part to the condition that decisions must be made promptly. Law will always be power oriented, but, thanks to its own normative nature, it also establishes a bond with the future in that general expectations of an individual's behavior are stabilized—even though these expectations may be disappointed in individual cases. An essential factor that fosters this function of law is the construction of its own temporality.

Self-reflexivity is a prerequisite for this construction of law's inherent time: Law exists, because it is valid—specifically as long as it is valid. Differentiating between natural and legal time is therefore relevant for the validity of law. For example, as long as law is carried out under the auspices of a particular ruler, the validity of the regulations is bound to the "lifetime" of that ruler. As a result, the effectiveness of a legal system decisively depends on whether it is possible to create and change norms according to its own legal rules, in other words, to separate them from a specific time period. This process is particularly evident, because there is usually no mention made about when the validity of legal norms ends. They are, in a certain sense, "timeless." In some cases possible changes are even explicitly excluded, for instance by rhetorical expressions, such as human rights are "inalienable," human dignity is "inviolable," and the core of a constitution is valid "forever." These examples make it clear how the normative nature of law tries to immunize itself against social changes, especially in the field of politics. From a legal perspective, it may not be possible to prevent rulers from violating human rights; but by no means should they claim to act in accordance with the law when violations are committed.

Positivity of Law

The construction of a legal time provides for law's ability to structure its relationship to natural time: Legal validity means the present, which is differentiated from life's unchangeable past but also from the open (and, in that sense, more or less uncertain) future. In this corridor of the present, legal norms can develop their own "history" but are also latently subject to becoming history by a stroke of the legislator's pen as a result of their positive nature (i.e., by being recorded in a fixed, written form). Yet, seeing as their "time" is left to the will of the legislature, their history must be differentiated from the historical course of events. In effect, legal norms represent a particular moment in history that is highlighted in the course of time and conserved. Their changeability takes place in accordance with the given rules of law, in other words, in accordance with those norms that are higher and that determine the changeability of the individual legal norms. If that were not the case, norms could be changed at any time and would never develop a "timeless" effect.

The positivity of legal norms structurally guarantees a somewhat anachronistic character by welding past, present, and future under the conditions of law and creating a context that detaches itself from natural time. That is immediately obvious in the power of legal norms to call forth a specific future. They determine which behavior will be right and which will be wrong in the future. Of course, it is neither possible to know what the future will bring nor how individuals will behave, but it has already been established how their behavior will be judged legally. Following Immanuel Kant (1724–1804), this does not relieve individuals of their freedom to select their own goals and determine how they want to behave, but it requires everyone to respond to the law. Only with this common reference, which can be taken into consideration by evaluating the consequences of one's own behavior, is it possible to establish a common present.

Law also reacts in a similarly selective way in regard to the past; for all that remains, from a legal point of view, is what the legal norms specifically deal with. Everything else is nothing but the preface to a case that plays no role in determining the actual verdict. On the one hand, the past is permitted only in accordance with legal proceedings and admissible evidence. On the other hand, the unchangeable nature of the historical past does not touch the legal past, because legislation can changed retrospectively.

Legal Time

Legal time is expressed in a number of regulations. The calendar, for example, can be of individual nature in creating time divisions or in differentiating between standard time and daylight savings time. Typically, law leaves the measurement of time up to the laws of time, but it also connects it with value judgments about the quality of legal persons (e.g., being of legal age) or legal relationships (e.g., obtaining possession by prescription). Furthermore, appointments or deadlines are also objects of legal value judgments, for instance, when "immediacy" is mentioned, meaning that the person in question is required to act without culpable delay.

A perfect example of an individual construction of legal time measurement is the "legal second," a second that has no counterpart in natural time. It is purely an invention of law. Nevertheless, legal time is not completely unrelated to natural time, especially in regard to the omnipresent social problems of time. If law is to do justice to its function of binding and steering the future, it should always keep the conditional possibilities of legal behavior in mind: Things should be done on time. And that requires a worldly adaptation, a synchronization of law in connection with worldly situations, so that the rules can be followed within an appropriate period of time. Law itself should be "just in time."

Oliver W. Lembcke

See also Democracy; Ethics; Evolution, Cultural; Evolution, Social; Hammurabi, Codex of; Hegel, Georg Wilhelm Friedrich; Kant, Immanuel; Morality; Scopes "Monkey Trial" of 1925; Statute of Limitations; Time Management; Values and Time

Further Readings

Greenhouse, C. J. (1989). Just in time: Temporality and the cultural legitimation of law. *Yale Law Journal, 98*(8), 1631–1651.

Kirste, S. (2002). The temporality of law and the plurality of social times: The problem of synchronizing different time concepts through law. In M. Troper & A. Verza (Eds.), *Legal philosophy. General aspects: Concepts, rights and doctrines* (pp. 23–44). Stuttgart, Germany: Steiner.

Luhmann, N. (2004). *Law as a social system.* Oxford, UK, and New York: Oxford University Press.

Leap Years

The calendrical convention of the leap year is important to how we keep track of time. In the Gregorian calendar, adopted in 1582, a leap year is a year to which an extra day (February 29) is added. This extra day occurs in every year evenly divisible by 4. There is one exception to this rule.

For years marking the turn of a century (e.g., 2000, 2100), if the year can be divided evenly by 400, it is considered a leap year. The year 2000 was a leap year, whereas 2100 will not be.

Leap years correct for the difference between a solar year and our calendar year. A solar year is the time (approximately 365.25 days) it takes the earth to complete a single orbit around the sun. Counting 365 days from January 1 to December 31 means that in four Earth orbits around the sun, the calendar difference (4 times .25) would have the New Year starting on January 2.

Early in history, the Egyptians, with sophisticated astronomical skills, realized the calendar would get out of date with the solar year. They therefore began adding a day every 4th year. Later, the Romans used a calendar with alternating months of 30 and 29 days. This produced a calendar year of 354 days, which came up short by 11.25 days a year, meaning in just 3 years the calendar became out of synchronization by more than a month. Their imperfect solution was to add a month every 2 or 3 years, thereby causing more confusion.

The emperor Julius Caesar solved the problem in 45 BCE by establishing a calendar of 365 days and adding 1 day every 4 years. In order to bring the calendar into alignment with the solar year, he added extra months to 1 year. This worked for a while, but the remaining inaccuracy led to a difference between the calendar beginning of spring and the vernal equinox, which defines spring.

The first day of spring occurs when the sun is directly above the equator while moving from south to north. This day, when the lengths of day and night are equal, is the vernal equinox. Similarly, in fall, the autumnal equinox occurs when the sun is again directly overhead but moving from north to south. The slow changes in calendar year versus the solar year meant that by the 16th century CE, the beginning of spring had moved from March 23 to March 11. Pope Gregory XIII ordained the change the calendar in 1582 to move the 1st day of spring to March 21. To do this, 10 days were eliminated, so the day after October 4 was October 15. Non-Catholic countries changed as well but not until 1752 or later. Other cultures use leap years but with different methods to calculate when to insert days or even months.

Even with the new adjustments, there is still a very small difference in the length of a calendar day and a solar day. However, it will take about 8,000 years before the difference will amount to a full day.

Charles R. Anderson

See also Calendar, Egyptian; Calendar, Gregorian; Calendar, Julian; Calendar, Roman; Earth, Revolution of; Time, Measurements of

Further Readings

Duncan, D. E. (1998). *Calendar: Humanity's epic struggle to determine a true and accurate year.* New York: Avon.

Steele, D. (2000). *Marking time: The epic quest to invent the perfect calendar.* New York: Wiley.

Leibniz, Gottfried Wilhelm von (1646–1716)

Gottfried Wilhelm von Leibniz was an outstanding German philosopher, mathematician, scientist, historian, and diplomat. He tried to develop an

Gottfried Wilhelm von Leibniz, German philosopher and mathematician.

Source: Bildarchiv Preussischer Kulturbesitz/Art Resource, New York.

adequate metaphysical system to answer the fundamental question, "Why is there something rather than nothing?" and examine the worldview resulting from his answer. After all, he observed, nothing is simpler and easier than something. But there *is* something, so why is that so? This entry discusses Leibniz's core ideas on metaphysics, including his concepts of space and time.

Two of Leibniz's guiding basic principles were the principle of contradiction (whatever implies a contradiction is false; thus, every true proposition is a tautology—always true) and the principle of sufficient reason (nothing exists without a sufficient reason why it is so and not otherwise). In an argument analogous to one of Saint Thomas Aquinas's five ways to prove the existence of God, he argued that the reason for the existence of the world cannot lie in the contingent things (they might have all gone out of existence at the same time, and then what?); it must lie in a necessary being—God. God is the metaphysically perfect substance, containing all perfections, such as omniscience and omnipotence. Leibniz's idea of God seems to be like a kind of supermathematician; God examined all the infinite number of possible worlds and chose the best, that one that is "simplest in hypotheses and richest in phenomena." In an effort similar to work done by Johannes Kepler in determining the optimum dimensions of a wine cask to contain the most liquid with the least material required, Leibniz's God might have applied a kind of minimax procedure to come up with the optimum combination of characteristics for the world. If there had been no best combination, there would not have been a sufficient reason for God to create a world, and there would be none; thus this must be the best possible world. When God *thought* the best possible world, his thoughts *became* the world. (Leibniz argued that thoughts require signs, and the world is the sign of God's thoughts.)

René Descartes (1596–1650) had thought that the essence of (physical) substance was extension (as contrasted with mental substance, whose essence was thinking), and so a geometrical account could explain all properties of bodies. Leibniz saw that this was inadequate, that a geometrical account of motion failed to take inertia and momentum into account. Thus Leibniz concluded that the essence of substance is *action,* it has a force (*conatus*), a striving to change (for the better). The basic building block of the world, thought Leibniz, must be indivisible, a formal atom—a *monad.* Leibniz's monads are like little minds; it is as if bodies are a byproduct of these minds (he sometimes refers to a body as a momentary mind). These monads are "windowless," unaffected by anything other than their own programs. It is as if each monad is driven by its own program (something like a computer program), its internal tendency to move from one state to the next. This "program" has existed as long as the monad and determines its current state and what state it will be in next. It is like a finite-state automaton, with its initial state and the function that describes how it changes; these totally define it. Its principle of change Leibniz calls "appetition"—it is a striving for perfection. The world itself cannot *be* perfect, for then it would be God, and there could not be two Gods (there is not a sufficient reason for *any* two identical things, according to Leibniz); but the world strives toward perfection, and it is this striving that underlies change. Each monad, since its program totally defines it, contains its future and the traces of its past: "The present is big with the future, the future might be read in the past, the distant is expressed in the near."

Each monad has perceptions, which are its perspective on the universe, and Leibniz says that each monad reflects the whole (universe), though imperfectly. Thus it may contain the whole, but not be aware of all its aspects, or some of them may be less "in focus" than the nearer ones. A monad's perceptions are its properties; thus the monads form a plenum, because otherwise a monad could perceive nothingness, but nothingness cannot be one of its properties. A monad is a "concentration and a living mirror of the whole universe, according to its point of view." Thus monads make up the world and perceive the world at the same time; they are all part of the world harmony created by God's thought. Thus there is hope for knowledge of the truth regarding objective reality (of that world). The dominant monad of the aggregation of monads that gives rise to a body is its *soul* monad, which is dominant over the others. It has memory and reason and is farther up the hierarchy of monads. A rational soul, in discovering truth through science (or mathematics or logic), imitates what God does in the world as a whole; it is a kind of image of God. It tries to know God, but since God is infinite, it can never achieve full knowledge, but it can continue striving in "perpetual progress" (and never get bored!).

Leibniz argues that there are two realms: the realm of Nature and the realm of Grace. Because perceptions (and feelings) cannot be explained by mechanical causes (like trying to find your perception/idea of red by surgically examining your brain), there must be another realm (of final causes) that governs the soul monads (in their striving toward the best, to maximize good over evil). In the realm of nature, bodies follow the laws of efficient causes; these two realms will, according to Leibniz, always be in harmony, as God thought them. There will be two possible explanations, one following final causes, the other following efficient causes in the realm of nature, for every event; Leibniz says they are "equally good" explanations. Thus the mental and the physical realms are in sync because of God's preestablished harmony; they are like two clocks created and started off by the same watchmaker that continue to tell the same time even though there is never any interaction between them, or like members of a chorus who sing the same music even though they never touch each other or directly interact. They run in perfect parallel (which is his explanation to Descartes' problem of how mind and body affect each other, without Descartes' desperate solution that they interact in the pineal gland).

Leibniz views space and time as relative (see the entry on Newton and Leibniz). Space is created by the positioning of bodies, bodies are not placed in an absolute preexisting container space, and time is the succession of states (physical or mental) of bodies or minds. Without bodies, there is no space; without change, no time. Space and time are thus, for Leibniz, relations; they are ideal (based in ideas), phenomenal. Time is the more fundamental, because monads have their internal programs to move from one state (condition) to another, in their striving toward perfection. The difference between one state and another state creates their temporal relation (first one state, then the next, creates the temporal relation of earlier and later time, of past and present, or present and future). This would be time in the realm of grace, from one perceived state to another. Monads that congregate together as a body guided by a soul monad act and change in the realm of nature, so time in that realm would measure the difference between different bodily states. Derivatively, physical space would be defined by the relative position of bodily monadic aggregates.

Stacey L. Edgar

See also Descartes, René; God and Time; Idealism; Metaphysics; Newton and Leibniz; Ontology; Space; Spinoza, Baruch de; Theodicy; Time, Relativity of

Further Readings

Leibniz, G. W. (1989). Monadology. Principles of nature and grace. Discourse on metaphysics. In R. Ariew & D. Garber (Eds.), *G. W. Leibniz: Philosophical Essays*. Indianapolis, IN: Hackett. (Original works published 1686 and 1714)

Leibniz, G. W. (1996). *New essays on human understanding* (P. Remnant & J. Bennett, Trans.). Cambridge, UK: Cambridge University Press. (Original work published 1764)

Lemaître, Georges Édouard (1894–1966)

Georges Édouard Lemaître, a Belgian engineer, astrophysicist, and Catholic priest, was known for his theoretical contributions to the understanding of the origin of the universe. Theologically unorthodox and based on available scientific evidence, Lemaître's theories postulated that the universe was expanding from an unknown point of origin. This expansion, as evidence suggested, would entail that the origin of the universe would require vast differences in space and time from the condition of the universe today. In what is now commonly referred to as the big bang theory, Lemaître speculated that the universe was a product in the breakdown of the primeval atom, whereby the stars, planets, and nebula exist in an expanding universe. Furthermore, he attempted to bridge the gap between science and religion by suggesting that there are two distinct metaphysics, one for science and another for religion. Lemaître was known for his publications *Discussion on the Evolution of the Universe* (1933) and *Hypothesis of the Primeval Atom* (1946).

Contrary to previous concepts of the universe as being both infinite and static, scientific contributions from Edwin Hubble (1889–1953) and Albert Einstein (1879–1955) suggested that the universe was not static but expanding and relative. This would have serious consequences for both the traditional concepts of time and space. Although Lemaître held that the mass within the universe is constant and distributed in a nonuniform manner, the expansion of the universe would indicate that the velocity of expansion will change in time and space. Insofar as the origin of the universe, Lemaître suggested, was based on quantum theory, the quanta would decrease in number and increase in the amount of energy. When reduced to a few quanta or a single quantum whose atomic weight would reflect the total mass of the universe, the concepts of both time and space would be devoid of meaning. This primeval atom would contain the undetermined nature of the present universe; whereas spatiotemporal reality did not begin until the disintegration of this primeval atom.

Lemaître's theory, though speculative, had a profound impact on traditional cosmology. Philosophically and theologically, the beginning of the universe would call into question previous human ontology and teleology. The existence of God, the concept of the void, the stability of the universe, and humankind's place in nature would conflict with traditional perspectives. Lemaître, a proponent of dissonance, never acknowledged this conflict between science and religion, for he held that science and religion were two separate and different types of knowledge. However, an exact epistemological synthesis—understanding and blending the temporal nature depicted by science and what is stated in scripture—was never stated, and thus the two accounts remain irreconcilable.

Although problematic, Lemaître's contribution to science and cosmology remains as important as it is controversial. According to Lemaître, the universe, like the planets, had a definite beginning. Time and space, in relation to the newly "created" universe, would provide the unwritten basis for the development of preexisting matter in the universe. Humankind, a minute part in this cosmological unfolding of time and space, would not only ponder the evolution of our species but also the evolution of the universe.

David Alexander Lukaszek

See also Big Bang Theory; Black Holes; Cosmogony; Einstein, Albert; Gamow, George; Singularities; Universe, Contracting or Expanding; Universe, End of

Further Readings

Lemaître, G. (1931). The beginning of the world from the point of view of quantum theory. In M. Bartusiak (Ed.), *Archives of the universe*. New York: Vintage Books.

Lemaître, G. (1931). A homogeneous universe of constant mass and increasing radius accounting for the radial velocity of extra-galactic nebulae. In M. Bartusiak (Ed.), *Archives of the universe*. New York: Vintage Books.

Lemaître, G. (1949). *Beaumarchais*. New York: Knopf.

Lemaître, G. (1950). *The primeval atom*. New Jersey: Van Nostrand.

LENIN, VLADIMIR ILICH (1870–1924)

The Russian revolutionary Vladimir Ilich Ulyanov, who later adopted the name V. I. Lenin, was born to Mariya Blank, a doctor's daughter, on April 10, 1870, in Simbirsk, where his father was an educator, schoolmaster, and inspector of primary schools. He was one of six siblings.

The second child and oldest son, Alexander (Sasha), went to St. Petersburg University in the fall of 1882, where he majored in natural science. While there, he joined an organization known as Narodnaya Volya, or the People's Will. This terrorist wing believed in a socialist party led by the working class. Socialism was the logical extension of democracy, but czarists did not allow for peaceful development of democracy. Legal opposition was not allowed. The only option for purging the official hatred of any popular movement toward socialist democracy was terrorism. In February 1887, the People's Will planned the assassination of Alexander II, czar of Russia. The police discovered the plot, and as a result, Alexander Ulyanov was executed in 1887 for being a part of the group that attempted to kill Alexander II.

Because of this experience, young Vladimir was propelled into revolutionary activity. As such, Vladimir would become a leader in the Russian Revolution. A diligent scholar, Lenin attained a mastery of social theory and a sound understanding of the history of social movements and historical trends. As a leading activist, Lenin wrote a series of articles that would not only serve as a guide for revolution in Russia but also lay the intellectual foundation for what would become Marxism-Leninism. These articles included *The Development of Capitalism in Russia.* In this work, Lenin tried to prove that that by 1900, Russia had already been incorporated into the world capitalist system. As a result, the peasants were rapidly being divided into capitalist farmers and the rural proletariat. Russian industry was divided between traditional handicrafts, backward manufacturing, and a modern machine industry in which a great deal of foreign capital was invested.

In 1902, Lenin wrote the pamphlet, *What Is to Be Done?* "Without revolutionary theory there can be no revolutionary movement," Lenin stated. He wrote that unions by themselves would only lead to struggles over wages and working conditions; a socialist consciousness needed to be introduced from outside the working class. This would require an organization of professional revolutionaries. The organization would need to be disciplined, conspiratorial, and centralized. The "party of a new type" would become the vanguard of the working class and would lead, but remain separate from, the broader democratic workers' movement.

In 1904, Lenin wrote *One Step Forward, Two Steps Back*. At this time, Lenin's writing was based upon the assumption that the workers' party needed to be taken over by those workers who were educated with a socialist awareness. The intellectuals were undependable, obsessed with eccentricity, anarchism, and egoism, and had an intense horror of discipline.

Materialism and Empiriocriticism was written in 1908 as a rebuttal to the physicist Ernst Mach, who had stated that reality was only the actuality of our experience, and therefore science could record only our subjective experiences. In *Materialism and Empiriocriticism,* Lenin affirmed that science is the observation of the material universe, existing independently of the observer. Physical sensations are the direct connection to the external world. Every ideology is conditioned by its historical setting. Science is no different, yet science is valid. It is independent of the observer to the degree it corresponds externally to tangible nature.

Sensations, wrote Lenin, are our obvious link between our consciousness and the external world. Energy affects our bodies, which are excited by stimuli and provoked by the external world. This in turn excites a chemical response in our nervous system and is transformed into consciousness by the mental activity of our brains. The energy of the exterior excitation changes physical and chemical corporeal activities and is transformed into sensations. Sensations are changed into consciousness. Consciousness is cast and grows. Consciousness interprets sensations. This implies a dynamic and interactive process in mental development. We learn through actively interacting with both the social and physical environment.

Physical and social realities, Lenin noted, are constantly changing. There is an eternal process of conflict and fusion of conflicting parts leading to the death of the old and the birth of the new. This simple logic is basic to anything that can be studied. It is more than a part of mental processes, or the way that the world is studied and understood. This logic is broadly similar to the way the universe is constantly evolving. The opposition and combination of components forming ever-greater wholes is an approximation of what is really happening to the universe outside the mind. When these opposing and interacting parts are fused, there is something basically different being formed that will replace what went before. The new thing soon develops its own tensions as it begins to break down. These new tensions not only lead to the extinction of this entity but also give birth to its replacement.

Science, according to Lenin, is a specialized form of logical practice, founded upon the certainty that there is an external reality that is independent of our consciousness. Through careful observation and the use of specific scientific method to analyze observations, this external reality is more closely revealed than by any other technique of understanding. Because all scientific observations are approximations, science is a constantly growing discipline. Every generation will get progressively closer to this external reality. The limitations of the categories used are always qualified, modest, changeable, provisional, and approximate. Each scientific breakthrough is built on earlier breakthroughs. Because every ideology is historically conditioned, science itself occurs in a specific historical setting. This is the basis of materialism; the fact that political states are a reality can be understood in terms of matter in motion.

In 1908, Lenin wrote *The Agrarian Program of Social Democracy in the First Revolution.* Most peasants in Russia were downgraded to farm workers and tenant farmers. Only a small number of peasants had enough land to endure as farmers. A minority of the farmers were rapidly becoming more like American capitalist farmers. The large feudal *latifundium* (large estates) remained. The *latifundiums* slowly developed into large farms modeled on the German Junker type. With the breaking down of feudalism, capitalism developed. The market economy merely meant that the state was becoming a major landowner.

Lenin contributed to the Marxist theory of imperialism with his text called *Imperialism: The Highest Stage of Capitalism.* According to Lenin, imperialism was "the final stage of capitalism," a sign of the breakdown of capitalism and the transition to socialism. Competitive capitalism of the early 19th century had become increasingly centralized, with fewer competitive firms surviving the increasingly intense competition. As a result, capital became concentrated in larger firms. In this way, "monopoly capitalism" was able to create ever-larger surpluses by limiting competition. Markets at home became glutted, and investment opportunities in the industrialized nations declined. This meant that corporate capitalists were forced to export capital to ensure future profits. This became, for Lenin, a major distinction between the earlier competitive capitalism and its later descendent, monopoly capitalism. Competitive capitalism exported finished goods in exchange for raw materials produced in the poor areas of the world. Monopoly capitalism exported its capital to these areas. Capital was invested to create modern ways of extracting those same raw materials. Instead of mines being owned by the local traditional elite, capitalists in the rich industrial nations owned them. This caused an increase in overall capital on a world scale while arresting development in the main capitalist countries.

The principal feature of modern capitalism was the domination of monopolist consolidations by giant capitalist firms. The monopoly control was most firmly established when all sources of raw materials were jointly controlled by several large surviving firms. Monopoly capitalism, with a few highly centralized firms effectively dominating the economy, created imperialism out of its own needs. In order to find continued profits in an already overdeveloped economy at home, investments flowed to less developed areas of the world, where the capitalist economy had not reached a saturation point, therefore making profits much higher. Export of capital was the fundamental principle of imperialism. The export of capital greatly influenced and hastened the growth of capitalism in those countries to which it was exported.

The next two most important of Lenin's works, which outlined his sense of history, were *State and Revolution* and *"Left-Wing" Communism: An Infantile Disorder.* Both were models for the direction revolution would take. In *State and Revolution,* Lenin maintained that the workers could not merely take over control of the existing state; they needed to smash it. Then, when the returning bourgeoisie was overthrown, the state would wither away. In *"Left-Wing" Communism: An Infantile Disorder,* Lenin disapproved of leftists in the West for disregarding parliamentary tactics and legal opportunities to create their own socialist revolution. Lenin also summarized the significance of all communist parties that had become centralized and disciplined and were following the lead of the Russian party.

Michael Joseph Francisconi

See also Consciousness; Dialectics; Economics; Engels, Friedrich; Mach, Ernst; Marx, Karl; Materialism

Further Readings

Lenin, V. I. (1939). *Imperialism: The highest stage of capitalism.* New York: International.

Service, R. (2001). *Lenin: A biography.* Cambridge, MA: Harvard University Press.

White, J. D. (2001). *Lenin: The practice and theory of revolution.* Hampshire, UK: Palgrave.

Leonard da Vinci

See Fossils, Interpretations of

Libraries

A library is a repository for recorded information. The concept of a library has evolved but has existed in some form for thousands of years. The ability to record information in a format more permanent than oral tradition added another dimension to human communication time. Information that has been transcribed into a solid, visual format can be accurately remembered over generations. While libraries have physically changed over the course of history, their cultural role has not. Libraries and librarians are responsible for acquiring, maintaining, and providing access to information. They keep business, legal, historical, and literary records of a civilization. Libraries could be considered the memory of a society.

The word *library* is derived from the Latin *liber,* meaning "book." Traditionally, library refers to a collection of books, or a room in which such a collection is kept. In the earliest days of recorded information, however, there was no distinction made between a record room (archive) and a library, so it could be said that the concept of a library has existed for as long as writing.

The Ancient World

The emergence of large, complex civilizations in Egypt and Mesopotamia 6,000 years ago necessitated the development of writing to provide the record keeping needed to maintain a stable and orderly society. Ancient civilizations in East Asia indicate similar development, with collections of official records dating to as early as the 12th century BCE in China.

Hieroglyphs emerged from the artistic history of Egypt, starting a tradition of literacy and recorded knowledge. This writing system used pictures to reflect words and ideas. As writing became more widespread and vital in Egyptian society, simplified glyphs were developed, resulting in hieratic (priestly) and demotic (common) scripts. These cursive writing forms were better suited to writing texts on papyrus, greatly increasing the speed in which scribes could write business or literary texts.

In Mesopotamia, the most abundant material for information storage was clay. Cuneiform writing, done with a wedge-shaped tool, was impressed into tablets of damp clay. After the tablets dried, they were permanent. A temple dating to the 3rd millennium BCE in Nippur had several rooms filled with tablets, indicating the existence of a well-developed archive. Large collections of tablets also appear to have been deliberately organized with a catalog listing the contents of the collection.

In East Asia, records were first inscribed on bone, stone, bronze, or tortoise shell and date to the Shang dynasty (approximately 1200 BCE). By the 8th century BCE, less durable materials such as bamboo or wooden slats were used. Lengths of silk appear in the historical record during the 4th century BCE. Paper was invented in China in the 1st century CE, but it would take several centuries for it to completely replace the cumbersome bamboo or the expensive silk. In China, records were often destroyed during war or purged when new rulers assumed the throne, so history would appear to begin during their reigns. The Han dynasty, which succeeded in 206 BCE, ended the repression. They recovered earlier works that were hidden, encouraged writing and record keeping, and developed formal methods to classify information.

In the Western world, libraries had their origins in classical Greece and Rome. Most of the larger Greek temples appear to have had libraries and record rooms. As early as the 6th century BCE, Greek leaders were constructing large public libraries, and a sophisticated book trade existed in Athens by the 5th century BCE. Many large book collections were owned by wealthy citizens. One of the finest private collections of ancient times was owned by Aristotle. His collection was seized and taken to Rome by Sulla in 86 BCE as war booty. From there, copies of his texts became the basis of the greatest library in antiquity at Alexandria.

The Alexandrian library was planned by Ptolemy I in the 3rd century BCE and established by his son Ptolemy II. The founders of this library intended to collect the finest copies available of every piece of Greek literature and arrange it systematically to facilitate research. It was staffed by many famous Greek writers and scholars and was estimated to contain 700,000 scrolls of parchment and the first use of vellum.

Private libraries were common in classical Rome. It was considered fashionable to have a library in your home. Interestingly, imperial Rome is known for military skill, not intellectual life, but Romans revered books and transported hundreds of collections virtually intact back to Rome when plundering foreign lands. Most of the captured libraries were incorporated into the private libraries in officers' homes. Eventually, Romans decided that placing these collections in large public buildings would display the glory of Rome. Julius Caesar is credited with actually planning the first public library facility, but he died before the plans could be completed. Tiberius, Vespasian, Trajan, and many later emperors created libraries throughout the city.

The Middle Ages

Books were thought to be essential to spiritual life. As monastic communities were established in the 2nd century, monasteries included a library for reading and study. They also incorporated a *scriptorium,* a room where manuscripts were copied. Strict rules existed for the use of the books, but at the same time, monasteries often lent materials to other monasteries or to the public. The contents of these libraries included scriptures, religious histories, philosophical writings, and some secular literature. Unknown scribes copied texts repeatedly for generations, preserving cultural transmission through the Middle Ages. Important developments during this time include the codex, or book, and the use of vellum (animal skin) for the pages of books. This new format for recording information was far more durable than papyrus. After universities were founded in the 11th century, students who were also monks returned to their monasteries and deposited their lecture notes in the monastery collection, expanding its contents. The libraries of newly founded universities and monasteries were the main places to study until late in the Middle Ages. Books were very expensive, and only the wealthiest individuals could purchase copies.

The Renaissance

Private book collections developed again through the 13th to 15th centuries. The growth of commerce, widespread education and literacy, the new learning of the Renaissance, and the invention of the printing press by Johannes Gutenberg widened the circle of book collectors. Paper also became the preferred writing surface in the 15th century. Paper and the printing press made books far cheaper, faster, and easier to produce for the rapidly growing reading market. Along with a sophisticated book trade, many fine public libraries opened in Italy and throughout Europe.

17th and 18th Centuries

In the 17th and 18th centuries, book collecting everywhere continued to expand. In Europe and North America, many fine private collections were formed that eventually became the core of national and university collections. National libraries today receive one free copy of every book and periodical produced in that country and are maintained with national resources. They attempt to collect and preserve the nation's literature while keeping an international scope. A new form of library also developed at this time, the circulating library for popular literature. Circulating libraries were operated by booksellers for profit, but they made a large body of literature available to the general public for a nominal cost.

20th Century

The look and feel of libraries has changed drastically since the 19th century. A leading figure in transforming library service was Antonio Panizzi, an Italian refugee who began working for the British Museum in 1831 and was its principal librarian from 1856 to 1866. He revolutionized library administration and developed a code of rules for catalogers. He also recognized the potential of libraries being open to all for research and reflected this notion in his planning of the British Museum reading room. With the emergence of a large reading public and an enormously expanding stock of books and periodicals, libraries had to expand their organization and storage capacities.

The paradigm for libraries shifted again in the 20th century with the advent of new information technologies. An information explosion after World War II created a need for new methods to store information. Compact movable shelving, microfilming, and remote storage evolved to address this need. Today, the vast quantity of information available through databases and other online resources requires computers and highly qualified professional librarians to help the public navigate through the overwhelming amount of information freely available to everyone. Many types of libraries and services are available today. There are great national libraries, university and research libraries, and public libraries that are generally open to everyone. In addition, there are special libraries founded to meet the research needs of a specific group, school libraries for the students of that institution, and private libraries that reflect the interests of the collector. Archives exist as separate entities today and are generally collections of papers, documents, and photographs preserved for historical reasons.

The Future of Libraries

Libraries have always been driven by the needs of their users. That will not change. Today, most libraries open to the public are fairly neutral in their collections—they have something for everyone. This may have to change given the exponential growth of information available. To be able to manage diverse subjects and formats, while also preserving existing collections with limited funds, is becoming increasingly difficult. Libraries of the future will likely have to specialize and tailor their collections to specific groups of users. Resource sharing between libraries will continue to grow in importance.

While the appearance of libraries and the methods of doing research will continue to change, the main purpose for their existence is unchanging. Libraries and librarians will continue to be responsible for acquiring, maintaining, and providing access to the collective knowledge of a civilization, no matter what form that knowledge may take in the future.

Jill M. Church

See also Evolution, Cultural; Hammurabi, Codex of; Information; Museums; Rosetta Stone

Further Readings

Battles, M. (2003). *Library: An unquiet history.* New York: Norton.

Casson, L. (2001). *Libraries in the ancient world.* New Haven, CT: Yale University Press.

Harris, M. (1999). *History of libraries of the Western world.* Lanham, MD: Scarecrow Press.

Lerner, F. (1998). *The story of libraries: From the invention of writing to the computer age.* New York: Continuum.

Maxwell, N. K. (2006). *Sacred stacks: The higher purpose of libraries and librarianship.* Chicago: American Library Association.

Rubin, R. (2004). *Foundations of library and information science.* New York: Neal-Schuman.

Staikos, K. (2000). *The great libraries: From antiquity to the Renaissance.* New Castle, DE: Oak Knoll Press.

Life, Origin of

The origin of life remains today one of the most challenging puzzles to science. The challenge is twofold: (1) qualify the essence of life and (2) explain its appearance on Earth. Although both aspects have been subject to much scientific investigation, no satisfactory explanation has been formulated so far.

Life is often defined as the distinctive property of particular physical systems: living organisms. One way of defining life is to say that a physical system is alive if and only if it can replicate with variation and therefore be submitted to natural evolution. From a temporal perspective, the origin of life can therefore be defined as the point in time when, for the first time on Earth, a particular physical system simultaneously displayed a set of given properties, namely replication and variation.

How life is defined has a strong impact on the question of its origin: Taking a more restrictive definition of life, one that would for instance require that such replicating systems with variation be able to complete at least one thermodynamic cycle, would move forward the point in time when the origin of life might be traced back to. In addition, defining life as a collective set of properties of living organisms also raises the question of the temporal order of appearance of each of these properties: For instance, which appeared first, replication or variation?

Roughly speaking, life most likely appeared on Earth some 3.8 billion years ago. This dating is framed, on the one hand, by the formation of the planet some 4.5 billion years ago, with still some heavy meteoritic bombardment until about 4 billion years ago; and, on the other, by the oldest cellular fossils dated 3.6 or potentially even 3.8 billion years ago. As such, the time frame available for life to appear is about 200 to 400 million years.

The first modern hypotheses of the origin of life were formulated in the 1920s by Alexander Oparin and John B. S. Haldane, separately: The first living systems would have appeared in a primitive ocean of organic molecules, all of them resulting from prebiotic chemical processes, that is, chemical processes compatible with the physicochemical conditions believed to be those of the primitive Earth, before the appearance of life. The first scientific experiments supporting these hypotheses are those of Stanley Miller in 1953, who demonstrated the possibility of synthesizing certain organic molecules—amino acids—under prebiotic conditions. Since then, the prebiotic synthesis and chemical behavior of numerous other organic molecules in prebiotic conditions have been investigated, including those of proteins, lipids, and nucleic acids. Today, the scientific field of research on the origin of life draws upon a large number of disciplines: molecular biology, biochemistry, prebiotic chemistry, and theoretical biology but also planetology, geology, or even astronomy, in order to define the environmental conditions of the primitive Earth or to search for primitive life forms on alternative planets.

Far from having occurred at a particular moment or point in time, as a sudden event, the origin of life is likely to have been the result of a long and gradual process. The question remains whether this gradual process is truly continuous or might otherwise display some sorts of sudden steps akin to phase transitions, for instance. In the latter case, such steps could be used as particular landmarks for defining the origin of life, even if these are still speculative today. Due to this specific time frame of several hundred million years during which life is thought to have appeared on Earth, experimental research on the origin of life has to consider a broader scope of physicochemical possibilities than usual, for instance chemical reactions with longer characteristic times than in usual laboratory experiments, or environmental conditions that would be much different from current ones (temperature, pressure, pH, etc.). Over such long periods, the role of chance also might come to play an important role, enabling unlikely molecular encounters to happen or precellular components to assemble and disassemble in many different ways as in a "tinkering" process. Therefore, life as we know it on Earth would somehow also keep the trace of numerous specific events or "frozen accidents," all of them highlighting the very historical nature of life.

Life as we know it on Earth might be one particular instance of a more generic phenomenon, the characterization of which is among the goals of artificial life research. What is more, not only could life appear under different forms, but it might also appear in different places in the universe. Exobiology research focuses in particular on the quest for extraterrestrial signs of life. Such a discovery would not only be an astounding discovery, but it would also shift the question of the origin of life and raise the question of its potential perennial existence over the known history of the universe, an old theory known as panspermia. In addition, life as we know it today might not be life as it has been in past, or, as a matter of fact, life as it will be in the future. Life as we know it today might not be life wherever nor forever.

Could there be, as well, multiple parallel pathways leading to the origin of life? If life is defined as a set of collective properties of particular physical systems, its origin might thereby be traced back to the chains of events that led to the appearance of each property separately and, as such, of those specific components enabling the physical systems to display such properties. Hence, for instance, the origin of life on Earth might be traced back to the origin of prebiotic proteins, prebiotic nucleic acids, or even prebiotic lipidic compounds, all of them being basic components of current living systems. In such a case, the origin of life could dissolve into as many origins as there are components necessary to build a living system.

Could life still be originating on Earth as we speak? This would make the origin of life a continuously recurring event, continuously generating new origins, so to speak. Such a hypothesis appears unlikely: It would require not only abiotic chemical processes, that is, chemical processes able to produce organic molecules without appealing to compounds of existing living organisms, but also physicochemical processes that could lead to the organization of these molecules into living systems. However, it appears extremely likely that most abiotically synthesized organic molecules today would end up being immediately assimilated by existing living organisms, without any possibility to further assemble themselves into new living systems, life thereby preventing any new origination of itself.

Christophe Malaterre

See also Creationism; Evolution, Chemical; DNA; Evolution, Issues in; Evolution, Organic; Genesis, Book of; Gosse, Philip Henry; Materialism; Oparin, A. I.

Further Readings

Bernal, J. D. (1951). *The physical basis of life.* London: Routledge & Kegan Paul.

Brack, A. (Ed.). (1999). *The molecular origins of life: Assembling pieces of the puzzle.* Cambridge, UK: Cambridge University Press.

De Duve, C. (1995). *Vital dust: The origin and evolution of life on earth.* New York: Basic Books.

Eigen, M. (1992). *Steps towards life: A perspective on evolution.* Oxford, UK: Oxford University Press.

Fry, I. (2000). *The emergence of life on earth: A historical and scientific overview.* New Brunswick, NJ: Rutgers University Press.

Popa, R. (2004). *Between chance and necessity: Searching for the definition and origin of life.* Heidelberg, Germany: Springer-Verlag.

Life Cycle

All living organisms have a life cycle beginning with the initiation of life and continuing until death. Scientists generally consider a life cycle to encompass the changes that an organism experiences from the beginning of a specific developmental stage until inception of the initial developmental stage in the next generation. The stages an organism will experience and the length of the life cycle varies widely across species. Species survive only when sufficient offspring complete the life cycle to continue the species. Such cycles vary from minutes to multiple years.

The time to complete a life cycle is generally correlated to the size of the organism. Bacteria complete their life cycle in 30 minutes by dividing to form another generation. Higher organisms take much longer. The giant sequoia, for example, produces its first fertile seeds after 60 years. Some plants and animals die after reproducing, with reproduction symbolizing the end of the life cycle. Other animals, notably humans, live for many years after their reproductive cycle is complete.

Most simple organisms complete their life cycle in one generation with an initial splitting in two of an adult, the growth of the new organisms, and upon reaching maturity, the division of each one into two new individuals. Higher animals can also have a single generation with the fusion of male and female sex cells to create the embryo and the growth of the offspring to reproductive maturity when they produce sex cells that create new offspring. Plant life cycles, however, are usually multigenerational. A spore will germinate and grow into a gametophyte. At maturity, the gametophyte forms gametes. With fertilization, the gametes develop into sporophytes. Once reproductive maturity is reached, the sporophytes produce spores and a new life cycle begins. This process is frequently referred to as “alternation of generations” and occurs in some fungi and protists as well.

The time the young animals spend developing prior to being born (the gestation period) or hatched varies across species. Small marine animals frequently produce large numbers of tiny eggs that hatch at a very early developmental stage, while others produce fewer, larger eggs with the young exiting at a more advanced developmental stage. The smaller young will need longer to develop before becoming adults, while the more fully developed young move quickly into adulthood. This effect is common in higher organisms as well. Generally the more developed the young, the fewer produced in one reproductive cycle, as there is more chance of the young surviving. Larger animals take longer to bear their young, as the young must be ready for the hardships of life. Elephants have the longest pregnancy period of any mammal at 22 months. Smaller animals have shorter gestation periods. For example, the domestic cat has a pregnancy term of approximately 9 weeks.

Hibernation

Hibernation is a state of dormancy that some animals enter into during cold months of the year. Bears are well known for this; however many other animals hibernate, including rodents. Hibernation allows the animal to exist during times of food shortage and unfavorable conditions. In the spring, the animal rises and is generally ready to reproduce. Plants and seeds also experience dormant periods until conditions improve to allow them to continue their life cycle.

Metamorphosis

A number of animal species include metamorphism in their life cycle. Metamorphosis is a process of great change between stages in the cycle. The stages provide a way for the organisms to live separately from other stages in order not to compete for food or habitat. For example, frogs lay eggs in the water. The embryo quickly grows and hatches into a tadpole. The tadpole lives in the water and breathes through gills. As the tadpole grows, its tail shrivels, and legs and lungs develop. When the gills disappear, the tadpole comes to the surface and is now considered to be an adult frog. Most species of frogs grow into adults within one season and reach reproductive maturity within a year. Thus, mature frogs and tadpoles live in very different habitats, lessening the competition for food and enhancing other aspects of survival.

Butterflies also use metamorphosis in their life cycle. Each one moves quickly from a caterpillar (larval) stage to a pupal or chrysalis stage, when the larva is dormant, and then emerges from the pupa as a full adult ready to reproduce, with one cycle normally taking a year to complete. Fruit flies also undergo metamorphosis, changing from one form to another completely different form, moving from an egg to larva to pupa to adult. Each phase is a natural phase of the life cycle. The whole process normally takes about a week. Other animals that use metamorphosis are amphibians (toads, newts, etc.) and a wide variety of insects.

Invertebrate animals have a variety of life cycles. Metamorphosis, a series of rapid physical changes, is common. Most insects lay eggs. Incomplete metamorphosis, or simple development, involves the eggs hatching into nymphs and moving to the adult stage. Complete metamorphosis, or complex development, includes a pupal stage between the larval and adult stages. As immature larvae and nymphs grow, they shed their exoskeleton, which is a tough exterior skin. Each time the exoskeleton is shed, the new stage is called an *instar.* The final instar develops into a pupa in complex life cycles or into an adult in simple life cycles. Most common insects generally have three to six instar stages; thus a complete insect life cycle includes the egg, larval, three to six instar, and adult stages. Ladybugs provide a good example of complex development. The adults lay eggs that hatch into wormlike larvae, which go through several instar stages, and the final instar covers itself in a hard pupa and emerges as a new adult. The life cycle takes 4 to 7 weeks. Most insects have a 1 year life cycle. However, wide differences exist. For example, the life cycle of a fruit fly is 1 week, while one species of cicada has a life cycle of 17 years.

Reptiles

Most reptiles are egg laying (oviparous). There is great variety in reptile mothers. Some eggs are laid and left on their own, although usually in well-protected and hidden nests. Sea turtles lay their eggs on sandy beaches and return to the water, leaving the young to fend for themselves. Other species stay with the eggs and aggressively defend the nests. Examples of these include crocodiles and pythons. Some reptiles are ovoviviparous, including many species of snakes and lizards, with very thin shelled eggs remaining in the mother's body. These species appear to have live births, but in reality the eggs hatch just before the young are born, making it seem that the young are born rather than hatched.

Reptiles produce hatchlings that are exact replicas of the parents. The hatchlings must quickly grow and learn to defend themselves. Many reptiles grow through a process of molting, where the outer layer of their skin is shed to allow for physical growth. The molting times will vary. Most reptiles will molt shortly after hatching. During periods of rapid growth, molting can occur four or more times a year. Adults still molt but more infrequently, generally one or two times a year.

Fish

Fish are primarily egg laying. Many species lay the eggs and leave them alone to survive. Most eggs are soft shelled. Some species of sharks lay eggs with a tough outer coat to help protect the eggs. A few species protect the eggs through burying them in the sand or by being "mouth brooders," where one parent will hold the eggs in his or her mouth until they hatch. Male seahorses have a special pouch where they hold the eggs. Baby fish are called "fry." The young are generally able to reproduce within a year after birth.

Birds

Birds lay eggs on land even if, like ducks and loons, they spend more time on the water. Most birds stay with the nests (brood) to keep the eggs warm and safe from predators. Eggs vary in size, from the very small robin egg, approximately 1 inch around, to the large ostrich egg, which is 5 to 6 inches around. Hatching time is 12 to 14 days for robins and 35 to 45 days for ostriches. Ostriches will reproduce at 2 to 4 years of age, while robins reproduce within a year. Comparing the robin and the ostrich provides further evidence that the size of the organism affects the time taken for each stage of the life cycle.

Humans

Humans are generally considered to have four stages in their life cycle: infancy, childhood, adolescence, and adulthood. The gestation period is 9 months. Infancy is the stage between newborn and 2 years of age. Many changes occur in this stage, and the infant learns to walk and talk. Childhood occurs between 2 years of age and puberty (adolescence). Many physical changes occur in childhood, such as the rapid development of teeth and bones. The time of puberty varies but usually starts at 8 to 12 years of age. Adolescence is a period of many changes, including the sexual maturing of the human body. Males continue to grow physically until they are 21 years old, while females usually reach peak physical growth by 18 years of age. During adulthood, considered to be 18 years of age and over, the body begins to slow down. Changes occur, including thinning hair and body shape modifications. Sometimes old age is added to the life cycle stages. In developed countries the average life expectancy is 77 to 80 years. A few people live for more than 100 years. Life cycles are thus complex and show immense variation across species.

Beth Thomsett-Scott

See also Birthrates, Human; Clocks, Biological; DNA; Dying and Death; Extinction and Evolution; Fertility Cycle; Gestation Period; Hibernation; Longevity; Malthus, Thomas; Maturation; Metamorphosis, Insect

Further Readings

Kalman, B., & Langille, J. (1998). *What is a life cycle?* New York: Crabtree.

McGraw-Hill encyclopedia of science & technology. (2002). New York: McGraw-Hill.

Light, Speed of

The physical qualities of light have always been important, but its speed has been difficult to measure. Light is the fastest known physical phenomenon, so it took the development of modern timing equipment to be able to measure it. The early civilizations, such as that of the ancient Greeks, tried to quantify light but found its qualities elusive. It was only in 1973 that the speed of light in a vacuum was accepted at the current value of 299,792,458 meters per second (m/s).

One of the first observed facts about light was that it was faster than sound. When something produced both a loud sound and a bright light, such as a cannon firing, the light always reached the observer before the sound. The difficulty trying to quantify this difference was the huge difference in the speed of the two phenomena and the lack of good clocks. Sound has a speed of 331.3 m/s (at 0^0 C, 0% humidity, and 1 atmosphere of pressure) while light goes at 299,792,458 m/s. To early observers light seemed to travel instantaneously. For many centuries the speed of light was a philosophical concept, and there were debates between those who believed it had an infinite speed and those who felt it had to be finite.

It was the invention of more accurate clocks that help generate the first realistic calculation of the speed of light. One of the first experiments to yield a rough estimate was made by Ole Christensen Roemer in 1676, who used the orbital motion of Jupiter's moon Io to make his measurement. By recording the exact moment Io entered Jupiter's shadow when Jupiter was closest to Earth and comparing that time to the time many months later when Jupiter was a known distance farther from Earth, he calculated a speed of 220,000,000 m/s for light. In 1728, this observed estimate was improved by James Bradley, who measured the apparent motion of stars at different times as compared to the speed of Earth in its orbit. His calculation of 298,000,000 m/s was accepted as the more accurate value.

As clocks and clockwork mechanisms improved, it became possible to divide time into smaller and smaller segments. The first earthbound measure of the speed of light came in 1849, when Hippolyte Fizeau used a mechanical apparatus to measure the speed of light. He used a beam of light focused on a mirror several thousand meters away. By forcing the light to pass through a rotating cogwheel, he found that at a certain rotation, light would pass through the cogwheel on both its forward and return journeys. A calculation based on a combination of distance of the light source from the cogwheel, the number of teeth on the cogwheel, and the rotational speed of the cogwheel yielded a speed of 313,000,000 m/s. This type of experiment was later refined using rotating mirrors and prisms to estimate a speed of 299,796,000 m/s in 1926. It took the development of oscilloscopes with time resolution in the subnanosecond range to further refine this number by measuring the delay of a light pulse from a laser or LED.

One of the interesting behaviors of light is that its observed speed lowers when it passes though media other than a vacuum. The refraction of light as it passes from air to water is a visible manifestation of the slowing of light as it moves into a denser medium. This has led scientists to explore the concept of "slow light" by increasing the index of refraction of various media. It is possible to increase the path that photons must take through a medium by using specialized conditions such as a Bose-Einstein condensate. Scientists have succeeded in slowing the measurable apparent speed of light to less than 1 m/s.

Since 1983 the speed of light has been treated as a defined constant, with refinement of its present value by further experimentation not needed. As a constant it functions as an absolute measure of distance (1 meter = the path traveled by light in 1/299,792,458 of a second), which has allowed for finer and finer descriptions of the velocity of objects as time measurement tools have improved.

John Sisson

See also Black Holes; Clocks, Atomic; Einstein, Albert; Experiments, Thought; Newton, Isaac; Observatories; Planetariums; Time, Relativity of; Singularities; Space Travel; Stars, Evolution of; Time, Measurements of; Twins Paradox

Further Readings

Clegg, B. (2008). *Light years: An exploration of mankind's enduring fascination with light.* London: Macmillan.

Nimtz, G. (2008). *Zero time space: How quantum tunneling broke the light speed barrier.* Weinheim, Germany: Wiley-VCH.

Logical Depth

The time necessary to generate an object, given a concise description of it, is a factor that intuitively plays an important role when we assess the value of this object. We are inclined to consider an object valuable if we believe that a long sequence of rather difficult actions has led to its existence. It is, thus, a promising idea to use the length of the process in which an object has been generated as an indicator of its complexity, on which indication we then base our assessment of its value. The measure of logical (or algorithmic) depth brings this reasoning into a mathematical form. It was introduced, in the 1980s, by Charles H. Bennett, a physicist and computer scientist doing research at IBM. Along with being one of the founders of quantum computing, Bennett is also among the most important contributors to the structural science of complexity.

Bennett's definition of logical depth is based on central ideas of algorithmic information theory. The algorithmic information content of a string of binary digits (bits) is, broadly speaking, equal to the bit length of the shortest computer program that, if run on a certain type of computing machine (a universal Turing machine), outputs this string and then halts. Such a program is the most concise algorithmic description of the bit string. If this string can, again, be interpreted as the digital representation of an object (e.g., as containing a detailed account of parameters of a physical system at a certain time), then the shortest program outputting the string encodes the algorithmically most economical hypothesis about the causal history of the digitally represented object.

Bennett defines, in its simplest version, the logical depth of an object represented by a binary string as the run time of the shortest program that outputs the binary string and then stops; this run time is measured in execution steps of the program on a universal Turing machine. A long time that elapsed in the real-world generation of an object does not correspond necessarily to a logically deep time: If, in a long period of real time, there did not occur many events that contribute to the generation of the object, this stretch can be summarized by a few steps in the simulated causal history of the object. Thus, a logically deep object is one whose simulation on a computer proceeds slowly when the shortest program outputting its digital representation is run. In contrast, logically shallow objects are either very regular objects that can be simulated by short and fast programs or very irregular objects that can be simulated by incompressibly long and fast programs. Under the general constraint, stated by the second law of thermodynamics, on the possible growth of order in physical systems, a fast increase of order, measured by logical depth, is very improbable.

From an information-theoretical perspective, the logical depth of an object is not equal to the Shannon entropy of its digital representation, given a probability distribution of the binary digits. It is equal to the number of operations necessary to generate an object starting from its most concise description. These operations can, at least principally, be reconstructed if we know the digital representation of the object and search for the most concise program that outputs this representation and then halts. Logical depth is, thus, correlated with the redundancy in the causal history of the object, that is, with the difference in the number of bits between an explicit digital representation of the generation of the object and the shortest program that outputs the digital representation of this object and then stops.

The simple definition of logical depth given above is, however, not robust enough. If, for example, a program that generates the digital representation of an object much faster than the shortest program is just a few bits longer than the latter, the exclusive focus of logical depth on the minimum length program leads astray. The simplest solution to this problem is to define a mean logical depth of an object on the base of a rate of exchange between run time and program size. Such a rate of exchange must guarantee that, whereas short and fast programs outputting the digital representation of the object contribute most to its logical depth, long and slow programs contribute least. In calculating the average run time of all programs that output the digital representation of an object, the shorter and the faster the program that generates the desired output, the higher its run time must be weighted.

Stefan Artmann

See also Entropy; Information; Maxwell's Demon; Time, Asymmetry of; Time, Measurements of

Further Readings

Bennett, C. H. (1988). Logical depth and physical complexity. In R. Herken (Ed.), *The universal Turing machine* (pp. 227–257). New York: Oxford University Press.

Bennett, C. H. (1994). Complexity in the universe. In J. J. Halliwell, J. Pérez-Mercader, & W. H. Zurek (Eds.), *Physical origins of time asymmetry* (pp. 33–46). Cambridge, UK: Cambridge University Press.

Gell-Mann, M. (1994). *The quark and the jaguar: Adventures in the simple and the complex*. New York: Freeman.

Longevity

Longevity can be defined as either a duration or a life span. Although the term might bring to mind the time spent by a living being in a situation, such as a job or living, the term can also be seen as much more. The length of an occurrence, or its longevity, can be measured in various ways. It can be measured in clock time, which measures all occurrences according to the same scale, such as a 24-hour day, separated into durations of equal size; or it can be measured relatively, as compared with the longevity of another event. It can be accurate according to the clock, or it can be seen in terms of perceived duration, also known as social time.

Measuring longevity, or the duration of an event or occurrence, has changed as the methods of accurately depicting the passage of time have enabled its division into smaller and smaller intervals. Time was once measured by passages of the sun or recurrences of events, such as seasons or the appearance of a star in the sky. Time now can be measured in increments far shorter than a second.

Measuring time in relation to another occurrence, such as a natural event, enables one to better comprehend longevity. However, recording and communicating such a duration to others requires their awareness of the relative measuring stick. The advent of the calendar, whether cyclic or linear, solar or lunar, enabled the consistent measuring of longevity according to a predetermined scale. Once this became possible, one could accurately date to the year, as defined by that calendar, a person's life span or the duration of an event. However, because a variety of calendric measurements coexisted, the definition of a year could vary greatly, causing inaccuracies in comparing longevities over the eons based on the generic term *year.*

The advent of the clock, which first determined time by the hour (the shortest interval that could then be measured with reasonable accuracy), enabled one to define the longevity of shorter events, such as meetings or the time of prayers, with the result that events could be more closely defined. However, again there was the difference in the length of hour, whether it was solar or "of the clock." Therefore, the hour of the day would have to be defined as clock time when stating a time; this is the basis for the term *o'clock,* meaning "of the clock," as opposed to a time based on another measuring system of the hours.

When examining longevity, one must look not only at the number but also the measuring system used at the time the number was created. In Biblical times, for example, longevity of life, if considered by the same time spans used today, might seem extremely long. However, when examining the length of a year in the times written about, one might determine that a year's length was much shorter than that measured today by the Gregorian calendar.

Without a standard measure, duration is notoriously subjective. An hour spent, for example, at a baseball game can seem to be much briefer than an hour spent in a dentist chair, and thus the longevity of these events, while they appear the same when measured by the standard measurements, seem to differ greatly to those experiencing them

The ability, and desire, to measure longevity is an essentially human trait. By knowing how long it takes for a plant to grow, or the length of time a dog lives as compared to a fish or hamster, humans gain a degree of control over the environment. A growing dependence on clock and calendar time has led to increased desires to measure more by these standards. Although society has benefited from a standardized method of measuring longevity, the existence of the method has also led to more of a dependence on such measurements. Actual time is becoming more important than perceived or social time.

Sara Marcus

See also Dying and Death; Fertility Cycle; Gerontology; Life Cycle; Medicine, History of; Time, Measurements of

Further Readings

Kurtzman, J., & Gordon, P. (1976). *No more dying: The conquest of aging and the extension of human life.* Los Angeles: J. P. Tarcher.

Newton, T. (2003). Crossing the great divide: Time, nature and the social. *Sociology 37*(3), 433–457.

Trivers, H. (1985). *The rhythm of being: A study of temporality.* New York: Philosophical Library.

Whitrow, G. J. (1972). *What is time?* London: Thames & Hudson.

LONGITUDE

Longitude is a geographical measurement that describes the position east or west of the prime meridian for a given location. On maps, longitude is illustrated by vertical lines called meridians of longitude. Unlike parallel latitudinal lines, meridians of longitude all intersect at the north and south poles. Using longitude measurements for east and west along with latitude measurements for north and south, the location of any place on the earth can be precisely described. While the equator provided the logical starting point for latitudinal measurements, there was no such obvious place for measuring longitude. Eventually the Greenwich Meridian—on which the original British Royal Observatory was located—was internationally accepted as the prime meridian. In relation to time, longitude corresponds directly to the local time of any location and is the basis for time zone divisions.

The concept of longitude originated in ancient Greece, but the quest for accurate measurement of longitude continued until modern times. While many methods were proposed and attempted for calculating longitude, the most significant development came with the production of the first highly reliable mechanical clocks. These enabled travelers to compare the time of a known location with the observed local time in order to calculate their longitude on land or at sea. Modern satellite technology now enables precise latitude and longitude to be calculated using the global positioning system (GPS).

Longitude is closely related to time, because the local time of any place on the earth is directly relative to its longitude. Each of the earth's 24 time zones represents a section 15° wide in longitude, the distance over which local time changes by one hour (1/24th of 360°). The relationship is also historical; the need for an accurate way of finding longitude, especially while navigating at sea, was a primary driving force in the advancement of timekeeping technology.

Longitude was used at least as early as 300 BCE in ancient Greece. In the 2nd century CE, Claudius Ptolemy published *Geography,* one of the earliest developed mathematical works concerning latitude and longitude, in which he discussed an earlier theory of Hipparchus for figuring longitude. Recognizing that longitude could be calculated by observing the same event in two places and comparing the local time of each, Hipparchus proposed that lunar eclipses could be used for this purpose. The soundness of this theory was outweighed by the fact that sundials, the only available timekeeping devices, would not work well when observing something that occurs only at night.

After centuries with no scientific advancements, in 1514 Johann Werner surmised a new theory for finding longitude: the lunar distance method. Werner proposed that longitude could be found by precise comparisons of the moon's apparent position relative to the stars. This method had its problems, but with necessary observation data it had potential. Precisely for the gathering of such data, the Royal Observatory was founded in Greenwich, England, in 1676.

In an age that depended upon maritime travel, the need for more accurate navigation became urgent, prompting several European countries to offer generous rewards for anyone who made breakthrough discoveries toward calculating longitude. John Harrison received the largest of such rewards ever given by Great Britain in 1770 CE for his invention of a highly accurate portable timekeeper called a chronometer. The chronometer enabled mariners to use a simpler, more accurate method of finding longitude. A traveler could compare the observed local time at noon with the time of a known location kept on a chronometer; the difference in time told the difference in longitude between the two places. With so much data already available in the almanacs published by the Greenwich Observatory, it was the natural location to which chronometers were set, and the longitude at which it was located later became the prime meridian for the entire world. The chronometer method for identifying longitude remained standard until more advanced technology replaced it in the 20th century—first radio based systems, then GPS satellites.

Adam L. Bean

See also Astrolabes; Earth, Rotation of; Harrison, John; Observatories; Time Zones

Further Readings

Harrison, L. (1960). *Sun, Earth, time, and man.* Chicago: Rand McNally.

Howse, D. (1997). *Greenwich time and the longitude.* London: Philip Wilson.

Sobel, D. (1995). *Longitude: The true story of a lone genius who solved the greatest scientific problem of his time.* New York: Walker.

LUCRETIUS (C. 99–55 BCE)

Titus Lucretius Carus was a Roman poet and philosopher who is best remembered for his comprehensive epic *On the Nature of Things.* This remarkable work offered a dynamic worldview that departed significantly from the Aristotelian interpretation of this universe, life forms on earth, and the place our human species occupies within nature. Because his ideas differed greatly from those of the Greek thinker, Lucretius was not taken seriously by his contemporaries. In fact, his provocative thoughts on time, change, and reality would not be appreciated by scholars until his lost manuscripts were revived from philosophical oblivion during the Renaissance.

Aristotle had presented a geostatic and geocentric model of the universe. He separated the ethereal heavens from our material planet and claimed that the finite but eternal spherical cosmos is enclosed by a fixed ceiling of stars, each star equidistant from the earth. For him, both terrestrial linear motion and celestial circular motion are caused by the existence of the Unmoved Mover beyond the stars; this perfect entity of reflecting thought is the ultimate object that all desiring things attempt to emulate in terms of their development from potentiality to actuality. Within his philosophical system, Aristotle taught that species are eternally fixed, with the human animal occupying the highest position in a static ladder of planetary organisms. Lucretius boldly challenged each of these basic Aristotelian assumptions.

Rejecting religious beliefs and ignorant superstitions, but indebted to the earlier thoughts of Epicurus, Lucretius presented a strictly naturalistic interpretation of and explanation for the existence of this eternal and infinite universe. He argued that endless reality consists only of material atoms and the void, there being no difference in makeup between celestial and terrestrial objects; thus, his natural philosophy taught the cosmic unity of all existence. Furthermore, Lucretius saw this dynamic universe as a creative process within which, over time, material atoms combine by chance to form an infinite number of stars, planets, and organisms. As a thoroughgoing naturalist, he taught that all objects and events are a part of an ongoing material reality that has no center, design, purpose, or goal.

For Lucretius, if there are immortal gods somewhere in this universe, then they have no interest in human existence. Nevertheless, with his powerful imagination, he speculated that life forms and intelligent beings (perhaps beings even superior to humans) exist elsewhere on other worlds throughout the cosmos. Within this dynamic worldview, Lucretius glimpsed the forthcoming evolutionary framework. He held that, over time, the material earth itself gave birth to those plants and animals that now inhabit this planet, including our own species. Furthermore, for him, organic history is full of both creativity and extinction.

With exceptional insight, Lucretius outlined the sociocultural development of the human animal. In their prehistoric state, our naked but robust ancestors lived in caves and subsisted on pears, acorns, and berries. They wandered through the forests and woodlands searching for wild beasts (e.g., boars, lions, and panthers) with clubs and stones. Later, our ancestors wore animal skins, learned to use fire, and lived in nomadic hunting/gathering societies that waged war. Over time, humans even developed the use of symbolic language as articulate speech. With the emergence of agriculture, they learned to cultivate plants and domesticate animals. Eventually, civilizations appeared and flourished, with people living in cities, using metals (first copper, then bronze, and later, iron), and developing art, law, and religion.

Lucretius offered penetrating insights into the nature of our universe and the history of life on earth that far surpassed the cosmology of Aristotle. He enlightened later thinkers with his bold speculations, influencing several recent major philosophers from Herbert Spencer and Henri Bergson to Alfred North Whitehead and Pierre Teilhard de

Chardin. This is an impressive testament to Lucretius, whose astounding vision was first presented over 2,000 years ago.

H. James Birx

See also Aristotle; Bergson, Henri; Bruno, Giordano; Cosmogony; Materialism; Ovid; Poetry; Presocratic Age; Rome, Ancient; Spencer, Herbert; Teilhard de Chardin, Pierre; Whitehead, Alfred North

Further Readings

Birx, H. J. (1984). *Theories in evolution.* Springfield, IL: Charles C Thomas.

Gale, M. R. (Ed.). (2007). *Oxford readings in classical studies: Lucretius.* Oxford, UK: Oxford University Press.

Gillespie, S., & Hardie, P. (Eds.). (2007). *The Cambridge companion to Lucretius.* Cambridge, UK: Cambridge University Press.

Lucretius. (1995). *On the nature of things: De rerum natura* (A. M. Esolen, Trans.). Baltimore, MD: Johns Hopkins University Press.

Luther, Martin (1483–1546)

Martin Luther, a German priest, monk, and theologian, was among the leading figures of the Reformation. As part of the exceptional role he played in the history of religion during his lifetime, Luther added some new thoughts to Christian thinking about time.

He was born to a burgher family. From approximately 1490 onward, Luther attended a variety of schools. In 1501, he began his basic philosophical studies at the University of Erfurt; these basic studies were required for further studies in theology, medicine, or law. In the spring, Luther decided to follow his father's wishes and began to study law. On July 2, 1505, he experienced a severe thunderstorm and, believing himself to be in mortal danger, vowed to become a monk if he survived. Fifteen days later, he joined an Augustinian monastery in Erfurt. In spring 1507, he received his ordination to the priesthood. In the same year, also in Erfurt, he began his studies of theology, which were to continue later in Wittenberg. From November 1509 to April 1510, he traveled to Rome on behalf of the brotherhood. In 1512, he received his doctorate in theology, was appointed as professor of theology at the University of Wittenberg, and became subprior of the monastery in Wittenberg.

On October 31, 1517, he sent 95 theses about indulgences to archbishop Albrecht of Mainz and other theologians with the demand to discuss them. In these theses, Luther proclaimed that the selling of indulgences as it was practiced at this time was not the right way to salvation. The theses were followed by turmoil in the church. Luther was asked to abjure his theses, but he insisted on having a disputation. In 1518, he wrote to Pope Leo X to inform him better of the situation. The answer was the issuing of a Papal Bull in 1520 in which 41 of Luther's theses were called heretical and which contained a warning that Luther risked excommunication.

In consequence of his refusal to recant, Luther was excommunicated from the church on January 3, 1521. In May 1521, he was ordered to the Reichstag zu Worms (Diet of Worms) with the promise of free passage on the way. Luther refused once again to deny his claims without their falsification by arguments from the Bible. On his way back to Wittenberg, Luther was kidnapped by men of his own sovereign and supporter, Frederick III of Saxony, and brought to the Wartburg in Eisenach to be kept there hidden in safety. In this exile, Luther translated the New Testament into German.

Luther stayed in Eisenach until March 1522, when he returned to Wittenberg to moderate the movement for religious reform, which was initiated by Andreas Karlstadt and which exceeded Luther's goals. In the following years, the reform movement quickly spread, first to Saxony and later to other parts of Europe. From 1524 to 1526, peasants whose discontent had been fueled by Luther's writings revolted. After attempting to pacify the peasants, he took a position on the side of the sovereigns in this evolving war. In 1525, he married Katharina von Bora, a former nun. Over the years, there were many debates, especially with Müntzer, Karlstadt, and Zwingli, on the right course of the reformation and its theological contents.

At the Reichstag zu Speyer (Diet of Speyer) in 1529, the Catholic members of the diet wanted to cancel the provisional acceptance of the reformed members of the diet. The protestation against this decision established the name "Protestants." During the Reichstag zu Augsburg, the reformed parties presented their confession, the so-called Confession of Augsburg (*Confessio Augustana*), which was composed by Luther's friend Philipp Melanchthon. In 1534, Luther's translation of the Old Testament was published.

During the following years Luther's state of health deteriorated, although he stayed head of the German reformation and was often called upon in case of conflicts in theological disputes as well as in worldly matters. In February 1546, he traveled (although seriously ill) from Wittenberg to Eisleben to mediate in a conflict threatening the livelihood of his siblings' families. He died there, after successfully settling the matter, on February 18, 1546.

Luther's view of time is always eschatological. Influenced by Pauline theology, two of the bases of his view of time are the virtues of *fides* (belief) and *spes* (hope). The difference between these two virtues is practically irrelevant for Luther's concept. The Christian hope and belief aim for a future in which the realm of God is present. The suffering in this world for the Christian has two parts: first, the suffering every human has to endure due to illness and misfortune, and second, the worry about life, because every real Christian knows himself to be a sinner. In Luther's view, the life of the Christian is justified because he endures the second suffering. In his view, Christ gives the promise that the realm of God is open for the people who are worrying about their sins.

But the object of Christian hope, the realm of God, cannot be perceived during one's lifetime but stays hidden from the physical world. According to Luther's belief, the exact design of the realm of God cannot be imagined by a human being. It will always stay hidden from the searcher's mind and eyes. But in his view, it is possible that hell and heaven are not worldly places in real time and space but exist only within the soul. According to this line of thinking, every believer's conscience might be the place of final judgment and hell. Therefore, resurrection might take place directly after every individual's death, because it would not be bound to the dimension of time as humanity understands it. Here, the influence of Saint Augustine of Hippo is obvious. For Augustine, time exists only within the soul, because neither past nor future exist in the present, while the present itself has no extent.

Luther does not subscribe to the idea, however, that to believe is a pure decision of the individual. Following the tradition of Paul and Augustine, he is convinced that God manifests the true belief in people. In this way, he pleads for a kind of predestination. Belief is to be understood as a gift given by God to humanity. This gives humankind also a kind of freedom of conscience and belief, because its belief is not made by itself. But in the end, rational thinking is not an adequate means to fully understand the working of God.

Markus Peuckert

See also Augustine of Hippo, Saint; Bible and Time; Christianity; Eschatology; Genesis, Book of; God and Time; Gospels; Sin, Original; Time, Sacred

Further Readings

Bainton, R. H. (1995). *Here I stand: A life of Martin Luther.* New York: Meridian.

Kittelson, J. M. (2003). *Luther the reformer: The story of the man and his career.* Minneapolis, MN: Augsburg Fortress.

McKim, D. K. (Ed.). (2003). *The Cambridge companion to Martin Luther.* Cambridge, UK: Cambridge University Press.

Lydgate, John (c. 1371–c. 1449)

John Lydgate was a poet and monk of the Benedictine abbey of Bury St. Edmunds in Suffolk, England. Adept at writing for a variety of patrons and purposes and in a wide range of styles, he penned short devotional lyrics as well as vast moralistic tomes running to tens of thousands of lines each. Although after the Protestant Reformation, his reputation waned, during the 15th century Lydgate was the most popular didactic poet in England. Some of his works survive in more late-medieval manuscript copies than even certain poems by Geoffrey Chaucer, whom modern readers generally consider to be Lydgate's superior as a poet. The longwinded didacticism of "the Monk of Bury" has left him open to the frequent charge of tediousness. This and the apparent irregularity of his meter (in comparison with Chaucer's) drew widespread critical disparagement from the 19th to well into the 20th century. In the context of discussions about time, however, Lydgate is interesting both because of his attitudes toward the history of civilizations and because of his place in the history of literature.

Born around 1371, the poet apparently followed customary practice among medieval monks by taking his surname from his place of birth, in this case what is now the modern village of Lidgate in the county of Suffolk. He entered St. Edmund's Abbey as a teenager and was sent to the University of Oxford for further training in theology. Although he was a Benedictine monk, he spent plenty of time in the world outside the cloister and, because of his skill as a moralistic versifier, garnered the patronage—essential to premodern poets—of some of the most illustrious figures of his day. These included Henry V (whom he evidently met at Oxford), Henry VI, and Humphrey, Duke of Gloucester, among others; they were either the recipients of or the guiding influences behind some of Lydgate's longest productions. For example, *The Troy Book* (c. 1420–1422) addresses Henry V's victory over the French at Agincourt, while *The Lives of Saints Edmund and Fremund* was written to commemorate Henry VI's Christmastide sojourn at St. Edmund's in 1433–1434. The immense *Fall of Princes* (c. 1431–1439), Lydgate's longest work at over 36,000 lines, was commissioned by Duke Humphrey.

Both in his so-called courtly works, written for royal or aristocratic patrons, and in his less ambitious poems, Lydgate was chiefly concerned to praise God and his saints and remind his readers of their own dependence upon them. As creatures living out their lives in earthly time, Lydgate's readers were expected to conform their wills to Christ's in eternity and to prepare their souls for final judgment at his hands.

Until late in the 20th century, literary critics dazzled by Chaucer and other contemporary poets like William Langland and the anonymous (presumed) author of *Pearl* and *Sir Gawain and the Green Knight* found little to commend in the writings of a derivative, digression-prone moralist. Since the 1980s, however, scholars have returned to literary history with a keen interest in the relationship between writers and the sociopolitical conditions of their times. Much has been done of late to salvage modern understanding of his importance by situating Lydgate in the contexts of contemporary court politics and religious devotion.

To broach the topic of Lydgate and time, however, is to return to older critical discussions that dismissed 15th-century English literature as little more than an artistically arid interim between the ages of Chaucer and Spenser (or, alternatively, Shakespeare). In some respects, Lydgate does indeed seem self-consciously traditional. He affirmed pious orthodoxy at a time when the church in 15th-century England sought to curtail speculation on religious matters. Moreover, he appears to confirm modern scholars' suspicion that medieval writers lacked a sense of historical change, a basic awareness that customs, religious rituals, and dress did not remain the same over the course of 2,000 years. Finally, Lydgate was seemingly unaware of, or hostile to, the advances in humanistic thought characteristic of the Renaissance taking place in the Italy of his day.

Even so, the Benedictine poet had clear notions about time and history, whether or not those notions were reactionary. His interest in classical antiquity was real. It is evident in his long historical romances, *The Siege of Thebes* (early 1420s) and *The Troy Book,* as well as in *The Fall of Princes,* a series of didactic vignettes about illustrious biblical, classical, and medieval personages who rose to great heights of prosperity only to suffer abrupt downfalls. Yet Lydgate was no archaeologist: He was not concerned to investigate the distant past as it "really" unfolded. On the contrary, in his work he often rails against those pagan customs that he judges to be irreconcilable with Christianity.

To say that he therefore lacked a historical sensibility, however, is to assume that he should have shared the modern historian's dispassionate interest in learning exactly what happened and where and why it did. His reasons for studying antiquity were very different. He used ancient narrative materials such as the Troy and Thebes legends partly because he had a bookish interest in old stories, partly to find evidence for what he believed were eternally valid moral principles, and partly for the purpose of addressing political concerns that were current in the England of his own day. In unfolding the tragedies of Thebes with unstinting attention to their violence, he may have wished, as some scholars have argued recently, not so much to condemn the "ancient" and the "pagan" out of hand as to warn English kings and princes against the recurrent perils of empire building in all times and places.

Admirable attempts were made in the 1950s (by Walter Schirmer) and 1960s (by Alain Renoir) to treat Lydgate as a harbinger of English Renaissance humanism. Derek Pearsall's landmark study of the poet (1970) instead argued, without apology, that the Monk of Bury was much the product of his time and place. Debate continues apace, with ever more energetic scholarship focusing on the very meaning of formerly unexamined terms like *medieval, conventional,* and *humanistic.* To this ongoing conversation scholars like Lee Patterson, David Lawton, Paul Strohm, James Simpson, and others have made valuable contributions. All agree that Lydgate was a more active thinker and a more purposeful commentator on history than earlier scholars suspected.

Joseph Grossi

See also Alighieri, Dante; Chaucer, Geoffrey; Christianity; Humanism; Novels, Time in; Poetry

Further Readings

Nolan, M. (2005). *John Lydgate and the making of public culture.* Cambridge, UK: Cambridge University Press.

Pearsall, D. (1970). *John Lydgate.* Charlottesville: University of Virginia Press.

Scanlon, L., & Simpson, J. (Eds.). (2006). *John Lydgate: Poetry, culture, and Lancastrian England.* Notre Dame, IN: University of Notre Dame Press.

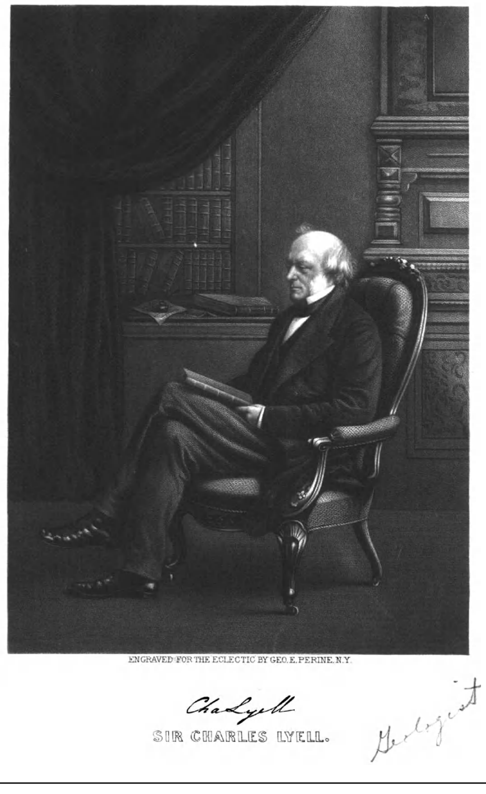
Schirmer, W. (1961). *John Lydgate: A study in the culture of the XVth century* (A. Keep, Trans.). Berkeley: University of California Press.

Simpson, J. (2002). *Reform and cultural revolution: 1350–1547. The Oxford English literary history* (Vol. 2). Oxford, UK: Oxford University Press.

Lyell, Charles (1797–1875)

Charles Lyell is widely regarded as one of history's most notable and influential scientists. His work in historical geology helped cement our understanding of the earth's formation. Yet, for all Lyell's efforts to gain acceptance and recognition of geological theory and the emerging science of historical geology, it is his impact on Darwinian evolution and the understanding of humanity's place in time that is arguably his greatest achievement.

Born in Scotland in 1797, Lyell took an early interest in nature studies, eventually focusing on geology for his career path. Inspired by geologist James Hutton's idea of *uniformitarianism,* Lyell supported the idea that Earth's geological elements are continually affected by slow processes of change (erosion, uplift, etc.) and always have been. Between 1830 and 1833, he summarized many of his emerging ideas in his chief work, *Principles of Geology,* which ultimately influenced



Lyell's version of geology came to be known as uniformitarianism because of his insistence that the processes that alter the earth are uniform through time.

scientists not only in geology but also in the fields of archaeology and biology as well. Lyell continued to publish his findings, which were widely read and admired by his scientific peers. He was knighted in 1848 in recognition of his many contributions to science.

Charles Lyell's primary legacy revolves around uniformitarianism and the earth's age. Whereas Hutton formalized uniformitarianism, Lyell arguably became its most influential proponent. Lyell's research and argumentation helped cement the idea that the earth's landscapes took eons to form, a thought in stark contrast to Archbishop James Ussher's Bible-based estimate that the planet was formed approximately 6,000 years ago. The premise that billions of years instead of thousands were required to form Earth, the solar system, and the entire universe was radical in the extreme and challenged doctrines whose authority lay in religious scripture. Lyell helped revolutionize not only geological thought but scientific thought in general by helping scholars look beyond conventional ideas of time and change.

Lyell's *Principles of Geology* made an impression on countless scientists, including Charles Darwin. For Darwin, Lyell's arguments supported the idea that organisms, including humans, needed as much time to change as rivers needed to carve out canyons and mountains needed to rise and fall. Such a conceptualization made Darwin's evolutionary ideas appear all the more plausible. Consequently, Lyell, though initially hesitant to embrace the ideas of evolution of organisms, provided Darwin with direction. The ensuing shift in humanity's understanding of time, the pace at which events unfold in the natural world, and our own place in the natural order is due in part to Lyell's contribution, which cannot be overvalued.

Neil Patrick O'Donnell

See also Darwin, Charles; Earth, Age of; Geological Column; Geology; Hutton, James; Huxley, Thomas Henry; Lamarck, Jean-Baptiste de; Materialism; Paleontology; Smith, William; Spencer, Herbert; Steno, Nicolaus; Stratigraphy; Uniformitarianism

Further Readings

Matson, C. C. (2006). Uniformitarianism. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (Vol. 6, pp. 2239–2241). Thousand Oaks, CA: Sage.

McKready, T. A., & Schwertman, N. C. (2001). The statistical paleontology of Charles Lyell and the coupon problem. *American Statistician, 55*(4), 272–278.

Recker, D. (1990). There's more than one way to recognize a Darwinian: Lyell's Darwinism. *Philosophy of Science, 57*(3), 459–478.

Young, P. (2006). *Lyell, Charles.* In H. J. Birx (Ed.), *Encyclopedia of anthropology* (Vol. 4, pp. 1503–1505). Thousand Oaks, CA: Sage.

Lysenko, Trofim D. (1898–1976)

A biologist and agronomist, Trofim Denisovich Lysenko was director of the Institute of Genetics in the Academy of Sciences in the Soviet Union under the regime of Joseph Stalin. To the public he was portrayed as a heroic example of the self-educated peasant. Although the theories he espoused were based largely on misunderstandings of genetics and scientific principles, the exercise of political influence and power enabled Lysenko to hold sway over biological research in the Soviet Union for decades. Lysenko's genetic theories rejected the theories of Gregor Mendel; they were the result of blending a superficial understanding of the theories of Jean Baptistede Lamarck with specific selections from Charles Darwin's theories that would support Lysenko's latest interpretations of inheritance.

Born near Poltava in the Ukraine, the son of a poor Russian farmer, Lysenko's first employment was as a gardener. In 1921, he studied at the Uman School of Horticulture. Shortly thereafter, he was chosen for the Belaya Tserkov Selection Station, and in 1925 he received a doctorate at the Kiev Agricultural Institute. Lysenko was highly interested in the theories of Ivan Vladimirovich Michurin, who taught that the environment is directly responsible for the development of hybrids that are very different from their parents. By controlling the environment, a breeder can select the type of hybrid to be developed. Individuals are highly plastic and not limited to the genetics of their parents. The results are then under the authority of the breeder. Although Michurin claimed many successful results, no one else seemed able to replicate his outcomes.

While working at an agricultural experimental station in Azerbaijan in 1927, Lysenko came up with the idea that fields could be fertilized by planting a winter crop of field peas. The field peas would then provide livestock with forage through the winter. Lysenko claimed that the use of chemical fertilizer did little to improve crop yield. Chemical fertilizers were successful the first year, but failed in succeeding years in areas of poor soil fertility.

This was the beginning of a career that would last until 1964. Each of Lysenko's failures would be rapidly followed by a new stunning success by the "peasant genius," as reported in the Soviet press.

In the Soviet Union, the long winters required that seeds survive long cold periods. Lysenko claimed that cooling the seeds before planting increased their strength and therefore the yield of the next crop. Lysenko selected spring wheat with a short "stage of vernalization" (exposure to cold) and a long "light stage," which he then crossed with wheat of a longer stage of vernalization and a short light stage. This led to increased yields and new varieties of grain. Largely as a result of the adulatory reports of this experiment by the Soviet press, Lysenko became editor in 1935 of his own agricultural journal, called *Vernalization*. His failures were not reported but led rather to new claims of success. His only real success, however, was his popularity among Soviet farmers, who were unenthusiastic about Soviet agriculture in the early 1930s. While most of his experiments ultimately hurt the Soviet farmer, because he was one of their own, his popularity remained intact. This served the needs of the Soviet government.

Lysenko was most noted for his criticism of the genetic theories of Mendel, Morgan, and Weisman, which he saw as antiscientific, decadent, and metaphysical. Lysenko set out to save science founded upon dialectical materialism from religious dogmatism masquerading as empirical science. His claim was that these genetic theories made the same errors as those of Thomas Malthus, who was exposed by both Karl Marx and Friedrich Engels for using deductive logic instead of empirical science.

Lysenko made the following argument: Intraspecies competition would only weaken the species in its adaptation to a changing environment. Morgan-Mendel genetics would be too slow to allow any species to survive in the real world; fixity of species was the core of the metaphysical superstition of the Morgan-Mendel school. Darwin proved that species do adapt to their environment and, in the process, species evolve into new species. Morgan-Mendel's ilk destroyed the insights of Darwin. According to them, genes and chromosomes that were fixed and passed on from generation to generation could not change fast enough to prevent extinction. This is why genetic theory would be metaphysical and not scientific. It created a dilemma that could only be avoided by introducing mutations or genes that would randomly make mistakes in the next generation. Furthermore, they said that most mutations were lethal, making all life on this planet impossible. Their only solution was divine intervention. Thus Morgan-Mendel genetics introduced religious dogmatism as a replacement for honest science. Lysenko claimed to merge Marx and Darwin; in fact he was closer to Lamarck than either Marx or Darwin.

By 1927, the Soviet Union had survived the First World War, revolution, civil war, invasion by 18 powerful nations, an economy in ruins, famine, isolation, and a desperate need for solutions. Simple remedies for complex problems were more attractive than more complicated solutions. The Soviet Union emerged from chaos with a political structure that was both rigid and bureaucratic. The Communist Party's tight control over all aspects of society led to fear of innovative ideas out of step with party directives among the top party leadership. The scientific community was particularly controlled in an inflexible and mechanical way. Science was defined as part of a larger global class struggle. There were two kinds of science: bourgeois capitalist science and revolutionary proletarian science guided by dialectical materialism.

The Communist Party used hero worship as a way to gain support for its policies. Lysenko, being a peasant himself, was a hero figure. When Russian farmers were resisting forced collectivization, both Stalin and the resisting peasants loved Lysenko. Lysenko was the son of a poor farmer who used commonsense arguments. His lack of understanding of genetics proved to most farmers that he had more connection to the land than most professors who had been "corrupted by Western ideas." With this support, he could make the case for genetics as part of an imperialist conspiracy to destroy true science.

Lysenko used anti-intellectual values and the support of a coercive government to secure his tight control over agricultural science and biology for many years. By early in the Cold War, his control was complete. The resolution in 1948 of the Lenin Academy of Agricultural Sciences of the USSR made any disagreement with Lysenko's findings illegal. Textbooks at all levels of education did not even mention Mendel's genetics. As a result, many serious biologists were exiled, tortured, imprisoned, murdered by the government, or committed suicide. With Stalin's death in 1953, there was a slight thaw in Soviet biology, and in 1956, more criticism of Lysenko's theories became possible. Nikita Khrushchev offered some protection. However, Lysenko resigned as president of the Academy of Agricultural Sciences in 1954, and in 1956 his resignation as president of the All-Union Academy of Agricultural Sciences was announced. In 1965 he was removed as director of the Institute of Genetics, and Lysenko was officially blamed for much of the failure of farms in the Soviet Union. Trofim Lysenko died in 1976.

Michael Joseph Francisconi

See also Darwin, Charles; DNA; Evolution, Organic; Lamarck, Jean-Baptiste de; Materialism

Further Readings

Carroll, S. B. (2006). *The making of the fittest: DNA and the ultimate forensic record of evolution.* New York: Norton.

Joravsky, D. (1986). *The Lysenko affair.* Chicago: University of Chicago Press.

Lecourt, D. (1977). *Proletarian science? The case of Lysenko* (B. Brewster, Trans.). Atlantic City, NJ: Humanities Press.

Lewontin, R., & Levins, R. (1976). The problem of Lysenkoism. In H. Rose & S. Rose (Eds.), *The radicalisation of science: Ideology of/in the natural sciences* (pp. 32–64). London: Macmillan.

Medvedev, Z. A. (1969). *The rise and fall of T. D. Lysenko.* New York: Columbia University Press.

Roll-Hansen, N. (2004). *The Lysenko effect: The politics of science.* Amherst, NY: Humanity Books.

Safonov, V. (1951). *Land in bloom* (J. Fineberg, Trans.). Moscow, USSR: Foreign Languages Publishing.

Soyfer, V. N., Gruliow, L., & Gruliow, R. (1994). *Lysenko and the tragedy of Soviet science.* New Brunswick, NJ: Rutgers University Press.

M

Mach, Ernst (1838–1916)

Perhaps best known as a founder of the field of philosophy of science, in which he held a chair at the University of Vienna, the Austrian physicist, mathematician, philosopher, and science historian Ernst Mach also had a major influence on the emerging discipline of physiological psychology as well as on the development of physics itself. Albert Einstein would later credit Mach's critique of Newtonian concepts of absolute time and space as a decisive influence on the development of relativity theory.

A prominent element in Mach's thought is antimechanism, or the refusal to accept the doctrine that reality, including psychic phenomena, consists essentially of matter in motion. Along with naturalism, the principle that nothing exists beyond nature, it was largely Mach's embrace of Darwinian evolution that shaped his ideas. According to Mach, human culture, science, mind, and the senses have an evolutionary history, and indeed knowledge itself is a product of biological evolution. The earliest organisms responded to simple experience, thereby constructing an elementary picture of the primordial world; out of these first interactions, more complex understandings emerged, forming innate capacities in our remote ancestors that gradually developed through adaptation into increasingly elaborate constructions. The acquisition of memory permitted greater scope for awareness of spatiotemporal relations than what is given directly to the senses; much later on, memory was greatly extended by the capacity to communicate culturally. For Mach, scientific activity is not only the product of biological evolution; it also serves to advance the evolutionary process by giving rise to further adaptations as new data are confronted and understood. From among all available ideas, whether derived logically or from dreams or fantasy, scientists select those theories that best fit the data. In this way science proceeds, as does biological evolution, by a process of selection.

After earning a degree in physics, Mach undertook studies in anatomy, physiology, and chemistry at the medical school of the University of Vienna, where he later designed and taught a course in physics for medical students. From the pioneering work of Gustav Fechner, the founder of experimental psychology, Mach learned that there are quantifiable thresholds of perception, in other words, that sensations can be measured. Thus, a mathematical relationship exists between the psychological realm and the physical. Here lay the key to an experimental methodology that would produce, in studies by Mach and his contemporaries and up to the present day, significant advances in the psychology of perception, including color, sound, space, and time.

Today Mach's name is commonly associated with measurements of the velocity of sound. The development in the mid-19th century of more powerful guns and cannons had led to the production of bullets and shells that traveled at speeds greater than that of sound vibrations. Mach's research into supersonic motion, published in 1877, helped to establish the field of modern aerodynamics; the Mach number, still in constant use by engineers, is the ratio of the speed of a projectile to the speed of sound.

Mach's investigations into optical phenomena included the discovery of so-called Mach bands, an effect of contrast perception that creates the illusion of narrow light and dark bands at the boundaries of contrasting areas. Of greater significance is Mach's more fundamental insight that *perception itself is always relational;* that is, we perceive not the world itself, but relations between sensations. Our senses have evolved to perceive contrasts between stimuli. It is the interaction of a new experience with the residue of a previous experience, or the difference between successive sensations, that forms the basis of perception.

Sanford Robinson

See also Darwin, Charles; Epistemology; Evolution, Organic; Memory; Perception; Psychology and Time; Space, Absolute; Time, Absolute; Time, Relativity of

Further Readings

Blackmore, J. T. (1972). *Ernst Mach: His work, life, and influence.* Berkeley: University of California Press.

Mach, E. (1984). *Analysis of sensations and the relation of the physical to the psychical* (C. M. Williams, Trans.). Chicago: Open Court. (Original English publication 1897)

Mach, E. (1986). *Popular scientific lectures* (T. J. McCormack, Trans.). Chicago: Open Court. (Original English publication 1898)

Machiavelli, Niccolò (1469–1527)

Niccolò Machiavelli was a Florentine diplomat, political theorist, historian, and poet. He was politically active in the courts of Louis XII of France, Cesare Borgia, Maximilian I, and Pope Julius II. After the return to power of the Medici in Florence in 1512, Machiavelli underwent banishment and withdrawal to Sant' Andrea, where he wrote his two major political works: *The Prince* (*Il Principe,* 1513), and *Discourses on the First Ten Books of Titus Livy* (*Discorsi sopra la prima deca di Tito Livio,* 1513–1522). These political writings present themselves as political counsel. They deal mainly with the possibilities for the lasting stabilization and self-preservation of polities. The theme of time emerges against the background of this practical problem. Machiavelli's analysis of history focuses on the way different factors are persistent or variable with time. He formulates advice for different time frames and deals with the correct handling of the opportunities and dangers of time as a factor of political action.

The Prince

Machiavelli's project can be understood as an answer to the then current political crisis of an Italy that was splintered into city-states. *The Prince* is his most influential work. Formally the work follows in the Middle Ages tradition of "mirrors for princes" that deal with the presentation of the kingly virtues. But Machiavelli breaks with the tradition in content. Instead of a normative orientation around Aristotelian virtue ethics and the Christian natural law tradition, he lays out a series of rules for political cunning. Not the ideal, but rather the actual determines Machiavelli's advice. Most of this advice relates in particular to the acquisition and maintenance of power by a new prince. Machiavelli's achievements in *The Prince* testify thereby to his efforts to recommend himself to the Medici for reinduction into the service of the state.

The virtues (*virtù*) Machiavelli recommends for princes should not be understood as classical virtues. These would even be harmful. The prince must appear to have those virtues that are considered good, but he must also have the ability to contravene mercy, humanity, and religion. For Machiavelli, justice and political success are not connected.

This counsel, directed to the achievement and preservation of the power of the autocrat, gave Machiavelli the reputation of a "teacher of wickedness." This emancipation of politics from morality was influential in the history of ideas. The directives, focused on the preservation of the prince, provided a basis for later thought on questions of national interest and are to this day a point of reference for political realism.

The *Discourses*

The *Discourses* are a commentary by Machiavelli on the Roman histories of Titus Livy. But at the same time, he unfolds a republican theory of the state. His analysis of the history of Rome has the goal of enabling a revival of Rome's political success. Since the basic structure of the world is invariable, history can serve as a teacher in current political questions. The imitation of ancient Rome could thus be the solution to the political crisis of contemporary Italy.

Machiavelli claimed that there are particular, necessary rules in history that hold for all time. These *necessità* are not interventions into history by a god (*providentia dei*) but rather regularities comparable to natural laws. Throughout time, political events follow necessarily from particular preconditions. This compulsion can result from natural circumstances or from the actions of humans.

For Machiavelli, human nature is a constant. Humans always tend to the bad rather than to the good, and they ceaselessly follow their appetites and ambitions (*ambizione*). They are not political beings by nature but must be domesticated and cultivated by institutions. Only in the well-ordered state can they develop the necessary powers for the preservation of the polity.

Politics, Government, and Time

The connection between *The Prince* and the *Discourses* has always created difficulties for interpreters. The techniques aimed at the retention of autocratic power and the reviving of republicanism are two different, situation-dependent proposals for solving the problem of the stabilization of a polity. A consistent reading presents itself against the background of Machiavelli's conception of political time.

Human nature imprints a determinate structure on the course of history. Following the ancient historian Polybius, Machiavelli formulates a cyclical model of the forms of government. States change from a condition of order to a condition of disorder. They thereby pass through various forms of administration, from autocracy to popular government. Monarchy degenerates to tyranny, aristocracy to oligarchy, and democracy to anarchy. For Machiavelli, all of these forms of government are to be rejected, the good ones because stability is ephemeral, the degenerate forms because of their badness.

According to Machiavelli, periods of political decline require an autocrat to bring new order to the polity, because the people are not in a position to do so. The advice in *The Prince* is directed in particular to this politically effective agent (*uomo virtuoso*). But the function of the *uomo virtuoso* seems to be temporally limited. If the polity is able to maintain itself after the establishment of laws and institutions, then the republican mixed constitution is for Machiavelli the better form of government. The considerations in the *Discourses* apply to such a government.

Republics are best able to maintain their inner stability and external capabilities of expansion. In them, the prince, the nobility, and the people can govern and oversee themselves together. Republican freedom is the result of orderly conflict between the nobility and the people.

Machiavelli makes temporal continuity the criterion of success in politics. The other goals of political action are subordinated to it. The key to defense against the permanent dangers of decay and corruption is *virtù*. In Machiavelli's usage, this denotes a category of accomplishments that lead to political success. *Virtù* can be found in individuals, in a people, or in the military.

Since *virtù* cannot be inherited, the competence of a people is better than that of an autocrat as the starting condition for a stable polity. The mere continuity of a republic over generations is grounds for its precedence as a form of government. Republican freedom can be a means of achieving enduring political stability.

Virtù represents power in the fight against *Fortuna*. Opposed to *necessità, Fortuna,* often personified as a female deity, stands for unpredictability in politics. She is the irrational moment in time. Her temper can help a polity to greatness or bring about its fall. She predestines the path of human action, but not absolutely. Machiavelli sees about half of the action as being left to human skill.

Even if the arrival of *Fortuna* is uncertain, there are ways to take precautions against her. Machiavelli compares her with a raging torrent that in its times of calm allows dams to be built. But the human tendency is to not think about changing times. This idleness is a sign of lacking *virtù* and offers *Fortuna* easy prey.

On the other hand, correct *virtù* can harness *Fortuna* for political success. The goddess of fortune can appear as the bringer of favorable opportunities (*occasione*). If they are recognized and exploited, then the agent has a share in luck. Machiavelli talks of the *occasione* as hurrying by, with the hair brushed forward covering the face so as not to be recognized. If the opportunity passes by, then one tries in vain to grab it by the bald back of its head.

The contest with *Fortuna* requires a deep sense of situation and adaptiveness to actual temporal circumstances (*qualità dei tempi*). Time, writes Machiavelli, drives everything before it, and it is able to bring with it good as well as evil. But time waits for no man, and only the one who adapts to it will have luck in the long run. Republics offer here the best conditions because of the diversity of their citizens; they are more flexible and adaptable than an autocracy. The *virtù* of one person fit for one time is not likely to change when circumstances change.

However, even the degeneration of a republic cannot be stopped, only slowed. Machiavelli calls time the father of truth. The enduring badness of humanity becomes manifest and in time spoils goodness. Thus, for Machiavelli, there is a natural limit to the life of all things in the world. Decay is inherent to time.

Robert Ranisch

See also Ethics; Law; Magna Carta; Morality; Rome, Ancient; Time, Cyclical; Values and Time

Further Readings

Machiavelli, N. (1983). *The discourses*. London: Penguin Classics. (Original work published 1513)

Machiavelli, N. (2003). *The Prince*. London: Penguin Classics. (Original work published 1513–1522)

Orr, R. (1972). The time motif in Machiavelli. In M. Fleisher (Ed.), *Machiavelli and the nature of political thought*. New York: Atheneum.

Skinner, Q. (2001). *Machiavelli: A very short introduction*. Oxford, UK: Oxford University Press.

Magdalenian Bone Calendars

A number of authors (e.g., André Leroi-Gourhan) have examined the possibility that Paleolithic engravings may have constituted a form of notation—certainly this is the case with the Azilian painted pebbles, but the name most associated with Magdalenian bone calendars is that of Alexander Marshack of Harvard's Peabody Museum. Marshack determined that certain objects of art from the late Stone Age Magdalenian, Solutrean, and Aurignacian periods of the Upper Paleolithic may have been not simply *objets d'arts* or hunting tallies but may have served as lunar calendars. The Upper Paleolithic period stretched from roughly 30,000 years ago to 10,000 years ago, with some range of variation. This was during the height of the Würm glaciation, when much of the classic "cave art" is believed to have been produced.

Although polychromatic paintings of ice age animals found on cave walls (parietal art) in southwestern France and northern Spain, most notably those of Lascaux and Altamira, are the best-known examples of Upper Paleolithic art, portable art also exists from this time. Venus figurines often are displayed as examples of Upper Paleolithic portable art, but there also are objects of unknown use. Among these are pieces that Marshack claims represent calendars or seasonal notations. These are exemplified by a piece carved in the round on an antler. This carving, when rolled out on a flat matrix, represents reindeer, snakes, and salmon. The carvings show scratches that have been taken to be arrows. Marshack showed them to locals in the area where the piece was found, and they proclaimed the scratches to be *farin sauvage,* or wild wheat. Marshack determined that because of the antlers on the deer, the exposed genitalia on one of the snakes, the appearance of a hook on the jaw of a salmon on the carving, and the wild wheat in seed head, that the carving represented a short period of time in the spring when all of these factors co-occur.

Further, Marshack believed that he had found evidence of thousands of engraved and painted notational sequences from Spain to Russia and an actual lunar calendar showing phases of the moon carved into a piece of mammoth ivory from the Ukraine. For some, the most convincing evidence comes from a 10-centimeter-long ovaloid Aurignacian antler plaque from Blanchard, Dordogne. The Blanchard plaque shows 69 round and "paisley" pocks in a complex line that snakes back and forth across its flat surface. Marshack argues that when the pock-marks are microscopically examined, it is apparent that they were made over an extended time with multiple tool points and engraving pressures. The paisleys and circles correspond to the waxing, full, and waning moons over nearly two and a half months. The snakelike arrangement of the marks appeared to be the moon's rising and setting positions to an observer facing south. Some of Marshack's claims have been seconded in recent years by Francesco d'Errico by use of a scanning electron microscope. Although a number of people remain unconvinced by Marshack's discoveries, it is undeniable that he has made a significant contribution to our understanding of Upper Paleolithic observational abilities.

Michael J. Simonton

See also Anthropology; Time, Prehistoric; Timepieces

Further Readings

Elkins, J. (1996). On the impossibility of close reading: The Case of Alexander Marschack. *Current Anthropology, 37*(2), 185–226.

Leroi-Gourhan, A. (1993). *Gesture and speech* (A. B. Berger, Trans.). Cambridge: MIT Press. (Original work published 1964)

Marschack, A. (1964). Lunar notation on Upper Paleolithic remains. *Science, 146*(3645), 743–745.

Marschack, A. (1972). Cognitive aspects of Upper Paleolithic engraving. *Current Anthropology, 13*(3–4), 445–477.

Marschack, A. (1991). *The roots of civilization* (rev. ed.). Mt. Kisko, NY: Moyer Bell. (Original work published 1972)

Magna Carta

The Magna Carta (Latin for "Great Charter") is considered one of the most significant documents in history. First issued by King John of England in 1215, it formalizes the covenant whereby the king was compelled by the barons and the authorities of the church to make a series of promises regarding rights and privileges, thus imposing constraints on the powers of a monarchy hitherto regarded as absolute. Over the following centuries, the Magna Carta has had a strong influence not only on British constitutional history but also on the democratic development of other nations.

The signing of the Magna Carta has long been lauded as a defining moment in human history and has been cited as a touchstone of English common law by those seeking the guarantee of rights and freedoms in nations throughout the world. It is important, however, to note that the charter did not grant rights and privileges to all people in 1215. The English barons, or noblemen, and the church drafted the Magna Carta to assert their own rights and thereby check the power of the monarchy. The common people of England initially gained little. The document's prestige increased over time with the development of parliamentary government. It became a symbol for liberty and individual rights against oppressive rule.

Earlier English kings had made agreements with their barons. The Magna Carta differs in that it is the first important example of the king's subjects demanding rights and forcing him to concede. John became king in 1199 and lost little time in angering his subjects. He waged war unsuccessfully in France, which required him to raise taxes and conscript more nobles for military service than had his predecessors. He broke with feudal tradition by failing to consult with his barons on important issues. John also clashed with Pope Innocent III over the appointment of the archbishop of Canterbury. This quarrel resulted in John's excommunication from the Roman Catholic Church in 1209. Reconciliation with the church was immediately followed by additional military defeats. In 1213, the disaffected barons and clergy met and outlined a list of articles. John dismissed these twice before the barons raised an army. The king then reluctantly arranged to meet with them at Runnymede, south of London, and agree to terms.

The Magna Carta was concluded on June 19, 1215, following much squabbling. Written in Latin, as was the custom during the age, it was essentially a peace treaty. It contained a preamble and 63 articles, which were for the most part reactionary rather than revolutionary. The articles were divided into separate groups dealing with issues such as law and justice, conduct of royal officials, trade, the independence of the church, and the royal forests. The concluding articles concerned King John's loyalty to the Magna Carta and the right of the barons to challenge the king should he ignore the charter. The Magna Carta was reissued and amended a number of times in subsequent years. The vague wording of many of the articles has left considerable room for interpretation over time. Later generations interpreted clauses 39 and 40 in particular as protections of habeus corpus and trial by jury, but the reasoning has been much debated.

The stature of the Magna Carta increased over time as English lawyers and members of parliament cited it in arguing the rule of law. In addition to English common law, the charter has influenced constitutions throughout the world, including that of the United States. Four of the original copies are known to remain.

James P. Bonanno

See also Hammurabi, Codex of; Law; Morality

Further Readings

Holt, J. C. (1965). *Magna Carta.* Cambridge, UK: Cambridge University Press.

Turner, R. V. (2003). *Magna Carta: Through the ages.* London: Pearson Education.

Maha-Kala (Great Time)

In the tradition of India, the creation of the universe is the purpose and significance of Maha-Kala, or Great Time. The Great Time is personified by the god Siva and his alter-ego Maha-Kala. Siva is the artistic part of creation. Maha-Kala is the power (called Pralaya or the Great Dissolution) to dissolve the universe. Destruction is necessary for creation; reproduction requires both creation and destruction. This interaction is the reproduction of nature and the cycle of birth and death. Both male and female principles are at work: The female is destructive by dissolving what is ceasing to exist into herself; the male is creative by being the source of new existence continually being created in the universe; this interaction is represented by the concept of Sankara.

Siva Maha-Kala represents the continual rebirth of the universe, which is going on continuously. Also, it is the life cycle of the universe, which is born, matures, and dies. The universe is created by Siva and destroyed by Maha-Kala. New universes are created out of the destruction of the previous universe. This then brings about the Mahadaeva, who is the deity without comparison—the Great God who is Siva.

Unity is the restorer, which is symbolized by Linga the Phallus, or Global Oneness. The linga is the erect penis of Siva, which represents the respect and meaning of life. When combined with Yoni, the symbol for the female genitals, it becomes the reproduction of the universe. Yoni is the center of all that is spiritual. Through this union of the material and the spiritual, the universe is formed.

Maha-Kala is the destroyer essence of Siva; but she is more than that. She is the force that absorbs all of creation unto her. From this material, which Maha-Kala allocates into her womb, Siva can fashion the universe once more. The destroyer is the regenerator. Through destruction, rebirth and evolution are possible. Through understandings of the nature of destruction and creation, union with true enlightenment becomes possible.

Mahayogin is the knowledge of the secrets of the universe. Because of this, Maha-Kala is the destroyer of human passions. With the annihilation of all excitement, true enlightenment is possible. With illumination, it is possible to achieve ultimate understanding and tranquility in the endless shifting cosmos and escape from the affliction and suffering of life, existence, death, and fate.

Siva Maha-Kala is also the Nataraja, the lord of dancers and the dance of creation, destruction, embodiment, liberation, and maintenance. With the invention of the cosmos, the devastation of creation is realizable. The personification of the interaction of contrary forces brings release and preservation from stagnation. Nataraja is the artistic representation of Siva Maha-Kala through dance. The dance expresses the continuing creation and destruction of the universe as a single interactive and ongoing process. The dance makes clear that creation is a movement in which the universe creates itself out of its own destruction. This is why Nataraja is important in this vital understanding.

In different regions, people find different ways to express this insight. Different stories were developed to understand Siva Maha-Kala nature. In South India, in the woods of Maharashtra, lived a group of sages who had strayed from the Way. Siva and Vishnu tried to win the mystics back and restore rule over the area. Vishnu took the form of a beautiful woman, and the anger of the monks increased. Siva Maha-Kala danced to break down the priests' control over the region. The philosophers then created a tiger out of fire to pounce and kill Siva Maha-Kala. Siva Maha-Kala very gently removed the pelt of the tiger and covered himself with the fur of the tiger as if it were a robe. Then a venomous serpent was formed. Siva placed the snake around his neck, which became a most beautiful garland. The heretics then shaped together a giant who looked like an overgrown and deformed dwarf. Siva Maha-Kala broke this monster's back, returning substance to the earth. With song and dance, malevolence was overcome, and everything foul was recycled to create beauty.

Nataraja the dancer produces ecstasy, through which the divine embraces human life. Through the dance, life embraces the four directions. Siva Maha-Kala holds the hourglass drum, which is creation. The drum becomes the pulse of the universe. Sound is the first element created by the universe. From the sound and songs of the universe came the Sanskrit language—the second element and the carrier of wisdom.

Siva Maha-Kala then holds up the tongue of flames that is the next element. Fire is the destroyer. It is the element of destruction, annihilation, and extinction that generates the raw materials for creation to begin again. From this, Abahaya, or protection, is born. Protection is needed for life. Through this dance, Siva Maha-Kala gives birth to the son he sired. Ganesha, the son, removes obstacles to enlightenment, leading to the escape from birth and death.

Original beginnings and inspired strength are possible when slothfulness, apathy, and preoccupation with self are overcome. The soul of the universe rests within the spirit of each individual. Through wisdom, the understanding of this relationship can be appreciated.

Eternity and Time embrace each other. The mountain streams feed the oceans of the world. Siva is both Kala (fleeting time) and Maha-Kala (the Great Time or eternity). Mahayugas, or Great Eons, are but flashes of time. Eternity and Time stand in continual unity, conflict, disintegration, and reunity at every point from the eternal past to the eternal future. Time is the tension between destruction and reproduction.

Buddhism and Maha-Kala

With the rise of Buddhism, Maha-Kala became the realization of the eternity of ever-changing time. Ngawang Drakpa founded the Dhe-Tsang monastery. While traveling in the region of Eastern Tibet, a large crow flew down to the monk and pilfered his scarf. Days later and some distance away, the monk discovered his scarf draped over a juniper tree. This became the spot the monastery was built. To this day in Tibet, Maha-Kala means the "great black one."

The local Bonpo (the indigenous animistic masters) feared the coming of Buddhism. They used magic to prevent the building of the Buddhist monastery. What the Buddhists built during the day would collapse at night. When the crow, Maha-Kala, saw this, he carried a correspondence between Ngawang Drakpa in Dhe-Tsang and the Most Holy Master Tsongkhapa in Lhasa. From this communiqué, the solitary hero Bhairava Sadhana was gathered. This enhanced and intensified the decisive factors of Buddhism. Due to this improved Buddhism, the Bonpo monks became Buddhists.

With the construction of the monastery, it was agreed upon that there was a need for a guarding statue to protect the abbey. That very day, three black men from India showed up and offered their services. These sculptors were contracted to complete the sculpture. When work began on the figure, there was only one black man left. When the icon was only half-completed, a rite was planned and implemented to celebrate the holiness of the site. Tibetan dancers were asked to perform a dance of rejoicing for the ceremony that celebrated the founding of Buddhism in this region of Tibet. With dancing in progress, the black Indian began to dance. No human ever saw a dance more wild or beautiful. Everyone stopped what she or he was doing to watch the untamed magnificence. At the height of the performance, the sculptor disappeared and the image of Maha-Kala was completed. The same mysterious event occurred at the same time at other sites in which two other icons were constructed in exactly the same way. This was the work of none other than Maha-Kala, protector of the holy site and guardian to the Great Time.

Concluding Remarks

In the tradition of India, Maha-Kala represents time, eternity, destruction, and creation. This Great Time leads us to realize that our lives are transitory flashes in the eternal ocean of change. Because of this, our ignorance creates wisdom, pride becomes humility, desire leads to detachment, jealousy gives support to secure accomplishments, and anger gives way to inner peace. Eternity is forever and changes constantly, being destroyed and reborn. The universe also returns to its beginnings and starts over. What happens to every individual happens to the universe.

*Michael Joseph Franciscon*i

See also Cosmogony; Cosmology, Cyclic; Eternal Recurrence; Eternity; Nietzsche and Heraclitus; Time, Cyclical

Further Readings

Many forms of Mahakala, protector of Buddhist monasteries. (2005, January). Retrieved July 3, 2008, from http://www.exoticindiaart.com/newsletter

Miller, B. (1986). *The Bhagavad-Gita: Krishna's counsel in time of war.* New York: Bantam Classics.

Olivelle, P. (1998). *The early Upanishads. Annotated text and translation.* Oxford, UK: Oxford University Press.

Ramanujan, A. K. (1973). *Speaking of Siva.* New York: Penguin Classics.

Rig Veda. (2005). New York: Penguin Classics.

Shiva as Nataraja—Dance and destruction in Indian art. (2001, January). Retrieved July 3, 2008, from http://www.exoticindiaart.com/newsletter

Tulku, U. R. (2004). *As it is.* Berkeley, CA: North Atlantic Books.

Valenza, R. (1994). *Maha Kala in the center.* Occidental, CA: Nine Muses.

Malthus, Thomas Robert (1766–1834)

Thomas Robert Malthus was an English political economist of the classical school and a representative of utilitarianism as well as of early demographic science. He is best known for his *Essay on the Principle of Population* (1798), in which he assesses the problems of the growth of the human population in respect to their supply of food and other vital products. Malthus is considered an economic pessimist, an economist of crisis whose theories were of high impact despite their being partially erroneous.

Life and Writings

Thomas R. Malthus was born on February 13, 1766, in Surrey, southern England, as the sixth child of a prosperous family. His father, Daniel Malthus, is said to have known the philosophers David Hume, James Mill, and Jean-Jacques Rousseau personally. Little Thomas was educated by his father and private tutors; starting in 1784, Malthus attended Cambridge University's Jesus College, where he studied mathematics, classical languages, and literature. He obtained a master's degree in 1791 and became a fellow of Jesus College only two years later. In 1797 Malthus was ordained in the Anglican Church and decided to officiate as country clericalist in his home county.

In 1804, however, Malthus resigned from the priesthood to marry Harriet Eckersall, with whom he had three children. Soon after, in 1805, he became the first professor of political economy at the college of the East India Company at Haileybury, Hertfordshire. Already in 1798, *An Essay on the Principle of Population, as it Affects the Future Improvement of Society, With Remarks on the Speculations of Mr. Godwin, M. Condorcet, and Other Writers* had been published anonymously. In this, Malthus's main work, which he revised continually until his death, he showed his deep economic and social pessimism, as he was convinced that any increase in productivity and wealth would inevitably be outrun by the evoked growth in the population's number. Consequently, he doubted the benefit of a high birth rate for an economy.

Around 1810 Malthus met one of the most important economists of the time, David Ricardo; an active correspondence and a close friendship developed. In 1819 Malthus obtained fellowship in the Royal Society; moreover he became a member of the Political Economy Club, and in 1834, he was one of the founders of the Statistical Society of London.

In his *Principles of Political Economy Considered With a View to Their Practical Application* (1820) Malthus wrote about the motivating parameters of individual economic decisions as individually rational cost/benefit considerations.

Population Theory

Following David Hume's empirically scientific attempt, Malthus generated his insights with respect to the constitution and the prospect of the society in a completely nonidealistic way, based solely on direct observation. He thereby formed one contradiction of significance to the French Revolution's idealists' and in parts even anarchists' (e.g., Rousseau, William Godwin, and M.-J.-A.-N. de Caritat marquis de Condorcet) theoretic idea of a perfect society.

Malthus did not believe in any kind of utopia. He instead came to the conviction that a steady state of a society's economic prosperity would be utterly impossible due to an inevitably geometrical growth of population combined with at best an arithmetical growth of production of food. In consequence, at any time, the population will be too numerous to live in comfort. War, diseases, and famine are considered natural regulators and necessary to constrain the excessive growth of population and following misery. This bad fate Malthus deemed divine destiny to keep morality and to evade profane idleness. However, later in his life Malthus came to regard self-imposed moral restraint as an alternative check on population-food equilibrium.

Malthus sometimes is criticized for his unfounded usage of statistical methods and subsequent generation of his arguments. On the basis of a sophisticated empiricism, Malthus unfortunately built somehow arbitrarily theoretical constructs of ideas.

Impact

So-called Malthusianism had a sudden and deep impact, especially on English social policy. Malthus thereby vigorously turned the balance against public generosity toward the poor. On the other hand, in stating public investments as a means to resolve economic slumps by stimulating the aggregate demand in his *Principles of Political Economy,* Malthus preceded or at least influenced John Maynard Keynes.

For decades, Malthus's economic doctrine was crucial to the economic and especially welfare-related politics of several European nations. Because of his influence on Ricardo and Keynes, for example, Malthus's thought remains, to some extent, still vivid today.

In evolutionary theory Malthus left his mark as well; Charles Darwin admired him all his life and followed Malthus's thoughts about the struggle of existence and the implication of the fitness of a species' individual representatives for the evolution of the species.

Despite their popularity, wider parts of Malthus's thoughts proved false. As one of numerous examples, he did not anticipate the technological advances leading to the agricultural revolution, which resulted in discharging growing parts of the population from the necessity of agricultural work, thereby paving the way for industrialization. Industrialization in turn finally led to a considerable increase in prosperity.

Matthias S. Hauser

See also Darwin, Charles; Dying and Death; Economics; Extinction; Extinction and Evolution; Extinctions, Mass; Hume, David; Rousseau, Jean-Jacques

Further Readings

Bonar, J. (2000). *Malthus and his work*. Boston: Adamant. (Original work published 1885)

Hollander, S. (1997). *The economics of Thomas Robert Malthus*. Studies in Classical Political Economy/IV. Toronto, ON, Canada: University of Toronto Press.

Malthus, T. R. (1998). *An essay on the principle of population*. New York: Prometheus. (Original work published 1798)

Mann, Thomas (1875–1955)

Thomas Mann was a highly regarded German novelist and social critic of the 20th century. He won the Nobel Prize for literature in 1929, and his works were considered classics by the end of his life. His novels and essays combined philosophy, psychology, and political insights with his literary craft. His themes often centered on dualism: the coexisting physical and spiritual human natures, the life of action and the life of thought.

Mann's writings detail the complexity of reality and time. *The Magic Mountain,* his novel published in 1924, most clearly explores the inner time-consciousness of the main character, Hans Castorp, as he seeks knowledge and adjustment to life in a tuberculosis sanatorium. This novel is full of references to understanding time. Mann insists that time cannot be narrated and is not linear. Hans remarks about time being a turning point in a circle. The daily routines and seasons circle around the characters' lives.

Thomas Mann was born Paul Thomas Mann into a prosperous middle-class family in Lübeck, Germany, on June 6, 1875. He was baptized as a Lutheran. He was one of five children of a prominent merchant and city councilman. When his father died, the family moved to Munich, where he received his early education. He began the daily habit of writing in his personal diary when he was a schoolboy in the 1890s. In 1905, he married Katia Pringsheim, an educated woman and the only daughter of a professor in Munich. She devoted herself to him, his career, and their six children. He traveled on the lecture circuit and vacationed around Europe. They had a life of culture, order, and comfort. He had many famous acquaintances in the fields of literature, music, psychology, and politics of the time.

In 1933, while Mann and his wife were vacationing in Switzerland, they were advised not to return to the political turmoil of Germany. Adolf Hitler's actions forced Mann into a reluctant exile. Mann was very concerned about getting his private diaries back. On July 7, 1935, Mann received Harvard University's honorary doctor of letters degree with Albert Einstein. In 1938, Mann and most of his family settled in the United States, where he continued his writings in the German language. His children grew up to succeed in a variety of literary and scholarly endeavors. In 1944, he became a U.S. citizen. Mann moved back to Switzerland and died there on August 12, 1952.

Major Novels and Essays

After writing several essays and journal articles, Mann published his first novel, *Buddenbrooks,* in 1901. This novel thoroughly detailed the story of three generations of a family as they declined physically but grew to include several failed artists. The values and attitudes of the middle class were in conflict with those of the artists. These internal conflicts of opposing forces leading to change are associated with the philosophy of dialectics. Mann read the classics, and his writings reflect his thinking about the nature of Western middle-class culture as well as his version of his own family.

His short novel *Death in Venice,* published in 1912, also is considered a mirror of his own life and his psychological issues. This novel details a writer's moral conflict and collapse through a humiliating, uncontrollable, and unfulfilled passion for a young boy.

During the period from 1914 to 1918, Thomas Mann supported Germany's slide in World War I. He wrote a lengthy essay published in 1918 as *Reflections of a Non-Political Man.* This was part of a disagreement with his older brother, Heinrich Mann, who was also a published author but who was very opposed to the military buildup in Germany. At this point, Thomas Mann praised Nietzsche for supporting the acceptance of ambiguity as a great personal strength. His essay claimed the romantic view that art would not surrender to the system but could remain isolated from politics. Later he realized that this position was political itself, and he finally reconciled with Heinrich in California in 1942.

The publishing of *The Magic Mountain* in 1924 marked the end of 12 years of work. Just as he had come to believe that there is no turning point in politics, this work incorporated the notion of time's circular nature in both the novel's form and its content. The reference to time not being linear seems to refer to Hegel's idea about bad infinity being linear but real infinity being circular and dialectical. The protagonist Hans Castorp notes that the longest day of the year, June 21st, is called the first day of summer, yet the days start getting shorter at that point, so it truly is the beginning of winter. Joy and melancholy can exist at the same time in a dualistic philosophy.

Mann used techniques of the composer Richard Wagner to tell this story: multiple themes with variations and the exploration of the characters' emotional lives. This novel is based on the setting of the Davos Sanatorium, where his wife spent 6 months in 1912 for a lung condition. *The Magic Mountain* is an allegory of Western civilization's sickness as well as a sympathetic telling of the story of individuals dealing with personal sickness, real or imagined. Man is the master of contradictions, and the human goal is not to decide but to reach harmony with the human condition.

Through the years Mann wrote essays on Freud, Goethe, Nietzsche, Tolstoy, and Wagner. These essays detail his intellectual struggles, which shaped his fiction writing. He wanted to understand people completely and took great interest in understanding himself and his world, as is minutely detailed in his diaries.

In 1943, Mann published a four-novel series on the biblical Joseph, *Joseph and His Brothers*. The project took him 10 years to complete. This epic begins in the timeless tribal existence of the desert and moves into the historical timeline of Egyptian civilization. Mann wanted to restore a belief in the power of humane reason. These novels show the individual as a reflection of his epoch as well as of his personal story.

Doctor Faustus, published in 1947, tells the tale of a great German composer who bargains with the devil and rejects love and moral responsibility in favor of artistic creativity. Mann connects the 12-tone musical system to totalitarianism. He writes that a chord has not one key but is all about relationships. This became a novel about commitment and the failure of accepting ambiguity. At the end of his career, he finally chastised the dialectic and recognized the importance of fighting evil. He aided the Allies through his writing and saw Franklin D. Roosevelt as saving the world. He chose to leave the United States when the anticommunists and Senator Eugene McCarthy held power and influence.

Ann L. Chenhall

See also Dostoevsky, Fyodor M.; Goethe, Johann Wolfgang von; Hegel, George Wilhelm Friedrich; Hitler, Adolf; Joyce, James; Nietzsche, Friedrich; Novels, Time in; Proust, Marcel; Time, Cyclical; Tolstoy, Leo Nikolaevich; Wagner, Richard

Further Readings

Kesten, H. (1982). *Thomas Mann diaries, 1918–1939* (R. Winston & C. Winston, Trans.). New York: Abrams.

Kurzke, H. (2002). *Thomas Mann: Life as a work of art: A biography* (L. Wilson, Trans.). Princeton, NJ: Princeton University Press.

Mundt, H. (2004). *Understanding Thomas Mann.* Columbia: University of South Carolina Press.

Maritain, Jacques (1882–1973)

Jacques Maritain, French Catholic philosopher, composed numerous influential works on topics including epistemology, metaphysics, moral philosophy, sociopolitical philosophy, philosophy of art, and mysticism. In Maritain's metaphysical philosophy he discussed the experience of the progression of time by finite beings in contrast to the divine, eternal perspective of time. In the latter, all moments of time are simultaneously known in a single instant, which has neither beginning nor end. Maritain also held that the human soul, which he associated primarily with intellectual activity, was eternal, existing always in the thoughts of the creator. Maritain's Christian-humanist perspective has been called Thomist, owing to Maritain's great affinity with the perspectives of 13th century philosopher and theologian Thomas Aquinas.

Born in Paris in 1882 and baptized into the French Reformed Church, Maritain studied philosophy and science from 1901 to 1906 at the Sorbonne, where he met Raïssa Oumansoff, a Jewish Russian student whom he would marry in 1904. Jacques and Raïssa Maritain became disillusioned with the rationalist scientism at the Sorbonne, and they resolved together to end their lives in suicide if they could not find a satisfactory understanding of truth. In their subsequent quest the Maritains were influenced first by the metaphysical perspectives of Henri Bergson and then by the writings of Léon Bloy, which led them to convert to Roman Catholicism in 1906.

Maritain began to study Thomas Aquinas's immense work, *Summa Theologiae,* in 1910. Aquinas's perspective appealed to both the philosopher and the Christian in Maritain, and its impact on him was acute and enduring. Maritain soon began publishing, and he lectured in philosophy at the Institut Catholique de Paris from 1913 to 1933 and at the Pontifical Institute of Medieval Studies in Toronto from 1933 to 1945. During these years he wrote without ceasing, becoming the dominant philosophical voice for Catholics in France and the United States. After World War II Maritain served as the French ambassador to the Vatican from 1945 to 1948, personally befriended Pope Paul VI, and taught philosophy at Princeton until retiring in 1956. After Raïssa's death in 1960, Maritain joined a Dominican order, The Little Brothers of Jesus, and lived with them in Toulouse as a hermit until his death in 1973.

In *Existence and the Existent,* Maritain discussed the relationship between time—the experience of finite beings—and eternity—the divine perspective of all existence. From the perspective of divine eternity, all moments of time—past, present, and future—are present and tangible in a single instant, Maritain reasoned. This eternal divine perspective does not imply absolute determinism, according to Maritain, but included acknowledgment of the free choices given to created beings, which rightly operate within the measurable succession of time. Along similar lines, Maritain viewed the human soul or intellect as eternal and timeless, presupposing that the intellectual activity observable in human beings must always have been and must always be existing, even before its creation in the thoughts of the creator.

In reflections and observations about history, Maritain—though highly modern in many ways—despaired of much of the course of the modern world. Maritain saw in history a pattern of contrasting progresses. He observed that while modern civilization had clearly achieved many advances in scientific knowledge and humanitarian causes, these gains were mirrored by moral and spiritual depravity, political totalitarianism, and wars with unprecedented cost of human life. The answer for Maritain lay in neither capitalism nor communism but in a renewed Christendom characterized by justice, truth, love, and tolerance. Seen in many ways as a liberalizing influence in Catholicism, in 1967 he shocked many by writing very critically of Vatican II in one of his last works, *The Peasant of Garonne.*

Adam L. Bean

See also Aquinas, Saint Thomas; Bergson, Henri; Christianity; Eternity; Immortality, Personal; Metaphysics; Mysticism

Further Readings

Barre, J.-L. (2005). *Jacques & Raïssa Maritain: Beggars for heaven* (B. Doering, Trans.). Notre Dame, IN: University of Notre Dame Press.

Dunaway, J. (1978). *Jacques Maritain.* Boston: Twayne.

Kernan, J. (1975). *Our friend, Jacques Maritain.* Garden City, NY: Doubleday.

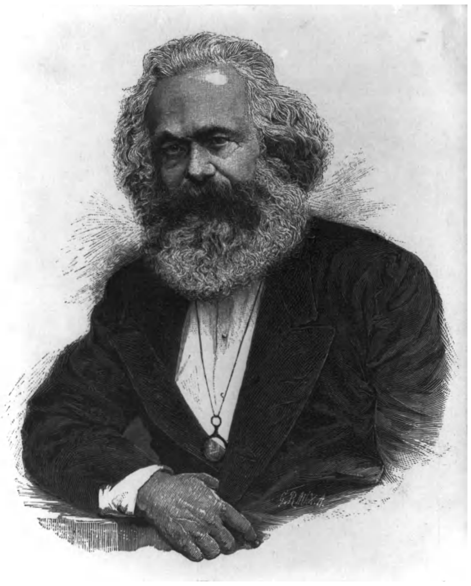
Marx, Karl (1818–1883)

Karl Marx is often named as one of the two greatest intellectual innovators of the 19th century, the other being Charles Darwin. He helped to redefine the fields of sociology, history, economics, and anthropology. Much of what followed in these disciplines is a response to the theories he outlined in his writings. Known as the father of Marxism, a revolutionary socialist movement worldwide, he also strongly influenced and in part defined such topics as social stratification, historical sociology, materialist anthropology, cultural ecology, social history, and social economics, just to name a few areas. For example, sociologists since Marx have tried to disprove, defend, or reform his theories. Few can ignore the writings of either Marx or his followers.

Karl Marx was born in the German Rhineland city of Trier on May 5, 1818. Both his mother and father were Jewish by birth. However his father, who was well read in the humanist writings of the Enlightenment, converted to the Lutheran faith to secure employment opportunities at a time when many occupations were closed to Jews. Marx's mother and the rest of his family converted later. Having been born into a Jewish family and raised as a Protestant in a Catholic city helped mold the character of young Karl.

At age 17, Marx enrolled in law school at the University of Bonn. At Bonn he became engaged to Jenny Von Westphalen, the daughter of a baron who was also a professor at the Friedrich-Wilhelms University in Berlin. The next year, Marx transferred to the University of Berlin. There he became interested in philosophy. He associated with the Young Hegelian movement, which was a radical humanist movement. Because a university career was closed to all Young Hegelians, Marx took up journalism as editor of the radical journal *Rheinische Zeitung*. This would eventually result in Marx's exile to Paris.

In Paris, Marx made contact with the French socialists. As a result of pressure brought to bear by the Prussian government, who feared the anti-Prussian underground in France, Marx was labeled a radical and an undesirable foreigner and was forced by the authorities to leave Paris; he moved to Brussels, where he lived for three years. There Marx dedicated his time to an intensive study of history and expanded the materialist conception of history. He developed what later would become known as historical materialism. In 1848, Marx moved back to Paris in support of the revolutions in France and Germany. In 1849, he moved to Britain, where he died in 1883. Marx developed his methodology of historical materialism in the early years, and it served as a model for his later work in political economy. It is important to analyze the evolution of his life from the days when he was influenced by the Young Hegelians until he wrote *German Ideology* in 1847 as he moved from philosophy to historical sociology.



Karl Marx, the father of modern communism. Marx believed that the downfall of capitalism by revolution and its replacement with a society based on socialism was inevitable.
Source: Library of Congress, Prints & Photographs Division.

Marx the Scholar

According to Irving Zetlin, Karl Marx is credited with establishing sociology as a discipline. Since then, sociology has been defined by a debate with the ghost of Marx. Karl Marx was a true heir of the Enlightenment. Marx's sociology was historical, materialist, and dialectical, and it was part of a social, political, and economic revolution. In his early years, Marx was interested in philosophy, encouraged by his association with the Young Hegelians. These philosophers wore their radical atheism as a public badge of honor. Particularly influential in the life of young Marx was Ludwig Feuerbach. Feuerbach taught that God is a human creation in which human characteristics, requests, requirements, and promise are projected onto an entity that is creative fiction. We then worship that entity as if it were real. He believed that ideas actually come to pass from the lives of real people. Therefore, only when people come to realize this can they end their alienation and restore their species-being. This is our shared common humanity. From this, Marx arrived at the idea that we would need to look at how real people live in their environments in order to study properly the content of their cultural ideas, ideology, and religion. Political beliefs, values, ways of life, and religious convictions all develop and change within human communities. These communities are embedded in an ever-changing environment. The environment is rooted in a constantly evolving set of conditions.

In the following sections, the principles Karl Marx espoused are briefly outlined.

Early Marx

Following is a summary of the young Karl Marx's views on democracy, power, the state, religion, bureaucracy, and law. According to Marx, democracy makes the assumption that all people are equal, even if they are not. The nature of any state is the specific historical circumstances that reflect particular social relations. The state is the design of unequal amounts of power that competing groups use to control the administrative system of political institutions.

Power, within the politics of a state society, often appears to operate independently of individuals within that society. In point of fact, groups compete with vastly different amounts of political power. Power cannot exist as a force independent of individuals within these competing groups. Economic classes and social groups compete over control of resources that are necessary for wealth and power. The state appears to operate externally to and autonomous of these struggles. This is a hallucination. The state is constantly changing, reflecting changes in these power struggles. While the political appears to be the cause of these changes, it is more like the effect. The state as a neutral arbiter of these conflicts is reflective of power, wealth, and class interests. Not all classes, families, or individuals are equal in their influence on the state. Being a neutral arbiter is an illusion.

Social interaction between real people, like families and the surrounding community, can be observed empirically. This includes how people provide for their material needs collectively in that community through working together. This is called interaction in civil society. Civil society is an abstraction that reflects authentic social relationships. Civil society is the private satisfaction of personal desires in a social setting. The state reflects the public expression of power; it is also an abstraction that illustrates genuine social relationships. The state is the public manifestation of the private yearnings expressed in civil society; it is made up of real individuals interacting and competing for political power. These human beings relate mutually to nature and each other through work, forming groups to cooperate in meeting their real physical and social needs. The state is the public expression of this, and civil society is the private expression.

Because ideology is used to justify one group's control over economic resources necessary for political power, it is usually declared that the dominant group represents all of society, including the powerless.

The state, according to Marx, cannot be separated from real individuals. There are real people doing what they must to survive. In order to live, people need access to economic resources. Each group competes for power with unequal political resources. Sovereignty is understood as the abstract reflection of who has more real power. This abstraction is often confused by the fact that appearances mask reality. Sovereignty appears as that which gives people power. Individuals define their citizenship within this struggle for sovereignty. However, with control over basic resources, political freedom masks real oppression and exploitation.

Humans are human only in a social context. The "social" is made up of definite individuals. The individual is a social product. The state and civil society are interconnected abstractions, and the separation of the two is an intellectual tool that makes the science of society possible. The government (state) only appears as outside of and above individuals of civil society. The monarch is a real person who abstractly stands for the state. The state is an abstraction of power used to coerce the people. The monarch uses real power supported by other individuals, the military and police, to enforce his will. Others who work for the monarch use implements of coercion to force people to obey the will of the monarch. This threat of violence is reinforced by ideology, doctrine, and religion. The monarch is the personification of the sovereignty of power. People are excluded from the use of power. The monarch represents the unity of the people, a people without power.

Sovereignty of the people is a concept that stands opposed to the sovereignty of the monarch. The monarch speaks for God and not the people. In a republic or democracy, the government is the imagination of an abstraction called the people.

Instead of sovereignty defining citizenship, it is the belief of the citizen that gives sovereignty its perceived reality. Each type of government reflects real power relationships between groups of individuals. Thus, each government defines sovereignty to meet the interests of the more powerful group. The military, the courts, the church, and the media define what most people believe to be real about sovereignty. Political consciousness and political culture are learned in institutions that are largely controlled by the power elite. These learned explanations justify and hide real power in society. In order to operate more smoothly, the established power relations are often falsely represented as being in everyone's best interest. Alternative views are learned, in opposition to the established political culture. Each form of government is part of a cultural completeness, which everyone is taught to see as true. Imperial democracy is no contradiction. These abstractions reflect the interests of those who control the political resources of the state. Political constitutions operate on faith. A republican body of laws reflects the development and evolution of commerce and private property. Government based on a constitution is a bourgeois artifact. During the Middle Ages, property, economy, and society were embedded in the political structure. In capitalist society, the separation of the economic from the political is possible because of political action and reflects the interests of the economically powerful.

Religion in a monarchy is the foundation of the political constitution. A republic or democracy uses the private lives of its citizens as its justification. Private property and commerce are the material groundwork for the republic. In a monarchy, private property and commerce are political gifts of the sovereignty.

Bureaucracy is the practical structure of the state. It is the social relationship in which the abstract state becomes real. There are hierarchies of power that used specialized knowledge as their justification. The imaginary state functions through a real bureaucracy.

Bureaucracies specialize in carrying out the mundane details of the state. Formal goals are translated into action, coming into conflict with real goals. Specialization creates a hierarchy of knowledge. The upper echelons of the hierarchy are in charge. The lower levels carry out the mundane details. The bureaucracy operates outside of government and is a real part of the state. In carrying out the law, the law is changed. This is a daily process, continually causing the constitution to become obsolete; therefore, it must be updated when the discrepancy becomes too great.

The law exists only in people's imagination. The law becomes real because people, including people who enforce the law, believe it to be real and behave accordingly. Laws must first be interpreted, and the interpretation is constantly subject to change. When people in power replace old laws with new ones, change is amenable. Individuals must inevitably give up their interpretations and accept the official one.

The private realm in a republic is established through economic inequality. In public, the political lives of the citizens appear to be equal. Inequality requires the illusion of equality to make it seem acceptable. Freedom is established through a lack of freedom. This means that persons are free to work for anyone who will hire them. If they do not work for someone and accept that individual's authority, they die. The republic has freed them from the feudal lord only to enslave them to the owners of business.

Marx: Jews in a Christian State

In Marx's view, the Christian state oppresses everyone. The issue of emancipation of the Jew requires the emancipation of the Christian at the same time. The Jew is a Jew because he says no to Christ. The Christian cannot free the Jew and still be a Christian. The Christian state, because it represents Christianity on some level, must exclude Jews from being treated as fully equal. Religious constraints undermine political emancipation. The official recognition of one established faith as being more important than others oppresses everyone. People must insist on the complete separation of church and state. The legal abolition of any established religious privilege is a prerequisite for popular sovereignty or democracy. Religion must remain a private decision. If one chooses to have no religion, that decision must be protected. Not any one religion should be necessary for political power.

Freedom from religion and freedom of religion are two sides of the same struggle. The ultimate religious freedom is when the state recognizes no religion as superseding any other. Only when religion is recognized as a private decision, and only when one is free not to believe in any kind of higher power, is there freedom of religion for all.

The state must become secular. Humanism is a belief in all religion as superstition. Humanists believe than humans can be ethically decent and richly fulfilled without a higher power. Because secular humanists do not believe in a god, their religious freedom is the test case. If they are free to not believe, all others are free to worship in their own way. Religion becomes a private decision and is kept out of the public discourse over policy. In a secular state, people become the universal abstraction, replacing God as the political explanation of the state. The secular state then unites the believer and nonbeliever. The public realm protects the private realm, allowing for a great deal of diversity in society.

There cannot be much freedom of diversity in a Christian state. Religion limits choices. The state remains incomplete, because it continues to exist only by being attached to religion. Faith supplements coercion. In a democracy, the paramount hypothetical excuse for the state is "the people" and not "God." It is necessary for a democratic state to stay away from any religious commitment to God, or the philosophy of democracy is compromised. Religious accountability must remain independent of the commonly shared political culture of a nation. The foundation of democracy is the secular state. A Christian state, an Islamic state, or a Jewish state cannot be democratic.

Human rights struggles are historically a contest against tradition. Traditional religions are the heritage of the chosen. Even if a Christian state guarantees religious freedom, it still favors Christians over Jews. The confinement of privilege divides. Equal rights to diverse opinions in a matter of faith can exist only in a secular community. The state protects the religious rights of all by restraining the religious power of the favored group.

Liberal democracy requires egoism, individualism, private property, and freedom of expression in matters of faith. The liberal will claim that the rights of one individual are limited only when they threaten to injure the rights of someone else. This assumes equality, yet because of private property the society is founded upon enormous inequalities. Freedom of egoistic individualism was the result of political revolution. The civil society of religion was replaced by a secular egoistic civil society.

When the individual Christian is no longer Christian, individualism replaces the Christian community. The commitment to "other" as the basis of the Christian community is replaced by the selfish crusade of greed. The new state protects the individual citizen who is atomized in his greedy quest for power and material things.

Beyond Capitalism

According to Marx, people create their religious beliefs from their own imaginations. Religious beliefs reflect the real world and the lives of real people. Faith is the hope of the powerless. The only real power that can overturn the attraction of faith is the power of people who have real democratic control over their lives. The lack of collective control over the political power and the economy of a society make religion a necessity to help people get through each day. Happiness in this life requires people to be the authors of their lives and not victims. Political struggles need to deal with social and economic conditions of life, not merely to provide philosophical debates over religious issues.

Political action and philosophy cannot be disconnected without making both negligible in changing the lives of the poor. People cannot have genuine political power without first having collective control of their actual lives. This means they must have cooperative control over the economy. This can happen through joint action of a social movement. The capitalist came to power by way of a liberal political revolution. Liberal philosophy and capitalism are tied together and cannot be rent asunder. Private property and individualism are represented in each person's self-interest. Only when it is questioned whether some groups benefit more than other groups does liberal philosophy begin to unravel. The capitalist now replaces the feudal aristocrat as the major oppressor of the direct producers, the poor.

The liberator soon becomes the new oppressor. The capitalist class fights for liberty, human rights, and private property against the ancient feudal order. When capitalists gain power, human rights cannot threaten their private property. The working class must be kept in tow. The poverty of the worker becomes a necessary condition for the wealth of the capitalist. Workers need their own revolution to go beyond the liberal society of capitalism.

Alienation

Workers, wrote Marx, create wealth; the wealth belongs to the capitalist. The capitalist becomes rich and powerful because of the wealth created by the workers. The workers become weak and poor as a result of their labor. This is because the labor of a worker is sold to the capitalist like any other commodity, and the capitalist will try to buy it as cheaply as possible. By selling the products of labor, the capitalist gains his wealth. This wealth is the source of the capitalist's power over the worker. Workers sell the source of their own slavery. The products made by workers become their chains of bondage.

Nature, which is necessary for life, must first be changed through labor into the means by which we are able to live. Humans, being a part of nature, are free only as a part of nature. Because the resources of production belong to the capitalist, nature becomes an unavoidable condition for the enslavement of the worker. They can live only if they get jobs. Their physical survival is possible only if they can find work.

The true nature of work is art. Work is the creative relationship between the worker and the rest of nature. Only through labor can we develop our full creative potential as humans. Yet the planning and design of labor is taken away from the worker. For the capitalist who owns the resource, the final product, the labor power, and the labor process, work becomes a source that cripples the worker. This turns workers into an adjunct to a machine. They can live only at the pleasure of this stranger who has plundered their humanity. Workers, once a vital part of nature, are now foreigners. Nature, their human essence and their birth, is now an unfriendly centaur prepared to devour their lives. The artistic celebration of life through labor is forever shattered. Our kinship with nature is eternally vanquished.

Workers stand in open competition with their coworkers. Their community has been plundered from them. Private property separates workers not only from nature but also from their own community. Greed and envy, as well as lewdness and ill will, become the glue that holds together a society founded upon accumulated wealth, individualism, and private property. The wealthy are always in awe of the wealthier but are also spiteful and afraid of the very rich. Wealth requires the cunning to live off the income looted from the workers. Until everyone becomes a worker and all wealth is held in common, the rich can only survive by stealing wealth from the poor.

The abandonment of private property is only the first step in returning the wealth to the poor who originally created it. We can democratically control our own society only after everyone becomes a public employee. Democracy grows only by empowering everyone through democratic control over the process of production. This process reintroduces the aesthetic and harmonious connection between the workers and nature. The alienation of all workers from nature, from the products they make, and from the community in which they live amidst the very process of creation will come to an end. Only then will the estrangement of one's work that has been plundered be returned. Democracy, socialism, and communism are our rediscovery of nature. Humans are not only a part of nature; they are human only in a natural and social setting.

It is through labor that this unity between the individual, the community, and nature becomes real. Humans are as much a product of social labor as they are a part of nature. We not only produce, we create ourselves. We write our own history through our social interactions in a natural and social setting.

Logic and philosophy become separated from the practical. Intellectual work becomes separated from physical work. This is a counterfeit way to live. Nature becomes alienated from nature, and our lives from reality. Living nature becomes a lifeless fact. Workers can regain their souls only if they are able to bring together abstract thought with the natural setting through their joint activities with other workers.

Equality is achieved through the celebration of nature and our common humanity. This is communism. Communism occurs where nature and humanity meet through democracy. Socialism is the path to communism. The mind and the body are reunited. Political democracy is transcended by economic democracy. Alienation is replaced by a communal relationship with nature. Thought, action, and creation are brought together as people are reintroduced to nature. We, as humans, live life as a ceremony to be fully indulged and as a burden to be endured. Work becomes entertainment and not drudgery.

Labor can become fulfilling only when private property has been eliminated. When owners possess nature, those who do not own anything become objects for sale. The life of workers becomes sold to the highest bidder; where slaves are abundant, their price is low. Capitalism cannot be reformed, and it can never be democratic. Workers are not human but objects of trade. Their lives are those of slavery and alienation. The ethics of communism require that all people should be the composers of their destinies and not their blood offering. People must be reunited with themselves.

Marx's Method

The real study of history, in Marx's view, begins with the material formulation of real people living their everyday lives, with people's relationship to nature. Through these relationships, humans produce their own means of subsistence. Each generation inherits and reproduces this means of subsistence and then changes it to fit their changing needs. This happens in the context of a historically and culturally specific setting and shapes individual human nature. Production determines how people are organized and interact.

Production molds all other social relations. This includes the relations of one nation to another as well as the internal social structure of a single nation. With every new change in the forces of production, there exists a corresponding change in the relations of production. These changes lead to changes in the division of labor. With changes in the division of labor, there are changes in the property relations of the nation. Ultimately, this means ideology changes as well.

The earliest division of labor is between the town and country. Industrial and commercial interests are separated from agriculture. With these changes in the division of labor, there are changes in property relations. When private property restricts access, the resources of subsistence become constrained. Each type of stratified society is founded upon this unequal access to needed resources. Each society has its own type of ownership and its own type of property relations. Historically, specific relations then develop between groups of people.

The first type of property is tribal or communal. This undeveloped stage of production has simple technology. The social structure is based upon the family and the extension of family called kinship. This evolves into ancient communal or state ownership. Private property develops but remains subordinate to the communal property of the state. With the development of an economic surplus, the town or administrative center stands opposed to the countryside that supports its life.

Feudal ownership begins with estate ownership. Peasant serfs are the economic foundation. Property is organized through hierarchical land ownership. Nobles are an armed body of retainers. In the city, the guilds of master, journeyman, and apprentice copy the feudal relations of the country. Property ownership changes to meet the changes in production relations; this causes changes of the status of the serfs and in relations between the town and the rural aristocracy. This occurs because social relations continuously change. The ideas of the age are the direct result of the real material life of the people. People produce ideas through their productive lives.

The first historical act is production to satisfy material life. Following the first historical act is the production of new needs that are the practical result of satisfying the needs of material life. People reproduce themselves, their families, and their culture daily. These acts of production and reproduction are exhibited by the historical past of a people; but this very activity also changes both the people and their culture. Old needs are changed and new needs are created. With expanding needs, production of life is both social and natural. Humans are both the animal creations of nature and the social creations of society. Each society creates its own social organization based upon its own historical mode of production. The nature of society is based upon the mode of production and consciousness. People's relation to nature molds their relation to each other. People's relation to one another affects their relation to nature. Production, human needs, population pressure, and change will follow.

The division of labor begins within the family. After that, within the rest of society, the division of labor continues to evolve. It subdivides between mental and physical labor. With this division of labor, an unequal distribution of property (both quantitative and qualitative) and its resources occurs. This leads to the development of private property. Private property results from the activity of the property-less and grows as a result of that activity. Because of the development of the division of labor, there is a concurrent development of the contradiction between the individual and the community.

With these divisions between ownership and work, mental and physical labor, and the community interests and particular deeds of labor, property becomes an alien force. The alienation of the worker occurs within society. Tools, resources, and human activities appear to control people rather than being controlled by the producing people. Through increasing specialization, labor is imposed upon the individual as a source of exploitation. The job also appears to own the individual. What we produce becomes an objective power over us. These illusions take on a reality that frustrates our best-laid plans.

During the evolution and development of alienation, the state develops as a community divorced from the realities of the individual. The state becomes a community unto itself. It is important to remember that the struggles within the state are class struggles. These struggles are class wars for mastery of the political powers of the state, whether peaceful or violent. Each class tries to conquer power in order to best represent the interests of that class. Any cooperation that exists is determined by the division of labor of that particular mode of production and by the class that controls the state. This cooperation is not for the benefit of all. The goal of cooperation is to benefit property owners who control the power of the state. Property relations, cooperation, and the state all change as a result of these class struggles. Society changes and the culture itself changes because of events brought about by this class struggle. Any kind of property relation that restricts access to resources causes resistance among the people who have limited or no control over the property that they work with to produce a surplus, which the nonproducers accumulate. Any indigenous class struggle is always an international class struggle. The world market economy exacerbates this struggle, and international struggles are then expressed locally.

Because property ownership restricts people's access to needed resources, direct producers become estranged from themselves. Material and intellectual production, as well as the producers themselves, do not belong to the producers but to the nonproducing minority. Until people are reunited with their creativity, work becomes a painful experience. When people become united with their own creative activity, they then achieve the capability to experience a joy that life holds dear. Cooperation must be transformed from cooperation for the benefit of the few into cooperation for the benefit of all, so that work and joy may be reunited. With the universal development of the productive forces of a market economy, a contradiction between the worldwide interdependent social economy and the private control of that economy for the benefit of the few is established. Only a world revolution can resolve that contradiction.

The universal development of production is a precursor to most people becoming property-less on a global scale. At the same time, world history replaces local history. Civil society is the result of the historical development of a new global system of production. Civil society is then seen as the material relation between people, people and nature, and the forces of production. This civil society exists only because of the rise of the bourgeoisie along with the evolution of the modern state, industrial production, world commerce, and professional bureaucracy.

History can be defined as a succession of economic systems along with changing ideological traditions. History modifies old circumstances by changing activities. The products of consciousness are the products of social life. Ideas reflect material production and its social relations that are historically inherited. Circumstances create people the same way that people make circumstances.

Humans need each other for survival. People cannot be free if they are hungry. Freedom is a historical action and not a state of mind. Freedom, if it is to exist, must have historical and technological foundations. Because the world is altered by the changes in industrial production, it can either increase alienation and exploitation of the direct producers, or it can increase freedom, depending on who controls the means of production. In the end, society changes according to the changing needs of social production.

Human unity with nature exists through industry. Social science must reflect this if it is to understand the deeper underlying connections between specific social actions and global trends. Industry, commerce, production, and exchange establish distribution, which in turn gives birth to ideological possibilities. Along theses lines, socioeconomic classes are determined by the mode of production. Every class society creates its own ideological support. Bourgeois society develops science to meet the needs of its mode of production. This is possible because the ruling ideas of any class society are those of the ruling class. Those who control the material forces of society rule the ideas of that society. Workers are subject to those ideas. The dominant ideologies reflect the dominant material relations.

Division of labor begins with the separation of physical and mental labor. Class antagonism soon develops. The exploited classes become the revolutionary classes. Each new ruling class presents its particular interests as the interests of society as a whole. This means the class making the revolution speaks as the new leader for the entire society. In the beginning, the revolutionary class leads the opposition against the old ruling class. The revolutionary class at this time is connected with the oppression of other exploited classes. Once the new class gains control of the state and the new means of production, opposition to the new class fully develops from yet other exploited classes. The old ruling ideas die with the new ruling class, and their new ideas become the dominant ideology. New opposition develops a new alternative ideology for a new struggle against the current ruling class.

Nature is constantly altered through human labor. This causes nature to become a product of human labor. The separation between town and country develops with the separation of mental and physical labor, and this leads to the development of state society. The class of nonproducers controls the coercive powers of the state and the means of production. When this happens, private property develops out of the surplus created by the producers who now have no property.

In the Middle Ages, the urban rabble controlled no resources; thus they were the most oppressed. The journeymen and apprentices were organized to meet the interests of the guild masters. Peasants remained isolated and weak and were controlled by the lords. Fear of the rabble united the nobles, the masters, the journeymen, and the peasants against this element in the towns.

Separation of production from commerce arrived with trade. Merchants became the new class. Manufacturing grew out of this marriage of merchants and guilds. Merchant capital became movable capital; the guilds became increasingly independent from the merchants. The merchant could then hire workers outside the guilds for manufacturing. With new types of manufacturing, unemployment became common.

With the rise of manufacturing, nation-states increasingly competed with each other. Trade wars became common. Within the nation, the capitalist and the worker related and competed with each other. The big bourgeoisie came to dominate the means of production but not the state. Commerce and navigation expanded rapidly, making the national bourgeoisie international in scope. Navigation and colonial monopolies went together. Protective laws sheltered the older bourgeoisie, making them dependent upon the state. The colonial monopolies controlled the market, and at home the market was administered and protected. Free trade was banned.

Competition came with big manufacturing. Movable property evolved into real private property. Competition separated the bourgeoisie and the workers from their own classes. Through private property, the state became independent of other forces in society. This was done even though the state organized society for the general interests of the bourgeoisie. Through the state, individuals of the ruling class asserted their common interests in spite of internal conflicts among the capitalist class. This was done because the state mediated the larger common interests of the capitalist class. There was a disintegration of natural communities with the evolution of private property, and civil law grew to define private property and natural interests.

Civil law defines property as if it were the general world of the people, not the property owners. The bourgeoisie, as a class, slowly absorbs the other propertied ruling classes. Its mode of production becomes dominant. The proletariat without property develops at the same time as this capitalist class. Industrial, financial, and commercial property becomes the dominant theme that relates to all forms of property. One class has conflicting antagonisms with another class. Class position limits life choices and defines the limitations and potential of every individual. This division of labor creates a reality independent of the will of the parties involved. Freedom can only be established on material grounds in a community in which the division of labor has been outgrown. In the past, economic reality acted independently of the will of the individuals of that society. Class is defined as a community that shares a common interest. Class is a condition of life and lifestyle.

Freedom is possible in resistance to oppression. Communism overturns all earlier forms of relations of production. Control of necessary resources returns to a community of individuals. This struggle is shaped by the material life and the history of a people. The conditions of real activity, which are the preconditions for the movements of a society, become a fetter to further movements of a people at a certain point. The resulting effect is that one type of material activity replaces another.

Historical conflicts grow out of contradictions between coexisting productive forces and between those forces and the rest of a society. The industrial capital of an advanced nation exports those conditions all over the world. Big industry equals social production while it is privately owned. This type of private property is the result of the accumulated labor of others. The division between ownership and labor becomes complete under capitalism. Forces of production do not belong to those who work with the tools of production but rather to the nonproducers. In modern industry, the workers are separated from the tools, their work, the products they make, themselves, and their coworkers. In addition, the state looms over them like an alien power opposed to the workers' class. The ruling class sets forms of distribution in motion that reproduce this inequality. In Marx's view, revolution becomes the only hope of the oppressed and exploited.

Michael Joseph Francisconi

See also Christianity; Dialectics; Economics; Engels, Friedrich; Evolution, Cultural; Evolution, Social; Feuerbach, Ludwig; Hegel, Georg Wilhelm Friedrich; Humanism; Judaism; Lenin, Vladimir Ilich; Materialism; Religions and Time;

Further Readings

Althusser, L. (1969). *For Marx*. New York: Vintage Books.

Berlin, I. (1996). *Karl Marx*. Oxford, UK: Oxford University Press

Marx, K. (1964). *The economic and philosophical manuscripts of 1844*. New York: International. (Original work published 1932)

Marx, K., & Engels, F. (1970). *The German ideology*. New York: International. (Original work published 1932)

Novack, G. (1971). *An introduction to the logic of Marxism*. New York: Pathfinder Press.

O'Malley, J. (Ed.). (1994). *Marx: Early political writings*. Cambridge, UK: Cambridge University Press.

Materialism

Philosophical materialism maintains that all things can be understood in terms of matter in motion. The only things that exist are matter and energy. Because of this, there is an association between different varieties of materialism and the scientific method. Many scholars credit Greek philosophers such as Democritus and Epicurus as the intellectual predecessors to philosophical materialism.

During the 17th and 18th centuries, materialism emerged as a philosophical tradition. Pierre Gassendi (1592–1655) raised the question of consciousness as integrated into the physical world and known through the senses. Julien Offray de La Mettrie (1709–1751) and Baron Paul Heinrich Dietrich von Holbach (1723–1789) taught that consciousness is simply the consequence of the biological structure and activity of the brain. Dialectical materialism and physicalism have existed since the 19th century as the modern expression of philosophical materialism. Physicalism is the point of view that any observed study can be articulated as a record of visible physical objects and events.

The main principle of dialectical materialism is that everything consists of matter briskly in motion, and everything is constantly changing, breaking down, and dying, while constantly being renewed and reborn. This is "the struggle of opposites."

Physicalism, or logical positivism, states that most things can be understood through science and mathematics. The pronouncements made by metaphysics, ethics, and religion are pointless, because their proposals cannot be verified by observation and experimentation or by logical deduction.

Three themes relate historical materialism to social action. They are materialism, action, and freedom. Action within nature is central to movement. Freedom through action is central to liberation and sovereignty. By way of action, we continuously alter the orchestration we have with nature. Given this, preexisting but changing boundaries limit freedom. Frontiers we cannot transgress include the physical universe, biology, ecology, social arrangements, technology, populations, organization, social design, and the mode of production. Theory leads to action; from action comes theory, freedom, determinism, and moral choice. This interaction cannot be separated. Natural history, which consists of geology and biology, is in inseparable unity with human history, which includes history, sociology, anthropology, and psychology.

Methodological Materialism

Karl Marx

The German economist Karl Marx (1818–1883) subscribed to the concept that there are real regularities in nature and society that are independent of our consciousness. This reality is in motion, and this motion itself has patterned consistencies that can be observed and understood within our consciousness. This material uniformity changes over time. For Marx, tensions within the very structure of this reality form the basis of this change; this is called dialectics. These changes accumulate until the structure itself is something other than the original organization. Finally, a new entity is formed with its own tensions or contradictions.

Human interaction in a natural setting is a given, because people are, at their core, a part of nature. It is because of this interaction that people are able to live. Through cooperation and labor, people produce what they need to survive. People live both in a community and in a natural environment. Any study of history cannot separate people from either the social or the natural environment.

According to Marx, the interaction between a social organization, called *relations of production,* and the use of technology within an environment, called *forces of production,* can be used to understand many particulars about the total culture. The evolution from band-level society to tribal-level society, tribal to chiefdom, and chiefdom to state-level society, has to take into consideration changes in the organization of labor, including the growing division of labor and ultimately changes in the technology people use.

With changes in the organization of labor, there are corresponding changes in the relationship to property. With increasing complexity of technology and social organization, societies move through these diverse variations to a more restrictive control over property; eventually, in a state society, restrictions develop around access to property based upon membership in economic classes.

A social system is a dynamic interaction among people, as well as a dynamic interaction between people and nature. The production required for human subsistence is the foundation upon which society ultimately stands. From the production of the modes of production, people produce their corresponding sets of ideas. People are the creators of their ideology, as people are continually changed by the evolution of their productive forces and of the relationships associated with these productive forces. People continually change nature and thus continually change themselves in the process.

Julian Steward

Julian Steward (1902–1972) is credited with the twin concepts of *multilinear evolution* and *cultural ecology.* Multilinear evolution is the exploration of recurring themes in cultural change. Cultural laws are then described in ways that make these changes clear. What become apparent are patterns of historical change that explain arrangements of the interaction between parts of a society and the larger environment. Cultural traditions are made up of basic characteristics that can be studied in context. Similarities and differences between distinct cultures can be studied in a meaningful way, and cultural change becomes more understandable. The evolution of recurrent forms, processes, and functions in different societies has similar explanations. However, each society has its own specific historical and evolutionary movement.

Cultural ecology is the adaptation of a unique culture, modified historically in a distinctive environment. This provides for observation of recurrent themes that are understandable by limited circumstances and distinct situations. The importance here is to discover specific means of identifying and classifying cultural types. "Cultural type" serves as a guide in the study of cross-cultural parallels and regularities. This allows investigation into the reasons for similarities between cultures with vastly different histories. This, of course, depends upon the research problem. But for problems related to historical change, economic patterns are important, because they are more directly related to other social, cultural, and political arrangements. This is the "cultural core." Cultural features are investigated in relation to environmental conditions. Unique behavioral patterns that are related to cultural adjustments to distinctive environmental concerns become more understandable. The cultural core is grouped around subsistence activities as demonstrated by economic relationships. Secondary features are related to historical possibilities and are less directly related to historical change. Changes are, in part, evidenced by modification in technology and productive arrangements as a result of the changing environment. Culture is a means of adaptation to changing environmental needs. Before specific resources can be used, the necessary technology is required. Social relations reflect these specific technological adaptations to the changing environment. These social relations organize specific patterns of behavior and its supportive values. A holistic approach to cultural studies is required to see the interrelationship of the parts.

Leslie A. White

Leslie A. White (1900–1975) looked at culture as a superorganic unit that was understandable only in cultural terminology. The three parts of a culture were the technological, the social, and the ideological. All three parts interact, but the technological was the more powerful factor in determining the formation of the other two. Thus, cultural evolution has all three parts playing important roles, with the technological influencing the sociological to the greater degree, and the sociological ultimately determining the ideological. Culture becomes the sum total of all human activity and learned behavior. It is what defines history. Through technology, humans try to solve the problem of survival.

To this end, the problem arises of how to capture energy from the environment and use this energy to meet human needs. Those societies that capture more of this energy and use it most efficiently are in a more advantaged position relative to other societies. This is the direction of cultural evolution. What decides a culture's progress is its capability of "harnessing and controlling energy." White's law of evolution, simply stated, says that a society becomes more advanced as the amount of energy harnessed per capita per year is increased, or as the efficiency of the activity of putting the energy to work is increased. This is cultural evolution.

Marvin Harris

Cultural materialism is based on the concept that human social existence is a pragmatic response to the realistic problems that are the consequence of pressures of the interaction between populations, type of technology, and the environment; with the economy as ever-important. Marvin Harris is the major spokesperson for this model, in which the social scientist investigates the basic relationship between particular social activity and overall tendencies.

Human communities are connected with nature through work, and work is structured through social organization. This is the foundation of the production of all societies. The way people come together to provide for their necessities, how these goods are distributed within the population, and networks of trade and exchange establish what is possible for the social organization. This relationship between environment, technology, population pressure, and social organization sets up the potential alternative ideologies within any culture.

How the basic needs are met within a society affects all members of that society, though often not equally. Ideology reflects not only the interaction between culture and nature but the understanding of this relationship. The model used is one that begins with the infrastructure, which includes environment, technology, and population pressure, Infrastructure is roughly similar to the Marxist concept of forces of production.

The structure or social organization is similar to the structure in the Marxist theory of relations of production or social organization. Structure is one step removed from the human interface with nature, and therefore the infrastructure has more influence on the structure than vice versa. The superstructure is what would be called ideology, or the symbolic and the ideational by other theories. The superstructure is twice removed from the human interface with nature and thus influenced more by both the infrastructure and the structure. The economy is the interaction between the infrastructure and the structure. This would be the mode of production of Marxism.

Unlike Marxism, cultural materialism emphasizes the primacy of the infrastructure over the structure in the formative relationship between the various parts of society. Changes in technology that are adaptive, given the environment and population pressure, are likely to be selected for and kept. This, in turn, will create long-range changes in both the structure and superstructure. Marxism, because it is dialectical, explains the relationship between forces of production and relations of production and is more reciprocal than cultural materialism. In Marxism, the forces and relations of production together make up the mode of production or, roughly, the economy. Again, cultural materialism would show, more than Marxism would, that the economy or infrastructure and structure more closely influence the substance of the superstructure. Only in cultural materialism do the forces of production determine the relations of production, and only ultimately does the mode of production control the superstructure using a Marxian model. The materialism of the Marxist is founded upon Hegelian dialectics; the philosophical foundation of cultural materialism is logical positivism.

Marxism, cultural ecology, and cultural materialism all begin with the first premise that the study of any social system is the dynamic interaction between people, as well as the dynamic interaction between people and nature. Because people come together in groups for human subsistence, they are social animals. This is the foundation upon which society ultimately stands. In producing what people need to live, people also produce their corresponding sets of ideas. In this way, it can be said that people are the creators of their history and ideology, though usually not in ways they are aware of. The process is historical, because people are continually changed by the evolution of their productive forces, and they are always changing their relationships associated with these productive forces.

Cultural core is the central idea of cultural ecology. This core is made up of economic patterns, because they are more directly related to other social, cultural, and political arrangements than are interactions between populations, types of technology, or the environment. The cultural core sets the limit of what is possible rather than directly determining what other theorists would call superstructure. Current scholars in the field add the use of symbolic and ceremonial behavior to economic subsistence as an active part of the cultural core. The result of cultural beliefs and practices continuing sustainability of natural resources become more likely. Symbolic ideology is as important as economics in defining the cultural core. Through cultural decisions, people continually become accustomed to a changing environment. Cultural ecology is closer to Marxism than it is to cultural materialism.

Finally, in the debate between Hegelian dialectics and logical positivism as the philosophical foundation for methodological materialism, the radical behaviorism of B. F. Skinner stands closer to the cultural materialism of Marvin Harris.

B. F. Skinner

The radical behaviorism of B. F. Skinner (1904–1990) begins with the idea that psychology is the science of behavior and not the science of the mind. The ultimate source of behavior is the external environment, not the world of ideas. Skinner maintained behavioral explanations of psychological observable facts as physiological influences. Behavior includes everything that an organism does. Thinking and feeling are other examples of behavior. All behavior is what psychologists try to explain. Skinner promoted the explanation that environmental characteristics are the correct causes of behavior. Environmental factors are external and separate from the behavior being studied, and one can influence behavior by manipulating the environment. Conditioning is caused by the influence of the total environment, including physiology. Conditioning is also influenced by culture and the ability of the organism to learn its own history. Each individual observes private events, like thinking, which is also a behavior. Introspection is also a behavior that is affected by the environment.

Radical behaviorism claims that behavior can be studied in the same manner as other natural sciences. Animal behavior is similar enough to human behavior that comparisons can be made. Ultimately, for all animals including humans, the environment is eventually the cause of the behavior that is studied; and an inclination for operant conditioning, or the modification of behavior. The occurrence or nonappearance of rewards or punishment is conditional upon what the animal does. This is achieved through reinforcement of already existing behavior, either by introducing a stimulus to an organism's environment following a response, or by removing a stimulus from an organism's environment following a response. Reinforcement will cause a behavior to occur with a greater rate of recurrence. Punishment or removal of the stimulus, also called negative reinforcement, will lead to a decrease in frequency, leading to extinction of such behavior. When an aversive stimulus is inflicted, a subject learns to avoid the stimulus. The avoidance learning may still be in place for a time.

Consistent with the theory of operant conditioning, any behavior that is repetitively rewarded, without error, will be more rapidly changed than when behavior is reinforced sporadically. This will lead to a more constant occurrence of a particular behavior and is comparatively more resistant to extinction.

Michael Joseph Francisconi

See also Darwin, Charles; Dialectics; Engels, Friedrich; Farber, Marvin; Feuerbach, Ludwig; Harris, Marvin; Lenin, Vladimir Ilich; Marx, Karl; Presocratic Age; White, Leslie A.

Further Readings

Afanaslev, A. G. (1987). *Dialectical materialism.* New York: International.

Afanaslev, A. G. (1987). *Historical materialism.* New York: International.

Bakunin, M. (1970). *God and the state.* New York: Dover.

Cameron, K. N. (1995). *Dialectical materialism and modern science.* New York: International.

Engels, F. (1975). *The origin of the family, private property and the state.* New York: International. (Original work published 1884)

Engels, F. (1977). *The dialectics of nature.* New York: International. (Original work published 1883)

Engels, F. (1978). *Anti-Dühring: Herr Eugen Dühring's revolution in science.* New York: International. (Original work published 1878)

Foster, J. B. (2000). *Marx's ecology: Materialism and nature.* New York: Monthly Review.

Harris, M. (1980). *Cultural materialism: The struggle for a science of culture.* New York: Vintage Books.

Harris, M. (1998). *Theories of culture in postmodern times.* Walnut Creek, CA: Rowman & Littlefield.

Marx, K., & Engels, F. (1970). *The German ideology.* New York: International. (Original work published 1845)

Materialism. In *Columbia electronic encyclopedia* [Electronic edition]. Retrieved February 27, 2007, from http://www.reference.com/browse/columbia/materialsm

Skinner, B. F. (1971). *Beyond freedom and dignity.* New York: Vintage Books.

Skinner, B. F. (1974). *About behaviorism.* New York: Vintage Books.

Steward, J. H. (1955). *Theory of culture change: The methodology of multilinear evolution.* Urbana: University of Illinois Press.

Vitzthum, R. C. (1995). *Materialism: An affirmative history and definition.* Amherst, NY: Promethus Books.

White, L. A. (1949). *The science of culture: A study of man and civilization.* New York: Noonday Press.

Maturation

Maturation, the growth and transformation of a single-celled zygote to a multicellular organism, has fascinated humans for centuries. In only a matter of months, a single cell can develop and mature to a complex organism. Although the maturation period for each species is different, the result is the same: a complex living organism.

No matter the species, the early stages of maturation are common to almost all animals. The first step is fertilization, in which the male and female sex cells or gametes fuse, creating the single-celled zygote. In species living in an aquatic environment, external fertilization is the usual method, in which the female deposits eggs into the environment to be immediately fertilized by the male. This method of fertilization usually requires courtship and environmental cues to be sure a male is present for fertilization, as well as to prevent the destruction and drying out of the eggs. In dry environments, the only way for sperm to reach the egg is by internal fertilization. By this method, sperm are deposited in or around the reproductive tract of the female. After fertilization, the newly formed zygote creates a fertilization envelope to prevent polyspermy, or union with more than one sperm cell.

Two distinct development modes begin after fertilization, protostome development and deuterostome development. Examples of common organisms that feature protostome development are molluscs and arthropods, while chordates and echinoderms are common examples of organisms that feature deuterostome development, among many others. From this point, maturation begins with the first cell divisions, known as cleavage. Unlike normal cell division, cleavage divisions are rapid, with no time for cell growth between each division. This process virtually partitions off the single-celled zygote into smaller cells called blastomeres, each complete with its own nucleus. In deuterostome cleavage, the cells divide in a radial pattern, in which the planes are parallel or perpendicular to the vertical axis of the embryo. Cleavage in deuterostomes is also indeterminate, meaning these new cells are not yet fated and can form an entire organism if isolated. In protostome development, the cleavage pattern is spiral, in which the planes of division are diagonal to the vertical axis of the embryo. Cleavage in protostomes is also determinate, in that these new cells are already fated and cannot form a whole organism when isolated.

This cleavage continues, forming a multicellular ball of blastomeres, known as a morula. Eventually, the number of blastomeres grows to form a single-layered ball of cells known as a blastula, featuring a hollow cavity in the center, known as a blastocoel. In humans and mammals specifically, this stage forms a blastocyst, with the key difference being the presence of an inner-cell mass within the blastocoel, as well as an outer epithelial lining to the blastocyst, known as the trophoblast. Also, in many other species, different concentrations of yolk, stored nutrients for maturation, tend to offset cleavage patterns. This is due to high concentrations of yolk found at the vegetal pole of the blastula and low concentrations of yolk at the animal pole. Thus the blastomeres at the animal pole tend to be smaller then the blastomeres at the vegetal pole. Yolk concentration can be so high that cleavage is hindered and even incomplete, a phenomenon known as meroblastic cleavage. Alternately, cleavage that is unimpeded by yolk and continues to completion is known as holoblastic cleavage. This uneven distribution of yolk is very distinct in different species and characterizes how they develop.

Although at these stages of maturation we start to see characteristic differences in each species, gastrulation generally follows cleavage blastulation. Gastrulation is the rearrangement of the blastula to form a gastrula consisting of two or three germ layers: the ectoderm and endoderm, with the mesoderm as the third and middle layer. Gastrulation also forms a primitive gut, known as the archenteron. This rearrangement allows the cells to interact in new ways and causes changes in cell shape, motility, and adhesion. One process of rearrangement is invagination, in which the single-celled blastula buckles into the blastocoel to form a second layer. This invagination causes the direct formation of the archenteron as well as the blastopore. This blastopore becomes the primitive mouth in protostomes and the primitive anus in deuterostomes. A second mechanism is involution, in which cells "roll" over the lip of the blastopore into the interior of the embryo. The combination of these two processes forms the gastrula. The archenteron and coelom, the primitive body cavity, differ in deuterostomes and protostomes. In deuterostomes, the body cavity formation is described as enterocoelous, in which the mesoderm forms outpockets from the archenteron and forms the body cavity. In protostomes, the formation of the coelom is described as schizocoelous, in which mesoderm near the blastopore split and outpockets to form the coelom.

Organogenesis is characterized by the development of primitive organs, vessels, and body systems in the embryo. Each of the three germ layers of the gastrula gives rise to the beginnings of very specific organs throughout the body. The ectoderm, the outermost layer of the gastrula, develops into the epidermis (skin) and sense receptors, as well as a majority of the nervous system. The mesoderm, the middle layer of the gastrula, gives rise to the skeletal and muscular system, as well as the reproductive system, circulatory system, and excretory system. The endoderm, the innermost layer of the gastrula, forms the epithelial lining of the digestive and respiratory tracts and the liver pancreas, as well as several glandular organs. One of the first organs to develop is the neural tube. The ectoderm thickens and pinches inward, forming the primitive spinal cord.

In mammals, all of these maturation processes occur during pregnancy, or gestation. The length of the gestational period directly correlates to the size of the growing organism. The typical human gestational period is about 40 weeks. However, the typical gestation period of a rodent may be only 21 days, while the gestation period of a cow averages about 270 days. Gestation in elephants can last as long as 600 days. In humans, pregnancies are usually split into three trimesters of about 3 months each. Organogenesis is usually completed by the end of the first trimester. At this point, the embryo is no longer considered a gastrula, but a fetus; fetuses average only 5 cm in length. In the second trimester, the fetus becomes more active within the womb and grows to approximately 30 cm. The final trimester results in birth of the child, or parturition. It is believed that hormone levels within the blood control labor, the process of birth. However, the mechanism behind this is not yet fully understood. Labor consists of three phases: the thinning and dilation of the cervix, the delivery of the baby, and the expulsion of the placenta.

Modern science has provided this insight into these complex processes, but this has not always been the understanding of maturation. As far back as 2,000 years ago, Aristotle proposed the idea of epigenesis, in which the animal develops from a relatively formless zygote. This theory, which was more accurate than most then believed, contrasted with the theory that prevailed to the 18th century, that of preformation. In preformation, it was believed that within the egg or sperm was a preformed miniature infant or homunculus and that this homunculus simply grew and matured within the womb until it was born. It wasn't until the 19th century, with the invention of light microscopy, that scientists were able to get a more accurate understanding of the complex process of maturation.

Christopher D. Czaplicki

See also DNA; Fertility Cycle; Gestation Period; Life Cycle; Metamorphosis, Insect

Further Readings

Campbell, N. A., & Reece, J. B. (2005). *Biology* (7th ed.). San Francisco: Pearson Education.

Ulijaszek, S. J., Johnston, F. E., & Preece, M. A. (1998). *Human growth and development.* Cambridge, UK: Cambridge University Press.

Maximus the Confessor, Saint (c. 580–662)

Born in Constantinople (present-day Istanbul, Turkey), Saint Maximus (Maximos) the Confessor influenced Eastern Christianity through his writings, debates, and personal witness as a Byzantine monk, spiritual writer, and opponent of monothelitism. Maximus's primary writings consist of Biblical commentary (*Quaestiones et Dubia, Quaestiones ad Theopemptum Scholasticum, Quaestiones ad Thalassium),* Christological debates (*Opuscula Theological et Polemica*), explanations of the liturgy (*Mystagogia*), and ascetic practice (*Liber Asceticus*). From his writings, it is evident that Maximus showed a great interest in the concept of timelessness and its relationship to the temporal world.

Maximus came from a wealthy household in Constantinople and received a good education. From 610 to 613, he worked as a secretary for Emperor Heraclius I, but he retired to the monastic life. Maximus resided in two monasteries in Turkey: Philipikos in Chrysopolis and Saint George in Cyzcius. Threatened by the Persian invasion of 626, Maximus moved to North Africa, making stops in Crete and Cyprus before reaching Carthage in 628. From North Africa, he defended the Christological teachings of the Cappadocian and Chalcedonian fathers against the Christological heresy of monothelitism, which taught that Jesus Christ had two natures but only one will, in contrast to the orthodox view that Jesus had two natures and two wills, human and divine. Maximus disputed this heresy with expatriarch Pyrrhus I, and later condemned monothelitism at the synod of the Lateran, in Rome, in 649.

Refusing to sign the conciliatory declaration of Emperor Constans II, Maximus was arrested in 653, charged with treason, and exiled to Bizye (Byzia), in Thrace, in 655. Tried and convicted again for treason in 662, Maximus endured torture and amputation of the tongue and right hand. This time the Byzantine monk was exiled to Lazica (on the eastern coast of the Black Sea) where he remained until his death in 662. Following his death, the Eastern Church called Maximus "the Confessor," for his faithfulness under torture in defending the orthodox teaching on the nature of Christ.

Maximus studied the classical Greek philosophies and labored to find their relation to or compatibility with the Christian worldview. Particularly interested in Neoplatonism, Maximus looked at the connection between Plotinus's "one" and the "many" (or creator and created). This examination made Maximus believe in the concept of timelessness, in which the individual achieves a supratemporal state or existence. The Eastern doctrine of deification complemented his view of timelessness, because the individual works to become one with God through prayer, meditation, and other ascetical practices. The "one" (God) became like the "many" through the incarnation (*logos*), and the "many" possess the ability through grace to become divine like the "one" because of the resurrection and ascension.

Although Maximus thought individuals reached a supratemporal state, he also recognized that the individual lives in a temporal world and experiences a beginning and an end, following a sequence of events in history. In his writings, Maximus makes this distinction using the term *aion* in reference to an endless amount of time and the term *chromos* in reference to the daily passage of time and events in history. Maximus, like other Neoplatonist Christians, had to reconcile the Greek understanding of a cyclical calendar with the Judeo-Christian understanding of linear history. For Maximus, the Christian scriptures focus on the history and chronology of past events, as well as point toward a fixed goal in the future (the eschatology). Both views of time share the concept of process and movement. Maximus acknowledges that God created the universe and interacts in history, but time does not restrict God. Therefore, the individual follows the movement of time and events in a linear sense, but through the process of deification, time does not restrict those who achieve union with God.

Because he was recognized as a saint, Maximus's life and works greatly influenced Eastern orthodox theology, and this Byzantine monk worked diligently to defend the nature of Christ. In his writings, Maximus the Confessor played a key role in bringing together Greek philosophy and a Christian worldview and contributed to the discussion or study of timelessness in a temporal world.

Leslie A. Mattingly

See also Christianity; Eternity; God and Time; Mysticism; Plotinus

Further Readings

Maximus the Confessor. (1985). *Maximus Confessor: Selected writings* (G. C. Berthold, Trans.). New York: Paulist Press.

Plass, P. (1980). Transcendent time in Maximus the Confessor. *The Thomist, 44,* 259–277.

Maxwell's Demon

Maxwell's demon is the name of a thought experiment that has been intensely discussed by physicists and philosophers investigating the relation between energy, information, and time. In this experiment, an imaginary but not supranatural being is using his extraordinary sensorial and intellectual powers to violate the second law of thermodynamics and, therefore, to falsify the fundamental principle by which modern physics explains the irreversible direction of time. The demon is named after one of the greatest physicists of all time, James Clerk Maxwell (1831–1879), who developed the theory of the electromagnetic field and conceived, in 1867, the experiment with the fictitious being.

The problem Maxwell wanted to solve by his thought experiment is whether a physical process might be conceived that, though being consistent with all known laws of physics, breaks the second law of thermodynamics. This law states that the entropy of a thermodynamically closed system never decreases so that it is possible to objectively measure the irreversible flow of time by comparing the entropy of different states of such a system. How did Maxwell suppose his demon to perform the feat of violating the second law? The demon, who has superhuman abilities but must act according to the laws of physics, is sitting in a closed container that is filled with gas and divided, by an impermeable partition, into two halves. In the partition there is a door that can be opened and closed at will. The demon observes the gas molecules approaching the door in both halves and sorts them by deciding which molecules are allowed to move through the door so that, for example, the faster ones will be gathered in the left half and the slower ones in the right half. Because the left half gradually becomes warmer and the right one cooler, the resultant temperature difference can be used to do work. Suppose that Maxwell's demon and the door could operate in a reversible manner, giving up some amount of energy when opening the door without friction and taking in the same amount of energy when closing it without friction. Then the container would constitute, for all practical purposes, a *perpetuum mobile* that, thanks to the demon, could completely transform heat flowing from a reservoir at lower temperature to a reservoir at higher temperature into work.

Even a short description of Maxwell's demon shows that information plays a crucial role in reasoning about the thought experiment. The demon must know the positions and the velocities of the molecules that are approaching the door to decide reasonably whether it is to be opened or closed. To bring order into a disordered system (thermodynamically speaking, to lower its entropy), information about the components of the system is needed. Therefore the physical nature of information must be taken into account if we want to find the weak spot of Maxwell's demon and to show that the thought experiment is not a counterargument against the universal validity of the second law of thermodynamics. The history of the discussion about Maxwell's demon mirrors the difficulties encountered in the development of a physics of information. Arguments for the possibility of Maxwell's demon, and against it, revolved around the information-gathering activity of the imaginary being: How does the demon come to know the location and speed of single molecules, and is the thermodynamic cost of gathering this information high enough to rescue the second law of thermodynamics because it produces at least the same amount of entropy that it makes possible to consume?

In 1982, a quantum physicist and computer scientist, Charles H. Bennett, brought forth the conclusive argument against the possible existence of Maxwell's demon. Bennett showed that it was not the gathering, as everyone had thought before, but the erasure of information that is decisive for an adequate understanding of the demon. The reason for this is that the demon needs a memory in which information about the molecules can be stored. Because the demon is, though fictitious, a physical being, this memory is finite. At some time the demon must begin to forget—that is, to erase information about the locations and velocities of molecules he has observed; otherwise, he could not memorize new information about molecules approaching the door. "Erasing information" means here that it is impossible for the demon to gather the deleted information once again. Bennett calls this kind of irreversibility that concerns the inability to infer a former state of a system from information about its given state, *logical irreversibility.*

Because different pieces of information must be represented by different physical states, logical irreversibility is combined with thermodynamic irreversibility. The higher the number of different equiprobable pieces of information a system can have, the higher its entropy is. Erasure of information thus decreases the entropy of the demon's memory: At first, the memory unit containing the information could have been in a number of different equiprobable states ("molecule x is in state y at time t"); then the erasing process resets it to a predefined state ("unknown molecule is in unknown state at unknown time"). Because the erasure of information in the demon's memory shall be logically irreversible, this process must emit an amount of heat into the environment of the demon that increases the environment's entropy to a higher extent than the entropy of the demon's memory is decreased. Bennett shows that this net increase at least counterbalances the decrease in the environment's entropy that happens thanks to the information-gathering activities of Maxwell's demon. Altogether, the entropy of the whole container is at best constant, and the second law of thermodynamics is rescued. By the power of information-theoretical and thermodynamical reasoning, Maxwell's demon thus shows us that the irreversibility of time is the same as the loss of information that we, as finite beings, must inevitably experience.

Stefan Artmann

See also Entropy; Experiments, Thought; Information; Logical Depth; Time, Arrow of

Further Readings

Bennett, C. H. (1973). Logical reversibility of computing. *IBM Journal of Research and Development, 17,* 525–532.

Bennett, C. H. (1987). Demons, engines, and the second law. *Scientific American, 257,* 108–116.

Leff, H. S., & Rex, A. F. (Eds.). (2003). *Maxwell's demon 2: Entropy, classical and quantum information, computing.* Philadelphia, PA: Institute of Physics.

McTaggart, John M. E. (1866–1925)

John M. E. McTaggart, a British Hegelian philosopher and one of the most independent minds of his generation, produced, among other things, a logical and coherent argument for the essential unreality of time. He was the son of Francis and Caroline Ellis; the surname McTaggart was added by his father in order to fulfill a condition for an inheritance. The now prosperous family sent young McTaggart to the prestigious Clifton School and Trinity College, Cambridge. While visiting his widowed mother in New Zealand in 1892, he met Margaret Elizabeth Bird. The two married during his next visit to New Zealand, in 1899. His entire academic career, between 1897 and 1923, was at Cambridge, where he developed his brilliant, though idiosyncratic, blend of quasi-Hegelian idealism and atheism.

A genial man, McTaggart was a longtime friend of G. E. Moore (1873–1958), despite the latter's role as the most influential critic of British Hegelianism. And along with Moore and Bertrand Russell (1872–1970), McTaggart was a member of the irreverent Cambridge club known as the Apostles. But his friendship with Russell came to an end during the First World War, when McTaggart led a campaign to have Russell thrown out of Cambridge University for his vocal opposition to conscription. McTaggart died suddenly and unexpectedly in January 1925.

One of the many paradoxes of McTaggart's life is that he produced no disciples and yet generated some of the most exhaustive commentary of any British philosopher of his generation. His importance among philosophers was given graphic illustration in C. D. Broad's massive three-volume *Examination of McTaggart's Philosophy* (1933, 1938), which remains one of the most comprehensive expositions of a 20th-century philosopher's body of work. Broad succeeded McTaggart at Trinity College. McTaggart's views on time were defended as recently as 1960 by the British antirealist philosopher Michael Dummett. McTaggart was a philosopher's philosopher, and he devoted little time toward engaging the interest of nonspecialists. But among professional philosophers he is best remembered for his work in logic, which remains influential to this day. An important example of McTaggart's logical power is his theory of the unreality of time.

Aspects of McTaggart's Philosophy

McTaggart's earlier career was spent articulating a comprehensive though idiosyncratic interpretation of the philosophy of Hegel. *Studies in Hegelian Dialectic* (1896) reworked the notion of proceeding with successive stages of thesis, antithesis, and synthesis. *Studies in Hegelian Cosmology* (1901) was more radical in its reexamination of Hegel's concept of the absolute idea, and *A Commentary on Hegel's Logic* (1910) dissected Hegel's argument from pure being to the absolute idea.

The closest McTaggart ever came to writing a popular work was with *Some Dogmas of Religion* (1906, with a second edition in 1930). Once again, being an atheist with respect to questions of the existence of God or gods while also maintaining a highly individual conception of immortality, he came to conclusions that were characteristically idiosyncratic. His justification for religion was dauntingly rigorous. Any religious belief, he argued, required the prior belief that the universe is good. But there is no reliable method by which one can believe this other than dogmatically. And dogmas, in turn, require a metaphysical investigation, for which most people lack the time or inclination. Therefore, regardless of whether the religion is actually true, the vast majority of people accept their religion on false grounds. This in turn will lead to a larger number of people living without religion, but also without its consolations, and who are therefore unhappy. This said, McTaggart was no more convinced that there was a link between religious belief and happiness.

But as against this line of argument, McTaggart advocated a mitigated version of immortality. After criticizing most arguments against, as well as many of those for, personal immortality, he advocated a disembodied mind that linked with a universal spirit that was composed principally of love. His contribution to the development of 20th-century atheism is more substantial than he is given credit for, although the fault for this lies with McTaggart himself.

McTaggart on Time

Many of these arguments came to rest on McTaggart's core belief in the unreality of time, which were first given serious expression in *Mind* in 1908 and developed in the 33rd chapter of his main work, the two-volume *The Nature of Existence* (1921, 1927). Like much of his work, this book was broadly Hegelian in outlook rather than proceeding specifically from a particular argument of Hegel's. He worked along Cartesian lines, postulating the existence of any one thing to existence of pluralities of things, to the existence of "the Absolute," which is the sum total of all the various substances without being anything more of itself than any of its constitutive parts.

Attempts had been made before McTaggart to construct arguments along these lines, though none with anything like his attention to logical detail. For instance, it has been claimed that a series of paradoxes by Hui Shi (c. 380–c. 305 BCE) was an argument for the unreality of time as part of a general program of problematizing the distinctions between space and time. And arguments for the unreality of time were advanced by the Sarvastivadin school of Buddhism about 500 CE. Only with McTaggart, however, was a concerted and deliberate aim made to argue for the unreality of time. His argument began with the observation of two types of temporality. There are events (which he called the A series) that figure either as past, present, or future, while others (the B series) operate either as earlier or later. Only the A series of events are essential to the idea of time, because only those sorts of events require a distinction between past, present, and future. Consequently, any difficulty in regarding the A series as real means an equal difficulty in regarding time as real. Past, present, and future can, more or less, be described, McTaggart admitted, but they cannot be defined.

The next step in the argument is crucial. McTaggart then argues that past, present, and future are clearly incompatible, and yet the A series needs each one at every event. To the objection that past, present, and future happen successively rather than simultaneously, he replied that any one moment still has its past and future and, as such, remain incompatible, and insofar as time depends on this series, time cannot be real.

He then infers that if a B series without an A series can constitute time, then change must be possible without an A series. A change of this sort means that an event (a position in time in McTaggart's usage) ceases to be an event while another one begins to be an event. But this cannot be, as nothing can cease to be an event or begin as an event. So without the A series there can be no change, because the B series is not sufficient in itself for change. And as events in the B series are time-determinations, it follows that there can be no B series where there is no A series, because where there is no A series, there is no time.

Now McTaggart does allow for events having an order—this he calls the C series—and events in order may become relations of earlier and later, in which they would become a B series. But this order does not necessarily imply that they must change, because change must be in a particular direction.

Having demonstrated that there can be no time without an A series, McTaggart then goes on to prove that the A series cannot exist. The characteristics of A series—the supposed sequence of past, present, and future—are either a relation or a quality. Either way, a fatal contradiction exists. Each event is the same, whether in the past, present, or the future, and its relation to each event's past and future must also always be same. McTaggart also argues that past, present, and future are incompatible. Each event has a past and future, and is in this way predictable, and yet events are also incompatible with each other. It presupposes the existence of time to erase the incompatibility, and yet the existence of time is what this argument sets out to demonstrate.

McTaggart conceded that it may well be possible that the realities we perceive as events in time are part of some nontemporal series in the manner of the C series. This seemed compatible with Hegel, who argued for a timeless reality, of which the time-series is but a distorted reflection we have of it. But this did not affect the core argument that the A series is "as essential" as the B series in that the distinctions of past, present, and future are essential to time, and that, if these distinctions are never true of reality, then one cannot include time as part of reality.

As mentioned above, McTaggart's theory of the unreality of time has not found general acceptance. It is not coincidental that his most loyal defender after Broad was Michael Dummett (1925–) the British exponent of antirealism. Others, like Roy Bhaskar (1944–), have found value in McTaggart's distinction between the A and B series without endorsing his conclusions about time's unreality. Opponents of the theory claim it amounts to little more than a play on tenses. J. J. C. Smart (1920–), for instance, argues that the idea of change can be expressed in the language of the B series by speaking of points in time *differing* from each other, which does not require us to say that events change. In effect, McTaggart's nonuse of tensed verbs with respect to the B series and use of them with respect to the A series is what sustains the apparent contradiction his argument rests upon. A simple reversal in the distribution of tenses, and the problem disappears.

McTaggart's denial of the existence of time is the best known of his arguments, although he did not stop there. *The Nature of Existence* also featured arguments that denied the existence of material objects, space, and a range of mental processes. These claims rested on a quite different argument, however. These entities could not exist by virtue of not meeting the requirements of a relation he called determining correspondence, a complex relation of any substance to the almost infinite range of divisible parts it could possibly be divided into.

Conclusion

Notwithstanding the solid support of Broad and Dummett, McTaggart's arguments have not found wider favor. The very strength of the argument—its logical power—was also its weakness, because the argument rested on logical grounds alone. Even if we overlook Smart's powerful objection to those logical grounds, McTaggart's argument for the unreality of time is fatally undermined by virtue of having taken too little account of the facts of science. At much the same time McTaggart was working out his theory of the unreality of time, developments in physics were establishing that time was very real indeed. The second law of thermodynamics and its corollary in entropy makes it clear that time is a fundamental part of the universe and that it is unidirectional. The fate of McTaggart's theory of the unreality of time is an object lesson in the need of scientific understanding, or at least of a multidisciplinary approach, when doing serious philosophy. Though not a contender as an explanation of the universe, McTaggart's argument for the unreality of time is an impressive intellectual achievement.

Bill Cooke

See also Hegel, Georg Wilhelm Friedrich; Humanism; Idealism; Nietzsche, Friedrich; Russell, Bertrand; Time, Nonexistence of

Further Readings

Berman, D. (1990). *A history of atheism in Britain.* London: Routledge.

Broad, C. D. (1933, 1938). *Examination of McTaggart's philosophy.* Cambridge, UK: Cambridge University Press.

Mace, C. A (1957). *British philosophy in the mid-century.* London: Allen & Unwin.

McTaggart, John M. E. (1921, 1927). *The nature of existence.* Cambridge, UK: Cambridge University Press.

McTaggart, John M. E. (1969). *Some dogmas of religion.* New York: Kraus Reprint. (Original work published 1906)

Passmore, J. (1967). *A hundred years of philosophy.* London: Penguin.

Westphal, J., & Levenson, C. (Eds.). (1993). *Time.* Indianapolis, IN: Hackett.

Media and Time

In the context of 19th and 20th century modernity—its technical revolutions and specific ways of experiencing time—the insight has grown that our ideas of time are decisively shaped by our interaction with media: Media influence our understanding of time. Particularly in investigations in cultural and media theory, there have been attempts to work out the dependencies between media and conceptions of time. The following cultural-historical transformation can be considered as paradigmatic for the assumption of media-time dependency: the change in our experience of time through the invention of the clock.

Thanks to a uniform mechanical process, time became precisely measurable, independent of subjective impressions of time and independent of sequences of natural events (e.g., day/night). The cultural establishment of clock time since the 13th century has not only changed social processes but also changed and extended our consciousness of time. In contrast to the experience of event time, cultural awareness of qualitatively indifferent, infinitely divisible time has grown through clock time, which made possible a massive economization of time with all the known accompaniments, such as lacking time and acceleration. In a media-theoretical perspective, this historically indubitable finding serves as evidence for the assumption that a certain conception of time (idea of abstract linear time) depends on the invention of a medium (the clock). But whether the clock, as a "time machine" (Marshall McLuhan), can form a model for proving a media-time dependency is problematic. The question is whether a clock is a medium at all. A clarification of the relationship between time and media, and a differentiation of ideas of time using media parameters, cannot take place without a preceding differentiation of the concept of media.

Both in everyday language and in the sciences, the ways in which the term *media* is used are very varied and not to be subsumed under one category. If, along with the media philosopher Marshall McLuhan, one pursues a very broad media concept, according to which media are technical inventions (artifacts), indeed artificial extensions of the human, then the clock (as a technically optimized form of time measurement) can also be treated as a medium. The advantages of such an approach lie in the possibility of treating very different technical inventions (e.g., the car and the telephone) in their cultural context. The disadvantage of such a broad understanding is conceptual imprecision. The differentiations between medium and tool and between medium and machine remain largely unclear. How broadly one grasps the media concept ultimately depends on which questions and aims one has and which facts are relevant in an academic context. The connection between medium and time thus cannot be described generally but only by considering the respective perspectival character. This entry distinguishes four perspectives in which the connection between temporality and mediality is respectively outlined.

The Media-Theoretical Perspective

Although the definition of the media concept is still quite controversial in media studies, there is nonetheless widespread agreement as to what counts among the central determinations. The material and technological basis of information and communication processes belong essentially to mediality. Relevant to this, however, are not only media in the sense of equipment and its technological changes and progress but their consequences for human information and communication processes. That is, mediality encompasses both the equipmental aspects of communication (in the broadest sense) and communicative practice as such.

In a media-historical perspective, significant changes in our ideas of time become clear. From a macroperspective, three phases can be distinguished above all. In a first phase, in which communication is primarily shaped by nonwritten media (gestures, voice, etc.) and ritualized oral tradition, cyclical ideas of time dominate. In the context of a culture of orality, events and series of events are largely considered as occurrences within larger cycles. In a second phase—starting with the development of phonetic writing (alphabet) in the 11th century BCE, via the invention of movable type printing in middle of the 15th century, through to writing as a mass medium since the 18th century—the idea of linearity develops into the dominant conception of time. Time is comprehended less according to the structure of cyclic recurrence and more as a linear order of the succession or sequence of events. By contrast, in a third phase—starting with the invention of new communications technologies (telegraphy and the telephone) and representational media (photography and cinematography) in the 19th and 20th centuries (radio and television in the first half of the 20th century, the computer and the Internet in the second half)—the ideas of simultaneity and nonlinear temporality develop. The transitions between these three phases are quite fluid, with overlap and interference being the norm. Already on historical grounds it is not convincing to assume, as is sometimes suggested, that different media paradigms like orality, scripturality, or digitality imply a strict difference in conceptions of time.

Whether the connection between media development (from a culture of orality, via written culture, to the digital world) and a changing conception of time (from the cyclic idea of time to the idea of linearity and finally to simultaneity) is to be considered as monocausal dependency or merely as a (theoretically difficult to grasp) correlation is controversially discussed. There are different arguments—according to which media concept is taken as basic—for there being a connection.

1. If one first considers media as *information and communications media,* then two lines of argument can be highlighted as examples using developments within writing culture. The first relates above all to the performative aspect, or the type of activities, in media use. The cultural techniques (writing and reading) linked with writing are shaped by the primarily linearly shaped *performance* of information processing. Information is here initially ordered not pictorially or sculpturally but in a strict linearity. The cultural dominance of the medium of writing and the performances linked with this forces the priority of the linearity of temporal succession (over the temporally indifferent division of space) in the sense of a temporal schema that regulates both the production and the reception of writing. That writing and reading are not only linear but also highly complex cognitive feats shaped by forward and backward references is not a compelling objection to the linear conception of time; this complexity is rather the condition for developing an idea of linearity (cf., Edmund Husserl's concept of retention/protention).

The second line of argument for a time-media correlation results from the observation that certain media practices encourage the emergence of certain epistemic rules and systems of order. In the context of writing culture, media practices interact with the *order systems* of knowledge, which are characterized by essentially linear ideas of temporality. For the ideas of open, transpersonal, and cross-generational development processes (i.e., not only the tradition of knowledge but also growth and progress in knowledge) are reinforced by the media production, storage, distribution, reception, and reprocessing (reinterpretation or change) of knowledge. Furthermore, the media practice of writing culture is one factor in the dominance of a model of perfectibility that is based on generally accessible and examinable (i.e., also methodically reproducible) knowledge and aims at an open, infinite progress in knowledge.

The perfectibility here ultimately lies less in what has in fact respectively been attained than in the possibility of constant improvement. Further, it is a factor in the development of a modern self-consciousness, which not only addresses its temporary and local environment in writing but nourishes its self-consciousness not least from the fact that as an individual it simultaneously understands itself as an expression of humanity and addresses all of posterity ("writing for eternity"). Linear conceptions of time gain in importance both through the knowledge orders (cf., in particular the idea of encyclopaedic knowledge pursued by Diderot and others in the spirit of Enlightenment), which developed in writing culture (above all after the invention of movable type printing) and aimed at general comprehensibility and infinite progress, and through the individual that, so to speak, in writing comports herself toward the whole of humanity. These linear conceptions of time are not restricted to local conditions and events, or to the mere recurrence of events, but take account of open processes and events that build upon one another. The dominance of a linear conception of time in the context of writing culture manifests itself particularly in the historical thinking that is typical of modernity and that has been spreading into practically all areas of knowledge since the late 18th century.

2. Alongside the first line of argument for media-determined changes in and shaping of ideas of time, which is based on the aspect of media *practices* (performances) and the forms of discourse and *order systems* shaped by media practices, a further line of argument results when one treats media primarily as *representational media* and not as *information and communications media.* Representational media, which are distinguished less technologically than functionally from communications media, are more precisely characterized by not only transmitting given (physical, biological, technological, social, or historical)

information but by generating meaning or semantic units. In this perspective media are considered not with regard to their transmission function but with regard to their function in the production of certain contents (media contents).

Representational media (e.g., dance, music, written text, film) produce semantic units, that is, they generate individuable and reproducible complexes of meaning. If one focuses on the level of semantic units articulated by representational media (instead of the paths of transmission for given information and media practices), then different (both fictional and nonfictional) temporal conditions, in part media-specific ones, can be recognized. Examples are, say, the distinction between *narrative time* and *narrated time* in literature, and the possibilities for extreme time contraction and time extension, or—partly analogous to literature—the extreme leaps in time in film though jump-cut or flashback methods. Thus well-known films such as *The Matrix* also show in exemplary fashion how specific forms of imagination and temporal conditions can be generated through the specific representational possibilities of a medium. Think, say, of the so-called bullet time, in which natural speed conditions are suspended and a normally invisible bullet is slowed down extremely in its motion, becomes visible, and is overtaken or moved around by naturally much slower bodies (e.g., humans). What such examples make particularly clear is the possibility of using representational media to generate temporal conditions that must be considered to be naturally highly unlikely, if not even impossible. That is to say: Representational media articulate temporal relations in a manner largely independent of the basic physical beliefs that are indispensable in our everyday life.

At this level of consideration—the level of media-dependent and, so to speak, physics-independent semantics of imagined time constellations—two aspects should be emphasized: (1) First, focusing on representational media shows that certain ideas of temporal processes are generated in a way dependent on representational methods and possibilities. At the semantic level, not only are established patterns of temporal information processing (according to the model of "natural" sequences of events) presented, but new "naturally" "meaningless," but semantically "meaningful" ideas of temporal arrangements are (also) generated. (2) Furthermore, the representational capacities of representational media permit humans a particular relationship to temporality. Using representational media, we can become aware of dimensions of time that are naturally inaccessible to us (past sequences of events or possible future scenarios). They enable us on the one hand to submerge in a past (either historical or fictive) beyond our own biographical horizon, but on the other hand they also enable us to imagine our future and to exchange views about possible future scenarios.

The particular cognitive ability of humans to process information with the help of time concepts and to comport themselves toward nonpresent events finds its adequate expression in the use of representational media: Released from what is respectively present, meaningful patterns of events are articulated in representational media, the meaning of which reaches beyond the time field of individuals. It is only through the production and storage of such semantic units that we can comport ourselves toward the past and future independently of the narrow horizon of our own experiences (cf., for example, the mythical past articulated in the Homeric epos or in aborigines' songs).

3. A third line of argument for the time-media correlation relates less to systematic connections, starting from relatively broadly conceived and functionally differentiated media concepts (information and communications media, representational media), and is based rather on a primarily historical and quantitatively defined class of media. Central to this are modern mass media (newspapers or the press, posters, radio, television, Internet) through which information can be spread in quantitatively high numbers (in "masses") and within a very short time. Four different aspects should be emphasized here:

- A first temporal aspect of mass media consists in the particularly fast, tendentially synchronous informing of a large number of information receivers.
- A further temporal aspect of mass media becomes recognizable when one considers complex communications situations (primarily not dialogical,

but marked by feedback processes). The understanding of information spread by mass media is essentially shaped by the demands of being up-to-date and the high frequency and fleetingness of the associated importance of information. The value of a piece of information (but also of a transmission format) is here measured in terms of its up-to-dateness. The rhythm of information determined by this (e.g., periodic appearance of newspapers or magazines, continuous transmission in radio or television) and the respective program structure (e.g., news or entertainment programs) have an effect on the audience's everyday life and feeling for time. Overall it holds that the semantics of information in the context of mass media is shaped by its specific communicative functions. The importance of information is here temporally indexed in a particular way. It is coupled to the relatively short intervals of time during which information, subjects, fashions, or program formats are perceived as being up-to-date.

- A third aspect is seen in the context of electronically based mass media (radio, television, Internet): News about real events, but in particular television pictures of events, is made accessible to the audience not only close to the time the events occur, as with newspapers, but instantaneously ("live") and "in real time." Being able to observe spatially distant events almost instantaneously through mass media is part of everyday experience these days. This fact encourages the idea (which is misleading, because it abstracts from the medium's selective mechanisms) of being able to adopt a quasi-divine standpoint in which all events in the world can be made simultaneously accessible, independently of their spatial position.
- A fourth aspect results from the *internal temporality* of the basic technical processes of information transmission, which have changed significantly through progress in the history of technology. The time interval between information production and reception has constantly become shorter; information transmission is so accelerated that the transmission time is converging on zero. An example of technical progress is the contrast between the sending of letters made possible by stagecoaches and the digitally based information transmission in an e-mail. The duration of information transmission diverges considerably. Instantaneous information transmission, live programs and real time, and the ideas of time shaped by their mass-media presence here appear to be determined in equal measure by the internal temporality of the underlying technology. This fact seems to confirm a thesis that has been much discussed in media studies, namely that ideas of time might be determined by the speed of technical processes. This thesis, which ultimately amounts to a medium a priori (the assumption of a medium basis that precedes, makes possible, and structurally determines our cognitive abilities), should however be rejected, because it starts with a very one-sided and abstract basic idea (i.e., from a media concept that lacks evolutionary and conceptual embedding; see point 2 below).

The Social-Pragmatic Perspective

In this perspective, the media-theoretically propounded thesis of a medium a priori is largely retracted and relativized. As a consequence, the assumption that experience and ideas of time are primarily determined by the history of media or the respectively guiding media is no longer dominant. For within this perspective, the accent lies not on the technological aspect but on the aspect of the human practices in which media are functionally defined and embedded. Here primordial connections between human actions are the starting point for focusing on the dependencies between media and ideas of time. Two approaches can be distinguished here: (1) a socioeconomic approach and (2) a communications-theoretical approach.

A brief general comment beforehand: For a theory that examines human practice and the social forms shaped by this, time plays a central role—and not only because of the historical nature of these phenomena. Humans must possess a concept of time so as to be able to act at all (e.g., so as to make end-means distinctions); beyond this they must possess a particular degree of time concepts (such as the differentiation of past, present, future) and be able to communicate these in order to act socially, that is, to be able to coordinate their actions with other agents.

Against this background, the extent to which media are an important factor precisely in a social-pragmatic perspective can be better understood: In order to coordinate actions socially, not only is the cognitive competence to be able to deal with temporal processes needed, but also an exchange of information between agents, in part over large temporal and spatial differences, is required. The functioning of communication between agents also depends essentially on the functioning of communications media and the speed of information transmission. Which actions are possible and are realized also depends on how, and above all how quickly, the communicative routes run.

1. Within a socioeconomic approach, the media-time correlation is treated above all in the context of an acceleration theorem. The sociologist Hartmut Rosa argues that we are today living in an age in which all social processes are being shaped by a ubiquitous tendency toward acceleration. This line of argument can initially draw support from the media-theoretical finding that especially through the introduction of digital media, and that means through the detachment of information transmission from bodily media (such as postmen, for example), a maximal acceleration of data transfer has come about. But the fact is now interpreted in the context of complex social systems and leads to the thesis that technical acceleration is embedded in different acceleration processes (acceleration of life processes as well of social and cultural changes) with in part paradoxical consequences (e.g., processes slowing down as a result of maximal increase in complexity).

2. If one advocates a stronger communications-theoretical approach, there is a shift in the lines along which problems of the media-time correlation are developed. Here too the question of mediality is embedded in a superordinate reference system. Yet it is not so much social systems that are central, but rather anthropologically founded discourse structures that regulate communicative actions and within which meaning contexts are produced and handed on. In relation to modern media and multimedia methods of representation (especially on the Internet), the thesis of a fundamentally altered experience of time is advanced. Various authors (the communications theorist Vilém Flusser, the sociologist Jean Baudrillard, the speed theorist Paul Virilio, the German literature and media theorist Götz Grossklaus) agree that the altered experience of time is characterized by a new primacy of the present.

There are three arguments above all that support the thesis of a primacy of the present:

- The first (media-epistemological) argument is general. (It gets by without closer differentiation of media and usually occurs in combination with other arguments.) It emphasizes that the experience of time within media communication is fundamentally relative to the present. In particular, the dimension of the past (e.g., certain events) as such loses importance in the context of digital media and is primarily experienced and perceived as a mode of current execution.
- Alongside that, so to speak Augustinian and rather non-medium-specific argument, a media-ontological argument is also discussed. Starting with the media-specific network structure of communicative processes (cf., digital media, particularly the Internet with its almost instantaneous and worldwide transmission of sound, images, and/or text signs), the aspect emphasized here is that there is a tendency to synchronize spatiotemporally distant processes within such forms of communication (Niklas Luhmann, Götz Grossklaus). The primacy of the present appears in this line of argument as the *primacy of simultaneity:* For the audience and agents within the network structure, the present extends into a field of the present in which remote events are synchronized within a time window (cf., the preceding argument) into a media reality.
- The third argument for the primacy of the present also has media-ontological implications. However, it focuses not on the synchronization effects of media communication but on the *modality* of media reality for the media user (sender, receiver; information producers and consumers). What matters here is the conviction that in the conditions of global networking of mutually independent information producers and storage, as well as communicative agents, the dominant impression for the individual agent is that of stepping into an open space of possibilities. The experience of presence here has nothing, or hardly anything, to do with the idea of a progression of transient present points but rather culminates in the idea of a field of the present generated

by selective individual decisions and which are surrounded by an open horizon of possibilities. That is, the experience of time leads to an idea of time in which the classical directional vectors (e.g., a line of progression from the past through the present to the future) do not dominate. Rather the accent is here on an idea of time in which a field of presence is surrounded by a variable horizon of possibilities, that is, by the future in all directions, and in which the dimension of the past appears as a residue (lost possibilities) at most (cf., Vilém Flusser).

The Media-Philosophical Perspective

The media-philosophical treatment of the time-medium connection, the discussion of dependencies and fundamental changes in time experience, and the ideas of time that build on these, converge (also in authors) in part with the preceding perspectives and findings, but in part they also compete with these. In methodical and systematic respects, three media-philosophical approaches can be distinguished above all. It is true of all these media-philosophical approaches that they also pose the question of mediality in a broad frame of reference and thus develop the subject of time at a problem level that is to be respectively specified.

1. One media-philosophical approach that is much discussed and widespread, above all in Europe, operates with fundamental assumptions about the philosophy of history and tends to teleologize media-historical changes (cf., Jean Baudrillard, Paul Virilio, Vilém Flusser). Modern and postmodern experiences of time play a prominent role in this context. Starting with the basic assumption about the philosophy of history that the historical processes aiming at progress and humanity (in the spirit of Enlightenment and modernity) are being dissolved, the focus for culture-critical and time-diagnostic purposes is above all on the experiences of time that speak for a negative eschatology. Here again the phenomenon of acceleration affecting all areas of life is to be mentioned in particular. In this perspective too, acceleration does not prove to be a desirable effect in reaching certain ends (e.g., acceleration of information exchange up to the speed of light) but is regarded as the signature of an overall cultural process in which the realization of human ends is structurally undermined by excessive acceleration. In conscious contrast to the assumption that a media age might bring about a free exchange of information conducive to the project of a humane world (McLuhan), here the thesis is advocated that information is obliterated by the accelerating speed of information transmission and by the excess of information in electronic media. Paul Virilio puts it pithily in an interview: “In contrast to what we are told, information in real time is not real information, but an action—like a slap in the face.”

2. The second media-philosophical approach operates meta-theoretically and with conceptual criticism—in a highly cross-disciplinary perspective—analyzing the scope and coherence of media-studies theories and theses. Related to the problem of time, the central question is whether one can really infer fundamentally altered concepts of time from the media-determined development of new ideas of time. What is discussed above all are the facts that (a) time is a freely available and manipulable representational parameter, and (b) the respectively generated media reality depends on speed conditions (at the representational level or at the reception level). This approach challenges attempts to understand technical innovations and experiences of time that are in part interpreted as revolutionary (and the undoubtedly linked social changes gradually taking shape in the context of action of the Internet and cyberspace)—as the basis for a “revolution” in the time concept.

Against such attempts (which mostly go along with the thesis of a medium a priori) it should initially be objected, with a *transcendental argument,* that precisely the diagnosis of new experiences of time presupposes, and precisely does not dissolve, a relatively stable concept of time (i.e., a complex of certain categorical distinctions such as before/after, succession/simultaneity, etc.) in order to be able to register variations or changes in ideas of time. That is, as suggested, not an objection to the specifics of a media reality in which time is a freely available representational parameter leading to certain ideas of reality—in part independently of the sequence of events actually observed. Thus with TV weather forecasts, for instance, the (future) movement of weather fronts is calculated and visually simulated on the foundation of a certain data basis. The future's being visually brought to mind by simulating a complete sequence of events is a phenomenon that is just as everyday as it is interesting for the theory of science. It is, however, not yet any indication of a fundamentally altered consciousness of time.

Alongside the transcendental argument, a *genealogical or evolutionary argument* should also be asserted from a media-philosophical perspective. The assumption of a respectively media-determined, uniquely new time consciousness gets caught up in inconsistencies when it is supposed to explain transitions from one paradigm medium to the next. Only in a genealogical and evolutionary consideration (i.e., one incorporating both biological and cultural developments) does the origin become explicable of the foundation of cognitive abilities that are built on by the ideas of time that are respectively varied or extended by technological conditions. And only in this way can it be made plausible why, despite epochal changes in media history, we are quite able to understand past representations and time experiences—which on the assumption of strict epochal breaks would remain an explanatory gap.

In the framework of a *topological analysis,* in which media-theoretical theses are discussed in comparison with results from other disciplines and examined with regard to their coherence, it must further be pointed out that our media practice has until now not significantly changed anything about evolutionary and neurally based timescales of our time window. (Neurologically speaking, perception of the present spans only about three seconds.) The assumption that media-generated time windows, or experience of the simultaneity of remote events, directly correspond to our neurologically based time window should be corrected to the extent that the concern here can be only with a structural analogy. (Also, so far it has yet to be clarified what exactly the relata—media and mental processes—are and how they are connected). In media-philosophical terms, one cannot speak of a simply quantitative extension of the time field but of qualitatively, not quantitively, extended time windows having become possible within an evolved timescale. The comparative temporality of media (cf., primacy of the present), the extension of the present (the tendency to blank out the past dimension, and the time inherent to events before their media processing) is not to be equated with a basic change in our perception of time. "Extension of the present" means more precisely "conceptual extension of the present with relatively constant perception of time."

3. The third media-philosophical approach differs from the preceding ones—the (1) culture-critical and (2) concept-theoretical approaches—in not understanding the concept of mediality in terms of the sender-receiver model. The foundation is a deep-set (quasi-metaphysical) understanding of mediality that accentuates the significance of the "in between." The guiding conviction in this is that the structure of mediality is to be considered as an interval structure, which cannot be reduced to the structures of subjectivity or intersubjectivity, but which rather precedes these. This conviction has been developed through engagement with the tradition of phenomenology (Husserl) and structuralism (Ferdinand de Saussure), particularly in postmodern French philosophy (Jacques Derrida, Gilles Deleuze, Jean-François Lyotard). In the context of this—altogether nonanthropocentric—concept of mediality, time is a key theorem: Time is here conceived as a dynamic structure that cannot be reduced to the sphere of cognitive competences, subjectively available parameters, or the communicative exchange of information.

This conception of time was most radically advocated by Derrida, who characterized media dynamics as "dead time" (*De la Grammatologie*), as distinct from the (metaphysical and phenomenological) paradigms of subjectivity. Following on from this, many attempts have been made to comprehend time completely in terms of the underlying technologies (i.e., those underlying information processes; cf., Friedrich Kittler), which leads, however, to the inconsistencies of media-aprioristic approaches mentioned above. On the other hand, however, attempts have also been made to deploy this altered conception of time for the ontology of individual media without relapsing into a media a priori. Deleuze has carried this out in exemplary fashion for the medium of film by classifying the semantic potential of film on the basis of differentiating subject-dependent (or subject-centered) representations of time and subject-independent representations of "time itself." In so doing, he has created a thesis that the medium of film is particularly suited to the representation of temporal processes. Using the history of author cinema, he has drawn attention to a transformation in the direction of those temporal processes that are no longer to be comprehended via subject-centered conceptions of time.

An Outlook: Time and Media in the 21st Century

It is difficult to deny that experiences of time and ideas of time stand in a close connection with media and media practice. Yet the thesis that time must be specified using different media, and time concepts correspondingly revolutionized, is today—at the start of the 21st century—just as unconvincing as was the thesis that electricity must be differentiated into types of electricity according to the underlying substances (so that there might be, for example, a specific "resin electricity") at the beginning of the 19th century. Time is not a function of media technology. Nonetheless it is true that experiences of time vary, in part considerably, according to which media practice is individually or socially dominant. To put it in the way the social psychologist and cultural historian Robert Levine—who in view of culturally differing rules of social time talks of the "language of time" having different "accents"—does, the language of time also has different idioms and accents in the history of media. But different idioms are not yet different languages. Epochal misunderstandings are likely, but the ability to understand remains fundamentally possible even with a change in media paradigms.

Since the end of the 20th century—that is, since the introduction of the Internet and the development and use of computer animations, simulators, digital movement control, and cyberspace—and increasingly with the beginning of the 21st century, new experiences of time have been taking shape that have not been empirically researched much so far. In connection with the aspects already mentioned (cf., above all the primacy of the present discussed above), the idea of virtual time presents a particular theoretical challenge. This idea is linked with the suspicion of a problematic development. For in the context of digital media, the idea of virtual time seems to be establishing itself as dominant, both in the private realm (e.g., with PC gamers) and in the socioeconomic realm (in the "global player's" field of activity), at the cost of the idea of the time of real developments or a (biographical or sociopolitical) historical time. The much-discussed media-determined loss of reality here exhibits its time-theoretical implications: Virtual time seems to contain the loss of historical time.

Virtual time means here not so much that time is a freely disposable representational parameter but rather that time is an ordering of available events. That is, the idea of virtual time is marked by the image of events being located in a possibility space and standing freely at one's disposal. Here events do not stand under the dictate of irreversibility but are considered in the mode of "as if" and are, according to the aim, reversible. An example of this is the "different lives" in computer games. When your own figure in the game fails ("dies"), the game doesn't end; you simply don't yet reach the next level. To begin with, then, an event within virtual time has quite different consequences for your own actions to an analogous event in real time. That is, in the extreme case, where no more action is normally possible and everything is finished, in virtual time everything can start again anew.

The flipside of such media practice is that actions within virtual time can come at the cost of actions in real time. One should not only think here of the mostly young, intensive player of online games with an endless format, whose gaming passion leads him to neglect to attend sufficiently to his "real" life. Rather one should also think of possibilities for media actions of a global player who pursues abstract profit intentions, largely unburdened by local political or social circumstances, and must pay hardly any or no attention to the "real" life of a company or a social group on the ground. The specific profit intentions lead to a strategic set of actions that is guided by a complex play of information in a global framework. Thanks to the media networking of the world, the global player acts in an endless field of options (i.e., one not limited by local conditions) in which partial failure can be compensated for, or even itself transformed into elements of a win-win situation, by strategic turns. One of the problematic consequences of the action space created by media detachment, or the entry into virtual time, is a peculiar dissonance. The actions made possible by media (in the case of the global player, the global connection of information flows largely independent of local circumstances; in the case of the online gamer, submergence in a virtual world and an attractive role independent of the gamer's own social role or physical constitution) adhere to a different timescale and a different future, one less rooted in the past, than actions in real time.

The tensions between actions in virtual and real time are thus also structurally determined. One of the chronopolitical tasks for the 21st century is to bring geopolitically differentiated, local timescales on the one hand and global connections (of economic processes) made possible by media on the other into a balanced relationship. Admittedly no media-philosophical solution to this problem is to be anticipated; rather it should be recalled what the examples already show: Media-based virtual time and the complex structure of real time are not two spheres that are completely independent of each other. They are conceptually linked with each other (for the virtual time of media practice can only be comprehended in contrast to certain aspects of real time, with some aspects of real time being retained, others suspended) and factually connected with each other (an action in virtual time—e.g., "occupying and defending a country"—is always a certain action in real time too—e.g., "sitting at the computer").

Experiences at the beginning of this century have in the meantime shown that the entry into virtual time (reversible events) made possible by media does not have to mean an exit from real time (irreversible events) but is embedded in contexts of action in which different transitions in both directions and countless functional connections are to be registered. Thus in the realm of online games, it can be observed that the media practice of casual gamers or users of online forums (chat rooms) by no means have to lead to the oft-attested losses of reality. Actions in virtual time often function only as normal moments of relaxation in everyday working life; sometimes they even provide possibilities to try out communicatively and to form one's own identity beyond the often restrictive local conditions. That is, entry into virtual time does not have to come at the cost of time for individual development but can even benefit this. In addition, the media practice of intensive players ("heavy gamers"), for instance, shows that the entry into virtual time is by no means always completely detached from and unburdened by real economic processes.

That entry into virtual time also costs real time is a factor that is meanwhile represented within games in the form of certain advantages in the game and that leads to virtual time and real time standing in an economic relationship to one another that is no longer hidden. Players who lack the real time to work for the desired game advantages (the attainment of which is time-intensive) can nonetheless acquire these advantages by buying these from other players who have invested enough real time to work for the advantages (at the level of virtual time).

However one evaluates these different relations (and in view of some morally and politically problematic developments, one will not want to endorse them in every respect), in any case they show that theories are fundamentally too shortsighted that on the one hand reduce media-determined experiences of time to the logic of the underlying media technologies and on the other hand want to capture the specificity of these experiences of time with strict conceptual oppositions. The undeniable connection between time and media cannot be explained through simple certainties but only by starting with sufficiently complex descriptions of the respective media practice.

Ralf Beuthan

See also Film and Photography; Information; Language; Music; Time, Perspectives of; Timepieces; Virtual Reality

Further Readings

Baudrillard, J. (1994). *The illusion of the end.* Cambridge, UK: Polity Press.

Crary, J. (2001). *Suspensions of perception: Attention, spectacle, and modern culture.* Cambridge: MIT Press.

Deleuze, G. (1986). *Cinema 1. The movement-image* (H. Tomlinson & B. Habberjam, Trans.). Minneapolis: University of Minnesota Press.

Deleuze, G. (1989). *Cinema 2. The time-image* (H. Tomlinson & R. Galeta, Trans.). Minneapolis: University of Minnesota Press.

Derrida, J. (1967). *Of grammatology* (G. C. Spivak, Trans.). Baltimore: Johns Hopkins University Press.

Innis, H. A. (1991). *The bias of communication.* Toronto, ON, Canada: University of Toronto Press. (Original work published 1951)

Levine, R. (1997). *A geography of time.* New York: Basic Books.

McLuhan, M. (1964). *Understanding media.* New York: McGraw-Hill.

Postman, N. (1982). *The disappearance of childhood.* New York: Delacorte Press.

Virilio, P. (1984). *Negative horizon: An essay in dromoscopy* (M. Dregener, Trans.). New York: Continuum.

MEDICINE, HISTORY OF

Medicine is as old as civilization itself; humankind has always made attempts to heal, cure, and prolong life. Even in the nascent phases of our development, our hominid ancestors recognized disease and sickness, and they made attempts to combat this with what was available at that time, mostly herbs and rituals. In our current phase of evolution, technology and applied intelligence have improved our understanding of what disease, sickness, and even death actually are. Now with the completion of the Human Genome Project and the possibility of genetically tailored treatments, an unprecedented chapter in medicine is about to begin. This entry provides a brief account of medicine's evolution and speculates on its future direction.

Primitive, Ancient, and Modern Medicine

The word *medicine* is derived from the Latin word *medicus,* meaning "physician," and the feminine declension *medicinus,* which means "of a doctor." However, the actual definition of what medicine *is* has changed as our civilization itself has developed through time.

Medicine in its primitive form could be defined as a *ritual* practice, sometimes involving a sacred object that a society believes capable of controlling natural or supernatural powers that act as a form of prevention or remedy for physical ailments. This could involve the use of herbs, potions, prayers, or incantations and was usually performed by a specialized member of a society—a shaman or medicine man. These individuals held special status in their societies for their apparent ability to heal. It should also be noted that even though herbs and potions may have been believed to have supernatural effects by those giving and taking them, some of these herbs and potions did have potent pharmacological effects that were not understood as such until the modern era.

Evidence of prehistoric surgical procedures has been found, most notably for trepanation, a process in which a hole is drilled into the skull, evidently for therapeutic purposes. Trepanation is believed to be one of the oldest invasive surgical procedures, and without any doubt it is one of the first neurosurgical procedures. Evidence on prehistoric human skulls and in cave paintings of the Neolithic era (8500 BCE) establishes that this procedure was in fact practiced widely, most likely with the intent to cure aliments such as headaches, seizures, and possibly psychiatric disorders.

Some of the first evidence of ancient medical information and texts can be found in ancient Egypt in the so-called Edwin Smith papyrus, which has been dated to around 3000 BCE. This scroll is also believed to be one of the first ancient textbooks that illustrates in detail the examination, diagnosis, treatment, and prognosis of a large number of physical ailments. There is evidence of what are believed to be the first surgeries performed in manuscripts from 2750 BCE (250 years after the Edwin Smith papyrus is dated).

In ancient Greece and in early Europe, a natural system of medicine was devised that was called *humoral medicine.* Hippocrates is often credited with innovating this system, but it was actually derived from Pythagoras's idea of humoral medicine, which was based on the treatment of a patient by balancing what were called the four humors: blood, phlegm, black bile, and yellow bile. An imbalance in any of these four humors is what was believed to cause physical ailments. (Pythagoras's four humors were influenced in turn by Empedocles's "four elements.")

A modern definition of medicine is that it is an objective *science* of diagnosing, treating, and in some cases preventing disease and other insults to the body or mind. This type of science implements treatments with pharmacological drugs, diet, exercise, and other surgical and nonsurgical interventions. These therapeutic interventions are performed by a specialized member of society who has extensive education and training. In addition, modern medicine is now based increasingly on scientific evidence and clinical trials, or what is presently called "evidence-based medicine." More specifically, according to the definition provided by the Centre for Evidence-Based Medicine in 1996, evidence-based medicine is the conscientious, explicit, and judicious use of current evidence in making decisions about the care of individual patients.

Comparing and Contrasting Primitive and Modern Healers

There are several similarities between primitive medicine and modern medicine. First, the healers themselves share many similarities. They are in all accounts possessors of some form of specialized knowledge, be it of the spirit world or of anatomy and physiology. In order to perform healing, they all have to undergo some form of training or rite of passage that entitles them to special recognition within their society as a person who can heal. In the past, it was an apprenticeship or a ritual. Today there are formal study, graduations, clinical training, and certifications. In addition, healers hold a high status in their respective societies and command special recognition for what they do.

Second, healers, primitive and modern, have a similarity in their methods of healing, and that is the administration of medicines. Even though the actual types of medication given by the healers differ drastically, the intention is the same, which is to put something external into the body to elicit an improvement of physical symptoms. The universal expectation among patients, primitive or modern, is that the healer "make the pain go away."

Third, healers of any era must inspire the patients' belief. Modern physicians understand that patients' belief that the doctor can help them get well is a large part of successful treatment. The patient needs to have confidence in the physician's knowledge of medicine and experience of practicing it successfully. For ancient medicine as well, the patient had to believe that the shaman's connection with the spirit world was real and that the rituals and herbs would cure aliments.

Healers and Their Methods: Then and Now

Although ancient medicine and modern medicine are separated by thousands of years and have become very different in how they are practiced, another notable similarity is that, as previously mentioned, the function of healing and curing is and was performed by a specialized member of society; not just anyone could do it.

Evidence of shamanism has been dated back to the Neolithic period (8500 BCE), which would predate all organized religions. Presently, some forms and remnants of shamanism are still seen in some societies in Africa and South America. It is also seen in regions of Asia such as Korea, the Ryukyu Islands, and sparsely populated rural areas in Japan.

Many disciplines define a shaman and his function, in a basic sense, as an intermediate between the physical (or what is call the natural) world and the nonphysical realm (or what is sometimes referred to as the spirit world). It was believed that the shaman had the ability to travel between these two worlds and was able to commune with spirits and ancestors to assist them in the healing (or in some cases the harming) of another person. Essentially, the core of shamanism is based on the belief that the physical world is somehow interconnected with the nonphysical world and that the nonphysical world can have a profound effect on the physical world.

Contemporary physicians have long since been divested of their powers of enchantment and connection with the spirit world. They are equipped instead with scientific knowledge of disease and disorders of the human body, and they have access to a vast body of medical knowledge and research. They also have the benefits of modern technology, such as diagnostic imaging and laboratory tests, and thousands of pharmacological agents to choose from. Along with primary and family care physicians who treat a wide variety of general conditions, there are more specialized physicians who treat one specific bodily system or one type of disease or disorder—for example, cardiologists, dermatologists, and psychiatrists.

Medieval Physicians

In medieval Europe, a typical physician was neither well versed in the rituals of the spirit world nor educated in topics such as pharmacology or physiology. Rather, he studied humoral medicine, alchemy, astronomy, and dogmatic textbooks that were sometimes centuries old. These were his tools for diagnosing and treating patients, mostly on the basis of conjecture. Historically the medieval physician did very little to cure rampant outbreaks of diseases or plagues. In fact, most were unwilling to actually touch their patients for an examination. The transitional period between the medieval era and the Renaissance was the time of Paracelsus (1493–1541), who has been credited with pioneering the use of chemicals and minerals to treat sickness. He believed that the human body (and nature) should be studied and understood and that alchemy, whatever its purported ability to make gold and silver from base metals, was unsuited as a tool for medicine.

Sickness: Then and Now

How did our earliest ancestors view sickness and disease? Primitive humans would most likely have perceived sickness and disease as something unnatural or even as a supernatural event. Lacking knowledge of infectious diseases or microorganisms, sick persons could be perceived as being adversely affected by the spirit world or a curse, because they were being affected by something that was invisible or poorly understood. Therefore, only an individual capable of communicating with, and able to influence, the spirit world could abate these supernatural events and thus heal.

In mainstream Western culture today, when someone becomes sick, it now automatically comes to mind that "she has a virus" or "he needs an antibiotic for his infection." No longer do most people blame evil spirits or retribution from the spirit world for illness. Spells, curses, and the "evil eye" have been discounted as causes of illness; the average person today has a better understanding of what "being sick" is and what can be done to cure various aliments.

Pharmacology: From Plants to Human-Made Pharmaceuticals

A change has taken place in *what* is used to cure illness and disease. Early humans had to be very resourceful and use what was abundant and available to them at the time, mostly plants. Today, medical botany or herbalism, the use of plants and plant extracts to cure and heal aliments, has largely been supplanted by modern pharmacology, and most drugs are now manufactured in high-tech laboratories. They are distributed in exact doses, taken for prescribed periods of time, and have extensively studied effects.

In 1960, a Neanderthal skeleton (determined to be over 60,000 years old) was uncovered from a burial site in what is known today as the Shanidar Cave (in Iraq). This specimen was buried with eight species of plants that are believed by medical anthropologists to be used medicinally all over the world. However, the earliest record of the use of plants for medicinal purposes is found in paintings in the Lascaux Cave in France, which have been dated to between 13,000 and 25,000 BCE.

It is believed that early tribal societies eventually created a small semireliable repertoire of medical knowledge based on generations of trial and error experience. The observed effects of specific plants and herbal preparations were transmitted from generation to generation and used therapeutically by a specialized member of society. Ancient societies and early European physicians would use potions and tinctures to treat patients, although they lacked the knowledge of what these potions were doing in a pharmacological or physiological sense.

Penicillin, a byproduct of a fungus, was one of the first antibiotics discovered and used therapeutically. Originally noted by a French medical student, Ernest Duchesne, in 1896, it was rediscovered by Alexander Fleming in 1928. However, the internal use of penicillin as an antibiotic did not begin until the 1940s. Since that time, thousands of medications and hundreds of classes of medications, from blood pressure medication to antidepressants, have been manufactured and administered to patients.

Eventually, with the continued growth and application of knowledge gained from the Human Genome Project, medications may be developed that are genetically tailored for optimum effectiveness with a given patient's genetic makeup. With further research, some genetic diseases will be treated directly by genetic therapies, that is, by actual alteration or manipulations of the genome. It is believed that this will improve the efficacy of treatments and reduce side effects and adverse reactions. The treatment of a patient with therapeutics engineered to correct underlying genetic causes is call "gene therapy" or "genetic medicine." The concept of genetic medicine will challenge the manner in which modern medicine treats life-threatening illness such as cancer, which currently utilizes the surgical extraction of tumors, radiation treatments, and chemotherapy. Our current approach to treating cancer with chemotherapy and radiation inevitably involves some toxic effects for the patient as physicians attempt to localize these effects to the actual cancer.

Modern medicine, despite some shortcomings, has provided our present-day population with several tremendous benefits. With the advent of new medications, treatments, and vaccines, people are now living longer and more productive lives. In fact, global life expectancy has increased from about 37 years in the year 1800 to 67 years in the year 2000, for a global average increase of 40 years.

Medicine in the Future

As medicine has developed from rituals, through alchemy and astrology, to modern technology and to the possibility of genetically tailored treatments, one fact has remained and will remain consistent: The human body becomes ill, breaks down, and dying and death continue to occur. Given humankind's desire to prolong life, the human body will always need healing, repair, and medical treatment by specialists.

The future prospect of space travel suggests the possibility of encountering new forms of diseases and ailments as a result of exposure to the outer space environment. This new environment could also put us into contact with alien microorganisms that could cause different types of illnesses. In addition, space travelers may need to be placed in hibernation for long journeys, and muscle strength would need to be maintained in zero gravity conditions. All of these possibilities would open up a new area of space-travel medicine, a new specialty that would deal with these unprecedented medical problems.

John K. Grandy

See also DNA; Dying and Death; Egypt, Ancient; Paracelsus; Time Travel

Further Readings

Ball, P. (2006). *The devil's doctor: Paracelsus and the world of renaissance magic and science.* New York: Farrar, Straus, & Giroux.

Harner, M. (1982). *Way of the shaman* (1st ed.). New York: Bantam.

Porter, R. (2004). *Blood and guts: A short history of medicine.* New York: Norton.

Porter, R. (2006). *The Cambridge history of medicine.* Cambridge, UK: Cambridge University Press.

Sackett D. L., Rosenberg W. M., Gray, J. A., Haynes, R. B., & Richardson W. S. (1996). Evidence-based medicine: What it is and what it isn't. *British Medical Journal, 312*(7023), 71–72.

MELLOR, DAVID HUGH (1938–)

David Hugh Mellor, emeritus professor of philosophy at the University of Cambridge, is known for his important contributions to metaphysics, philosophy of science, and philosophy of the mind, with studies, for example, on probability, time, causation, properties, and decision theory. His work stands in the Cambridge tradition of F. P. Ramsey and Richard Braithwaite, in whose honor he has edited anthologies and the works of Ramsey. Mellor's philosophy of time profits from this broad field of interest and combines them systematically; he is one of the advocates of the "new tenseless theory of time."

Two important theories of the early 20th century have influenced Mellor and, as he claims, the whole modern theory of time: McTaggart's A- and B-series theory of time (1908) and Einstein's special theory of relativity, published in 1905. Agreeing with McTaggart's argument against the reality of the dynamic, tensed view of time, Mellor adopts a theory of time based on the B series, which acknowledges only the static scale of the B series as fundamental for any concept of time. In contrast to McTaggart, Mellor does not conclude that time is unreal. He shows that the concept of spacetime as it is presented in the special theory of relativity does not spatialize time. In fact time differs from space in this concept, and that becomes obvious in the formalization of the theory. Time is therefore a problem in its own right. Mellor's position can be characterized as a B series of time that argues for the reality of time—more precisely: time as the causal dimension of spacetime.

A and B Series of Time Differentiated

The first step on the way to Mellor's theory of time is the differentiation between the A and B series of time established by McTaggart. The A series orders facts in relation to the present moment as past, present, or future. Their relation to each other does not change, but their qualification as past, present, or future changes with the flow of time. The B series orders facts or events only with respect to their successive occurrence, no matter which of them is the present one. Therefore it does not need the concept of a flowing time. In everyday language, facts involving time are usually expressed in A sentences; that is, by using tensed verbs. Mellor argues that all tensed propositions or beliefs have B facts as their truth conditions. The crucial question is what makes tensed sentences, or A sentences like "Peter arrived yesterday," true.

Mellor's answer to this question in general is the following: A sentences have B facts as their truth condition. That means they depend, first, on facts like the time when the sentence is uttered and, second, on whether the event that is mentioned really occurred at the time that the sentence says it did. Both conditions can be expressed in B terms as follows: (1) The sentence was uttered on March 2nd, and Peter arrived on March 1st; (2) Peter really arrived on March 1st. If both conditions obtain, the A sentence is true. If the truthmakers were A facts, they would cause contradictions, because the fact that Peter arrived yesterday would have to obtain in order to make the statement true if uttered on March 2nd and not obtain to make it false when uttered on March 3rd. The central thought in Mellor's B theory is that A sentences need B truthmakers in order not to fall prey to contradictions. He does not want to do away with the way of expressing subjective perspectives of time in A sentences. On the contrary, he recognizes the necessity of A sentences and A beliefs within a concept of agency.

As agents, Mellor explains, we depend on our A beliefs existentially. A true A belief at the right time is needed for an action to succeed. But, first, A beliefs are necessary to cause an agent to act. I need the belief that my train arrives at 2 o'clock, for instance, to cause me to leave the house by 1:30. For the success of this action, my catching the 2 o'clock train, the belief that the train arrives at 2 o'clock must be true. Again, the condition for this truth is not the A fact of it now being 2 o'clock, but the B fact that the train arrives at 2 o'clock. The function of A beliefs is to cause agents to act. Therefore A beliefs are indispensable. Beliefs about what is happening now are needed for any action.

Mellor states that the conviction that what is perceived is also present is not grounded in facts but in pragmatic beliefs. The presence of a perception is usually confused with the alleged presence of the object. This plays no role in everyday life, because the time light needs to travel from most objects to the eye and the time needed to process the information is negligible; in the case of cosmologic events, however, the events we perceive now may have happened millions of years ago. On the one hand, the fact remains that there is no presence in the strict physical sense of the word; on the other hand, as species we would never have survived if we had not taken the prey just seen or perceived the predators following us as present. So it is pragmatic and existentially necessary to have A beliefs.

Mellor explains this necessity in terms of evolution: It was necessary for the survival of humanity and even animals to have such A beliefs. Furthermore he thinks that having an A belief is more basic than having a language. It is not necessary to be able to express an A belief or to have a concept of the self or the present for acting on such a belief. The range of A beliefs is not limited to sentences about time. All subjective perspectives, all beliefs about time, place, and the subjective situation belong to its range. A beliefs are subject-relative, which means they belong to the subject that has them in order to cause it to act: "I" have to believe something at the present moment "now" in order to act. No one would act on someone else's belief or on the belief in true B sentences alone.

Besides granting A beliefs a pragmatic necessity, Mellor also says that A sentences have different meanings from their B analogues and therefore cannot be replaced by B sentences. Although A sentences and their B analogues have the same content according to Mellor, they have a different character, because their relation to their truth conditions differs. While a B sentence, for example, "It is raining at *t* (let *t* be the exact time)" is always true (if and only if it rained at *t*); the A sentence "It is raining now" will only be true if said at the time *t;* if said before or after *t,* it may be false. This is the reason why Mellor says that A sentences "mean the functions from any *B*-time to their *B*-truth-conditions at *t.*" In other words: The truth of an A sentence depends on the position of its token on the B scale of time (when it is uttered) in relation to the B-scale position of its content, the event or fact expressed in the A sentence.

The fact that A sentences constantly change their truth values is crucial for Mellor's version of a B theory of time. Their constant change is caused by the constant change of our A beliefs, which determine our perception or understanding of time. A beliefs about what is now change nearly every moment, and their spatial analogues about what is here change similarly. Through the constant change of A beliefs, Mellor explains how the impression of flowing time arises. Despite the fact that the flow of time does not exist as a property of time itself, it is a psychological truth. The phenomenon of flowing time is a mere construction of our minds, which are constantly concerned with changing A beliefs. It is important to stress the point that the psychological and dynamic character of A beliefs does not invalidate them in their function. According to Mellor, these subjective beliefs, or at least some of them, are also fundamental to a concept of the self, even though they do not deserve such a concept to function as a cause of agency. The concept of the self is a second-order belief. A beliefs belong to the first-order beliefs that make us eat if we perceive food; no concept of self is needed for this belief to cause an action, according to Mellor.

Mellor's tenseless theory of time explains how subjective sentences involving time can be made true by nonsubjective truthmakers. It becomes obvious that he acknowledges the tensed view of time as essential only for time-consciousness and in a pragmatic perspective, but from that he does not infer an ontological relevance of the A series. Only the static B series is of ontological relevance. In order to strengthen the ontological argument, Mellor raises the question of what time is. This question entails, among others, the problems of the difference between time and space and of time as the dimension of change, as well as the question of causation.

Time and Space Contrasted

In fact, if time should be a subject of ontology, then it must not be reducible to something else. In special relativity it could seem as if time had been identified with space. Mellor attempts to show that this is not the case. Even though time resembles space in more than one way, it is not the same thing. The four dimensions of spacetime seem to be treated quite equally, because both space and time are systems of order, and time can be represented as a dimension just like space—the three dimensions of space are combined with the one dimension of time. Nevertheless they are not equal. Mellor explains that a difference between spacelike and timelike separations of events or entities is made in special relativity. The three dimensions of space represent an array of possible ways by which things can be in contact, interact, or fail to do so. The dimension of time has basically the same function, but, in contrast to space, things in time can fail to be in contact although they are in the same place, because they are there at different times, or in different words, it is possible for two things or events to occupy exactly the same place, because they can do it at different times. These kinds of separations are called timelike separations. They are treated differently from spacelike ones. This can be shown in the mathematical formalization of distances in spacetime:

The spacetime separation has a positive sign if it represents a spacelike separation and a negative one if it represents a timelike one. Therefore time differs from space in special relativity.

In the next step, time is described as the dimension of change, which leads to the definition of time as the causal dimension of spacetime. Time defined this way is marked off from space not only in terms of formalization but also by nature. McTaggart characterizes time as the dimension of change. Mellor seeks to defend this view without sharing McTaggart's opinion that the A series, which had just been shown as containing contradictions, is fundamental. Taking the A series as fundamental for change would lead to contradiction in the concept of change.

Mellor wants to give an account of change from the B theory's point of view and in respect to special theory of relativity. The first question that arises here is, What is change? The answer Mellor gives is the following: A thing has undergone a change when it possesses incompatible properties at different times; change is a variation over time in the properties of a thing or an entity. This definition excludes various events that might in general be called changes but that do not meet the conditions of the definition: Mellor claims that spatial variation cannot be called change, because the properties that are subject to change have to be intrinsic, not relational. Changes in relational properties are not changes in the thing; they are a variation in its relation to some other thing. Neither spatial variation nor variation in temporal parts or in relational properties can be defined as change, because there is no change in intrinsic properties of the thing. Mellor also states a difference between things and events: Both terms denote particulars, but events, because they are stretched over a certain period of time, consist of temporal parts, while things do not have temporal parts, they are wholly present at more than one time. This is why only things can undergo change in the strict sense of the word, meaning they can possess incompatible intrinsic properties at different times.

McTaggart's restriction of change to the A series was due to the fact that B facts never change; being true at one time means that a B fact is always true. The sentence "It is raining at *t*" will always be true if it really rained at *t*. Facts that change are A facts: that it is raining now might obtain at the present moment and be false a few minutes later because it has stopped raining in the meantime. McTaggart's reason for change relying on the A series is the possibility of continuity. The continuous change of the A series (of the present state to a past one and so on) constitutes the flow of time, and therefore time can be the dimension of change only if the A series exists. Since the A series contains a contradiction, time as the dimension of change does not exist. Mellor does not share McTaggart's conclusion. Although the B series account of change is being criticized for not being able to explain the continuity of change, Mellor attempts to show that indeed it can. If change is described as the possession of incompatible properties at different B times, which entails that every single B fact at its B time does not change, that does not mean that the succession of different B facts cannot be a continuous change. The facts in themselves need not change for change to occur: they only have to follow each other along a causal chain.

Causality

For Mellor, causality is the basic concept that grants time reality. Time differs from space in spacetime, because only in the temporal order are causes and effects necessarily separated. In space, cause and effect can occupy the same place, but they do not occur at the same time. According to Mellor it is not time that fixes the causal order (that would mean accepting the A series), it is causation that gives time its direction: Time order is synonymous with the causal order. Mellor gives several reasons for adopting a causal theory of time order (see Mellor, 2005). In short, his basic assumptions are that (1) causation links only events separated in time, not in space, because causation is never unmediated, and (2) causes always precede their effects. On the basis of these assumptions, a causal theory can explain the differences between past and future as well as the continuity of change. The causal concept of time explains why, according to Mellor, "We can perceive but not affect the past, and affect but not perceive the future" without the necessity to state modal or ontological differences between past, present, and future.

A profound survey of Mellor's approach to the philosophy of time can be found in *Real Time II;* for a concise and informative entry into his thinking, his article "Time" in the *Oxford Handbook of Contemporary Philosophy* is recommended. A deeper understanding concerning the theoretical fundamentals of the definition of time as the causal dimension of spacetime is given by *The Facts of Causation.*

Yvonne Foerster

See also Causality; Determinism; McTaggart, John M. E.; Metaphysics; Ontology; Time, Relativity of; Space and Time; Spacetime Continuum; Relativity; Special Theory of; Time, Real; Time Travel

Further Readings

Lillehammer, H., & Rodriguez-Pereyra, G. (Eds.). (2003). *Real metaphysics. Essays in honour of D. H. Mellor.* London: Routledge.
Mellor, D. H. (1981). *Real time.* New York: Cambridge University Press.
Mellor, D. H. (1991). *Matters of metaphysics.* New York: Cambridge University Press.
Mellor, D. H. (1993). The unreality of tense. In R. Le Poidevin & M. MacBeath (Eds.), *The philosophy of time* (pp. 47–59). New York: Oxford University Press.
Mellor, D. H. (1995). *The facts of causation.* London: Routledge.
Mellor, D. H. (1998). *Real time II.* London: Routledge.
Mellor, D. H. (2001). The time of our lives. In Anthony O'Hear (Ed.), *Philosophy at the new millennium* (pp. 45–59). New York: Cambridge University Press.
Mellor, D. H. (2005). Time. In F. Jackson & M. Smith (Eds.), *The Oxford handbook of contemporary philosophy* (pp. 615–635). New York: Oxford University Press.
Oaklander, N., & Smith, Q. (Eds.). (1994). *The new theory of time.* New Haven, CT: Yale University Press.

Memory

Memory is the ability to retrieve learned or acquired information. This information can be of previous events, a learned skill, or factual knowledge. Memory is usually distinguished as short-term memory, which is the recollection of recent events, and long-term memory, which is recalling the more distant past. Memory as a biological phenomenon is a record of time.

Ideas and theories about memory have changed in recent decades. Theories regarding memory, much like the theories regarding consciousness, have been profoundly influenced by research in the neurosciences and understanding the functioning of the brain (physiologically and biochemically).

The clinical assessment of memory of the human brain is specified by three categories, which can give insight into the functioning of a person's cognition. First is immediate memory, which functions over a period of seconds. Second is recent memory, which applies over a scale of minutes to days. Third is remote memory, which typically encompasses a period of months to years. These classifications differ only slightly compared with stipulating them as short-term and long-term memory.

Memory can be further classified according to how it is utilized. Working memory is not only classified by the duration of memory retention, but also by the manner in which it is used in daily activities. For example, performing a series of simple calculations would utilize working memory. The actual process of retaining this information (in this case, numbers to be used in a calculation) for short-period use is the working memory, because it is being used at that time. However, working memory is not to be confused with short-term memory, which is memory stored for a short period of time that is not being used functionally.

In addition to classifying memory by the length of time a particular brain is able to retrieve information, it can also be described in terms of implicit (also called procedural) and explicit (also called declarative) memory. Implicit memory is defined as memory that is retrieved automatically, or without conscious involvement. For example, memory for learned skills is claimed to be largely implicit, in that it is automatic. This is in contrast to explicit memory, which requires conscious awareness and intentional recollection to recall. An example of this would be recalling events that took place several years ago, which would require an intentional recollection of that neurological data.

Ivan Pavlov: Early Experiments in Conditioning

Ivan Pavlov (1849–1936) was a psychologist, physiologist, and physician who is well known for his work done in what is known as *classical conditioning*.

Also well known is "Pavlov's dog," a phrase that arose from experiments he performed on dogs. These experiments consisted of producing a stimulus (such as ringing a bell, blowing a whistle, or striking a tuning fork) prior to feeding the dog. This was done repeatedly, and eventually that same stimulus would cause the dogs to salivate even in the absence of food. This process was called *conditioning*.

Early experiments in conditioning were important to the understanding of memory, because the conditioned response relied on the fact that a memory of that stimulus was associated with the presentation of food. Thus, memory is a component of learned behavior.

Human Memory

In establishing an understanding of human memory, four basic elements of memory have been explained: encoding, storage, retrieval, and forgetting. The first element is encoding, the registration of neurological data. This is an active procedure of processing and combining information. For example, while watching a television program, one would see (visual stimulus) and hear (auditory stimulus) information that would be processed by the brain as an event, (e.g., watching the weather report).

The second element is the storage of memory in the brain, which creates a neurological record. Currently, this is understood to take place in three stages: sensory store, short-term store, and long-term store. The sensory store is the perception of the image (e.g., the meteorologist reading the weather forecast), which is thought to last only a split second or just long enough to be perceived by the brain. Short-term store is the storage of this information for only a short period of time, typically only minutes to hours; for example, if someone just entered the room, having missed the weather forecast, and then asked you what it was, your recollection would then be based on short-term store. Long-term store is the storage of that same information hours, days, or years later. The retention of this information for longer periods of time requires rehearsal. In fact, memorization is a method of rehearsal that allows an individual to recall information verbatim.

The third element of memory is the retrieval of memory. This is the recollection of stored information, which is not a random process. In fact, it is an intentional process that is typically in response to a cue, in reaction to a stimulus, or to perform a particular activity. However, it is also thought that memories are reconstructions of the actual event, and these reconstructions can contain errors or inconsistencies in perception when recalled; for example, one might make errors in reporting what the weather forecast was.

The fourth element of memory is forgetting. This is the loss of or the inability to retrieve stored information. There are several theories on forgetting, such as *pseudo-forgetting* (which is held to occur due to ineffective attention in the acquisition phase), and retrieval failure (which is claimed to be an inability to retrieve information at a particular time and, consequently, the inability to be able to recall it at a later time). It is also held that memory loss happens naturally due to decay over time or because of lack of use. Another theory, known as *motivated forgetting,* is an individual's intentional attempt to forget events that are unpleasant or traumatic. This phenomenon was studied extensively by Sigmund Freud (1856–1939); he called these *repressed memories*. He maintained that repressed memories were not lost or forgotten; rather, they were stored in the unconsciousness and are responsible for certain psychiatric conditions that he called *neuroses*.

Long-Term Potentiation

For almost a century, scientists were baffled about how the neurons in the human mammalian brain were able to store memories. In 1973, the first neurological research was published by Timothy Bliss on what he called *long-term potentiation* (LTP), today also known as long-term enhancement. He characterized the phenomena of LTP, which was originally observed by Per Andersen in Oslo, Norway.

While conducting experiments on the hippocampus of rabbits, Timothy Bliss and his colleges discovered that a few seconds of high-frequency electrical stimulation on particular neurons would enhance synaptic transmission in the hippocampus for days and, in some studies, for weeks. This enhanced and prolonged stimulation in the hippocampus was held to be responsible for the formation of short- and long-term memory. Today, researchers of memory concur that the most current evidence supports the role of LTPs in both memory and learning.

Prior to the idea of LTP, the Hebbian theory was the accepted idea of how memory and learning occur. The Hebbian theory was named after neuropsychologist Donald O. Hebb (1904–1985), who stated that the strengthening of the neuronal synapses to one another was primarily responsible for memory and learning. This in part could still be true, and we are learning more about neuroplasticity, which is a process in which the brain changes, or, in this case, strengthens its neuronal connections.

The Neuroanatomy of Memory

Theories about what memories actually are and how memories are actually stored have changed over time. This is mostly due to decades of research in the neurosciences. It is now known that several areas of the brain are required for obtaining, storing, and retrieving memory.

In the human brain, memory is stored and retrieved from what is known as the neural network of the brain. Information from sensory organs travels through specific parts of the brain, is processed, stored, and then able to be recalled at later periods of time. The anatomic regions currently known to be critical to the formation and recollection of memory are the medial temporal lobe, certain diencephalic nuclei, and the basal forebrain.

The medial temporal lobe contains the hippocampus and the amygdala. The hippocampal region is where electrochemical activity converts short-term memory into long-term memory by via LTP. LTP is thought to be a persistent electrochemical increase in synaptic strength following high-frequency stimulation of a chemical synapse.

The amygdala is claimed to rate the emotional importance of a particular experience. For example, a very intense experience, such as pain or pleasure, would create a very strong memory. Conversely, a mild or indifferent stimulus, such as tying a shoelace, may be disregarded altogether and not stored as a lasting memory.

Certain diencephalic nuclei in the dorsal medial nucleus of the thalamus and the mamillary bodies are also involved in memory. This is known because, if these areas are damaged—for example, in thiamine-deficient states or alcohol impairment—then the brain has the inability to recall events. Neurological inactivity in these areas is also noted in Korsakoff's syndrome, a medical condition in which severe impairment is noted in recalling remote memory.

The basal forebrain consists of the basal ganglia and areas called brain-stem nuclei. These structures lie deep inside the brain and consist of the caudate nuclei, lentiform nuclei, portions of the amygdala, and claustrum. Collectively, these areas are involved in voluntary movement and nonmotor learning. It is known that damage to these areas can result in the decline and loss of memory, as well as loss of executive functioning (planning and the ability to pay attention) and loss of ability in set-shifting (the ability to alternate between two or more tasks). This is seen in Parkinson's disease and Huntington's disease.

Neuroplasticity: The Brain Can Change

Neuroplasticity (also known as *cortical plasticity*) is the ability of the brain to form new neuronal connections and to reorganize itself. This can happen in response to certain types of injuries or diseases and in response to new situations and changes in the environment. The concept of neuroplasticity has challenged the previous dogmas that the brain is immutable and that, after a certain age of development, it does not change. Neuroplasticity does allow changes in the brain, and it allows the brain to be incredibly adaptive.

How does neuroplasticity work? In the neuronal network of the brain, each neuron forms several connections with other neurons. Connections that are used infrequently eventually fade away, a process called *synaptic pruning*. Conversely, connections that are used regularly and frequently are strengthened (as proposed by Hebb before there was knowledge of neuroplasticity). In addition to this, neurons can also form new connections to other neurons. It is thought that these new connections are involved in forming long-term memory in response to new information.

It is maintained that the earlier hominid brain was similar to but not as complex as the more modern and evolved *Homo sapiens sapiens* brain. The anatomical and chemical changes in complexity had to have changed over time in order to improve the process of human memory. These changes were in all likelihood induced by natural selection. As our earlier ancestors began to evolve into a hunting and gathering species, an increase in neurological demand was made because of the increased need for communication and the ability to learn and remember more information. In short, an increase in the ability to remember equals an increased chance of survival, and this was provided by neuroplasticity. Neuroplasticity is not exclusive to *Homo sapiens sapiens*. The ability to learn and adapt to new information is apparent in most animals and organisms possessing a nervous system. However, it is not clear how human neuroplasticity differs from the neuroplasticity in other animals.

Virtual Memory

Like the human brain, computers are able to store and retrieve memory called *data*. Early computers used a two-level storage system that consisted of a main memory (RAM), which consisted of magnetic cores, and a secondary (hard disk) memory that was composed of magnetic drums. The problem with this two-level system was that the main memory was very limited, and most programs had to use the much slower hard disk (secondary memory).

In 1959, a one-level storage system known as "virtual memory" was conceived. This new system utilized a special automatic set of hardware and software that kept the majority of the current programs and memory in the faster main memory and, in conjunction with secondary memory, created the illusion of unlimited available memory.

Currently, computers are able to store and retrieve massive amounts of data in seconds, but they need to be programmed to do so. The computer's physical memory is stored using a binary code and can be stored on computer chips, disks, or electromagnetic tapes. This is slightly different from memory storage in the human brain, which is done primarily in the hippocampus using long-term potentiation. The human brain is capable of storing a large amount of memory, but modern computers can store practically unlimited amounts of data with greater accuracy than human memory.

Chimpanzee Memory

Much research has been done on primates, in particular chimpanzees, because of their similarities to humans. The dogma has always been that human executive and cognitive functions are superior to those in the apes. Recently, it was shown in a study done at Kyoto University that young chimpanzees could grasp many numerals at a glance and recall the sequence of these numerals. In most cases, they actually performed at a higher level than mature chimps and humans. This shows that other primates, besides humans, have extraordinary working capabilities for numerical recollection. As with our early human ancestors, this is likely a result of natural selection. Primates with better memory would have an adaptive advantage, and this would increase their chances of survival and reproduction.

Alzheimer's Disease

Several medical conditions that impair memory or cause memory loss have been mentioned already, such as Korsakoff's syndrome, Parkinson's disease, and Huntington's disease. There are several other such conditions including encephalopathy, vascular dementia, stroke, vitamin deficiencies, hypothyroidism, and psychiatric conditions. However, Alzheimer's disease is the most well-known condition that causes memory impairment and loss in humans; this disease is a progressive neurological disorder in which the loss of short-term memory is present in early stages. During the later stages, progressive memory loss will continue, and eventually long-term memory loss takes place.

Much has been learned about the pathology process of Alzheimer's disease. Neurologically, the brain develops extracellular deposits of amyloid-beta protein, intracellular neurofibrillary tangles, and eventually loss of neuron mass. In addition, certain genes have been identified in familial forms of Alzheimer's disease. This suggests that, in the future, perhaps gene therapy may be able to prevent or treat these forms of Alzheimer's disease.

Current treatments can potentially halt the progression of Alzheimer's disease. Medications known as cholinesterase inhibitors have been somewhat effective in treating Alzheimer's patients.

There are also other classes of medications that can help halt the progression of this disease. However, all these medications are very expensive and only slow down the eventual progression of the disease.

Enhancing Memory

Improving or enhancing memory is an interesting topic, because the ability to recall more information accurately and faster would provide an individual with a great advantage. Not having to look up information in a book or journal years after that information has been forgotten would be a tremendous advantage in the work place, pursuing research, completing academic projects, or learning other languages.

No current methods or medications have proven to be 100% effective in improving human memory. Certain didactic methodologies aim at improving the retention of memories (such as facts, words, and diagrams) that can help with learning and scholastics. Herbal medicines like *Gingko biloba* have been shown to improve the circulation in the brain. Proposals have been made that this medicine could, in theory, improve memory, but no conclusive evidence exists as of now. A more complete understanding of the genetics that may be involved in memory could in the future propose the possibility of the genetic enhancement of memory.

It has been well documented that exercise that increases circulation improves memory but does not enhance memory. This is because improved circulation increases oxygenation to the brain. It is also true that a healthy diet gives rise to a healthier brain and thus improved memory. Dietary vitamins, especially B-vitamins and omega-3 fatty acids, are known to maintain healthy memory. Again, maintaining healthy memory does not mean enhancing memory beyond its human capacity.

Our understanding of memory has changed over time, mostly due to neurological discoveries, in particular LTP and neuroplasticity. Likewise, over time, our ability to utilize memory has improved our species' ability to survive. However, human memory is not perfect; neurological information can become distorted, lost, or in some cases repressed. Disease can also degrade the memory process. Continuing biological evolution may gradually result in improvements in human memory. In the shorter term, perhaps our own efforts to understand the neurobiology of memory more completely will lead to future improvements in human memory through new medications or gene therapy.

John K. Grandy

See also Cognition; Consciousness; Information; Intuition; Perception; Sleep; Time, Phenomenology of

Further Readings

Basar, E. (2007). *Memory and brain dynamics: Oscillations integrating attention, perception, learning, and memory.* New York: CRC Press.

Eichenbaum, H. (2002). *The cognitive neurosciences of memory: An introduction.* New York: Oxford University Press.

Grandy, J. (2005). Consciousness. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (Vol. 2, pp. 563–566.). Thousand Oaks, CA: Sage.

Kandel, E. R. (2007). *In search of memory: The emergence of a new science of mind.* New York: Norton.

Pinker, S. (1999). *How the mind works.* New York: Norton.

Shaw, C. (2001). *Toward a theory of neuroplasticity.* Philadelphia, PA: Psychology Press.

Merleau-Ponty, Maurice (1908–1961)

Maurice Merleau-Ponty was a French philosopher in the tradition of phenomenology. He taught at the École Normale Supérieure, later held the chair of child psychology and pedagogy at the Sorbonne, and in 1952 became the successor of Louis Lavelle at the Collège de France. In 1946 he founded the journal *Les Temps Modernes* together with Jean-Paul Sartre, but he withdrew his cooperation in 1955 and subsequently left the editorial board.

Merleau-Ponty developed his thoughts under the influence of various schools of thought, the phenomenology of Husserl and Heidegger being the most important; others were dialectics (Hegel, Marx), existentialism (Sartre) and neocriticism

(Brunschvicg). His theory of time is based on the Husserlian phenomenology and is to be found in two of his major large-scale works: the early work *Phenomenology of Perception* (1945) and the unfinished manuscript *The Visible and the Invisible* (1964), which was posthumously published by Claude Lefort.

In the discussion surrounding his work, it remains contentious whether there is any continuity between the early and the late thought or not. Time as subject is treated quite differently in the two works mentioned above: In *Phenomenology of Perception,* Merleau-Ponty analyzes time in a phenomenological manner, and in *The Visible and the Invisible,* in which Merleau-Ponty seeks for a way of thinking beyond subject-object dualism, time becomes a subject of ontology. But already in his early work, Merleau-Ponty argued against the dualism of subject and object and the theoretical concepts of empiricism and idealism, which emphasize a dualistic way of thinking. Although his analysis of time exhibits a tendency toward a subjective notion, it would be a misinterpretation to speak of a subjective view of time. In fact, Merleau-Ponty's concept of time undergoes continuous development throughout his life's work.

In *Phenomenology of Perception,* Merleau-Ponty argues against the idea that time resembles a flowing river. This image of time is problematic from two perspectives: First, it suggests that time has an existence in itself and, therefore, is something in the world; and, second, that time flows from the past to the future or vice versa. Merleau-Ponty denies that time exists in the world; he says that there is no such thing as succession to be found in the world of things. This position has led to the widespread conviction that he defends a subjective view of time. But time is also not to be found in consciousness, according to Merleau-Ponty. The role of the subject is to unfold time, and it does so from the present, which Merleau-Ponty considers to be the source of time. Therefore, there is no flow of time from the past to the future. Moreover the concept of unfolding or constitution of time is not completely subjective, because contact with the world is necessary. Furthermore, this special kind of constitution does not imply a completion—time is never wholly constituted, it remains *in statu nascendi* as Merleau-Ponty calls it. That means it cannot become an object of complete recognition. Merleau-Ponty understands time in *Phenomenology of Perception* as a dynamic structure that constantly evolves from the primordial interaction of subject and world.

The constitution of time is bound to the present, and the reason for this present-centered view of time lies in the function of the body (the *corps propre*). The concept of the body takes over a transcendental function similar to the transcendental consciousness in Husserl's phenomenology: It is the condition of possibility for perception, because it situates the subject in the world and gives it a perspective. Husserl did not think of the body as basis for perception, because he held that the body is a concept that first has to be constituted in experience before it can function as a means of perception. The difference to Husserl's concept is that the transcendental consciousness is itself transcendent. On the contrary, the body has a transcendental function but is not transcendent itself. The body's significance for time lies in its presence for the subject. It is always present for the subject even if the subject has not attained self-consciousness yet. My own body cannot be compared to an ordinary object in the world, because I am not able to distance myself from it in order to perceive it as a whole thing or from all sides. That means my own body is always present for me, but it can never be wholly presented to me. Because the body is fundamental to perception, it also determines the time-consciousness to evolve from the present moment. But the present moment, just like time as a whole, remains *in statu nascendi;* in other words, it is never complete; the present as the source of time is never fully present, because it constantly evolves.

Merleau-Ponty states that time and the subject are identical, in the sense that their structure is alike. The identification of subject and time is programmatic for Merleau-Ponty: It expresses his aim to describe time from the perspective of the subject without limiting it to a subjective concept. Since time and the subject are not heterogeneous to each other, Merleau-Ponty doesn't require a higher-order subjectivity that synthesizes time to make it available for consciousness.

In *The Visible and the Invisible,* Merleau-Ponty's aim is to give phenomenology an ontological foundation. He stresses the notion of time as dimension of being and even speaks of time as an element in the ancient Greek sense. Time is the element in which structure becomes possible, and structure is necessary for the possibility of being; as a dimension of being, it is fundamental to the structure of subject and object. Merleau-Ponty expands the body-concept to the concept of "flesh." He uses this term to denote the irreducible bond of subject and world on the level of corporeality and perceptual structures. Because he connects the notion of flesh with time (the flesh of time), it becomes obvious that here at the latest he no longer defends a subjective view of time (if he ever had done so). The importance of the present has not lost weight. The flesh as universal structure is not restricted to the perceiving subject but contains both the perceived and the perceiver (perception has its place in between subject and object, it is not only an act of the subject); it is a structure of simultaneity. In the presence of the flesh, past, present, and future are contained simultaneously. The present is itself structured, this richer notion of presence is captured in the term *simultaneity.* In this expanded view of time, Merleau-Ponty also reflects on historicity from various, preferably nondualistic, perspectives. An ontology of time from a Merleau-Pontyan perspective will neither objectify it nor restrict it to subjectivity. Although being cannot become objectified, it is open to philosophical interrogation; therefore, Merleau-Ponty himself calls his ontology an indirect one.

Merleau-Ponty's late thoughts about time remained fragmentary and, as such, open to various interpretations. Nevertheless, they are worth considering for a nondualistic time theory. His philosophy influenced among others the works of Foucault and Derrida (for example, his critique of the metaphysics of presence) and is the subject of philosophical discussions in Europe and to a great extent in North America, where for example the relevance of his theory for the interpretation of recent results in the cognitive sciences is discussed.

Yvonne Förster

See also Bergson, Henri; Derrida, Jacques; Epistemology; Farber, Marvin; Hegel, Georg Wilhelm Friedrich; Idealism; Marx, Karl; Metaphysics; Perception; Ricoeur, Paul; Time, Phenomenology of

Further Readings

Barta-Smith, N. A. (1997). When time is not a river: Landscape, memory, history, and Merleau-Ponty. *International Philosophical Quarterly, 37*(4), 423–440.

Carman, T., & Hansen, M. B. N. (Eds.). (2005). *The Cambridge companion to Merleau-Ponty.* Cambridge, UK: Cambridge University Press.

Dillon, M. C. (1988). *Merleau-Ponty's ontology.* Bloomington: Indiana University Press.

Dreyfus, H. L. (2002). Intelligence without representation—Merleau-Ponty's critique of mental representation: The relevance of phenomenology to scientific explanation. *Phenomenology and the Cognitive Sciences, 1*(4), 367–383.

Kelly, S. D. (2005). The puzzle of temporal experience. In A. Brook & K. Akins (Eds.), *Philosophy and neuroscience* (pp. 208–238). Cambridge, UK: Cambridge University Press.

Merleau-Ponty, M. (1962). *Phenomenology of perception.* London: Routledge.

Merleau-Ponty, M. (1964). *The primacy of perception.* Evanston, IL: Northwestern University Press.

Merleau-Ponty, M. (1968). *The visible and the invisible.* Evanston, IL: Northwestern University Press.

Muldoon, M. S. (2006). *Tricks of time: Bergson, Merleau-Ponty, and Ricoeur in search of time, self and meaning.* Pittsburgh, PA: Duquesne University Press.

Priest, S. (1998). *Merleau-Ponty.* New York: Routledge.

Metamorphosis, Insect

Metamorphosis is a temporal process of development involving the interaction of hormones triggered at particular stages of growth. Metamorphosis of greater or lesser degree is found in most organisms where there is a developmental transition over time in body form between the egg and adult. Insects undergo a particularly noticeable metamorphosis involving distinct stages of development that often occur in different habitats or utilize different food resources. Developmental transitions occur between different juvenile stages and are terminated when the adult stage is reached.

With a relatively inflexible outer integument or exoskeleton, insect growth is only possible through periodic shedding or molting of cuticle between each instar followed by a rapid expansion of a soft, new cuticle until it hardens. This expansion facilitates further growth during each developmental stage or *instar.* At emergence from the egg, most insects are structurally different from their adult counterparts. This difference may be slight or pronounced. Juvenile stages are usually characterized by feeding, growth, and development of external and internal structures such as wings and reproductive organs that are not fully developed until the final molt into the adult. In many insects metamorphosis is confined to a series of instars during a single season or year for those species with an annual life cycle.

Metamorphosis between instars may be confined to a matter of days in species with rapid life cycles (such as insects feeding on ephemeral fungal fruiting bodies) or spread out over many years in long-lived species with an extended juvenile growth period. There can also be considerable variation within a single species. Juvenile development in the wood-boring ghost moth *Aenetus virescens,* for example, may vary from as little as 9 months between egg and adult to as long as 4 years within a single population. The number of instars is also variable between species, and sometimes within species. Many insects, especially those that develop through their life cycle each season, have relatively few instars, with four to five stages being common.

There are several distinct patterns of insect metamorphosis with contrasting developmental patterns that contribute to the structural diversity of a group of organisms that may otherwise have had a more homogenous appearance. Insects that never evolved wings, where juveniles resemble adults and adults also continue to molt, are called *ametabolous* (or *aptergota* = without wings). This development pattern occurs in five primitive insect orders that include springtails and the common silverfish. Most insect orders are *hemimetabolous* (also called *exopterygota* for their externally visible wing development) with a dimorphic life history divided into a series of nymphs that molt through several instars and adults that do not molt. In these insects, wings develop gradually as external wing pads in the older juveniles, and only the adult has fully functional wings (with the unique exception of mayflies, where the final juvenile instar has fully developed wings). Hemimetabolous insects include grasshoppers and their close relatives, such as stoneflies, and true bugs.

Insects with the most distinctive stages of metamorphosis are *holometabolous,* where there are three main stages of development: larva, a pupa, and adult. In this developmental sequence the larva is structurally and behaviorally different from the adults. Compound eyes are usually absent in the larval and pupal stages (where the eyes are otherwise absent limited to several single lenses). The holometabola are also referred to as *endopterygotes,* because the wings and other features develop internally until the pupal stage, when they become everted and visible externally, although they are not fully expanded to the adult structure. Evolution of holometabolous development is widely regarded as a key evolutionary innovation contributing to the comparatively diverse speciation within 11 orders that compose about 75% of all insect species.

Transitions between different stages during metamorphosis involve a sequential web of interacting genetic and biochemical factors and the balancing effects of hormones that effect molting with those that maintain the juvenile stage (juvenile hormone) by preventing the epidermis from depositing adult cuticle in response to the presence of molting hormone. The specific developmental triggers for the secretion of brain hormone are generally not understood. In some cases, metamorphosis is triggered by internal indicators of body growth, such as stretch receptors that indicate a particular level of body expansion has been reached, or the attainment of a critical body weight.

Molting proceeds through three major complementary processes:

1. Old cuticle is separated from the underlying epidermis, and 80% to 90% of this cuticle is reabsorbed through the action of enzymes while a new cuticle is secreted by the epidermis. This process is initiated by release of prothoracicotropic hormone in the corpora cardiaca (or corpora allata in Lepidoptera) of the brain, and this hormone stimulates production of ecdysome in the prothoracic gland. In turn, ecdysome results in the production of the molecule 20-hydroxyecdysome, which regulates the genes that produce new cuticle.

2. Molting is controlled by release of a molting trigger from the epitracheal glands. This hormone stimulates the brain to produce molting hormone

and behavioral changes in the insect as a prelude to molting. The molting hormone also produces a positive feedback loop between the brain and epitracheal glands resulting in a massive release of molting hormone that in turn results in the release of crustacean cardioactive hormone by the ventral ganglia. This regulates the transition from premolting behavior, such as body movements that help separate the overlying cuticle, and molting behavior, which comprises waves of body contractions that continue until the molt is complete.

3. Following the molt, the body undergoes expansion and hardening of the cuticle. Wing expansion in the new adult is facilitated through abdominal contractions forcing blood into the wings, and this activity also stimulates release of bursicon, which further increases the flexibility of wing cuticle and then initiates hardening of the cuticle.

In holometabolous insects, brain and juvenile hormones are both produced during the immature stages until the last immature instar, when juvenile hormone production is either terminated or decreases below a threshold level where metamorphosis into the pupal and adult stage occurs as adult characteristics are no longer inhibited. The adults of most insects do not molt, because the prothoracic glands degenerate either before or after adult emergence, and there is no longer the secretion of molting hormone. In hemimetabolous insects, the transformation between the immature and adult stages is more gradual. Brain hormone includes a number of steroids that act on genes through a receptor-mediated process that determines which genes are activated at a given time and consequently which enzymes and structural proteins are synthesized.

The transition between instars usually takes place over a few minutes as the old cuticle breaks open along the dorsal midline of the thorax and the insect extrudes is body through this opening, with the appendages such as legs and antennae along with the tracheal tubes being the last to pull away. This process is preceded by a separation of epidermal cells from the old cuticle and the secretion of a new cuticle as well as enzymes that digest 80% to 90% of the old cuticle. The insect pumps air into the body, which expands its volume, resulting in the breakage of old cuticle along the dorsal line. The body is extruded out of this break, and the insect pulls itself away from the old cuticle. This is followed by a period of resting as the new cuticle is hardened. It is during this process that the size of the body is expanded so the new instar is larger than the previous instar. The process of metamorphosis begins with hatching from the egg when all insects are small, sexually immature, and lack wings. As the juvenile and adult stages have often diverged evolutionarily in form and function, the juvenile is more efficient at feeding and growth, while the adult is more specialized with respect to dispersal and reproduction.

The size at which molting occurs is not absolute and depends on the size of the insect at the beginning of the instar. In some species and where food is insufficient, the molt may result in a smaller instar or in the retention of a juvenile stage rather than a subsequent instar such as the pupa. Environmental conditions may also modify the amounts or timing of hormone secretion, and where these factors are predictable components of development, they will result in characteristic differences between individuals composing different castes in social insects. Juvenile honey bees will develop into queen bees when fed a diet based on secretions of the nurse bee's mandibular glands, and they will develop into workers when fed higher proportions of hypopharyngeal gland secretions from worker bees. Ants will develop into minor or major workers or soldiers according to the quantity of food that will result in larger juveniles. These size differences affect the quantity of juvenile hormones, which is higher in the final instars of larvae developing into queen bees or major and soldier ants. In aphids, metamorphosis into the final adult form is affected by day length. Under long photoperiods, the largest embryos will develop into parthenogenetic forms, whereas under short photoperiods the embryos will give rise to sexually reproducing forms. The development of parthenogenetic forms is stimulated by the secretion of hormones from cells in the brain that respond to the amount of light passing directly through the cuticle of the head.

John R. Grehan

See also Evolution, Organic; Photosynthesis

Further Readings

Chapman, R. F. (1998). *The insects: Structure and function.* Cambridge, UK: Cambridge University Press.

Heming, B. S. (2003). *Insect development and evolution.* London: Comstock.

Metanarrative

A metanarrative is a theory of history that is said to move in a specific direction and, on the strength of which, confident predictions about the future can be made. Metanarratives have also been called Grand Narratives, or Master Narratives (usually complete with capital letters) and the philosopher Karl Popper spoke of historicism in the same context. The critical factor in a metanarrative, and what distinguishes it from a historical perspective, is the blending of the historical account into an assertion about how the future will unfold.

Several great systems of thought have articulated, or at least assumed, a historical narrative. Marxism and Christianity, for instance, both involve a metanarrative. For example, Christianity speaks of a creator God who made the world and then placed Adam and Eve in it as the most important products of that Creation. Eve's sin meant the expulsion of them and their progeny from paradise and into the world of sin, suffering, and death. People were then offered a way out of this condition when God sent his only son as savior, so those who believe in his salvific efficacy would be saved from death and live in bliss in heaven for eternity. Eventually history will be brought to a close when, at some time in the future, Jesus Christ returns (the Second Coming) to judge the living and the dead and confer punishments and rewards as appropriate. This is a metanarrative in that the theory of history blends seamlessly into a prediction about the future.

Metanarratives have been around for a long time. Ancient and medieval writers frequently spoke in terms of history being a succession of ages. In 725 CE, the Venerable Bede (673–735 CE) wrote of the ages of man in his *De Temporum Ratione* (*On the Reckoning of Time*). Bede followed the most popular route, thinking in terms of the four ages of man. This goes back to the Pythagorean numerology and to the association of the number four with the four seasons, the four cardinal directions, and the four original elements as outlined in Greek philosophy.

In the 12th century, the idea that human history is in fact punctuated by seven ages became more popular. Unlike the four-ages theory, the seven-ages theory was astrological in origin, working on Ptolemy's seven-planet (including the sun and moon) cosmos. It is most memorably recalled for us now in Shakespeare's *As You Like It* (act II, scene 7).

The extraordinary appeal of Marxism in the 19th and 20th centuries lay in the secular treatment it gave to what was fundamentally a religious metanarrative, with its confident belief that socialism would, in the future, be replaced by communism, which will mean that all material contradictions and inequalities will have been resolved.

Metanarratives found their most enthusiastic critics in postmodernist thinkers. Postmodernism was not so much a coherent philosophical movement as a diffuse mood. It remains influential in some humanities' disciplines but, since the second half of the 1990s, has faded from prominence in most areas. The classic definition of postmodernism was given by the French thinker Jean-François Lyotard as "incredulity toward metanarratives." This seemingly reasonable idea was promptly undermined, however, when Lyotard made it clear he did not mean incredulity at all, but outright opposition. It was also apparent that Lyotard was, if unwittingly, assuming a metanarrative of his own. A few sentences after talking of incredulity, Lyotard spoke of "the obsolescence of the metanarrative apparatus" and the time "after metanarratives."

The postmodernist hostility to metanarratives was expressed even more openly by Patricia Waugh. In her introductory essay to an influential anthology of postmodernist ideas, Waugh went further than Lyotard when she added that postmodernism was about the "abandonment of all metanarratives which could legitimate foundations for truth." More than this, Waugh also declared metanarratives were no longer even desirable. Another influential postmodernist, Zygmunt Bauman, spoke of modernity as a "long march to prison," one that was being undone by the "second Copernican revolution" of postmodernist thought, led by Martin Heidegger. And the most radical postmodernists spoke in terms of modernity having been vanquished and the theories that sustained it destroyed, leaving modernity redundant, never to be brought back. At whichever point they were located along the postmodern spectrum of thought, it appeared that, however much they declared their incredulity toward metanarratives, it seemed postmodernists could not free themselves from them.

Much more effective criticism of metanarratives came from Karl Popper's book *The Poverty of Historicism*. Written in 1935, it was not translated into English until 1957 but quickly established itself as influential after that. The key weakness of historicism, Popper argued, was to equate laws of development with absolute trends, which were arrived at by some metaphysical necessity. The historicist went on, Popper claimed, to want to change the course of history by virtue of superior knowledge of the dialectic of history. But this was to put the cart before the horse. While history needs to be written from a preconceived point of view, Popper wrote, this does not mean the historian's preconceived points of view should be taken as historical laws.

Others have wished to retain a place for metanarratives, even if only for their symbolic power. Some feminist thinkers, for instance, have been fiercely critical of the wish to jettison historical accounts of the progressive emancipation of women from patriarchal oppression. By dismissing such an important struggle as simply an arching tale, these critics suggest, the historical reality of those emancipations is jeopardized.

Bill Cooke

See also Bede the Venerable, Saint; Bible and Time; Language; Marx, Karl; Popper, Karl R.; Postmodernism

Further Readings

Bauman, Z. (1993). *Intimations of postmodernity.* London & New York: Routledge & Kegan Paul.

Lyotard, J.-F. (1988). *The postmodern condition: A report on knowledge.* Minneapolis: University of Minnesota Press.

Popper, K. (1957). *The poverty of historicism.* London: Routledge & Kegan Paul.

Waugh, P. (1994). *Postmodernism: A reader.* London: Edward Arnold.

Metaphysics

Metaphysics is one of the oldest, least explicit, and most controversial disciplines in Western philosophy as far as its evaluation is concerned. There has been no widely accepted definition, nor any strict delimitation of its subject and goal so far. In the last 2,500 years of its history, metaphysics was considered to be a basic philosophical discipline covering the question of "what really exists," or dealing with the first principles of being and cognition of all things. On the other hand, it has been questioned and rejected as a useless and nonsense activity. Thus, all of its history can be seen as a process of continual transformations seeded in the tension between its acceptance and the cyclical recurrence of critiques proclaiming its "crisis," "abolition," "termination," or "death." One of the most significant motives of the critique of metaphysics was metaphysics' prevailing tendency not to fully realize the role of time and temporality in the explanation of the world.

Origin of Name

The term *metaphysics,* handed down to the present, arose accidentally in the 1st century BCE when Andronicus of Rhodes, a peripatetic expositor of Aristotle, summarized his unlabeled treatises under the term *ta meta ta physika,* treatises that in his catalogue follow Aristotle's work *Physics*. Aristotle himself most commonly referred to these teachings as "the first philosophy" (*he prote philosophia*) but also as "wisdom" (*sophia)* or "theology" (*theologiké*). Late Aristotelians, especially Alexander of Aphrodisias in the late 2nd and early 3rd centuries CE, understood Andronicus's classificatory meaning of the word *metaphysics* as matter of content—as a teaching dealing with what is *beyond* the physical world, a teaching about the supersensible, transcendent, and intelligible entities (including God). Also in this sense, Simplicius and Boethius used the one-word term *metaphysica* in the 4th and 6th centuries CE, respectively. European philosophical thinking acquired this understanding of the term during the 13th-century period of scholasticism.

History of Metaphysics

Antiquity

In ancient Greece, the development of metaphysics is connected notably with the names of Parmenides, Plato, Aristotle, and Plotinus. Parmenides (540–450 BCE), by arguing that "being is, and nothing is not because nothing cannot be thought of, and so, the thought and the being are the same" and by his follow-up claim that being is one, continuous, changeless, and eternal, founded a qualitatively new variant of philosophical thinking about reality. His "thinking and being" correspondence principle, as well as his distinction between reality being ultimately true and appearing by sense perception, have become determining, and at the same time, limiting considerations for the entire field of classical metaphysics. Plato (428–348 BCE) elaborated on Parmenides' reflections, and in his middle writing period, he argued for the division of the world into two realms. One was *noumenon*—which exists by reason, and therefore is real, being the perfect world of original, eternal, changeless, and intelligible ideas; and the other was *fainomenon*—the imperfect world of appearances and derived, changeable, perceptibles.

Because metaphysics transcends the perceptible and reaches the top of the hierarchically ordered world of ideas—where the Good dwells as an origin of everything, factual thinking about reality is associated with axiological and at last, epistemological aspects. For metaphysics examines the fundamental principles of specific sciences (mathematics) as well. However, for further development of metaphysics, Plato's distinction of a privileged, timeless world of ideas and a disqualified temporal world of particulars became significant; time is understood there as something that metaphysics should overcome.

Aristotle (384–322 BCE), the founder of metaphysics as an independent philosophical discipline, critically elaborated on his predecessors' initiatives. This became obvious in his tendency to rehabilitate the dynamic world of perceptibles. Time as "a number of movement in respect of the before and after" is the fundamental element of entities to which belong motion and becoming in this context. Considering Aristotle's solution of this problem, as well as his delimitation of metaphysics' subject and goals, the factual legacy of his work remained ambiguous. Notably, his understanding of metaphysics, understood at one point as *ontology* and at another one as *theology,* proved to be historically significant.

In the first case, Aristotle distinguished metaphysics as a universal science about "being" (entity) as being science dealing with being as such, from specific sciences always dealing with a specific kind of being (entity). However, his ontology did not declare being to be one and beyond the diversity of things as Parmenides did. It just gives us an account of the most universal kinds of entities in their plurality—that is *a theory of categories*. Existing means to exist in a certain way, that is, in quite a few differentiations—as substance (e.g., a man), quality (e.g., whiteness), quantity, relation, etc.

However, further inquiries led Aristotle to understand metaphysics as a specific science about an ultimate type of entity, that is to say, substance, which testifies what a thing is and has an important position among categories. In reality, however, there are various types of substances, and the most perfect and dignified is the divine one (the self-thinking, eternal, unmoved first mover). Thus, metaphysics becomes a special kind of substantial ontology—*a theology.* Another definition of metaphysics by Aristotle, as a "knowledge of first causes and principles" of entities, led to a similar conclusion. The most crucial of the four causes—material, formal, efficient, and final—is the last one: Everything is carried out for some purpose, due to some good. And because the highest purpose and good is God, metaphysics, as a study of first principles, is (natural) *theology.* Here, the roots of the idea of unity between ontology and theology, according to Heidegger's so-called ontotheology, are to be found. This idea was later elaborated by scholastic philosophy.

It's worth mentioning that Plato as well as Aristotle did not understand metaphysics as a strictly descriptive contemplation on reality. On one hand, there's an axiological aspect—the cognition of reality is always interconnected with the cognition of the good and the values, and on the other hand, there's an epistemological-logical aspect—categories and principles do not only relate to the reality but to our thinking about it as well.

For Plotinus (204–270), metaphysics is mainly so-called *henology*—a teaching concerning the unthinkable and unspeakable, the not-being and the above-being *One* as the basic principle of all things. Out of this *One,* the entire reality emanates following a degenerative descending process. Even time is only a movable, imperfect picture of the eternal spiritual principle. The aim of philosophy is to free man from empirical plurality and temporality and to unify him with the perfect *One*. Plotinus brought strong elements of mysticism into metaphysics.

Middle Ages

There was an important transformation of metaphysics in the Middle Ages, especially with regard to the scholastic reception of Aristotle's work. Creationistic elaborations of its ontotheological traits, mostly performed by Thomas Aquinas (1225–1274), were of determining importance. For Thomas Aquinas, metaphysics, as a constituent of philosophical wisdom (*sapientia*), is a science about being as to what extent it is being (*ens inquantum ens*); hence it is a science covering the entire reality. However, investigating is not restricted to the perceptible world. It gradually proceeds to examinations into the supersensible (soul, angels) and results in rational contemplation on God. For if metaphysics is to understand being as such, first, being's cause must be understood. And the first cause is God, not only in Aristotelian terms as a *final cause of becoming of things,* but as *a cause and principle of being* of all things created. Metaphysics culminates in (rational) theology as in its ultimate ontology. Thomas Aquinas determines time likewise as Aristotle did, as a measure of changes that arise in bodies in respect of the before and after. It belongs to creature, not to God alone.

For such a concept of metaphysics, it was necessary to provide a rational evidence of God's existence; especially an ontological argument was needed. The argument was put forward by Anselm of Canterbury (1033–1109), who deduced an inevitable fact of God's existence out of the concept (essence) of God, understood as something that is the most perfect (and thus timeless and changeless also) and above which nothing greater can be conceived. Otherwise, there would be controversy. This proof, in its various forms, has become a constituent of great metaphysical systems of modern times.

The problem of universals led to serious consequences for metaphysics in the Middle Ages: Do the contents of universal concepts exist in reality or not? The answer to the dispute, with its prehistory in Plato, the Cynics, and Aristotle, resulted in the birth of *realism* (Anselm of Canterbury; William of Champeaux, 1068–1121) and *nominalism* (J. Roscelin, 1050–1120; Duns Scotus, 1264/1270–1308; William of Ockham, 1290–1349). According to the first, universals exist in reality, before particulars exist and apart from them, and only subsequently they appear in particulars, which are derived from them, or after particulars, in human mind. The opposite standpoint, in its most radical variation, supposes that universals are mere words (*nomina*), claiming that only particulars exist in reality. In its moderate variation, nominalism concedes the existence of universals in human mind (P. Abelard's [1079–1142] *conceptualism*). This controversy has endured, in its various forms, up to the present-day metaphysics, philosophy of logic, and mathematics.

Modern Times

In modern times, the classical understanding of metaphysics as a dogmatic teaching covering the problems of soul, world, and God has undergone significant changes in terms of its understanding, which tends to be more critical. René Descartes (1596–1650) was at the beginning of these critical efforts, and Immanuel Kant (1724–1804) concluded them.

Descartes considered the investigation of the highest principles providing certain knowledge of the world to be the goal of his *philosophia prima.* An epistemological motive, which had been of secondary concern for metaphysics until his time, became fundamental for Descartes. By means of methodological skepticism, he ended up asserting two principles. The first one, *cogito ergo sum,* anchors the certainty of every knowledge of the world not in the world itself, as it worked in the old metaphysics, but through intuitive self-evidence of a reasoning subject (*res cogitans*). This anthropological turn provides background for the second principle, *the existence of a perfect God,* as a source for the verity of the external world (*res extensa*). From these principles, like from roots, all efficient knowledge of humankind should grow (physics, mechanics, medicine, morals).

However, part of Descartes's heritage was *res extensa* (material, incapable of spontaneous motion, axiologically neutral) and *res cogitans* (spiritual, autonomous, evaluating) dualism. Primary, attributive determination of the first one is extension. Time (duration) is only secondary, modally characteristic of unattributive motion (alteration of position). It was especially rationalists who tried to offer an answer to varied forms of *mentioned dualism* (the problem of subject-object relations, mind-body problem, absence of values and dynamics in reality, etc.). For Baruch Spinoza (1632–1677), substance is one, that is, *Deus sive natura,* and metaphysics is identical to ethics. N. de Malebranche (1638–1715) presents an occasional correspondence of both substances through God. According to G. W. Leibniz (1646–1716), there are an infinite number of spiritual, that is, spontaneously dynamic and thinking substances.

Another division of metaphysics emerged in 1562 with the Spanish philosopher B. Pereira (1535–1610), who divided it into general (*metaphysica generalis*) and specific (*metaphysica specialis*). This division was systematically completed by Christian Wolff (1679–1754) in 1730. While general metaphysics (ontology) is a basic philosophical science, rational cosmology, theology, and psychology are disciplines of specific metaphysics.

The Modern Ages empiricists, unlike the rationalists, took quite a rejecting stance on the possibility of metaphysics; they demonstrated the empirical groundlessness of its basic concepts based on the thought/being correspondence. Thus, for John Locke (1632–1704), substance is unconceivable apart from the bundle of its attributes. George Berkeley (1685–1753) denies the existence of the external substance (*res extensa*) and David Hume (1711–1776) denies the existence of both external and internal substance (*res cogitans*) and the concept of causality as well, taking it as a result of everyday habit.

Kant rejected all of the previous "dogmatic" metaphysics as a fictitious knowledge, because by exploring the problems of the soul, world, and God, it applied concepts of pure reason in an inadmissible and transcendent way and beyond the borders of possible experience to a thing-in-itself (*noumenon*), which is unconceivable. Thus, metaphysical reason, not being able even to justify the existence of its subjects, had to cope with insolvable antinomies in all of its domains. As becomes obvious, an ontological proof of God's existence is impossible. Existence is not an attribute and cannot be deduced. The *cogito ergo sum* proposition is a paralogism as well.

Thus traditional subjects of metaphysics do not belong to theoretical reason but, like its postulates (the postulate of freedom, immortality of the soul, the existence of God), to a practical one. However, a new critical metaphysics is possible. It is a transcendental theory that does not pursue the objects themselves, but, provided that such cognition is a priori possible, it pursues our forms of their cognition. It is a study of categories, but these are not perceived as the most universal aspects of things (ontologically) but as a priori forms of data being linked in experience, as a "logic" of experience. It includes also contemplations about time, which according to Kant does not belong to things themselves but is one of two a priori principles of pure intuition (the second one is space) that provide humankind with an inner experience and vicariously an experience of external phenomena.

G. W. F. Hegel (1770–1831) took quite a different stance toward metaphysics. Although he blamed metaphysics for not being dialectical, he accepted and absolutized the thought and being correspondence principle. On its basis, he attempted to offer a dynamic, nondualistic view of reality in his absolute idealism. Within the evolutionary conception of reality, he identified ontology (general metaphysics) with (dialectic) logic. Here he describes the self-contradictory process of the self-realization of the freedom of absolute idea, which is developing from the "in-itself and for-itself" stage (*logics* as the overcoming of rational theology), through the "otherbeing in nature" stage (*philosophy of nature* as the overcoming of rational cosmology), to the stage where idea "recurs back from its otherbeing" (*philosophy of the spirit* as overcoming of rational psychology). The essential medium of this process is time ("intuitive becoming"), in which self-realization of the spirit is realized until is rounded off.

Hegel's influence on 19th-century metaphysics was strong but short-lived. In contrast to Hegel's approach, the majority of 19th-century philosophical movements (positivism, neo-Kantianism, etc.), being under the influence of Hume's and Kant's criticism, rejected classical metaphysics as a theory of reality (scientism, gnoseologism). The implication of this was that similar stances toward metaphysics, though not epistemologically motivated, were taken by Søren Kierkegaard (1813–1855), Karl Marx (1818–1883), and Friedrich Nietzsche (1844–1900).

20th Century

In the 20th century, understanding of metaphysics' subject and goals was considerably influenced by a linguistic turn in philosophy. The attitude of analytic philosophy, as a protagonist of this turn, changed. At its inception (until the 1920s), it offered a criticism of certain type of metaphysics (neo-Hegelian) for the sake of another one (G. E. Moore's [1873–1958] realism, or Bertrand Russell's [1872–1970] logical atomism). Later, in the 1950s and 1960s, under the influence of Ludwig Wittgenstein (1889–1951) and the activities of logical positivism, analytic philosophy became radically antimetaphysical. Following Wittgenstein, who claimed that philosophy is not a theory but a criticism of language, logical positivists including Moritz Schlick (1882–1936) and Rudolf Carnap (1891–1970), who understood philosophy as a logical analysis examining the meaningfulness of the language of science, whereas a criterion for meaningfulness resides in the feasibility of the sentences to be empirically verified (verificationism). Metaphysical sentences are not verifiable and thus are meaningless, because they refer to something above or beyond any experience. They do not account for referential but only for expressive function; they reflect their authors' personal sentiments and view of life.

Since the late 1950s, a renaissance of metaphysics within analytic philosophy has taken place, which was mostly associated with initiatives of Willard van Orman Quine (1908–2000) and P. F. Strawson (1919–2006). Quine recognizes metaphysics (or, to be more exact, ontology) as a reflection on what there is. However, it does not fall under the competence of philosophy (which was supposed to turn into so-called naturalistic epistemology) but belongs to (natural) sciences. This metaphysics concerns especially the so-called ontological commitment—a question as to which entities we are committed to adopt for a theory to be true—and Quine offers a specific criterion. Unlike Quine, Strawson allows for a possibility of an autonomous philosophical metaphysics. It resides in the clarification of the nature and relations between the key—the essential, the most universal and irreducible—concepts, which constitute a structural pattern of human thinking (both ordinary and scientific) about the world. Strawson also makes a distinction between descriptive and revisionist metaphysics. The former, which he prefers, settles for the description of the actual structure of our thinking about the world; the latter is engaged in rendering a better one.

The attitude of the 20th-century nonanalytic philosophy toward metaphysics was critical; however, there were efforts to propose a revised conception. Alfred North Whitehead's (1861–1947) nonsubstantial process philosophy (in which there is the fundamental metaphysical unit—event—well-founded temporally) may be an illustrative case, but the formation of ontologies figures significantly as well—for example, the critical ontology of Nicolai Hartmann (1882–1950) or Edmund Husserl's (1859–1938) eidetic science of intentional objects. One of the most important was Martin Heidegger's (1889–1976) fundamental ontology (elaborating on Husserl's phenomenological method), the aim of which is to manifest temporality as the meaning of being. A later important case was Jean-Paul Sartre's (1905–1980) phenomenological ontology.

An original critical response to the peripeties of this school of thought was provided by E. Lévinas. According to Lévinas, the fundamental weakness of previous metaphysics was that in finding the solution to its crucial question of *the same* and *the other* relation, it always turned into ontology. But ontology is egological and solipsistic in nature—in its efforts to master and usurp the other, it reduces it to itself (the same), canceling its peculiar (unique) otherness and exteriority. Such an identification of the other with the same occurs through the incorporation of a middle element between the two, a representative that the same finds in itself. This has been a universal concept since Socrates, including Berkeley's *individual perception* but also Heidegger's *being,* because Heidegger subordinates the relation toward the other (existing) to the relation toward its being. The path to the other is never direct; transcendence toward it is always embraced by immanence. However, metaphysics is not concerned with representations and thus allows the totalization of the other into the same. On the contrary, metaphysics' main effort is to maintain radical exteriority, the totally other. The transcendence is provided by a face-to-face encounter with the other; another human being and the bond established is thus ethical. Metaphysics as ethics, in this sense, precedes ontology as a philosophy of power and constitutes a philosophy of justice.

Totalizing inclinations within philosophy were again rejected in the last third of the 20th century. However, this occurred not by reinterpreting metaphysics as Lévinas did. It was postmodern philosophers, chiefly Michel Foucault (1926–1984), Jacques Derrida (1930–2004), Gilles Deleuze (1925–1995), Jean-François Lyotard (1924–1998), and Richard Rorty (1931–2007) who started proclaiming the death of metaphysics as such. The days of metaphysics as a privileged human (philosophical) activity aspiring to acquire a mirror cognition of *the Reality* in a metanarrative, absolutely valid and ultimate system, are over. Its common topics—truth, reality, humankind, history, mind, language—are no more perceived as being noumenal or transcendental in status. They are temporal—socially, historically, and linguistically determined. Metaphysics does not offer an absolute, genuine picture of reality; it is just one of the numerous narratives of reality, a mere rhetoric. "God's eye view" realism submits to relativism, monism to pluralism, totalization and sameness to the otherness, eternity to time and temporality.

Marián Palenčár

See also Aquinas, Saint Thomas; Aristotle; Becoming and Being; Berkeley, George; Causality; Cosmogony; Derrida, Jacques; Descartes, René; Dialectics; Hegel, Georg Wilhelm Friedrich; Heidegger, Martin; Kant, Immanuel; Kierkegaard, Søren Aabye; Marx, Karl; Nietzsche, Friedrich; Ontology; Parmenides of Elea; Plato; Plotinus; Postmodernism; Spinoza, Baruch de; Theology, Process; Whitehead, Alfred North

Further Readings

Aristotle. (1993). *Metaphysics.* New York: Oxford University Press. (Original work c. 350 BCE)

Carnap, R. (1959). The elimination of metaphysics through the logical analysis of language. In A. J. Ayer (Ed.), *Logical positivism.* Glencoe, IL: The Free Press.

Descartes, R. (1984–1991). Meditationes de prima philosophia (J. Cottingham, R. Stoothoff, & D. Murdoch, Trans.). In *The Philosophical Writings of Descartes* (Vol. 2). Cambridge, UK: Cambridge University Press.

Heidegger, M. (2000). *An introduction to metaphysics.* New Haven, CT: Yale University Press.

Kant, I. (1963). *Immanuel Kant's critique of pure reason* (N. K. Smith, Trans.). London: Macmillan.

Lévinas, E. (1969). *Totality and infinity.* Pittsburgh, PA: Duquesne University Press.

Strawson, P. F. (1964). *Individuals: An essay in descriptive metaphysics.* London: Routledge.

van Invangen, P., & Zimmermann, D. W. (Eds.). (2004). *Metaphysics: The big questions.* Oxford, UK: Blackwell.

Meteors and Meteorites

Both meteorites and meteors are classified more broadly as meteoroids, the simplest definition of which is a small body in space. The term *meteor* is applied to any streak of light in the upper atmosphere that is produced by a small body when it enters from space. They are more commonly referred to as shooting stars. Efforts have been made to predict and record the occurrence of the most impressive phenomena, and there is wide interest in observing them among both scientists and laypeople.

Meteorites are natural bodies that have managed to travel through the atmosphere to land on the surface of the earth. To accomplish this, they must normally be large and dense enough so that they don't crumble into fragments or vaporize completely. They are of great scientific interest because they provide an opportunity to examine extraterrestrial material older than any material found on earth. Whereas many of earth's early rocks have been destroyed by natural geologic processes, meteorites have remained unchanged since the birth of the solar system. It is now generally accepted that research to determine the age of the materials in meteorites will very likely help us to determine the age of our planet.

Knowledge about and attitudes toward meteorites have undergone significant change through the centuries. There is evidence that many ancient people did accept meteorites as heavenly bodies. Both meteors and meteorites inspired a variety of myths and folk beliefs, with the element of superstition emerging prominently during the medieval period. During the 17th and most of the 18th centuries, the possibility that meteorites had originated from beyond the earth was not even considered.

The last decade of the 18th century marked a distinct forward movement in the scientific study of meteorites. Luckily, witnesses were present when several thousand meteorites fell near L'Aigle in northern France. In 1794, Ernst Chladni, a German physicist, published a book asserting that bodies of rock and metal actually do fall from the sky. He is now considered the founder of the study of meteoristics.

From that time on, museums and interested individuals began collecting samples, making further research possible. At present there are around 1,000 samples available for scientific study. The earliest known meteorite still available for study fell near the village of Ensisheim in the province of Alsace in 1492.

Some specific scientific observations still lagged behind. It wasn't until the 1930s and 1940s that scientists concluded that some craters had originally been formed by the impact of meteorites.

Chrondites represent the most primitive kind of meteorite, making up about 80% of the total. They appear to have been formed with the same substances as the earth and other planets. Their composition is also very similar to that of the sun, with the exception that the sun also contains large amounts of hydrogen, helium, and other noble gases.

In the 1950s, Clair Patterson, of the California Institute of Technology, began the process of dating chrondites by a radiometric process that made use of a uranium-lead clock. He found their age to be 4.55 billion years, and the range of 4.5 to 4.7 billion years has been corroborated by five different radiometric dating methods. The basis for all of these methods has been the measurement of the radioactive decay that has occurred. About 70 meteorites have now been accurately dated. Radiometric dating has also been used to determine ages of many other subjects, including the earth, the moon, fossils, early humans, and a variety of geological events.

Comparing chrondites with rocks that appeared to have originated on earth, Patterson found a similar composition of lead isotopes. A logical conclusion is that both may have been formed when silicates condensed from the sun's nebula. It has also been concluded that the universe may be as old as 14 to 17 billion years.

Scientists now generally believe that most meteorites are pieces broken off when asteroids—or minor planets—collided. Asteroids themselves are large chunks of debris that circle the sun in the belt between Mars and Jupiter's orbits. Like the earth, these meteorites are composed mostly of silicates and metals. A few rare meteorite samples may have come from Mars or the moon, probably as the result of a crater being formed by another body impacting those surfaces.

In the 1980s, sediments from around the world were examined and found to contain chemicals of the same age. That suggested that a large body had slammed into the earth approximately 65 million years earlier. It is even possible that our moon might have been formed as the result of a collision between the earth and a body about the size of Mars.

It is estimated that about 30,000 meteorites with a mass larger than 3.5 ounces fall to the earth each year. They are classified by the amount of silicate and nickel-iron that they contain and fall into the three broad categories of irons, stones, and stony irons.

Meteorites are classified as falls or finds, and each is given a name that is usually based on the geographical area in which it fell. To be classified as a fall, the event must be witnessed. Because meteorites usually signal their arrival by a light display and a variety of sounds, it is not surprising that some are observed at the time of impact. Reporting of these events can allow scientific study to begin soon after the event. The largest recorded fall occurred in 1976, in Jilin, Manchuria. The total weight of its pieces was 2 metric tons.

The term *finds* applies to those that are discovered by accident and subsequently identified by the chemical and mineral content or their structure. The largest known meteorite find is the African Hoba meteorite, weighing approximately 66 tons.

The study of known meteorites is expected to reveal even more information about the solar system. The search for meteorites that are yet to be discovered will be ongoing. Two challenges that have been recognized are the need to search in the comparatively neglected desert areas and the need to identify very small meteorites.

Betty A. Gard

See also Comets; Dinosaurs; Extinction and Evolution; Extinctions, Mass; Geology; Nuclear Winter; Paleontology

Further Readings

Bevan, A., & De Laeter, J. (2002). *Meteorites: A journey through time and space.* Washington, DC: Smithsonian Institution Press in association with University of New South Wales Press.

Norton, O. R. (2002). *The Cambridge encyclopedia of meteorites.* New York: Cambridge University Press.

Zandra, B., & Rotaru, M. (2001). *Meteorites: Their impact on science and history.* Cambridge, UK: Cambridge University Press.

Methuselah

The epitome of an extended life span lies in the biblical tale of Methuselah or Metushélach (מְתוּשֶׁלַח / מְתוּשָׁלַח), the longest living Hebrew patriarch. Humankind's quest toward great longevity has been a common mission throughout the generations. From scrutinizing ancient texts to the exploration of advancing modern sciences humankind has endlessly sought a proverbial fountain of youth.

Methuselah is credited with having lived 969 years, making him the oldest person in recorded history, yet little else is stated. He is mentioned in Luke 3:37 (King James Version) when tracing Jesus of Nazareth's lineage and is noted as being the father of Lamech, Noah's father, in Genesis 5:25–27:

> And Methuselah lived an hundred eighty and seven years, and begat Lamech. And Methuselah lived after he begat Lamech seven hundred eighty and two years, and begat sons and daughters: And all the days of Methuselah were nine hundred sixty and nine years: and he died.

In the year of the Great Flood, or the Deluge, he eventually died.

> As long as Methuselah lived, the Flood did not come upon the world. And when Methuselah died, it was withheld for another seven days after his death to fulfill the period of mourning. (Avot d'Rabbi Natan 32:1)

The direct etymology of the word *Methuselah* is "his death shall bring"; this translation comes from the roots *mûth,* meaning "death," and *shelach,* meaning "to send forth." Based on the etymological translation, the year of his death, and his remarkable age, Methuselah has often been cited as an allegory in which God withheld judgment upon humankind for a great period of time.

Some scholars, however, dispute Methuselah's age and theorize that it is in fact merely an error resulting from mistranslations of text and loss of documentation through the ages. Within several early biblical texts, the numbers were written in an archaic, precuneiform Sumerian number system in which the decimal is placed differently than in latter Sumerian number systems. Their theory is that in the year 1700 BCE the scriptures were initially mistranslated into a later Sumerian system and then mistranslated again in 550 BCE when compiling the Hebrew Genesis 5.

Another theory speculates that certain dates are based on a standard using lunar instead of solar cycles. This theory would convert Methuselah's age upon death to 87, and to 15 when he fathered Lamech. However, this lunar theory also has met with skepticism, because it results in other patriarchs, such as Enoch and Mahalel, being merely 5 years old when they fathered their own children.

Other scholars have accepted Methuselah's remarkable age as fact, yet have speculated how such a prolonged age was once feasible. Numerous theologians hypothesize that human life expectancy was shortened due to humankind's falling from God's grace. This credence is marked by the biblical examples of Adam, Methuselah, and Moses. Adam marks the end of possible immortality, Methuselah marks humankind's potential life span preflood, and Moses sets the modern standard of 120 years. A recent theory as to why Methuselah lived to be nearly a millennium old is that the human gene pool experienced a massive bottleneck at the Great Flood. This theory speculates that a drastic loss in population, caused by events such as the Deluge, would result in small gene diversity and a loss of certain inherited gene qualities. This could have resulted in the trait for longevity to be lost or hidden deep within our genetic code. Currently, numerous scientific efforts, such as the Human Genome Project and the Methuselah Mouse Prize, are striving to discover the secrets of increased longevity.

Derik Kane

See also Adam, Creation of; Bible and Time; Genesis, Book of; Longevity; Moses; Noah

Further Readings

Best, R. (1999). *Noah's ark and the Ziusudra epic.* Fort Myers, FL: Enlil Press.

The Holy Bible (King James version). (1999). New York: American Bible Society.

Wieland, C. (1998). Living for 900 years. *Creation Magazine, 20*(4), 10–13.

MICHELANGELO BUONARROTI (1475–1564)

Michelangelo di Lodovico Buonarroti Simoni is universally recognized as one of the greatest artists in history, perhaps the greatest. He excelled as a sculptor, painter, architect, and poet of the Italian High Renaissance. During his long life, Michelangelo created some of the world's most recognizable works of art.

Mastery in a variety of skills has earned Michelangelo the title of *Renaissance man*. He rivaled his fellow Florentine, Leonardo da Vinci, as the embodiment of this role. His most famous sculptures include the *David* in Florence and the *Pietá* in Rome. Although Michelangelo claimed that he did not enjoy painting, he created many remarkable works, most famously the series of panels containing more than 300 figures depicting the Creation, the downfall of man, and the promise of salvation—the entire core of Christian doctrine—on the ceiling of the Sistine Chapel in the Vatican. Michelangelo also designed the dome of Saint Peter's Basilica, which remains the largest dome of any church in the world.

An intensely spiritual man, Michelangelo focused on biblical themes throughout much of his work. He was deeply concerned with the notion of time, depicting such scenes as God's Creation of man and the universe. His fresco *The Last Judgment* portrays the future of humankind, as based on scenes described in Dante's *Divine Comedy.*

Michelangelo Buonarroti was born to a Florentine family in the village of Caprese, Italy, on March 6, 1475. He demonstrated great talent as a painter at an early age while apprenticed to Domenico Ghirlandaio. He studied sculpture under the guidance of Bertoldo di Giovanni and was soon commissioned by the foremost family in Florence, the Medici. Following a brief fall from power of the Medici in 1596, Michelangelo fled to Rome. There at the age of 23 he completed the *Pietá* that now stands in Saint Peter's Basilica in Rome. He returned to Florence between 1501 and 1504, where he met Leonardo da Vinci; the two artists were temperamentally very different and did not become friends. During this time he carved the famous statue *David.*

In 1505 Michelangelo again traveled to Rome on invitation from Pope Julius II, a patron of the arts. Michelangelo reluctantly accepted the commission to paint the ceiling of the Sistine Chapel in the Vatican, a project that would require heroic effort and consume years of his life. This highly renowned work includes masterful depictions of the most significant events from the Old and New Testaments of the Bible. Michelangelo also carved the tomb of Julius II, which includes a powerful statue of Moses. He returned to Florence in 1515 to design the Medici Chapel containing the tombs of Medici princes. These tombs include carved allegories representing day, dawn, dusk, and night.

Michelangelo again returned to Rome in 1534 in a period of political turbulence when Florence ceased to be a republic. Commissioned by Pope Paul III, he painted *The Last Judgment,* in which the souls of humankind either ascend to paradise or are cast into the inferno. In 1546 the pope appointed Michelangelo chief architect of Saint Peter's Basilica in Rome, where he began supervising the construction of its dome. Unfortunately, he did not live to see the dome completed. Michelangelo died on February 18, 1564, at the age of 89, and was buried in Florence.

James P. Bonanno

See also Adam, Creation of; Dali, Salvador; Genesis, Book of; Last Judgment; Moses; Noah

Further Readings

Bull, G. (1995). *Michelangelo: A biography.* London: Viking.

Grimm, H. (1896). *Life of Michelangelo* (F. E. Bunnett, Trans.). Boston: Little, Brown.

Hughes, A. (1997). *Michelangelo*. London: Phaidon Press.

MIGRATIONS

Migration can be defined as a total or partial change of location (habitat) and/or movement into new areas for a certain period of time or forever. The term *migration* is widely applied in social and human sciences as well as in biology, geophysics, astronomy, and computer sciences with reference to plants and animals, fish and birds, insects and cells, planets, systems, and data.

In contemporary social and human sciences, migration interpreted as population displacement (translocation) usually is viewed as one of the four basic genres of human activity along with habitation, storage, and creation. The term *migration* is an integral part of the professional terminology of contemporary archaeologists, ethnologists, sociologists, demographers, cultural anthropologists, and geographers. The sphere of its application and meaning seem to be so clear that some reference books consider definition and interpretation of this concept unnecessary.

Nevertheless more careful analysis of the application of the term *migration* indicates that this concept is often applied to processes as they vary along spatial and chronological scales, as well as in their ecological, economic, ethnic, and social consequences.

Migration in Social and Human Sciences

The concept of migration applies to studies of displacements of population (group and individual movements) as well as to dispersion of created artifacts and culture in general. Sometimes anthropological and other data indicate that culture transmission does not accompany its human substrate displacement; in such a case migration of ideas is assumed.

The possibility of culture migration was widely discussed in cultural anthropology at the beginning of the 20th century in the context of several schools and theories of diffusion. The notion of cultural diffusion, understood as spatial transference of cultural phenomena, was put forward by them; human history was interpreted as a series of cultural clashes, adoptions, and transfers. Long-distance contacts, such as international trade and exchange, conquests, and conscious imitation were regarded as basic ways by which certain cultural phenomena and/or artifacts could surmount considerable distances from the point of their primary origin.

The origin and rapid upsurge of genetics during the second half of the 20th century provided the possibility of verifying a hypothesis about the translocation of ideas and artifacts without human displacement; this could be done by comparing the genetic makeups of human populations in certain areas. Such DNA spatial distribution studies, brilliantly developed by Luigi Cavalli-Sforza at the beginning of the 21st century, have resulted in a series of gene-flow theories that have brought studies of human migrations taken in historical perspective to a higher level.

Migrations in Human History

Purposeful changes of habitat were inherent to human beings since the very origins of the species. Human dispersion over the Old World in contemporary prehistoric sciences is interpreted as a result of migrations of early hominids and early human beings. Colonization of the New World and the European North happened at the end of the Pleistocene—at the beginning of the Holocene ias the next important example of large-scale migrations in prehistory. Human migrations often are regarded as the driving forces of agricultural dispersion in the Old World as well as the basic mechanism of Indo-European language origin and dissemination.

The origin of nomads and the formation of the nomadic mode of subsistence, strategy, and cultural morphology, as illustrated by Cimmerians, Scythians, Sarmatians, and other nomadic communities of the early Iron Age, is the next phase of human history connected with migrations. The period between 500 and 700 CE, traditionally called the Migration

Period, was characterized by barbarian invasions all over Europe and was marked by the collapse of ancient world empires and a transition to a new, early feudal phase of human history.

Human migrations of medieval times—the Muslim conquest (the Arab migration across Asia, Europe, and Africa between 632 and 732 CE); the Turkic migration across the Middle East, Europe, and Asia (between the 6th and 11th centuries CE); the long-distance migrations of Mongol and Turkic tribes over eastern and central Europe (between the 12th and 14th centuries CE); the Ostiedlung (movement of German tribes to eastern Europe); and others—in most cases were caused by the necessity of modern ethnic and political structures to find their proper places in the early medieval community. Hence these displacements usually are mentioned among the crucial factors of the reshaping of medieval political structures (early and centralized states and empires), often accompanied by the origin of modern nations and the creation of the contemporary ethnopolitical map, which is well traced over Europe even today. These displacements also are associated with the formation of basic principles of modern geopolitics.

The era of discoveries and the Age of Exploration showed most Europeans the impressive economic potential of newly opened and intensively explored territories (e.g., America, Australia, eastern Asia, Siberia), and so the economic aspect of human migration became its dominant motivation.

The modern era has brought new impact into human migrations, connected, first of all, with displays of religious background of human migration (the great Puritan migration from England to North America in the mid-17th century, the great Serb migration from the territory of the Ottoman Empire to the domain of the Habsburg monarchy from the end of 17th to the middle of the 18th centuries). In addition, the migrations of the age of imperialism and industrialization were motivated by the necessity to improve the quality of life through finding new workplaces and trade opportunities (transatlantic migration of Europeans to North and South America, the mass migration of African Americans out of the southern United States during the first half of the 20th century, exploration of eastern and southern Asia).

World War II and the following cold war demonstrated the importance of the political and ideological background of human migrations based on necessity of free self-identification and self-expression.The contemporary trend in the direction and motivation for human migrations resulted from the the fall of the iron curtain, the end of the cold war, and the economic problems of the developing postsocialist and so-called third world countries of Asia and Africa.

Problem of Causes and Motivation, Diversity of Forms and Cultural Consequences

Migrations have been one of the basic forms of human activity since the origin of humankind, and since that time reasons, backgrounds, and motivation of human displacement have continued to change in accordance with priorities and emphases of human culture and the development of various livelihoods. In contemporary social science, the problem of migration's causes and motivation usually is conceptualized through a system of "push and pull" factors mediated by "barriers and obstacles." Among the most influential push factors, one can distinguish among the restriction of subsistence resources (work shortage, low trade opportunities, low income), threats to human life (environmental disasters, poor medical care, insecurity, armed conflicts), the impossibility of free displays of political, ethnic, and religious self-identification, and restrictions on emotional life, family links, and education. Pull factors, in contrast, provide the possibility to overcome the restrictions imposed by push factors, and to change living conditions for the better.

The concept of human migration currently is applied to a rather wide variety of forms of human displacement that differ by their positions in space and time, by their mode of their personification, and by their motivation—whether migrators travel of their own free will or based on coercion.

Personification of Human Migration: Group and Individual Displacements

Defining the factors underlying instances of migration shows the diversity of its forms and genres; here the opposition of the individual versus the group character of migration is especially acute. History shows examples when translocations of individuals of separate families were the first steps of large group migrations, waves of which involved sometimes the population of the whole administrative unit (immigration to the United States). The opposite has also occurred; in the past one can find situations when a first impressive wave of group colonization was followed only by separate individuals or was not supported at all (primary colonization of Australia).

Detection of the social, ethnic, political, religious, economic, or other background of migrant groups' formation currently is at the center of the fields of demography, cultural geography, and cultural anthropology as well as of other social sciences dealing with the causes that force people to leave their dwelling place and search for another, more suitable one. Environmental and geographic parameters of primary living space were the agencies of principal importance in prehistoric and preindustrial societies, while in the contemporary world these have yielded to sociopolitical agencies.

Infiltration is a peculiar form of small-scale group migration that implies movements (often secret ones) of a restricted number of participants within a restricted time and chronological span. Usually infiltrations take place at the stage when a group is choosing its destination. Also this term could refer to attempts of small groups to cross a state border or guarded space illegally (contemporary Palestinian border infiltration).

Human Migration Distance Scale: Colonizations and Relocations

The geographic and spatial dimension of migrations is another factor giving rise to diverse forms of this process as well as to the variety of its sociocultural implications and consequences. One can distinguish long-distance movements (or colonization) and comparatively rapid movements (or relocation).

Colonization is regarded as durable and in most cases long-distance and repeated (wave) movements of human collectives (never individuals) to previously empty (i.e., unsettled by human beings) places. Their earliest examples in human history are the exodus of *Homo habilis* and *Homo erectus* (the first representatives of the genus *Homo*) from Africa, which happened at the beginning of the Pleistocene. Primary colonizations of America and Australia happened at the end of the glacial period and are regarded as the traditional examples of Upper Palaeolithic (i.e., earliest realized by anatomically modern humans) migrations of such a type. The times of glacial retreat and during the Holocene period had comparable results in the colonization of northern Europe: the Baltic region, Scandinavia, Greenland, and so on. Further colonization processes were directed toward mastering free niches in areas already more or less intensively explored.

The general tendency and intensity of colonization processes, as well as their typical undulating, multistage, and multilevel character, opens the possibility of interpreting them as phenomena with not only historical, cultural, ethnic, and economic consequences but also geographic and ecological consequences. In such a context, colonization is one of the basic features of general human evolution that causes a long-lasting effect on the landscape structure of human natural habitats.

Relocations are regarded as relatively strictly defined in time, isolated changes of habitat realized by a group or by individuals with a particular purpose. This category covers the overwhelming majority of all known historical and contemporary migration cases. Even at first glance one can distinguish at least two sorts of relocation: (1) transmigration, or population displacements that significantly enlarge or totally change the habitat of a particular group, and (2) movements of individuals or human groups of a different genre (social, gender, cultural, ethnic, professional, etc.) within their traditional living space.

Transmigration is more likely to be the means of preserving a group's culture in new territory but in the same ecological situation; in the case of oncoming movements, it is obviously one of the forms of ethnic contacts.

The Timescale of Human Migration

In accordance with the period during which human translocation takes place, it is possible to distinguish daily, episodic, seasonal, cyclic, and pendulous migrations and population movements with long-lasting consequences, or irretrievable migrations.

Daily migration implies traveling between residence places and working places, usually marked by the notion of "daily commuting" or "pendulous migrations." Daily migrations could be long distance (especially in hunter-gatherer societies and, sometimes, in contemporary highly urbanized areas and megalopolises), but in most cases transportation time does not exceed working time. This form of migration is practiced by the majority of the contemporary population and currently is showing a gradual but stable tendency of proportional growth.

The notion of *episodic migration* is used to define business, recreation, shopping, and other trips realized from one center of permanent or semipermanent occupation; such translocations usually are irregular and could engage different routes and paths as well as differ in their spatial scales.

Seasonal and cyclic migrations are practiced mainly by the able-bodied population moving to their temporary working places (often seasonal ones). Such translocations usually cover several months and include the possibility of return to migrants' permanent residential place. Cyclic migration recurrence can be related to employment (e.g., military service, seasonal agricultural jobs) or to peculiarities of economic cycles, which, in turn, usually are geographically and/or environmentally determined (as in the cases of horizontal migrations inherent to nomadic pastoral farming and of vertical migrations in other social groups"). Rural-urban and urban-rural migration also could be regarded as a special case of cyclic migration. In the case of cyclic migration, usually only part of a social group is moving, while the rest of the population (mostly women, children, and the aged) remains at the permanent or semipermanent living place.

Migration with long-lasting consequences, sometimes called irrevocable migration, usually involves long-distance movements and is accompanied by total changes of permanent residence of individuals or a certain group as a whole. In most cases such migration is external and stipulates dislocation not only between administrative units, but also between countries. In the case of colonization, irrevocable migration is the only source of permanent residents in newly explored territories. If displacement is directed to already inhabited and actively explored regions, most widespread forms of migration with long-lasting consequences are emigration, or leaving one's native country to live in another, and immigration, or coming to a foreign country to live. Neither of these last forms of migration could be declared irrevocable as far as durability of their consequences depends on people's free will and the coercive actions of authorities in their former and new countries.

Human Migration as an Act of Free Will Versus a Coercive Action

In the contemporary world, migration flows tend to be regulated by separate countries' authorities and are also subject to international legislation. In the context of the political realities and international relations of the second half of the 20th century and the beginning of the 21st century, a series of human migrations resulting from coercive actions of national governments (forced migration) can be distinguished. These include *deportation,* or coercive expulsion imposed on foreign citizens or individuals without citizenship; *repatriation,* or forced return to the home country of citizens who due to different (mostly unfriendly) circumstances have appeared on the territory of other countries; and *expatriation,* or eviction from the native country usually accompanied by denaturalization.

In contrast to migrations resulting from coercive actions of national governments and international institutions, some forms of human migrations could be regarded as acts of migrants' own free will. Thus, *re-emigration,* akin to repatriation, is realized mostly on the basis of conscious choice and maintained by international legislative acts, such as the Geneva Convention on victims of war. Expatriation also could be the conscious act of protest against certain actions of the native country. All forms of *illegal migration* are derived exclusively from the free will of migrants; nevertheless this free will usually has a fundamentally sociopolitical, economic, or religious background. *Chain migration,* widely applied in the contemporary immigration policy of the United States, allows foreign citizens to naturalize in the country on the basis of the acquired citizenship of their adult relative. The idea of migrants' free will expressed in their displacements is the basis of the concept of *free* or *open migration* with its emphasis on people's freedom to move to whatever country they choose as most preferable for their self-realization. *Brain drain,* or emigration of highly qualified professionals in the field of fundamental and applied sciences and hi-tech, could be regarded as a special case of free migration.

Olena V. Smyntyna

See also Anthropology; Archaeology; Ecology; Economics; Evolution, Cultural; Evolution, Social; Harris, Marvin; Shakespeare's Sonnets; White, Leslie A.

Further Readings

Anthony, D. (1990). Migration in archaeology: The baby and the bathwater. *American Anthropologist, 92,* 895–914.

Appleyard, R. T., & Stahl, C. (Eds.). (1988). *International migration today.* Paris: UNESCO; Nedlands, Western Australia: University of Western Australia, Centre for Migration and Development Studies.

Brettell, C. B., & Hollifield, J. (Eds.). (2000). *Migration theory: Talking across disciplines.* London: Routledge.

Cavalli-Sforza, L. L., Menozzi, P., & Piazza, A. (1994). *The history and geography of human genes.* Princeton, NJ: Princeton University Press.

International migration outlook: Annual report. (2007). Paris: Organisation for Economic Co-operation and Development.

Milton, John (1608–1674)

John Milton was an English poet and political critic, celebrated for his epic poem *Paradise Lost* (1667). In it he deals with the biblical account of Creation and the place of humankind in time. Total blindness late in life forced Milton to write this poem and others through dictation.

Milton was a devout Puritan with a deep interest in the Bible. His writing often deals with religious themes. His masterwork, *Paradise Lost,* is an immense poem in 12 books. It describes God's Creation of Adam and Eve in the Garden of Eden and their subsequent fall and expulsion. The poem describes the biblical story of Creation of the earth and the universe as well as of hell and the emergence of the devil (Lucifer). The devil is given a prominent role in Milton's poem, characterized as an overly ambitious angel banished from heaven. The timeless struggle between God and the devil, or good versus evil, is a major theme in the poem. Eve notoriously yields to the devil's temptations, resulting in the loss of paradise for humanity. Milton also argues for the doctrines of predestination and salvation.

John Milton was born in London on December 9, 1608. He attended Christ's College, Cambridge, from which he graduated with a master of arts degree in 1632. He demonstrated an interest and ability in writing poetry while a student. Following graduation from college, Milton retreated to his family's summer home in Horton and devoted six years to private study and poetry. His works from this period include *Comus* (1634), a masque, and *Lycidas* (1637), written to commemorate the death of a close friend. In 1638 Milton left Horton to take a tour of Europe, meeting the astronomer Galileo Galilei in Florence. He returned to England during the civil war to write political pamphlets defending the Puritan cause. These include *The Tenure of Kings and Magistrates* (1649), which argues that the people have the right to remove a tyrant from power. The Puritans won the civil war, and King Charles I was beheaded.

Milton was married three times. The unhappiness of his first marriage led him to write *The Doctrine of Discipline and Divorce* (1643). He wrote *Areopagitica* the following year in defense of the freedom of speech. The government of Oliver Cromwell appointed Milton to the post of secretary of foreign tongues, where he oversaw the translation of dispatches into Latin. In 1652 Milton suffered a permanent loss of his eyesight. Thereafter his work had to be dictated to an assistant. In spite of this challenge, Milton's final years were highly productive. He published *Samson Agonistes* and *Paradise Regained* in 1671. *Paradise Regained* deals with the future of humankind. These and Milton's other works have had a lasting impact on world literature and have influenced artists and writers for more than 400 years.

James P. Bonanno

See also Alighieri, Dante; Bible and Time; Genesis, Book of; God as Creator; Last Judgment; Poetry; Satan and Time

Further Readings

Levi, P. (1997). *Eden renewed: The public and private life of John Milton.* New York: St. Martin's Press.
Lewalski, B. K. (2000). *The life of John Milton: A critical biography.* Oxford, UK: Blackwell.
Parker, W. R. (1968). *Milton: A biography.* Oxford, UK: Clarendon Press.

Moon, Age of

The moon, a natural satellite of the earth, was formed at approximately the same time as the earth, roughly 4.6 billion years ago. The origin of the moon remains the subject of debate; differing theories have been advanced, each with its merits and defects. Scientists have created a lunar geological timescale and used radiometric dating methods to aid in estimating the age of the moon.

Theories explaining the formation of the moon include the fission theory, capture theory, cocreation, and collision-ejection theory. The fission theory states the moon was a piece of the earth that broke away in an early stage of the planet's development. The circumstances for this event to have occurred are considered somewhat implausible.

The capture theory states that the moon was an asteroid, or another similar spatial entity, that was pulled into orbit by the gravitational field of the earth. This theory is improbable given the size of the moon and the gravitational force needed to trap it.

The cocreation theory states the moon accumulated from the debris orbiting the earth as it, too, was forming. This theory succeeds in explaining the similar ages of the two bodies, but it fails to explain the difference in composition between the Earth and the moon.

The collision-ejection theory is the favored theory; it combines aspects of the different theories into one unified theory. It theorizes that an asteroid, possibly the size of Mars, collided with the earth, ejecting debris from both bodies and merging the fragments into one. The fragments fused over time while captured in an orbit around the earth. This theory is fairly consistent with the known facts about the moon.

The moon has its own geologic timescale consisting of five periods. Unlike the earth's geologic timescale, there are no subdivisions of these periods due to the insufficient amount of information available. Two of the major reasons for this lack of information are the limited accessibility of the moon and the nonexistence of fossils, which helped to detail the geological timescale of the Earth. A lot of what we know about the moon is through distant observations and rock samples returned from numerous lunar missions.

Using relative and radiometric dating methods, scientists have been able to determine that the moon sustained a period of bombardments after the surface solidified. This accounts for the vast number of craters across the moon's highlands. Toward the end of this period, known as the Nectarian period, asteroids 100 kilometers in diameter collided with the moon, leaving enormous craters. These craters were later filled with basaltic lava during the next 500 million years, also known as the Imbrian period. Early earthbound observers believed these lava-filled craters, long since solidified, to be large bodies of water and dubbed them *maria,* or seas.

Scientists tested the rock samples from lunar missions using radiometric dating methods. The age of these rocks varies between samples from the older highlands and the younger maria. The samples range from 3 to 4.5 billion years old. The older rocks confirm that the moon was formed when the earth was in a primordial state.

Mat T. Wilson

See also Earth, Age of; Eclipses; Moon, Phases of; Nebular Hypothesis; Satellites, Artificial and Natural; Universe, Age of

Further Readings

Dalrymple, G. B. (2004). *Ancient earth, ancient sky: The age of earth and its cosmic surroundings.* Palo Alto, CA: Stanford University Press.
Nicolson, I. (1999). *Unfolding our universe.* Cambridge, UK: Cambridge University Press.

Moon, Phases of

The phases of the moon have played an important role in the determination of time. The word *month* is directly derived from the word *moon.*

Traditionally, one month was equivalent to one revolution of the moon around the earth. As the moon orbits the earth, the visible reflective portion (called the lunar disk) seen from the earth varies in predictable patterns. At the beginning of the cycle, the moon is a very thin crescent that increases in size within hours. Because the full cycle of the moon is not exactly 28 days, a day-length based on the rising and setting of the moon results in inconsistent solar positions during the daytime.

Lunar Calendars

A lunar calendar is divided into even periods between phases. In using a lunar calendar, for example, the solstices and equinoxes are never the same. This calendar, utilized by the Greeks, was devised by the philosopher Metones of Athens and bears his name as the Metonic cycle. The Metonic cycle is equivalent to 19 solar years or approximately 235 lunar months. The lunar calendar was eventually abandoned, as it never remained evenly synchronized with the annual solar cycle. The Romans devised their own solar calendar to replace the Metonic calendar.

Lunar Phases

Lunar phasing is the visible change in the daily appearance as the moon orbits the earth. There are four major phases: new, first quarter, full, and third quarter. Additionally, the moon passes through phases as it rotates on its own axis. In modern times, the new moon occurs when the moon is positioned relatively between the sun and the earth. Because the moon orbits the earth at an inclined angle with respect to the earth's revolution around the sun, the moon is not always in a direct line between the sun and the earth (see Figure 1). Occasionally, a solar eclipse occurs when the moon does get into direct position, and the moon's shadow darkens the daytime skies of earthbound observers. At the new moon, the lunar age is zero days. Lunar age is defined as the number of days from the last new moon.

New Moon to First Quarter

As the cycle progresses, the lunar disk continues to gain luminescence (wax), and a crescent shape appears to the right of the lunar face. This stage is known as the waxing crescent and continues for approximately 7 days. To the observer, the moon shifts approximately 12° per day, an effect that causes the moon to rise 48 minutes earlier each day as it lengthens an apparent gap between itself and the sun. Occasionally, when atmospheric conditions are met, the darkened portion of the lunar disk can be seen as a very dull, gray feature in contrast to the illuminated area. This effect, called earthshine, is caused by the reflection of direct sunlight from the earth projected onto the moon (see Figure 2). Earthshine is best viewed when local weather conditions are clear, and the relative humidity is low. Another factor of waxing earthshine magnitude is cloud cover over a location westward of the observer. Clouds reflect more sunlight than land and water reflect.

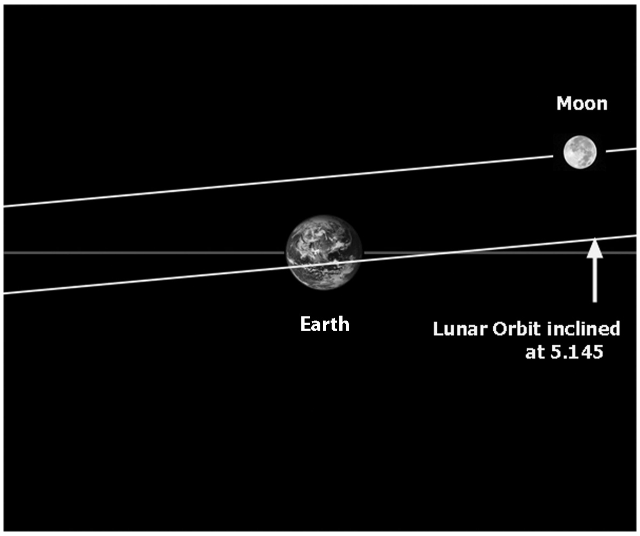


Figure 1 The moon's inclination to the Earth's orbit

Notes: Distances and diameters are not drawn to scale. The visible inclination is drawn to scale.

First Quarter to Full Moon

At the age of 7 days, the moon reaches a relative right angle with the sun and the earth (earth at the apex); the right half of the lunar disk is visible to the terrestrial observer. This phase is the first quarter, and the term quarter refers to two aspects. First, the moon has completed one quarter of its revolutionary period, and second only one quarter of the lunar sphere is visible. At this location, the

Figure 2 Earthshine on the lunar surface

Source: James P. Collins, reproduced with permission.

Note: The lunar cycle in this photo is 2.5 days old.

moon is exactly 90° east of the sun. Once the moment of the first quarter has passed, the moon continues to wax; yet, the crescent shape appears on the left, unlit portion of the lunar disk. This stage is a gibbous stage; therefore, the term *waxing gibbous* is used to describe the luminescent increase from the first quarter. This process continues for 7 days, after which time the moon gets to the halfway point in its revolution.

Full Moon to Third Quarter

The full moon occurs when the entire lunar disk is illuminated at an age of 14 days. Although it is not widely known, the full moon is technically considered second quarter phase. Throughout history, we have applied the term *full moon* to the visible portion of the lunar disk. However, this is a misnomer, as in reality the moon is a sphere, not a disk, so only half the lunar sphere is truly reflecting the sun's light. At this point, given the right circumstances on the inclined lunar orbit, we can see the moon passing into the shadow of the earth, resulting in a lunar eclipse. Lunar eclipses are much more common than solar eclipses due to the earth casting a bigger shadow over the moon than the moon does over the earth.

From the moment of the full moon, lunar disk illumination begins to recede (wane). Marking the second half of its revolutionary motion, the crescent face of the moon is again on the darkened side; however, the darkened portion shifts to the right side of the moon. This stage is termed *waning gibbous*. During the current lunar cycle, 21 days has elapsed.

Third Quarter to New Moon

The moon forms another right angle with the earth and sun and has now reached the third (last) quarter phase. From earth, the left side of the moon is illuminated and is exactly 90° west of the solar position. As lunar disk recession proceeds, the crescent shape returns to the left side of the lunar disk, and the stage is called waning crescent. During this stage, earthshine is prominent again; however, the magnitude of the projection depends on what is eastward of the observer's location. Figure 3 depicts the entire lunar cycle from start to finish. As it completes the nearly 28-day cycle, the moon is visible in the early morning until it returns to its starting position between the earth and sun, at which point none of the lunar disk is visible, as it is lost in solar glare. The new moon, under the right conditions, will provide a solar eclipse on earth.

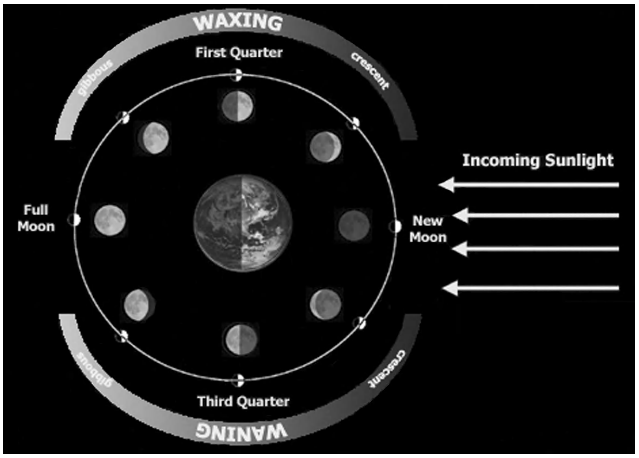


Figure 3 Complete lunar phasing diagram

Notes: As the moon orbits the earth, the sun illuminates half of the lunar sphere. Inside the lunar orbit is a photograph of the moon as seen on the observer's local meridian.

Period Lengths

The lunar sidereal period is one complete lunar cycle. It is equal to 27.321661 days, or the time needed for the moon to revolve around the earth. However, as the moon moves around the earth, the earth is moving around the sun. Observationally, it takes time for the moon to return to the local meridian over its orbital period around the earth. The earth has proceeded in its own orbit, and as a result, the terrestrial observer's moon has not quite reached the same location. When it does, it will have completed one lunar synodic period, which is equivalent to 29.53 days.

During the course of a lunar cycle, the positions of the craters tend to change slightly. Lunar libration is the apparent wobble of the moon as it revolves around the earth caused by the difference in inclination between the earth and moon, the shape of the moon's orbit, and the effect of the earth rotating, creating a parallax shift from the observer's perspective. Although the moon's daily rotation is locked to the terrestrial rotation, these factors result in approximately 10% more surface feature visibility. Time-lapse photography of all the lunar phases results in a slight shift in the daily positioning of lunar features such as craters, mountain ranges, and lunar maria or seas.

Timothy D. Collins

See also Calendar, Gregorian; Calendar, Julian; Earth, Revolution of; Eclipses; Moon, Age of; Seasons, Change of; Time, Measurements of

Further Readings

Cadogan, P. H. (1981). *The moon.* New York: Cambridge University Press.

Guest, J. (1971). *The earth and its satellite.* London: Hart-Davis.

Karttunen, H., Kroeger, P., Oja, H., Pouanen, M., & Donner, K. J. (2003). *Fundamental astronomy* (4th ed.). Berlin: Springer.

Morality

Broadly considered, morality encompasses all beliefs and practices associated with our concerns about humans and human conduct, along with all that we conceive or do to improve ourselves or others, all that we conceive or do to improve the world, and all that we conceive or do under the feeling that we must, should, or ought to, for any reason. It specifically includes all that we conceive and do, or don't do, either for or against what we think of as base, bad, evil, wicked, wrong, immoral, unjust, or cruel, by any name, whether in ourselves or in the world. It also includes our assessments of humans and their effects on the world, including assessments of human actions and human efforts, whether in gardening, governing, writing, dance, or sport. At this broadest level of description, almost all thought either is, or is importantly impacted by, moral thought. Given its emphasis on controlled or directed change, morality is implicated in every aspect, or almost every aspect, of our thinking about time.

Theory and Morality

Because it is otherwise too broad and unwieldy, most theorists restrict their conception of morality so that it encompasses only traditional practices and beliefs that are specifically concerned with human conduct toward persons. But even under this severe limitation, it still names a feature so general and pervasive that one cannot help but think of morality as fundamental to our lives, for nearly every greeting, parting, and discussion exhibits easily identifiable, traditional practices concerned with the well being of persons.

In the most remote reaches of theory, traditional expectations about conduct toward persons are encountered at every level. For example, in the sciences, where we expect to help one another find true statements, we also expect to be able to trust researchers to be honest about their findings. Intentional violations of these expectations about the conduct of colleagues have traditionally been severely dealt with. These dimensions of science as a moral enterprise are complemented by another, in which science is motivated by moral beliefs, such as the belief that science benefits humanity, or that its practice improves one's character. In the austere world of epistemology, morality is found in an ethics of belief formation, which proposes that it is wrong to form beliefs on the basis of inadequate evidence, not because the beliefs formed that way will be unreliable but because forming them that way is unethical.

Morality is also found in questions about the normativity, that is, the compulsory quality, of rules, rule-bound inference, and rational thought. Attempts to reduce epistemology to morality continue to receive many a hearing. Ethics, the branch of philosophy concerned with morality, has often been aided in its studies by metaphysics, the branch concerned with descriptions of reality. Together, they have produced centuries-long discussions about the nature and conceptual status of the self, obligation, value, evaluative judgment, pain, pleasure, envy, sympathy, privacy, freedom, conscience, justice, rights, acts, sin, redemption, and dozens of other morally charged items.

Questions about the spatial and temporal standing of these items are perennial sources of philosophical and theological lucubration. Is obligation extended in space? How, if at all, is it extended in time? Is the will temporally limited? Is sympathy? Is justice? The aging self and responsibility pose many a conundrum. At what point, if any, am I no longer liable for any one of the most minor moral lapses of my youth? And in what sense, if any, could I be responsible already for something I do in the future? If God is omniscient, and thus already knows what I will do tomorrow and every day after that, then am I really free? Doesn't an omniscient God entail a universe without free will and therefore without moral responsibility?

Among the more daunting problems arising for moral theorists who think about time is the problem of moral change. It is challenging merely to say what moral change is a change of. Shall we think in terms of changes in an individual's moral thinking, or that of a society? In both of these directions further questions await. Is it an alternation in conception? Rules? Judgment? Sentiment? Brain structure?

Consider a child who has moved from tolerance for the dismemberment of live grasshoppers to intolerance for it. An answer to the question of what has changed will determine how we explain it. If we think that he has altered his judgment, we might then imagine that he has learned a new rule, so that the set of moral rules he understands has grown by one. We might then hope to explain that acquisition environmentally. Perhaps an adult told him it was wrong or cruel. However, he might have long understood the rule that it is wrong to harm small creatures, but only recently began to conceive of grasshoppers as small rather than large creatures. In that case, his rule set remains the same, and the alteration of his judgment is based on a new way of classifying creatures. Thus, what needs to be explained is not a rule acquisition, but a new application of an old concept.

However, it is possible that his conceptions and rules have remained the same and the change we see is something else, such as a change in sentiment or taste. In that case, we might seek to explain his new attitude in developmental terms. Perhaps he has acquired sympathy for grasshoppers, or grown averse to the sight of struggling animals. This kind of change might then be explained in physiological terms, so that the child appears to acquire new attitudes because his brain is becoming more sophisticated. In this scenario, one will be tempted to conclude that moral changes in the child are not changes of judgment per se, but changes in something prior to and more fundamental than judgments that are in turn reflected in altered judgments.

The development of moral understanding in the individual might be studied by psychologists or biologists, while philosophers and historians are more likely to take an interest in social and cultural levels of description. At this more general level, the difficulties found in the individual case are multiplied and complicated, because a change at this level might involve more factors.

Moral Change

One may tackle the problem of collective moral change by tying the object of study to traditional judgments. At any given point in human history, there is a prevailing or traditional evaluation of typical, widely recognized practices, such as war, slavery, usury, monogamy, homosexuality, and cremation. At any other significantly distant point in human history, the prevailing traditional views of these same practices are likely to be very different as compared to those at the first. When the difference is plainly due to geography, or to a long temporal distance, we can speak of differing moral traditions. We can then restrict ourselves to speaking of moral change only when the difference is found in the same tradition at different times, and we can say that changes in prevailing traditional views are the moral changes we seek to study and explain. Although this is a simple and elegant first move, many difficulties await.

Consider a tradition that formerly disapproved of cremation but now shows a wide tolerance for it. Attempting to explain this change in traditional views will bring our system of thinking face to face with the fact that, as in the earlier case, these differing judgments might reflect a change in something more basic than judgments, such as rules, concepts, or sentiment. In addition, it could be that the alteration in reported judgments reflects a change in social or political conditions, such as an influx of cremation-favoring immigrants or the rise of a cremation-favoring regime. In the first case, demographics can account for the change in prevailing attitudes, while in the second, what we are proposing to treat as moral judgments might be nothing of the sort, because people might privately hold traditional anticremation views while tactfully compromising with the new authorities by publicly expressing only cremation tolerance. This possibility illustrates a difficulty in identifying moral views for study—when does a publicly expressed moral judgment express a moral belief, rather than tact, supererogatory good manners, or a fleeting taste?

Absolutism and Relativism

One means of avoiding all of these problems simply denies that there is any such thing as moral change. Moral absolutism is the thesis that there is only one moral standard that is universal, eternal, and static. Though the standard may remain undiscovered, it is not subject to change. Thus, for example, if slavery is in fact immoral, then it was always immoral, for all persons and at all times, regardless of the fact that it has been widely practiced and tolerated for many centuries and in many lands. For the absolutist, theorists of moral change study only the alterations of fickle human judgment, not morality as it is. That, they believe, never changes, and the problem of moral change is no problem at all, but a mistaken intellectual pursuit.

Ethical relativism, on the other hand, holds that moral standards depend on time and place and thus are subject to change as circumstances change. Morality as the absolutists describe it does not exist. What exists are human contrivances—rules, laws, agreements, conventions, knowledge, and expectations. For the relativist, the existence of morality implies a specific time and place. For the absolutist, it implies no particular human location at all.

Cognitivism and Noncognitivism

If all problems having to do with setting up the study of moral change could be handled, explanations of moral change would encounter further difficulties from the fact that moral beliefs, whether at the individual or cultural level, can be understood in either of two ways that are deeply incompatible.

One way emphasizes rational thought, while the other emphasizes nonrational, historical, or causal processes. The former method implies cognitivism, the view that moral judgments are the kinds of statements that can be either true or false, while the latter goes in the direction of noncognitivism, in which moral judgments, such as "cremation is an acceptable practice," are the kind of statements that cannot be either true or false. If moral beliefs are cognitive, then a decision to break with a traditional view in favor of a nontraditional one can, at least sometimes, be taken because the nontraditional view is or seems true, more plausible, more likely, or more probable on some moral ground. For example, duty might require that cremation be tolerated when duty is conceived as doing what is best for the health of the community, and cremation is discovered to be healthier than its alternatives. Or, where there is oppression of cremation supporters, a sense of justice might demand a more tolerant view of the practice wherever justice is taken to imply equal rights.

Causal and Normative Theories

If they are noncognitive, moral beliefs are held due to causal necessity and not for moral (or any other kind of) reasons. Many theorists account for moral change causally. The Marxist looks for economic forces to explain moral changes, the Freudian looks for psychosexual causes, and the postmodernist seeks underlying hegemonic powers. But all agree that moral beliefs are not held on the basis of moral insight, moral judgment, or morally based rational decisions of any kind.

In contrast to these causal theorists, normative theorists hold that moral changes are, at least in some cases, morally justifiable. If there are justifiable moral changes, it would be because the new attitudes reflect better normative insights or better moral reasoning or cognition. In holding that some moral changes can be morally justified, these views endorse the basic elements of a belief in the possibility of moral progress.

Normative theorists often search for rational grounds for holding to views different from prevailing or traditional moral views. The traditional view is likely to be held by most of the persons native to a given place and time. It is usually beneficial to hold the prevailing view, especially when we have no interests at stake. Nevertheless, rational insights might be capable of creating the conditions for disinterestedly accepting nontraditional moral beliefs. To begin with, one can become aware that norms in one area violate norms accepted in another area, rendering the tradition, which can be thought of as a body of practical knowledge, internally inconsistent. Perhaps the realization that abuse of pets is a felony, while the abuse of livestock is not, creates discomfort and prompts questions.

Other Conditions

In addition to inconsistency, general rules might prompt alternative moral views. For example, 19th-century Quakers strove for moral purity and clear conscience. On this basis they refused slave ownership due to its high likelihood of polluting the soul with unnecessary distresses of conscience. Meanwhile, knowledge of history and alternative traditions offer abundant examples of moral attitudes that contrast with those of our local tradition and can form a basis for criticism of it. A process based in this kind of reasoning appears, for example, when the ancient world's tolerance for homosexuality is employed to criticize less tolerant contemporary attitudes, or when attitudes toward a practice, such as prostitution, in a foreign tradition are appealed to in criticizing local attitudes. In the same way, knowledge of the Quaker attitude toward slavery could supply a moral example for non-Quaker critics of the practice.

Rationally justifiable alterations in traditional moral views might also be caused in part by a change in social conditions. John Langbein has argued that moral attitudes toward judicial torture evolved rapidly toward intolerance only after confessions ceased to be requirements for convictions in the most serious cases. Until this change in the law, moral criticisms of torture could gain little public footing. More recently, Lynn Avery Hunt has argued that the 18th-century appearance of the epistolary novel and the accompanying rise of portraiture allowed large numbers of people to grasp and to empathize with the subjective experiences of people very unlike themselves. On the basis of these new arts, talk of inalienable rights was able to move from the rarefied air of Enlightenment philosophy into the streets and, just as important, into the homes of the powerful.

Bryan Finken

See also Aristotle; Causality; Change; Cognition; Epistemology; Ethics; Evolution, Social; Globalization; God and Time; Humanism; Kant, Immanuel; Marx, Karl; Metaphysics; Postmodernism; Progress; Values and Time; Zeitgeist

Further Readings

Crane, R. S. (1934). Suggestions toward a genealogy of the "man of feeling." *English Literary History, 1,* 205–230.

Hunt, L. A. (2007). *Inventing human rights: A history.* New York: Norton.

Joyce, R. (2006). *The evolution of morality.* Cambridge: MIT Press.

Langbein, J. (1977). *Torture and the law of proof: Europe and England in the ancient regime.* Chicago: University of Chicago Press.

Noonan, J. (2006). *A church that can and cannot change: The development of Catholic moral teaching.* Notre Dame, IN: Notre Dame University Press.

Roberts, R. C., & Wood, W. J. (2007). *Intellectual virtues: An essay in regulative epistemology.* Oxford, UK: Oxford University Press.

Singer, P. (2002). *One world: The ethics of globalization.* New Haven, CT: Yale University Press.

Wallace, J. D. (1996). *Ethical norms, particular cases.* Ithaca, NY: Cornell University Press.

More, Saint Thomas (c. 1477–1535)

Thomas More, in former times also called Thomas Morus, was an English statesman, attorney, and author of humanism. More served as lord chancellor from 1529 to 1532. He was executed on the king's orders for refusing to accept the secession of the English Church under King Henry VIII from the Catholic Church of the papal Holy See. Today More is seen as an ideal of steadfastness in defense of morality and conviction, especially among Roman Catholics. More was declared Saint Thomas More in 1935; Pope John Paul II made him the "heavenly Patron of Statesmen and Politicians" in the year 2000. He is considered founder of the literary school of Utopia, picturing a vision of an ideal society.

More was born on February 7, 1477 or 1478, in London, the eldest son of the eminent and prosperous judge Sir John More. After attending St. Anthony's School and spending some time as a scholar with the lord chancellor and archbishop of Canterbury Cardinal Morton, More entered the University of Oxford in 1492. There he studied history, logic, and the classical languages. In 1494 More left the university to study law in London, where he became a lawyer in 1501 and was elected a member of parliament in 1504.

The following year More married Jane Colt, with whom he had four children. Upon the death of his wife in 1511 he married again.

By 1510 More had become an influential public servant in the city of London. In 1516 he became a diplomat of the crown for a short time; then, in 1521, he was knighted and appointed subtreasurer of the court. In 1523, More became speaker of the House of Commons according to the will of the influential confidant of the king, Cardinal Wolsey. In 1529 More was appointed the first layman in the history of England to become lord chancellor. Being known for refusing any Protestant influence in his new function, he also soon acquired a reputation as a persecutor of so-called heretics.

Starting around 1530 More ran into deep conflict with King Henry VIII, triggered by the latter's attempt to cancel his marriage with Catherine of Aragon and the king's later self-proclamation as the "Supreme Head of the Church," culminating eventually in More's absence on the occasion of coronation of the succeeding queen, Anne Boleyn. In 1532 the king finally accepted More's second request to resign as lord chancellor. Then, in a campaign against him driven amongst others by his successor Thomas Cromwell, More was charged several times and for different arbitrary reasons, imprisoned in the Tower of London, and deprived of any income and land. On July 6, 1535, five days after his sentence in an unjust trial for high treason, More was beheaded.

Literary Work and Influence

Notwithstanding his manifold duties, More left a rich humanistic literary legacy; as an author he was influenced by his correspondence with his friend Erasmus of Rotterdam. More's primary literary achievement is *Utopia* (1516), a thought experiment and a humoristic critique of the zeitgeist in which More flings off the restraints of his own times and describes an imaginary, ideal, tolerant, humanistic society. More thus became the originator of a new literary style and a mode of dealing with time and present circumstances that would exert considerable influence on thinkers in the centuries to come. *Utopia* is said to even have influenced Karl Marx, despite the fact that the communism More pictured was religious.

Furthermore his *History of King Richard III* (1518) attracted attention not only as a dispraise of Richard III but also as a cryptic critique of the royal totalitarianism of the ruling Tudors. This work exerted an influence on William Shakespeare's play *King Richard III*.

Thomas More was beatified in 1886, was canonized in 1935, and received the title "heavenly Patron of Statesmen and Politicians" in the year 2000. Especially his canonization is thought to have been intended by the Vatican to form a strong warning against the inhuman and un-Christian conduct of German National Socialists as well as of Soviet Communism. Thomas More, who preferred to die rather than betray his firm ideals, still serves as a symbol of humanity and a just societal order.

Matthias S. Hauser

See also Christianity; Humanism; Marx, Karl; Machiavelli, Niccolò; Time, Sacred; Utopia and Dystopia

Further Readings

Ackroyd, P. (1999). *The life of Thomas More*. New York: Anchor Books.

Marius, R. C. (1984). *Thomas More: A biography*. New York: Knopf.

Morgan, Lewis Henry (1818–1881)

Although Lewis Henry Morgan (1818–1881) was a successful New York attorney in the mid-1800s, he is remembered as a pioneer in the fledgling science of cultural anthropology. Morgan focused his study on the Iroquois Native American tribe, particularly the Seneca. His objective observations and chronicling of their daily cultural routines became the basis for the study of ethnology as we know it today. He is also credited with applying the idea of evolution to cultural behavior. Accordingly, some have called him the father of American anthropology. Scientists following Morgan's model have recorded the traditions of peoples that have since been acculturated to modern society, and their works have preserved these peoples' customs for future generations to study.

Morgan was born on November 21, 1818, in Aurora, New York. Little was recorded about his personal life. He attended Union College and earned his degree in law in 1840. Lewis married Mary Elizabeth Steele in 1851. His legal practice was very lucrative, and over the span of his career Morgan amassed a small fortune. He was greatly respected among his peers and served in the New York State Assembly and Senate.

Morgan's wealth allowed him to pursue his interests outside of the courtroom. One of his law clients was Ely S. Parker, a prominent Native American engineer and member of the Seneca tribe. Morgan's relationship with Parker inspired him to learn more about the native culture of the region. Setting out to learn firsthand about the customs and traditions of the Iroquois, he spent years immersing himself in the culture of the Seneca people. In 1847 he published his observations in a series in the *American Review* entitled "Letters on the Iroquois." In 1851 he released a longer work, *The League of the Iroquois,* explaining the social and political structures of this tribe. This is considered one of the first ethnographies, or scientific descriptions, of an ethnic group.

These studies led Morgan to think about the social structures of all societies and peoples around the world. He took a broad approach in examining the kinship systems and clan organization of many different cultures. Such a scientific approach to culture and behavior was a new concept in the 19th century. Morgan wasn't interested in individuals or societies in the ancient past but in the interactions of people in his contemporary world. He was also curious about how culture changed through time. As were many of his contemporaries, he was influenced by Darwin's theory of biological evolution and tried to apply it to cultural behaviors.

Morgan theorized that culture progressed unilinearly through time and that there have been three stages in cultural evolution; savagery, barbarism, and civilization. He linked technological progress with social change and published these ideas in *Ancient Society* in 1877. For better or for worse, he is often associated with the movement of social Darwinism, although he seemed to support equality for all ethnicities.

As did members of the legal community, his fellow scientists held Morgan in high regard. In 1879 he was elected president of the American Association for the Advancement of Science. He became an official adopted member of the Iroquois tribe and was given the name *Tayadaowuhkuh,* meaning *bridging the gap*. Morgan died on December 17, 1881.

Jessica M. Masciello

See also Anthropology; Evolution, Cultural; Evolution, Social; Harris, Marvin; Materialism; Time, Prehistoric; Tylor, Edward Burnett; White, Leslie A.

Further Readings

Moore, J. D. (2004). *Visions of culture: An introduction to anthropological theories and theorists* (2nd ed.). Walnut Creek, CA: AltaMira.

Morgan, L. H. (1877). *Ancient society.* London: Macmillan.

Mortality

Mortality is defined as "the quality of being mortal or subject to death." Death is the permanent end or ceasing of the life of a biological organism. A common thread that links all living creatures is the fact that someday they will die. Unlike their fellow creatures, human beings are aware that they are mortal and have devoted much of human history to the pursuit of overcoming this mortality.

One of the favorite themes throughout history in religion, literature, and art has been the theme of immortality or the escape from death and the extension of one's time. The belief in life after death is based on the notion that some part of the human person, usually described as the soul, goes on for an infinite period of time. This is a quest that has produce many stories and is the basis for many systems of belief.

The fascination people have with their own mortality is not a new phenomenon. The literature of the ancient Greeks mentions it frequently. One of the most well-known scenes in ancient Greek philosophy is Socrates' deathbed speech. Most of what we know about Socrates comes from Plato's account of this speech. Stories of the River Styx and Hades illustrate the early Greek ideas of mortality and death.

In the Judeo-Christian tradition, the Hebrew scriptures provide insight into the concept of mortality as understood by the ancient Hebrews, whose focus was very much on this world; little is said about the notion of an afterlife. A similar outlook underlies many of the beliefs and practices found in modern Judaism. With the advent of Christianity, however, ideas of the afterlife took on greater importance. Islam, which shares the Abrahamic tradition with Judaism and Christianity, also finds the basis of some of its beliefs about an afterlife in these early traditions.

In the Asian religious and philosophical traditions, reincarnation is a concept that takes on major importance; to be reincarnated is seen as a form of prolonging life, but in Hinduism and Buddhism, the cycle of endless reincarnation is understood as a form of bondage that the enlightened hope to escape into a state of nonbeing, thus attaining true immortality.

In popular culture, a continuing fascination with mortality and the human desire to escape the finality of death manifests itself in the current interests in ghosts, mediums, and other psychic phenomena. In an age when tangible evidence is often needed for people to believe in something, some are trying to find tangible evidence to prove the existence of life beyond death.

Science, too, is subject to a concern with mortality and the search for ways to overcome it. Studies in genetics have made some previously fatal diseases treatable. Advances in certain medical technologies have made physical life sustainable in cases where it previously would not have been. This has given rise to the debate over exactly what constitutes life.

In the health care and insurance industries, mortality usually refers to the measurement of life expectancy. Mortality rates, which assess the frequency of death occurring annually in a given population, have declined substantially over the last century in many countries because of progress in science, medicine, and sanitation.

Carol Ellen Kowalik

See also Cryonics; Diseases, Degenerative; Dying and Death; Fertility Cycle; Gerontology; Grim Reaper; Life Cycle; Longevity

Further Readings

Lief, J. L. (2001). *Making friends with death: A Buddhist guide to encountering mortality.* Boston: Shambhala.

Tarlow, S. (1999). *Bereavement and commemoration: An archeology of mortality.* Oxford, UK: Blackwell.

Moses

Moses is the most prominent figure in the Hebrew Bible, or Pentateuch. He is noted for receiving the law from God and for leading the Israelites out of bondage in Egypt to the promised land. Being such a pivotal figure, Moses plays an important role in later Jewish, Christian, and Islamic traditions. Through the centuries, Moses has been a prominent subject in art, literature, and, in modern times, film; even, most recently, as a toy action figure based on the young Moses as depicted in an animated movie.

Moses's life as described in the Bible is fairly straightforward. He was a Hebrew born in Egypt, raised by the pharaoh's daughter, and trained in the Egyptian court. Following an incident in which he killed an Egyptian who was abusing a Hebrew slave, Moses fled for his life toward Midian, where he lived 40 years. Moses received a calling to deliver the enslaved Israelites when he encountered God at a burning bush at Mt. Sinai. Upon returning to Egypt, he had several confrontations with an unnamed pharaoh accompanied by a series of

Iconic figure of Moses holding tablets with the Ten Commandments and a short staff.

Source: Library of Congress, Prints & Photographs Division.

divine signs and increasingly severe plagues. Finally, after the deaths of Egypt's first born, the pharaoh allowed Moses and the Israelites to leave Egypt. After a few setbacks, these people reached Mt. Sinai, where Moses met God on the mountain and received the law. Moses spent the rest of his life (about 40 years) wandering in the wilderness with the Israelites, dealing with their stubbornness and sins. After appointing Joshua to succeed him, Moses died on Mt. Horeb at the edge of the Promised Land.

Postbiblical Jewish sources depict Moses as lawgiver, prophet, priest, inventor, philosopher, holy man, and paradigm of a king. Both Philo and Josephus use the exploits of Moses to convince their audience of the viability of the history of the Jews. Artapanus, a 2nd-century BCE Jewish writer, claims Moses led an Egyptian military campaign against Ethiopia, where he won many great battles. Further, he says, Moses introduced the custom of circumcision to Egypt. Other Jewish writers wrote books containing Mosaic legends, such as the *Testament of Moses* and the *Assumption of Moses*. The book of *Jubilees* recounts the events of Genesis 1 to Exodus 12 and adds additional revelations of God to Moses.

Christian sources emphasize Moses's role as lawgiver and as a significant historical figure. He appears at the transfiguration of Jesus along with Elijah (Matt. 17:3ff.) representing the most significant persons in Jewish history. The writer of Jude adds to the Mosaic tradition by telling of a dispute between the Archangel Michael and Satan over the body of Moses after his death (Jude 9). Islamic sources treat Moses in a manner similar to that of the Hebrew Bible; however, it is in his role as a prophet that he is most often mentioned.

The portrayal of Moses in Roman sources is mixed. Generally, he is rendered as the Jewish lawgiver; however, writers like Manetho, Tacitus, and Quintilian blame Moses for teaching practices that go against civilization. Strabo wrote that Moses taught against making any kind of image of God, asserting that Moses left Egypt because the Egyptians made images of their gods.

Moses has been the frequent subject of western art, appearing in many paintings, sculptures, and stained-glass windows. In 1515, Michelangelo completed a marble statue of a seated Moses wearing horns, a pictorial convention now understood to be based on a mistranslation from the Hebrew phrase meaning "radiated light." This statue is the centerpiece for the tomb of Julius II. Moses has been the subject of several modern biographies and scholarly works, most notably Sigmund Freud's 1937 study *Moses and Monotheism*. Interestingly, Freud acknowledges that he was strongly influenced by Michelangelo's statue, which he viewed with fascination during a visit in Rome. In popular culture, Moses has been depicted in several movies, from Cecil B. DeMille's 1923 silent film *The Ten Commandments* to the 1998 animated feature *Prince of Egypt*. In the public imagination, however, the character of Moses is perhaps best known from the actor Charlton Heston's stoic and commanding portrayal in DeMille's 1956 remake of *The Ten Commandments*.

Terry W. Eddinger

See also Bible and Time; Egypt, Ancient; Genesis, Book of; Judaism; Michelangelo Buonarroti; Noah

Further Readings

Britt, B. (2004). *Rethinking Moses: The narrative eclipse of the text*. New York: T & T Clark.

Chavalas, M. W. (2003). Moses. In D. Alexander & D. W. Baker (Eds.), *Dictionary of the Old Testament: Pentateuch*. Downers Grove, IL: InterVarsity.

MULTIVERSES

The idea of multiple universes, or parallel universes that exist next to our own universe, has been discussed by physicists, cosmologists, and philosophers. Many different approaches and theories have been developed to consider the nature of such universes within a physical framework. If such multiverses do exist beyond our own, then one can easily imagine that the element of time could be very different in other universes.

One important theory is based on the picture of cosmic inflation. The idea of cosmic inflation, introduced by physicist Alan Guth at the beginning of the 1980s, describes a phase of rapid expansion of the universe in its very early stages. The concept behind this scenario is that the tension of the vacuum manifests itself in a repulsive gravitational force, and as a result the universe is blown up like a balloon. In more detail, a transition between different vacuum states, starting from a state with repulsive gravity and passing over to its state today, marks the beginning and end of inflation, while the vacuum energy is being released into a hot fireball of particles. After this, the normal cosmological evolution takes place. This so-called vacuum decay is not simultaneous for the overall universe as a result of quantum fluctuations during the decay process. This means that some regions have not yet reached the end of inflation, while others including our own have, resulting in island universes that can also be pictured as bubbles. This process is called eternal inflation and has been studied in detail by Alex Vilenkin; similar approaches also based on inflation have been proposed and discussed by Andrei Linde.

These island universes can be viewed as multiple universes, each following its own laws with its own time. A single universe has its own timeline, completely independent of any neighboring universe. It is possible to define a general "time" that includes all universes, although there are still problems in making any direct predictions. Such island universes can be completely different from our universe or be similar. An infinite number of such universes may exist, and it is possible that elsewhere our universe is repeated, complete with exact copies of ourselves!

Another possibility to describe and interpret multiverses comes from quantum mechanics (QM). Here, the many-worlds view of Hugh Everett and the so-called Copenhagen interpretation are two heavily discussed topics. In QM, any observable values (e.g., a subatomic particle's position and velocity) cannot be measured simultaneously, as stated in the well-known uncertainty principle of physicist Werner Heisenberg. This view is completely at variance with our common experience. In the quantum mechanical world, however, a physical object like an electron can occupy only states that have defined values (eigenvalues) with a certain probability. This probability is described by a wavefunction. Any measurement influences the system, thereby forcing the electron into one of the defined states (wavefunction collapse). In the many-worlds interpretation, the ensemble of possible states represents different universes. This means, if we measure that the electron is located in state A, it will be in state B in another universe. Note that all possible outcomes happen at the same time. Put most simply, one could say that any measurement leads to a number of universes presented by the different possible states.

The Copenhagen interpretation differs from the many-worlds view. Here, a measurement is taken over all possible universes (with different timelines), where we find ourselves in a universe with a high probability.

Many other theories have been proposed, some perhaps more plausible than others, regarding this fascinating subject. For now, all are necessarily consigned to the realm of speculation until such time as we gain the ability to test them by direct measurements.

Veronika Junk

See also Cosmogony; Cosmology, Inflationary; Histories, Alternative; Time and Universes; Universes, Baby; Worlds, Possible

Further Readings

Deutsch, D. (1997). *The fabric of reality.* New York: Penguin.

Guth, A. H. (1997). *The inflationary universe: The quest for a new theory of cosmic origins.* Cambridge, MA: Helix/Perseus.

Vilenkin, A. (2006). *Many worlds in one: The search for other universes.* New York: Hill and Wang.

MUMMIES

A mummy is the corpse of a human being or animal whose soft tissue has been preserved by either accidental or intentional exposure to airlessness, chemicals, extreme cold, or very low humidity. The presence of any of these conditions halts the growth of bacteria and fungi that would normally cause decay. Mummification freezes a moment in time, giving scientists a unique look at aspects of a culture that existed centuries or millennia earlier. Some mummies are so well preserved that autopsies could be performed on them. Details of diet, dress, hairstyle, tattooing, and more can be witnessed in their original context.

The English word mummy is derived from the Latin *mumia,* which was borrowed from the Arabic *mumiyyah* (bitumen). The Arabic word was also borrowed, from the Persian word *mumiyá,* which also means bitumen. Because unwrapped mummies had blackened skin, it was believed that bitumen, a black, tarry substance that seeps from cracks in the earth naturally in various locations in the Middle East, was used in embalming procedures by ancient Egyptians. Bitumen was widely used for a variety of medical applications in ancient times, so this was not an unreasonable assumption. However, the discoloration was actually caused by resins, used to prepare the body, that blackened over time.

Spontaneous mummification occurs when natural environmental conditions cause preservation without human intervention. It is rare, because very specific conditions are required. Better-known examples include Otzi the Iceman frozen in an Alpine glacier, bog people dumped in the peat bogs of northern Europe where acid and airlessness preserved soft tissue, the Greenland mummies preserved by cold and dry winds, and mummies from deserts in Chile and Egypt where heat and aridity preserved human and animal remains.

In anthropogenic mummification, humans deliberately halt the process of decay for a purpose. Examples of deliberate mummification have been discovered on every inhabited continent on Earth. While ancient Egyptians are the best known for making mummies, they were not the first to do so. The Chinchorros, a sophisticated culture occupying the northern coast of Chile, were embalming and reassembling their dead 7,000 years ago. Further to the north, the Incas used naturally occurring salts and the cold dry air of the region to preserve their mummy bundles. Human sacrifices left for the gods in caves on Andean mountaintops also were mummified in the cold, dry air. The Aleuts off the coast of Alaska processed bodies and dried them in the open air before placing them in caves. Island natives in the South Pacific smoke-cured their dead, covered them with clay, and displayed them in their villages.

Different cultures practiced mummification for different reasons. Some societies believed a person's spirit remains near after death. Mummification would pacify the spirit, hasten it along on its journey, or keep the spirit near for consultation. The preservation of enemies killed in battle gave status to the victor or filled them with the strength of those that perished. Mummification of leaders in some cultures linked the ruler to the gods and made them immortal. Animals would be mummified for use in rituals or to appease the spirit of prey after a successful hunt.

In most cases, mummification was an expensive endeavor, requiring a significant investment of time, effort, and materials. However varied the reasons for intentional mummification among the cultures of the world, the practice illustrates the power of motivation and the desire to endure through time.

Jill M. Church

See also Afterlife; Anthropology; Egypt, Ancient; Immortality, Personal; Museums; Rameses II;

Further Readings

Aufderheide, A. C. (2003). *The scientific study of mummies.* Cambridge, UK: Cambridge University Press.

Chamberlain, A. T., & Pearson, M. P. (2001). *Earthly remains: The history and science of preserved human bodies.* New York: Oxford University Press.
Cockburn, A., Cockburn, E., & Reyman, T. (1998). *Mummies, disease, and ancient cultures.* Cambridge, UK: Cambridge University Press.
Reid, H. (2001). *In search of the immortals: Mummies, death, and the afterlife.* New York: St. Martin's.

MUSEUMS

All museums can be said to have a common origin in certain institutions that began many centuries ago. Whether identifying when a historic event took place, when a species became extinct, or when an art form was popular, museums share a common theme that underlies their particular mission: namely, understanding changes to human, animal, plant, and inorganic artifacts that occurred through time.

The development of museums occurred over millennia, with the first museums originating in Old World nations nearly 2,300 years ago. The earliest forms, such as the Mouseion of Alexandria (Egypt), were sanctuaries that housed a multitude of collections, including gardens with diverse plant species, remains of unique and common animal species, technological innovations, and miscellaneous writings. These institutions also served as centers for discourse between scholars who sought to unravel intellectual puzzles and educate others. Additional museumlike institutions existed in areas of Asia, Africa, and Europe, but many were simply private gatherings of antiquities, far removed from the complex structure of the museums of today and from the view of the general populace.

Private collections remained a major source of collected antiquities until the spoils of war and discoveries of New World voyages, gathered by explorers and military commanders, made their way to Europe to be housed and displayed in museums developed to serve national interests during the 17th, 18th, and 19th centuries. These institutions, developed as part of universities and as individual establishments, included the Louvre in Paris and the British Museum in London and established the practice of exhibiting botanical, zoological, library, art, and other miscellaneous collections. American museums originated during the 18th and 19th centuries, focusing chiefly on natural and local history. By the early 20th century, these institutions were often supported by funds and collections provided by patrons who traveled the world and then donated antiquities they collected in their travels, including religious paraphernalia, paintings, sculptures, coinage, human remains, and ancient weaponry. Some of the unique items brought to the United States during this time included mummies from Egypt, coins of the Roman Empire, Japanese *katanas,* and paintings created by some of the world's most celebrated artists.

In the mid-20th century, museums collectively started to receive new sources of funding, such as grants from government and private endowments, and began to expand their missions to include more systematic exploration of their own existing collections. While a number of museums had devoted efforts to understanding collections throughout history, it was during the 20th century that a widespread reevaluation and modification of museums' research activities took place. These activities led to a deeper commitment to understanding the development of humanity and specific societies through time as well as an analysis of emerging technologies. It is to all these predecessors that contemporary museums owe their existence, public support, and direction.

Each type of museum has different temporal concentrations integrated into their missions and, consequently, their collections. History museums and historical societies are among the prevalent museum types found today and have one of the most uncomplicated focuses on time. Although history museums and historical societies exist that have a world focus in their mission, most museums of this kind concentrate their collection, research, and exhibit practices on their own locality, whether it be a town, city, state, or province. These institutions seek to acquire artifacts and oral history documenting the history of their respective regions, often collecting materials connected to events or people that significantly influenced the course of that society's history. In recent years, history museums and historical societies have placed particular importance on exhibiting the genealogy of families that most affected a region's history and materials documenting the contributions to the society of different ethnic populations through time.

Art museums, meanwhile, concentrate on the collection of works including paintings, sculptures, and print media that document the different historical styles of art. The foci of exhibits in such institutions may be on art techniques (e.g., Cubism or Impressionism), individual artists (e.g., Michelangelo or Picasso), or regions (e.g., Native American art of the Southwest). Whatever the art form highlighted, exhibits usually emphasize time, whether it be the duration of popularity of an art technique or the life of an influential artist.

Science museums and centers place emphasis on innovative technologies while also exploring scientific discoveries, particularly through the fields of archaeology, astronomy, paleontology, and zoology. Science museums and centers place a special focus on the emergence and evolution of individual animal and plant species, animal orders, planetary bodies, and the universe itself. In regard to technological advances, science museums often assess specific technologies and their impact on society, examining what technologies such innovations replaced, and industry progress through time.

Natural history museums are primarily concerned with organisms and their development over time. Such institutions vary in their exhibits, collections, and research goals, which may include understanding and illustrating life forms both in stasis and within an evolutionary context.

Ultimately, all kinds of museums—whether a history museum collecting art created by local artists, a natural history museum displaying watercolor renderings of birds, or a science museum exploring the evolution of dinosaurs through a virtual exhibit—share common collection goals. Museums also show a tendency to amass artifacts or whole collections outside their mandates. That said, all museums place an emphasis on time in their own research, within their exhibit designs, and when educating visitors to their institutions.

Neil Patrick O'Donnell

See also Anthropology; Archaeology; Egypt, Ancient; Fossils and Artifacts; Hammurabi, Codex of; Mummies; Observatories; Planetariums; Rome, Ancient; Rosetta Stone

Further Readings

Alexander, E. P. (1996). *Museums in motion: An introduction to the history and functions of museums.* Walnut Creek, CA: AltaMira.

Burkholder, J. (2006). Museums. In H. J. Birx (Ed.), *The encyclopedia of anthropology* (Vol. 4, pp. 1647–1650). Thousand Oaks, CA: Sage.

Trigger, B. G. (1993). *A history of archaeological thought.* Cambridge, UK: University Press.

Music

Many scholars regard music as the most important of all temporal arts. In ancient Greece music was called *μουσική τέχνη*—the art of the muses, or music drama, as it consisted in a combination of dance, singing, and instrumental music. The word *music* can still refer to musical genres like opera or music drama. There are, however, scholars who employ the notion "music" to refer solely to instrumental, or absolute music. For two reasons, a wider notion of music will be used in this entry, one that includes not only instrumental but also noninstrumental music. First, operas, musicals, and songs are usually referred to as music. Second, the etymology of the word *music* is such that the word has usually been connected with a broad meaning.

If they wish to define what music is in a short and specific phrase, scholars have to face many problems, as there are always musical pieces that are clearly musical but that do not correspond to the definition given. On the other hand, if they put forward a wider definition, it is usually the case that too many examples are included. Are bird songs music? The safest way to define music is to hold that music is everything that experts such as composers, musicologists, or music critics regard as music.

A central idea about music is that it is a temporal art, which implies that music needs to be performed in order for it to exist. All arts that need to be performed for their realization are temporal arts. Drama is a temporal art based upon a text, dance is one based upon corporal movement, and music is one based upon sounds. In temporal arts, an interplay between objective, intersubjective, and subjective time exists. Objective time refers to the time from God's perspective or from the perspective of an eternal realm of ideas in which musical works might exist. The existence of objective time can certainly be doubted.

Intersubjective time, on the other hand, is the time a watch tells us. This kind of time is based upon an interhuman agreement concerning the duration of intervals and how we calculate the duration of time. Human beings agreed to relate time to contingent natural constants like the period of time taken by the earth turning around the sun or the moon turning around the earth. Intersubjective time can be found on musical scores as *tempo,* which is discussed later in this entry.

Another type of time relevant for temporal arts is subjective time. Subjective time depends on our perception of something. If we perceive a musical piece as boring, instants seem to have a longer duration than when we regard the music as entertaining. Another kind of subjective time is related to the stage of life in which the maker or the listener happens to be. Human interests differ significantly between, say, a teenager and an adult in midlife. Concerning the difference between music makers and listeners, some distinctions need to be presented. In the case of music, there are makers of various orders. The first-order maker is often the composer who is responsible for the score. The score needs to be read and interpreted directly by the makers of the second order, whether musicians or a conductor. If the conductor is on the second level, then on the third order would be musicians. Even though the maker of the first order creates the music, the maker of the third order performs it and enables the audience, the receivers of music, to listen to it.

The following section presents some definitions of musical terms concerning the relationship between music and time, such as tempo, meter, and rhythm. Next follows a description of what the philosophers Plato and Schopenhauer put forward concerning the relationship between words and rhythm. Third is a short summary of the history of rhythm in music, and finally comes a discussion of the importance of time for the concept of the musical work.

Musical Notions and Time

Tempo

The *tempo* (plural form *tempi;* Italian for time; from the Latin word *tempus*) determines the basic pulse of the musical piece. Traditionally the tempi were described as follows (from slow to fast): *grave, largo, larghetto, lento, adagio, andante, andantino, moderato, allegretto, allegro, vivace, vivacissimo, presto, prestissimo.* When adjectives are added, the descriptions of the tempi became more precise, for example, *ma non troppo* (but not too much), *con fuoco* (fiery), and *molto* (much). In addition, there are terms specifying the change of tempo. If the tempo is supposed to become faster, the following expressions can be used: *accelerando, stringendo, piu mosso, poco piu.* If the tempo is supposed to become slower, the following expressions can be used: *poco meno, piu lento, calando, allargando, rallentando, ritardando, ritenuto.* Even though most of the time Italian tempo markings have been used, they can also turn up in French, German, or English.

By using words to specify the tempo of a musical piece, the subjective understanding of the respective notions of musicians, conductors, and the composer of a piece become more relevant. In order to fix the tempi, the metronome was invented. By means of the metronome, musical time is related to intersubjective time so that the tempo of a musical piece is specified by clarifying the amount of beats per minute (BPM). As minutes are defined on the basis of a human decision, the tempo of a musical piece that is specified by means of a description of beats per minute includes a relationship between musical and intersubjective time.

Meter and Rhythm

There are two further terms that are important for the temporal structure of a musical piece: meter and rhythm. The musical term *meter* (*μετρον*; ancient Greek for *measure*) is used to describe the organization of beats within a regular pattern. One single entity of such a pattern is called a *bar.* A *beat,* on the other hand, is the basic temporal unit of a piece—it is a type of pulse that may or may not be heard.

The specific temporal organization of a musical piece is referred to as *rhythm* (*ῥυθμός* ancient Greek for *flow*). The surface structure of a piece, which is called meter, is more constant and regular than the rhythm. However, meter and rhythm are not independent of one another. There are several theories that try to describe their relationship. It can be the case that both meter and rhythm are something similar, that rhythm is subordinate to meter, as rhythm is a meter come alive or that meter is regulated rhythm, which implies that it is a basic structure necessary for rhythm taking its proper shape.

Rhythm and Words

There are several possibilities for how rhythm can come about. In the history of music philosophy, two positions concerning the relationship between rhythm and words have been dominant. On the one hand, there is Plato's position. He defends the superiority of words over sound. His position had an enormous influence on the Florentine Camerata, whose members invented the opera genre. A similar position was also put forward by the composer Richard Wagner in *Opera and Drama*. On the other hand are thinkers like Immanuel Kant and Arthur Schopenhauer, who defend the superiority of sound over words. Concerning other musical aesthetic questions, such as that of the effect of music, those thinkers disagree significantly. Kant stresses the pleasure music provides listeners, whereas Schopenhauer regards the brief liberation from the personal will as the most important effect of great music. A more permanent kind of salvation can only be reached by means of asceticism, according to Schopenhauer.

According to Plato, a song (*melos*) consists of word (*logos*), harmony (*harmonia*) and rhythm (*rythmos*), whereby the word is supposed to be fundamental; that is, rhythm and harmony are supposed to follow the words, because words specify the content of a musical piece. Without words we would not understand the piece and would not know what it is about. It is important that we know what it is about, because music is supposed to convey the idea of the good, and only if words are at the basis of a song can it fulfill this task.

Even though Schopenhauer's philosophy of art includes many Platonic elements, he disagrees with Plato concerning the relationship of words and melody. According to Plato, words come first and determine harmony and rhythm. According to Schopenhauer, the instrumental sounds come first. The genius composer transcends the personal will and gets an understanding of the will in itself, which can directly be represented in the artistic genre of instrumental music. In order for music to have the highest kind of quality, the laws of instrumental music have to be dominant, and the words simply have to follow those laws as in the case of the composition of an opera. Here the aesthetic laws of sounds are supposed to be responsible for rhythm, melody, and harmony.

History of Rhythm

Rhythm has been dealt with theoretically as well as practically since antiquity. This entry provides a summary of the history of rhythm since the baroque era, because the history of music from that time onward includes most of the music we still listen to today. A significant notion in baroque music is the "monody," which then meant music for one voice which is accompanied with chords. The words of the one voice were supposed to bring about the sounds and with it the rhythm. The monody became popular together with the invention of the music drama by the Florentine Camerata at the end of the 16th century. Instead of simply entertaining the audience, music was also supposed to convey values. The members of the Florentine Camerata thought that music can achieve this best by means of the monody. They were inspired by a reading of ancient texts on philosophy of music, especially Plato. It was their intention to revitalize ancient Greek tragedies. They believed that ancient dramas were sung from beginning to end, a concept that scholars now regard as false. As a consequence, the opera genre was invented. Another important aspect of baroque music is its dancelike character. Hence, the general rhythmical stream was more important than each single beat, which had to be embedded in the general, overall structure.

In classical and romantic music, however, the rhythmic aspect within music became more complex. The tension between musical periods and meter became stronger. The meter of a musical piece represented its body, but the rhythm was an expression of the human spirit. Consequently, the rhythm was supposed to represent and deal with the variety of affects that human beings can have. Music was therefore far less schematic than in the baroque era. A particularly impressive representative of that period is Richard Wagner. He developed the concept of the "infinite melody," whereby rhythm also developed into something undetermined and unlimited.

In contemporary music we find an immense variety of rhythmic concepts. According to Adorno, one can distinguish two traditions within 20th-century music. The first is the avant-garde tradition, which is associated with Schoenberg. Various concepts of musical time turn up in this tradition. Here Luigi Nono has to be mentioned, because some of his scores contain no bars. The second is the neoclassical tradition, to which Stravinsky belongs; it consists mostly of linear music in which the rhythmic element is similar to that of 18th-century music, as often the rhythmical figures remain constant throughout a movement. Bartok is another composer who is representative of this tradition.

One might wish to add a third tradition to which one could refer as the postmodern one. It unites elements from various cultures and plays with these elements. The most important postmodern musical movement is called minimal music, and its leading representatives are Philip Glass and Michael Nyman. It is mostly tonal music based on simple harmonies. Of particular importance is the rhythmic element. Very often a type of polyrhythm is used, which means that various rhythms overlap. Polyrhythmic elements are usually associated with jazz and have their origins in African and Indian music. In minimal music, a simple pattern is repeated very often, whereby only simple variations occur. A piece of minimal music is in many cases constituted by uniting various such patterns and variations. Once a pattern is played at a different speed, phase shifting or phasing occurs.

Many non-Western traditions of music are even more challenging concerning the variety of rhythms. Within the Chinese, Japanese, Indian, and African traditions, irrational and polyrhythmic patterns were developed that have recently had an impact on Western minimal music. In India, the *talas* are of particular interest in this respect, as talas are rhythmical patterns that determine a composition of classical Indian music. The tempo of most talas, which are the basis of their classical compositions, can vary.

Musical Works and Time

In musicology one distinguishes between musical works and other musical pieces. A musical work is determined by means of the following qualities: it is autonomous, original, and unchangeable; was created by one composer who is regarded as its origin; is the center of attention when it is being performed; and was created for eternity.

When musical works first came about is a matter of controversy. Some scholars think that the beginning of the musical work is connected to the first formulation of the concept, which was done in the 16th century. Then Nicolaus Listenius used the phrase *opus perfectum et absolutum*. However, many scholars regard the beginning of the musical work tradition as related to its historical representation, and most scholars agree that around 1800 the tradition of the musical work became particularly strong.

There are various reasons for this position: First, before 1800, music was performed on the occasion for which it was written. From then on, older music was performed again; for example, in 1829, more than 100 years after its first performance, Bach's "St. Mathew Passion" was performed again. Second, before 1800, composers were considered not very important, but the occasion for which a piece was written or the person for whom it was composed was of significance. From 1800 onward, for at least 150 years, musical works were the dominant kind of music. After 1950 music became extremely diverse. Musical pieces were composed that were heteronomous (John Taverner, Arvo Pärt) or involved chance elements (John Cage, Iannis Xenakis), which cannot therefore be regarded as proper musical works. Most composers in the Western tradition before 1800 composed heteronomous music. Their music was created for a particular purpose, such as a coronation or a specific religious or royal celebration. These musical pieces were usually performed solely at the event for which they were made. The composition of a musical piece was, therefore, mostly related to a specific contemporary event in the here and now.

Autonomous music, on the other hand, is usually composed for eternity. Composers are sometimes seen as geniuses who manage to put together eternal music, maybe even by having access to an eternal realm themselves. What makes this music autonomous is that the music comes about via a composer who decides for himself which pieces he wishes to realize and which not. Antonio Vivaldi is an exemplary composer of heteronomous music who clearly did not write musical works; he composed about 300 concerts that all sound fairly similar. When he was alive this was not a problem, because then musical pieces were supposed to represent the type to which they belong in an exemplary matter, which is what his pieces did. A musical work, on the other hand, represents a specific solution to a detailed aesthetic problem. In the 20th century the development went so far that many works represent a type of music in itself.

Another aspect of a musical work is that it is original and unchangeable. After it has been created, it remains identical with itself. Iannis Xenakis, however, composed stochastic music, which means that it involves chance elements. It might include the demand that the audience makes a specific sound when the conductor tells them to do so. As the size of the audience is different at each performance, it is clear that his compositions involve chance elements, which is the reason why his works are not musical works. Magical music includes the Indian *raga,* a series of notes upon which a melody of classical Indian music is founded, and the tala, which knows only some vaguely given rules on the basis of which one has to improvise. As improvised music is not eternally fixed, such musical pieces are by definition not musical works. Until the 19th century, German folk songs (*Volksmusik*) were such as to enable people to have a pleasant or cozy evening together, and they were not written by a single composer. Both are reasons for their not being considered musical works.

The musical work represents a means of uniting objective, intersubjective, and subjective time. The composer grasps eternal music (objective time) and puts it together in a score so that it can be performed (intersubjective time), and listened to (subjective time). In any case, the relationship between music and time is a complex one, and it also has to be stressed that this relationship has been neglected by many modern and postmodern musicologists and philosophers of music.

Stefan Lorenz Sorgner

See also Kant, Immanuel; Nietzsche, Friedrich; Plato; Presocratic Age; Pythagoras of Samos; Schopenhauer, Arthur; Wagner, Richard

Further Readings

Begbie, J. S. (2000). *Theology, music and time.* Cambridge, UK: Cambridge University Press.

Hamilton, A. (2007). *Aesthetics and music.* London: Continuum.

Kramer, J. D. (1988). *The time of music: New meaning, new temporalities, new listening strategies.* New York: Schirmer.

Sorgner, S. L., & Fuerbeth, O. (Eds.). (in press). *Music in German philosophy: An introduction.* Chicago: University of Chicago Press.

Mutations

See DNA

Mysticism

Mysticism is a type of religious experience or altered state of consciousness in which a person senses intimacy or union with the source or ground of ultimate reality. Mystical states or experiences are qualitatively different from normal, everyday consciousness. They can be experienced variously as a vision, an ecstatic state, an emptying or silencing of the self, union with God, or absorption into God.

For the monotheistic Western religions, mysticism exists as a movement or school of thought within the religious tradition. For the Eastern world religions, mysticism is the central practice and goal. Mysticism is also a central aspect of primal religions such as shamanism. Some people without an explicit religious attachment also testify to personal mystical experiences; these include Aldous Huxley, Walt Whitman, Carl Jung, and Simone Weil.

Eastern forms of mysticism are directly related to the concept of time. For example, Hindus believe in an endless cycle of death and rebirth called *samsara.* Through the discipline of yoga, one can obtain *Samadhi,* the highest level of spiritual perfection. Through the resulting union of *Atman* (the essential self) with *Brahman* (that which is truly real), one experiences liberation (*moksa*) from *samsara.*

The Western religions of Judaism, Christianity, and Islam do not share the Eastern view of the reincarnation or transmigration of the soul, so they do not seek release from this cycle into a state of existence outside of space and time. However, many thinkers in these religions view God as existing outside of space and time. Therefore, when devotees experience mystical union with God, they often report sensations of the absence of space and time.

The adjective "mystical" (*mustikos*) was used by Christians from the 2nd century onward, but the noun "mysticism" was first used in French (*la mystique*) in the 17th century. Because it is a relatively new term, attempts to define it have varied greatly. The term can be defined broadly as consciousness of the immediate or direct presence of God (which many have claimed to experience). This broad definition would identify mysticism with spirituality or religion in general. It can also be defined narrowly as a union of the self with God or absorption of the self in the Absolute (which few have claimed to experience).

One of the most notable attempts to describe mysticism was William James's list of four characteristics of mystical experiences. First, they are ineffable: Mystics struggle to put their experience into words. Second, they are noetic: Insights gained from the experience inform a person's knowledge and understanding. Third, they are passive: They are experienced as an undeserved gift. Fourth, they are transient: Mystical experiences usually last for a short period of time. The last characteristic has proved to be less convincing to students of mysticism than the first three.

Religious traditions of mysticism have developed practices and disciplines that enable a person to achieve a state of mystical union. They provide systems of initiation and apprenticeship to inculcate mystical values and disciplines. Central to most mystical systems are the practices of meditation and contemplation, which are distinguished from each other in most traditions. In meditation, a person focuses attention and imagination on a religious idea or image. In contemplation, a person suspends the activity of the body and the thought processes of the mind in order to center the spirit on the presence of God. Meditation would be more closely associated with kataphatic mysticism, which utilizes images in order to experience intimacy with God. Contemplation is associated more closely with apophatic mysticism in which the union of the self with God is experienced as negation or absence. The terms *extrovertive* and *introvertive* mysticism are sometimes used to describe similar phenomena.

The mystical traditions in various religions reveal a diversity of practices and goals but also some similarities. Students of mysticism tend to emphasize either the common core found in all mystical traditions (e.g., Walter Stace) or the irreducible differences among them (e.g., R. C. Zaehner). Hindus practice various forms of yoga through which the conscious and the subconscious are mastered by means of moral, physical, respiratory, and mental discipline. In Zen Buddhism, the practitioner contemplates a nonsensical *koan* in order to free the spirit from the domination of the conscious mind. In Kabbalah, adherents mentally manipulate numbers and images in order to annihilate the ego, detach themselves from the physical world, and experience the presence of God directly. Christian mystics have relied upon contemplative prayer, fasting, solitude, and other forms of asceticism in order to focus the mind and spirit on the presence of God within the person. Sufi Muslims practice fasting, sleep deprivation, vigils, dancing, chanting, and contemplation to achieve annihilation of the self.

Mystical elements were present in the teachings of Plato. Centuries later, these were developed more fully by Plotinus, the founder of Neoplatonism, and his later follower Proclus. Plotinus taught that the soul must lose its present identity in order to find a transcendent self in the One or the First Principle. Neoplatonism was a major influence on mystical traditions in Judaism, Christianity, and Islam.

Mystical elements were present from the very beginnings of Christianity in the teachings and practices of both Jesus and Paul. The first Christian theologian to develop fully a theory of mysticism was Origen in the 3rd century, which led to the development of monasticism in the 4th century. Christian mystics have often spoken of three stages on the way to the vision of God: (1) purgation, which is a purification of the flesh and soul brought about through ascetic disciplines such as prayer, fasting, and almsgiving; (2) illumination, which is an enlightenment of the mind by the Holy Spirit; and (3) contemplation or union, which is an unadulterated awareness of the love of God.

Following John of the Cross, some mystical writers have identified a "dark night of the soul" that occurs before the final stage of union is reached. Notable Christian mystics through the centuries include Evagrius, Gregory of Nyssa, Pseudo-Dionysius, Augustine, Gregory the Great, William of Saint Thierry, Bernard of Clairvaux, Bonaventure, Marguerite Porete, Meister Eckhart, Henry Suso, John Tauler, Jan van Ruusbroec, Richard Rolle, Catherine of Siena, Julian of Norwich, Ignatius of Loyola, Teresa of Avila, John of the Cross, Jeanne Guyon, Emanuel Swedenborg, Thérèse de Lisieux, Thomas Merton, Karl Rahner, and John Main.

Some Christian mystics have offered theological and philosophical speculations on the nature of time. In Augustine's view, time was created by God, and it flows from the future into the present and recedes into nonexistence. One may access fleetingly and fragmentarily the experience of timeless eternity by means of a "rare vision" of enlightenment. These experiences result from withdrawal from the sensory world, an interior movement into the depths of the soul, and a movement above the soul to the vision of God. Meister Eckhart taught that the soul must look outside space and time in order to know God, because God exists outside of space and time. Giordano Bruno's mystical reflections on the heliocentrism of Copernicus led him to propose that both space and time were infinite, without beginning or end. Miguel de Unamuno y Jugo posited that the conflict between reason and the desire for human immortality gives rise to the need for faith in God. Pierre Teilhard de Chardin taught that the perfection of humanity through the evolutionary process will culminate in an Omega Point in the future.

Sufi mystics promote the role of single-minded love in the pursuit of God. Two crucial stages on the Sufi path are fana' and baqa'. *Fana'* ("passing away") is the annihilation or nullification of the ego in the presence of the divine, and *baqa'* ("subsisting") is subsisting in the divine reality, which is all that remains. In Iran, the development of the dervish as a method of achieving mystical trance popularized mysticism among all levels of the population. Some of the notable Sufi mystics are Ja'far as-Sadiq, Rabi'ah, Ibn Mansur al-Hallaj, Abu Yazid al-Bistami, Abu al-Qasim al-Junayd, Abu Hamid al-Ghazali, Ibn al-Farid, Ibn al-'Arabi, and Jalal al-Din Rumi.

Through the centuries, Judaism has produced various forms of mysticism. The earliest form of Jewish mysticism is found in Merkabah literature, written between the 2nd and 10th centuries. It promoted meditation on Ezekiel's vision of the heavenly throne room of God so that the seer might ascend through the various levels of heaven (*hekhalot*) until he arrived at the highest heaven where God dwells. Hasidism originated in eastern Europe in the 12th century. Kabbalah mysticism originated in Spain in the 13th century and was spread to the rest of the Jewish world when the Jews were expelled in 1492. Its most notable document was the *Zohar.* A new Hasidism arose in eastern Europe in the 18th century. Important figures in Jewish mysticism are Abraham ibn Ezra, Moses ben Shem Tov de Leon, Isaac of Acre, Abraham Abulafia, Isaac Luria, Dov Ber, Shne'ur Zalman, Aharon Halevi Horowitz, and Nahman of Bratslav.

Psychologists and scientists have tried to explain the phenomenon of mystical experience from the perspective of their disciplines. Sigmund Freud theorized that mystical experiences were illusions caused by a neurotic desire to recapture the infantile bliss of union with the mother. Carl Jung, who described his own mystical experiences in his autobiography, explained them more positively as encounters of the individual unconscious with the archetypes of the collective unconscious. Some psychologists view them as pathological symptoms of schizophrenia, psychosis, epilepsy, or other psychological and brain disorders, but others report that people who experience mystical states possess higher-than-average levels of psychological health.

Recently, neuroscientists have conducted brain-imaging studies of people undergoing mystical experiences. These studies suggest that repetitive, rhythmic rituals deprive the brain's orientation association area of sensory and cognitive input. As a result the brain would not be able to orient the self in its spatial context or identify the boundaries of the body. The mind experiences these sensations as a spaceless and timeless void.

Gregory L. Linton

See also Augustine of Hippo, Saint; Bruno, Giordano; Eckhart, Meister; God and Time; Kabbalah; Maximus the Confessor, Saint; Nicholas of Cusa (Cusanus); Nirvana; Plato; Plotinus; Sufism; Teilhard de Chardin, Pierre; Time, Sacred; Unamuno y Jugo, Miguel de

Further Readings

d'Aquili, E. G., & Newberg, A. B. (1999). *The mystical mind: Probing the biology of religious experience.* Minneapolis, MN: Fortress.

Ellwood, R. S. (1999). *Mysticism and religion* (2nd ed.). New York: Seven Bridges.

Epstein, P. (1988). *Kabbalah: The way of the Jewish mystic.* Boston: Shambhala.

Idel, M., & McGinn, B. (Eds.). (1996). *Mystical union in Judaism, Christianity, and Islam: An ecumenical dialogue* (2nd ed.). New York: Continuum.

James, W. (2008). *Varieties of religious experience: A study in human nature.* London: Routledge.

McGinn, B. (1991–2005). *The presence of God: A history of Western Christian mysticism* (4 vols.). New York: Crossroad.

MYTHOLOGY

In an effort to comprehend the whole of human experience and the place of humanity in time, ancient civilizations generated myths. The Romans chronicled time as beginning with birth and culminating in death, with great emphasis placed upon the need to be "good" in order to earn eternal life. Myths, then, are largely religious in origin and function and are in fact the earliest records of history and philosophy. Interestingly, myths have been created throughout the course of human existence and have been rendered timeless because they remain an integral part of the culture that framed them. Myths may be classified as traditional stories that deal with time and eternity, nature, ancestors, heroes and heroines, supernatural beings, and the afterlife that serve as primordial types in a primitive view of the world. Myths appeal to the consciousness of a people by embodying their cultural ideals or by giving expression to deep and commonly felt emotions. These accounts relate the origin of humankind, its place in time, and a perception of both the visible and the invisible world.

Why Were Myths Created?

It is not surprising that myths evolved in primitive cultures when people were faced with impersonal, inexplicable, and sometimes awesome or violent natural phenomena and the majesty of natural wonders. In comparison to these wonders, human beings felt dwarfed and diminished. As a result, they bestowed extraordinary human traits of power and personality to those phenomena that most profoundly evoked human emotions. The beginning of time, the miracle of birth, the finality of death, and the fear of the unknown compelled early humans to create deities who presided over the celestial sphere. In time, every aspect of nature, human nature, and human life was believed to have a controlling deity.

Initially, myths of cosmogony illuminated the origin of humankind. Virtually every culture embraces a Creation myth. Myths explain the beginnings of customs, traditions, and beliefs of a given society and reinforce cultural norms and values, thereby depicting what that society regards as good or evil. Myths assist in defining human relationships with a deity or deities. Judeo-Christian-Islamic societies have established a supreme power, a father figure, whereas the Norse tradition restricts the power and purveyance of the gods. Finally, myths help to dispel the fear and uncertainty that is part of the human condition. Fear of the elements may be explained by the activities of the gods. Fear of failure is overcome by reliance on them. Fear of death is often explained as the passage or transition to another dimension or to another domain. Simply stated, myths are a symbolic representation reflecting the society that created them. Although unjustified and unjustifiable, myths take the raw edge off the surface of human existence and help human beings to make sense of a random and threatening universe.

Universal Themes

Myths are seldom simple and never irresponsible. Esoteric meanings abound, and proper study of myths requires a great store of abstruse geographical, historical, and anthropological knowledge. The stories underscore both the variety and the continuity of human nature throughout time. The abiding interest in mythology lies in its connection to human wants, needs, desires, strengths, fears, and frailties. By their nature, myths reveal the interwoven pattern of circumstances that are beyond the control of the mortal and the immortal.

A study of the world of myths imparts greater appreciation for the subtle and dramatic ways that they pervade societies and that particular myths mirror the society from which they were created. Myths are decidedly human in origin. Ironically, it is the human ability to make myths, and the very need to do so, that ultimately sets us apart from other inhabitants of the earth. Only we humans can identify our place on the eternal timeline or calculate our brief appearance in time and space as we search for significance and immortality.

Myths may be drawn from any era and any geographical area. This entry examines components of Greek and Roman mythology, Norse and Teutonic (Germanic) mythology, Asian mythology, and commonalities among these and several other cultures.

Greek Mythology

To people of Western cultures, the most familiar mythology outside of the Judeo-Christian culture is that of Greek and Roman mythology. The mythology of ancient Greece and Rome stemmed from the human desire to explain natural events, the origin of the universe, and the end of time as we know it. Our journey through time commences with birth and continues on as we experience the tribulations and celebrations of life, and it culminates with death. Time encapsulates us. The Greek myths chronicle Zeus and his brothers, Poseidon and Hades, who exacted control of the universe from their father, Cronus, and the Titans, a powerful race of giants. Cronus himself had wrenched control from his own parents, Uranus (heaven) and Gaea (earth). Great epics were recorded of war and peace and proud heroes and courageous heroines who represented the basic cultural values of the Greek people.

Men and women alternately worshipped and feared a ménage of gods and goddesses who traditionally resided on Mt. Olympus. People attributed failure and defeat to the wrath of the gods and success and victory to the grace of the gods. The most powerful of the gods and goddesses were Clotho, Lachesis, and Atropos, the goddesses of destiny. It was they who determined how long a mortal would live and how long the rule of the gods would endure. When a mortal was born, Clotho wove the thread of life. Lachesis measured its length, and Atropos cut the thread at the exact point in time that life would end. Not even Zeus could alter their timeframe.

Roman Mythology

Much of Roman mythology had its roots in Greek mythology, although Jupiter and Mars were part of the Roman tradition long before the Romans interacted with and eventually conquered the Greeks. Subsequent to 725 BCE, the Romans adopted many Greek deities, renaming them, and making them their own. In both Greek and Roman mythology, realms of the universe were delineated. They saw the cosmos in terms of the skies, the earth, the seas, and the lower world. Jupiter (Zeus) ruled the skies from atop Mt. Olympus, where he controlled the movement of the sun, the phases of the moon, and the changes of the seasons. The fairest and the wisest of all immortals, Jupiter, when outraged, hurled lightning and thunderbolts down upon the earth. Neptune (Poseidon), the second-most-powerful god, ruled the seas, and Pluto (Hades), the god of wealth, ruled the lower world.

In Roman mythology, myth and time are closely related. The Romans equate the onset of time with the birth of Rome, which is accredited to Romulus and Remus. While these two were infants, they were set afloat to die in the river by their uncle who feared that they would usurp his power. The children survived their ordeal and eventually founded the city of Rome, named after Romulus, and this founding was considered to be the advent of time. Saturn, the father of Jupiter, Neptune, and Pluto, was believed to be the god of time, birth, and death. The Romans strongly believed that living an honorable life on Earth could earn for them eternal life in heaven and possibly a place among the gods. Evildoers, unless they appeased the gods, would be damned to the underworld, where they would spend eternity. The end of time for man was marked by death and reclaimed for eternity in the afterlife.

As we read these highly entertaining and often spiritually uplifting myths, we learn a great deal about human nature and of our debt to Greek and Roman cultures. Even today, in our struggle to survive, Greek and Roman myths help people to better understand humanity's obedience to a higher power, the relationships of men and women to one another, the power of love and friendships, the horror of war and natural catastrophes, and the passage of time, with death and the afterlife to come.

Norse and Teutonic (Germanic) Mythology

Germanic mythology refers to the myths of people who spoke Germanic dialects prior to their conversion to Christianity. These ancient Germanic people from the continent and England were illiterate. Most of what we do know about the mythology and beliefs of that era comes from literary sources written in Scandinavia and then transcribed into the Old Norse language of Iceland between the 12th and 14th centuries. Two collections of verse, known as the *Eddas,* exist. The earliest, the *Elder Edda* or *Poetic Edda,* contains the earliest Norse mythology; the *Younger Edda* or *Prose Edda* was written by Snorri Sturluson about 1220 CE. In the *Prose Edda,* Sturluson combined a variety of sources with three earlier poetic accounts of the origin of the world in order to create a wholly representative mythology.

In the *Prose Edda* version of the Creation, all that originally existed was a void called Ginnungagap. There was no time, and everything remained still. To the north of the void was the icy region of Niflheim; to the south, the sunny region of Muspelheim. Warm breaths from Muspelheim melted the ice from Niflheim, and a stream of water flowed into the void from which the giant, Ymir, ancestor of the Frost Giants, emerged. Created from drops of the melting ice, Audhumbla, the cow, nourished Ymir and was nourished herself by licking salty frost- and ice-covered stones. The stones were formed into a man, Bori, who was destined to become the father of Odin, Vili, and Ve. The brothers slaughtered Ymir and created the earth from his flesh, the mountains from his bones, the sea from his blood, the clouds from his brains, and the heavens from his skull.

The heavens, according to the *Prose Edda,* were balanced by four dwarfs: Austri, Westri, Nordi, and Sudri, the directions on a compass. Sparks from the fire-land, Muspelheim, became the stars of the sky. This newly created land, named Midgard, was to become the somber home of mortal humans. Even in Asgard, home of the gods, the atmosphere was grave, and the Norsemen believed that the end of time would come in a bleak and horrible way. The only hope was to face disaster and fight the enemy bravely to earn a seat in Odin's castle, Valhalla.

As did so many similar myths, Norse mythology reflected the attitude of the culture that in death there is victory and true courage will not be defeated. The final chapter in Norse mythology is called Ragnabrok, meaning the twilight of the gods. In this period it is prophesied that winter will continue for three years. On the last day, Odin will lead dead heroes in a fierce battle against the Jotuns (trolls) and the power of darkness. Odin, himself, will be devoured by the Fenris Wolf, and the world will become a smoking ruin swallowed by the sea. From this will come new life and a time of peace.

Asian Mythology

The myths of India, China, and Japan are highly complex and sophisticated. They differ from Greek, Roman, and Germanic mythologies in that rather than venerating anthropomorphic deities, the structures of their deities are often polymorphic, intricately combining human and animal forms. The gods and goddesses of the Hindus sometimes take extraordinary human forms, with numerous heads and eyes and arms. Hindus believe that their religion existed before the universe came to be. Their mythology on the afterlife is unique. They believe in karma and reincarnation. Simply stated, karma is the effect of an individual's actions resulting in consequences in present and future lifetimes. At the time of death, to be reincarnated as a human being is thought to be a blessing. Reincarnation as an animal or a plant is reserved for those for whom a spiritual life is not possible.

Deities in Chinese and Japanese myths were also animistic, but these myths were supplanted by mythologies derived from the three great religions: Taoism, Confucianism, and Buddhism (Buddhism having been brought to China from India in 300 BCE). Shinto, the religion indigenous to Japan, borrowed much from Chinese mythology, resulting in a tradition that paralleled that of the Buddhist pantheon. Notably, in Asian cultures, two or more religions may be observed simultaneously, because they are less eschatological but more ethical or philosophical in emphasis.

Generally speaking, before there was heaven or earth, there was chaos, devoid of time, shape, or form. First to materialize was the Plain of High Heaven and the three creating deities. Earth was born, and immortals procreated. It was due to the "divine retirement" of the goddess, Izanami, that the notion of death or life limited by time entered the world. It is interesting to note that there is difficulty in finding a Chinese word equivalent to the English word "time." "Shi" can be associated with time, but the meaning tends to mean "timelessness" or "seasonality." In Asian cultures, time is marked by history, as in the duration of a dynasty. Individually, time is of little concern, because a person's life is viewed as part of an ancestral continuum. Although the tenets of these religions encompass a belief in life after death, the focus is showing people how to live rather than what will happen to them upon their demise. We may deduce, then, that oriental myths not only explain the origin of the universe and the parameters of earthly time, but they also deal with commonly held distinctive aspects and cultural values of each civilization.

In ancient times, throughout history, and even today, the family is considered to be a critical part of oriental society and culture. Honor and obedience to one's parents is related to ancestor worship. During the Han period in China, emperors set up shrines for their ancestors because they believed that spirits could bring blessings to them and to their families. In general, oriental myths connect the actions of deities and other supernatural beings to the everyday actions of men, women, and the natural world around them. Individual gods protected the family, the home, and the country and represented the sun, the moon, and the planets. Myths describe how the islands of Japan were created and deliberately located by the gods in the very center of the world. The two main books of the Shinto religion are the *Koji-ki* and the *Nihon-gi*. *Nihon-gi* explains how all of the emperors of Japan are directly descended from the sun goddess. Today, the rising sun is symbolized in the Japanese national flag.

Commonalities

What the disparate mythologies from all over the world have in common is their heartfelt desire to explain the origin of humankind and to validate its existence. We are searching to satisfy the very human need to explain our relationship with the powerful and mysterious forces that drive the universe. Throughout the world, myths reflect those themes that deal with nature, supernatural beings, ancestors, heroes and heroines, life, death, and time. In Africa, where myths have been preserved mainly through the oral tradition, the natural elements are immortalized through myths. Many versions of Creation stories abound. The Dinka of Sudan believe that the first man and woman were made from clay and put into a tiny, covered pot, where they grew to full height. Australian aboriginal mythology deems that their community and culture were created during dreamtime, "the time before time," when spirited creatures came from the sky, the sea, and the underground to generate mountains, valleys, plants, and animals. We are familiar with the great spirit myth of North American Indians and the time that Native Americans identify for their ancestors in the happy hunting ground. The Aztec people of South America were polytheistic and offered sacrifices to appease their gods. Huitzilopochtli, the great protector of the Aztecs, was portrayed in the form of an eagle, and it was he who deemed where the great pyramid would be built as "the heart of their city and the core of their vision of the universe." From Ireland comes a myth about Cu Chulainn, a hero who could change form to oppose evil forces. A Polynesian myth from the islands of the Kanaka-Maori people centers on Maui, who brought the gift of fire to his people. In ancient Egypt, from pharaohs to peasants, each individual had a god or a goddess corresponding to his or her time and place in society.

As we can perceive, in every era and in every geographical area, myths have evolved as nearly sacred literature, devoid of theology. Each myth is unique to a culture and is in itself a monument to the precariousness of human existence.

As society becomes increasingly more global and less local, people continue to find experiential concepts that are impossible to fathom and beyond human comprehension. The beginning of time, the miracle of birth, the finality of death, and the fear of the unknown compelled early humans to create deities who presided over the celestial sphere. If myths are a symbolic representation reflecting the society that created them, how, then, will the mythology of our times satisfy our collective need to know?

Suzanne E. D'Amato

See also Beowulf; Cronus (Kronos); Rome, Ancient; Tantalus; Wagner, Richard

Further Readings

Baker, A. (2004). *The Viking*. Hoboken, NJ: Wiley.

Bellingham, D., Whittaker, C., & Grant, J. (1992). *Myths and legends: Viking, Oriental, Greek*. London: New Burlington.

Burland, C., Nicholson, I., & Osborne, H. (1970). *Mythology of the Americas*. London: Hamlyn.

Christie, A. (1983). *Chinese mythology*. Feltham, UK: Newess Books.

D'Aulaire, I., & D'Aulaire, E. P. (1992). *D'Aulaire's book of Greek myths*. New York: Doubleday.

DuBois, T. A. (1999). *Nordic religions in the Viking age*. Philadelphia: University of Pennsylvania Press.

Guirand, F. (Ed.). (1959). *Larousse mythologie générale*. London: Batchworth.

Kirk, G. S. (1974). *The nature of Greek myths*. London: Penguin.

Lip, E. (1993). *Out of China: Culture and traditions*. New York: Crabtree.

Poisson, B. (2002). *The Ainu of Japan*. Minneapolis, MN: Lerner.

Wolfson, E. (2002). *Roman mythology*. Berkeley Heights, NJ: Enslow.

N

Nabokov, Vladimir (1899–1977)

Vladimir Vladimirovich Nabokov, a Russian author and entomologist, was born into a wealthy patrician family in St. Petersburg, Russia, and died in Montreux, Switzerland. Time plays an important role in all of Nabokov's novels, and in all of his works a certain melancholy is noticeable.

Nabokov's father, Vladimir Dimitrijevich Nabokov, was a liberal criminologist, publicist, and politician who was one of the leaders of the Constitutional Democratic Party in Russia before the Russian revolution. His mother, Jelena Ivanova Nabokov, née Rukavishnikov, came from a family of industrialists and land owners. In the Russian October Revolution of 1917, the family lost all its property. The elder Nabokov was one of the leaders in the Duma in the February Revolution, but he had to flee after being captured by the Bolshevists in the October Revolution. The family left Russia for England, where Nabokov attended Cambridge and studied Russian and French literature; later the family moved to Berlin, Germany. In 1922, while shielding a friend from gunfire, his father was assassinated at a political meeting by a reactionary Russian exile.

In 1925, Nabokov married Vera Jevsejevna Slonin, a Jewish Russian. In the same year, his first novels, *Maschenka* and *Korol, Dama, Walet* (*King, Dame, Knave*) were published. In 1937, Nabokov had to flee to France because he was married to a Jew in Germany. In Paris, he wrote his first novel in English, *The Real Life of Sebastian Knight* (1939), was published in 1941. In the same year, his mother died in Prague. In 1940, together with his family, he moved to New York shortly before France was conquered by Germany. From 1941 to 1948, he worked as a lecturer in Russian language and literature and as a research fellow in entomology at Harvard University in Cambridge, Massachusetts. From 1948 to 1959, he was a professor of Russian and European literature at Cornell University, in Ithaca, New York.

Nabokov's first autobiography was published in 1951, and it was republished after many changes as *Speak, Memory* (1966). In 1955, what was to be his most famous work, the novel *Lolita,* was published. In this novel, the cultured Frenchman Humbert Humbert writes his memoirs concerning his love for a 12-year-old American girl. The book was a succès de scandale and a literary sensation; the substantial income from this novel allowed Nabokov to quit his work as a college professor and to move back to Europe, where he and his wife lived in a suite in a hotel at Switzerland from 1961 onwards.

His second famous novel, *Pale Fire,* appeared in 1962 and consists of two parts. The first part is a poem by a fictional author called John Shade. In the second part, the scholar Kinbote, who claims to be the king of a country called Zembla, comments at length on the poem and interprets it as the story of his own life.

In his most famous novel, *Lolita,* there is the contrast between the protagonist and the narrator of the story. Both are one person: Humbert Humbert.

But, the narrator Humbert tries to relive the pleasures he once had by telling the story of his time with Lolita. The pervading melancholia results from the feeling of being small and powerless in comparison with the universal laws of time and the universe. On the other hand, time does not matter for that work of art which can revive memories (even the memories of strangers). Unfortunately, these memories are always deficient.

While Nabokov's concept of time remains implicit in his novels, it is one of the main themes in his autobiography *Speak, Memory: An Autobiography Revisited* (1966). Many of his creative ideas were inspired by his reading of Marcel Proust. Nabokov's main theme in this context is human consciousness. For him, the human life is "a brief crack of light between two eternities of darkness." But in consciousness, a human life (even other human lives) can be preserved in memories. From this viewpoint, literature is a way to preserve memories (although a deficient one) and also a way to prevent others from dying. Moments and persons can be conserved in words, but not without a loss of reality. Consequently, consciousness is superior to literature.

From Nabokov's point of view, literature is a desperate fight against time and darkness, which, in his opinion, follow the consciousness of a human life.

Markus Peuckert

See also Consciousness; Memory; Proust, Marcel

Further Readings

Boyd, B. (1990). *Vladimir Nabokov: The Russian years.* Princeton, NJ: Princeton University Press.

Boyd, B. (1991). *Vladimir Nabokov: The American years.* Princeton, NJ: Princeton University Press.

Connolly, J. W. (Ed.). (2005). *The Cambridge companion to Nabokov.* Cambridge, UK: Cambridge University Press.

Nabokov, V. (1996). *Novels and memoirs 1941–1974.* New York: Library of America.

Nāgārjuna, Acharya (c. 150–c. 250 CE)

Mahayana Buddhist tradition attributes the founding of the Madhyamika School to Acharya Nāgārjuna (c. 150–c. 250 CE), but this attribution is probably incorrect, because there is no designation for such a school until the work of another monk named Candrakirti refers to it in the 7th century CE. Although he is credited with composing other works, Nāgārjuna's seminal text is *Fundamentals on the Middle Way,* in which he advocates a philosophy of the middle way between the extremes of being (eternalism) and nonbeing (nihilism).

This philosophical position means that nothing in the world exists absolutely and nothing perishes totally. Nāgārjuna's middle way is located beyond concepts or speech in the sense that it is transcendental. This philosophical position also means that no specific position is limitless or ultimate. In fact, the ultimate truth is that there is no correct view, final truth, or goal, because all views are flawed. Nāgārjuna's middle way implies rising above clinging to either existence or nonexistence. More precisely, the middle way is the practice of the perfection of wisdom (*prajnaparamita*), or ultimate virtue for a bodhisattva (enlightened being). When one achieves wisdom, one does not arrive at a particular type of knowledge, but one rather reaches a point at which all knowing and theorizing are terminated.

Nāgārjuna makes a distinction between two kinds of truth: conventional and ultimate. The former is valid and useful for practical living, but it is illusory, because it becomes self-contradictory if we push it too far. This is evident with the concept of time. From a conventional perspective, the concept of time represents the past, present, and future that appear as a series of moments; this is associated with human perception and conceptual formulation. The conventional concept of time is formed by the assumption of a self-substantiated reality that binds persons to their own emotional and conceptual habits. In short, for Nāgārjuna this is the realm of ignorance, which involves mistaking things or concepts for what they are not in fact, because ignorance obscures the real nature of things and constructs a false appearance.

In contrast to conventional truth, Nāgārjuna defines ultimate truth as a nondual type of knowledge that involves a contentless intuition. By viewing time from this perspective, we observe it simultaneously much as we view a painting on a wall by seeing the whole of it. This intuitive type of knowledge is beyond ordinary objective knowledge and reason, because it represents dissolution of the conceptual function of the mind, although it does not represent a total rejection of conventional truth. It is the realization that all distinctions, such as the three moments of time, are empty (*sunyata*), which is true of everything in the world.

If time and everything else in the world is empty, there can be no essential distinction between existing things. Nāgārjuna denies the distinction between self-being (*svabhava*) and other-being (*parabhava*). If self-being is the essential nature by which something is what it is and not something else, and other-being owes its existence to something else, Nāgārjuna denies that there is anything that is not dependent or conditioned. The heat of fire, for instance, is never encountered apart from fire, making heat something created and not self-existent. If the true nature of everything is emptiness, there is nothing that is self-existent, because it would have to be necessarily noncontingent and unrelated to anything else, which means that lack of self-existence is the nature of things.

These fundamental philosophical convictions motivate Nāgārjuna to criticize basic categories, such as causation, motion, and time. If all things are conditioned, each phase, for instance, possesses a before (future) and an after (past) relative to it. Using his dialectic that undermines all philosophical positions, Nāgārjuna asserts that each part of his dialectic is a counterpart to the prior step, which results in each part negating and canceling out its predecessor. Nāgārjuna's dialectic moves toward the negation of the final part. By thus disposing of all philosophical views, Nāgārjuna uses his dialectical method as a therapeutic device to cure humankind of its suffering, which is caused in part by its mental and emotional attachment to phenomenal and conceptual entities in preparation for genuine insight into the nature of things.

With respect to the notion of time, the dialectic indicates that neither the present, past, nor future can be seized as absolute, but they have significance only relative to each other. Thus the three moments of time are relational concepts. There is no such thing as the past in itself, the present in itself, or the future in itself. Moreover, time is pertinent merely to this world. If ultimate truth indicates that there is neither past, nor present, nor future, time is a derived notion or a mental construct. There are no individual entities of time.

This position means that time is not an immutable substance that can be grasped and measured. There is also no absolute time that continues to be real apart from successive moments. Time is merely a mode of reference that points to the arising and perishing of events. When a person witnesses these arising and perishing events, he or she names them "time" and draws distinctions among the moments of time in relation to each other.

From Nāgārjuna's perspective, the three moments of time enable one to grasp time as a set of relations. To be located in any particular moment—past, present, or future—means to be dependent upon the location of the other moments. Therefore, the present is, for instance, such only because it is located within the instants of the past and future, which suggests that time is a dependent set of relations among three moments. No single moment of time represents an entity in its own right.

From the perspective of attaining liberation, there is no escape from time, because there is nothing from which to escape. In the final analysis, Nāgārjuna does not deny the commonsense view of time. What he wants to show is that time and other categories are not ultimately real.

Carl Olson

See also Buddhism, Mahayana; Buddhism, Theravada; Buddhism, Zen; Dialectics; Intuition; Time, Nonexistence of

Further Readings

Nagarjuna. (1986). *The philosophy of the middle way: Mulamadhyamakakarika* (D. Kalupahana, Trans.). Albany: State University of New York Press.

Streng, F. J. (1967). *Emptiness: A study in religious meaning*. Nashville, TN: Abingdon Press.

Wood, T. E. (1994.) *Nagarjunian disputations: A philosophical journey through an Indian looking glass* (Monographs of the Society for Asian and Comparative Philosophy, No. 11). Honolulu: University of Hawai'i Press.

Navajo

The Navajo, or Diné (meaning "the people"), are the most numerous of the North American Indian tribes, having more than 290,000 people. The Navajo nation ("the big rez"), which is about the size of West Virginia, officially encompasses 25,000 square miles at the juncture of northeastern Arizona, southeastern Utah, and western New Mexico. The reservation itself was created in 1868 by the U.S. government; however, the Navajo live within the four sacred mountains, (Mt. Blanca, Mt. Taylor, San Francisco Peaks, and Mt. Hesperus), a place of great beauty where they feel they belong in accordance with the guidance of their holy ones. This space is actually larger than what is considered the present day reservation.

Life and time are cyclical in the Navajo cosmology, and everything has a place within it. Stories passed down in Navajo culture explain that the people emerged into this location after going on a long and arduous journey during which they passed through four different colored worlds. In the first world (black world), first man and first woman were formed. They passed through the second world (the blue world), the third world (the yellow world), and the fourth world (the glittering world). Quarreling forced them out of each world; they had encountered insect beings, several species of birds, and many mammals, including Coyote, a trickster who is an important figure in Navajo culture. The natural world was put into harmony or balance (*hozjo*) by the Creator or spiritual life force. Finally, a flood brought the Navajo to the fourth world or glittering world of the four sacred mountains. The Navajos are said to have emerged from a hole in the La Plata Mountains.

Early History

Archaeological and linguistic evidence shows that the Navajo migrated from present-day northwest Canada and Alaska to the American Southwest around 1000 CE. Linguistic similarities suggest that the Navajo and Apache tribes were once a cohesive ethnic group, speaking the dialect of the Athabaskan and Apachean language family. Navajos were considered highly adaptive to changing conditions and were able to incorporate things from other cultures. They were famously known to their Pueblo neighbors as traders and raiders. The Pueblo groups exchanged maize and woven textiles for meat and hides of deer, antelope, and elk. The Spanish arrived in the 1500s, bringing with them horses, sheep, and goats of European origin. After Spanish colonization in the 17th century, Navajo life became more sedentary as the people established camps to raise sheep and corn. They learned weaving from the Pueblos and silver crafting from their Mexican neighbors.

Shaping of the Navajo Nation

Anglo Americans and Navajos lived in relative peace during the 1800s until a Navajo leader named Narbona was killed in 1849. In the 1850s the U.S. government began to set up forts in Navajo territory, including Fort Defiance and Fort Wingate. After the Spanish were expelled by the Anglo Americans in the southwestern United States, the Navajos fell under the scrutiny of the U.S. government, which was determined to settle the West. The Treaty of 1868 is a significant event in Navajo history and Navajo/U.S. government relations. Unlike so many other Native American tribes during the 19th century, the Navajo were allowed to return to a portion of their traditional homelands. Attempts were being made to round up tribal groups in an effort to solve the "Indian problem" by creating reservations. In 1863, the dispossession of their lands was a major blow to the Navajo. The U.S. government was trying to prevent raids intertribally and on encroaching settlers. In addition, whites suspected that there were valuable minerals on Diné lands. Colonel Christopher "Kit" Carson was called in with his army to defeat the Navajo. Carson commanded his soldiers to shoot on sight men, women, and children. He also wiped out the Diné food supply, burning crops, killing domesticated animals, and torching houses. In February of 1864, the Navajo began to turn themselves in to army forts in surrender.

The policy of Indian relocation set forth by the U.S. government proved to be a disaster. The Long Walk (to Bosque Redondo) is an especially painful moment in Navajo history. The Diné were forced to walk for 3 weeks for more than 300 miles, and hundreds lost their lives. When the Navajo finally arrived at Bosque Redondo, they faced extreme living conditions. The water was unfit to drink, there was no firewood, and they were rationed poor-quality subsidized food from the U.S. government. Around 9,000 Navajos were relocated and were not allowed to return to their lands until the Treaty of 1868, which many Navajo leaders signed to recover their lands.

Navajo Family and Daily Life

The Navajo tribe is a group of more than 100 separate clans, including the four originals: Towering House, Bitterwater, Big Water, and One Who Walks Around. Families consist of extended kinship networks, with clans being traced through the mother's side ("born to"), and the father's side is acknowledged by saying "born for." Women have an important status in Navajo society. When a man gets married he joins his wife's family, and the wife's brother takes on many roles associated with fatherhood toward her children. Traditionally, marriage within clans is not permitted. Both men and women care for children. The women have land rights, in addition to owning the house, the goats, and the sheep.

When Navajos first meet each other, they state which clan they are from. *Ya'at eeh* is a common phrase, which means "greetings" in the Navajo language. Navajos live in isolation from one another on the landscape. It can be miles between two Navajo sheep camps, the land between can appear to be uninhabited. Physical and personal space is valued. It is estimated that 80% of the Navajo still speak their native language. Language, customs, and lifeways have been preserved and passed down in the Navajo culture despite strong outside Anglo influences to assimilate.

Hogans

Traditional houses are called *hogans*. The houses are eight-sided, domed, and nearly circular in shape. Old timers still use these as a dwelling, while more often in contemporary times these structures are used for ceremony. They are made of wood poles and earth with the doorway open to the east to welcome the morning sun and receive positive energy and blessings. The sun is an important symbol of the divine and Creation; however, the sun itself is not worshiped in Navajo religion. The Navajo find balance with an orientation within the four directions. East represents the dawn and thinking, south signifies planning and what needs to be done, west represents life and how to carry out plans, and north an evaluation and reflection of how to continue of the path of life. ("Before me, behind me, below me, and above me, with balance I pray" is a common morning prayer of centering along with the focus on beauty: "All is beautiful, if everything around you is beautiful, beauty is the way you live.")

Today, many hogans are constructed with modern materials and have windows. Sometimes, small hogans are built for sweat baths. The steam makes the body sweat and a cleansing occurs on both a physical and spiritual level. Additionally, some families build summer hogans and winter hogans near appropriate places where their sheep graze.

According to custom, it is considered rude to greet a person when visiting a hogan without waiting several minutes before entering. It is also considered rude to make eye contact or to shake hands with another with a firm grip. Religion is integrated into all other aspects of daily life for the Navajo. Life itself is considered sacred along with the earth and the idea of maintaining balance or harmony with all things. Life is cyclical, as well as time, and everything has a place and a season in Navajo religion and cosmology. In the Navajo culture there is no such thing as a coincidence; things happen because they were meant to. Religion ceremonies are elaborate and complex, lasting anywhere from 3 to 8 days or more. Religious gatherings include songs, chants, prayers, and sandpaintings. Ceremonies are called *Ways* and the religious leader is a *singer* who sings special songs and makes sandpaintings. Ceremonies were given to the Navajo by the holy ones, who instructed them in how to recite the prayers and songs. Important lessons have been passed down along with history and universal wisdom. Ceremonies are used for healing the sick, for blessing a person, or for celebrating a happy moment, such as the birth of a child. Corn and corn pollen are considered sacred and play an important role in Diné ceremonies. The content of ceremonies includes much sacred knowledge with great power, and parts of ceremonies remain secret and are not discussed outside the ceremony.

Sandpaintings

Sandpaintings are "a place where the gods come and go" in the Navajo language and are used in healing ceremonies and to connect with nature. These elaborate creations are filled with symbolism and often contain representations of the first man and first woman from Navajo cosmology. After the ceremony, the pictures are swept up and the sand is taken away.

Ways

There are several Way ceremonies that serve a certain purpose in Diné culture. The Night Way is a 9-day healing ceremony where friends and relatives gather around the sick person and songs, and prayers, are offered and sandpaintings are created. The enemy Way is used when a Navajo returns from a non-Navajo society to cleanse that person of foreign influences. The Blessing Way is a ceremony that is used to be sung over someone. It is unique, because it is not used for healing; rather, it is used to foster good luck, good health, and blessings relevant to a person's life.

Navajo Code Talkers

During World War II, 3,600 Diné men and 12 women entered military service. The Japanese had been able to decipher all U.S. military codes until the Navajo marines created a code in the Navajo language that was an impenetrable means of secret communication. This made the contributions of these Diné soldiers indispensable to the U.S. military. In 1982, President Ronald Reagan declared August 14th Navajo Code Talkers Day, and in July 2001, 29 code talkers were given Congressional Gold Medals.

The Navajo Today

The Navajo Nation today is a mixture of traditional and modern. There are houses and hogans, sheep farmers and engineers, silversmiths and nurses. However, much is preserved due to the organization of tribal government and Navajo schools with curriculums relevant to Navajo culture and staffed by Navajos, including Diné College. The Diné nation continues to grow and flourish in the 21st century despite some major dark points in its history. The Navajos have proven to be highly adaptable and have overcome adversities. Their determination and philosophy of life allows them to continue and to "walk in beauty."

Luci Maire Latina Fernandes

See also Pueblo; Sandpainting; Time, Cyclical

Further Readings

Iverson, P. (2002). *Diné: A history of the Navajo.* Albuquerque: University of New Mexico Press.

Kluckhohn, C., & Leighton, D. (1962). *The Navahos.* Cambridge, MA: Harvard University Press.

Underhill, R. M. (1956). *The Navahos.* Norman: University of Oklahoma Press.

Nebular Hypothesis

At the beginning of the 17th century, Johannes Kepler was able to illustrate that the planets tended to move elliptically. Subsequently, the publication of Isaac Newton's laws of motion and gravitation in 1687 marked the first systematic scientific approach to examining the origin of the solar system. Then, in 1755, the German philosopher Immanuel Kant proposed the theory that the solar system had its beginnings as a cloud of dispersed particles of both dust and gas and that it is a product of centrifugal and centripetal forces. In 1796, the French mathematician Marquis Pierre-Simon de Laplace refined the theory further. He described the original state of the solar system as a hot, rotating nebula. As the mass cooled and contracted, the nebula assumed a flattened shape. The sun was formed at the center, with rings of gaseous material surrounding it. Planets then condensed from the rings. By the same process, moons formed around planets. This theory seems to explain why planets generally move in the same plane and direction.

It was at this point in time that the theory first became known as the "nebular hypothesis." It has since sometimes been referred to as the Kant/Laplace nebular theory, because Kant apparently arrived independently at the modified version of the hypothesis about the same time that Laplace did so. Laplace thought that the theory supported the predictability of the universe, while Kant believed that it indicated the universe was likely to change through time.

Though the nebular hypothesis has been examined and modified through the subsequent years by the scientific community, Kant's original brilliant concept can still be said to serve as an important component of current theories on planet formation.

Early in the 20th century, several British and American scientists pointed out definite deficiencies in the nebular hypothesis and proposed that planets were formed by a rare encounter of a star and the sun. In the mid-20th century, these star encounters were shown to be impossible, as the gaseous material involved would naturally dissipate rather than condense as planets. Therefore it was generally concluded that the formation of planets and stars must take place during the same process. Scientists have indeed noted that planets tend to form around newborn stars, and they now refer to the disks of dust and gas they have observed around these stars as "protoplanetary disks."

Naturally, scientists have always been interested in determining how long it took the universe and specific planets to form. A common theory has been that there are two stages in the formation. It is during the first stage of accretion that small, rocky planets such as Earth form. Solids collide and stick together, with gases forming atmospheres around these smaller planets.

A smaller planet must have the time to grow large enough for the second stage to begin and for larger, gaseous planets to form. There is more limited opportunity for these larger planets to form, because the gas itself might disappear in a few million years. On the other hand, the formation of the smaller planets can continue more slowly for up to 10 or hundreds of million years.

It has been speculated that the disks around smaller planets disappear after 3 to 5 million years. Yet that time period may well be too limited to permit the formation of larger planets, such as Jupiter. A number of scientists now accept the theory that other solar systems with similar sized planets must be fairly common (and planets larger than Jupiter have actually been noted), but more research is needed to attempt to explain exactly how Jupiter—and all the other planets—did form.

Two theories of how the gas giants formed have been proposed. "Core accretion" would result in these giants forming relatively slowly, because a large, solid core would be necessary to attract a large quantity of gas. "Disk instability" proposes that a cold disk could break up on its own if it is cold and dense enough, resulting in gravitational abilities. The latter process could produce protoplanets in only hundreds or thousands of years.

The original concept that the nebular hypothesis involved a disk forming around a condensed center is still held regarding what is now commonly referred to as the Solar Nebula. As gas and dust collapsed toward the center, kinetic energy was formed and the temperature rose to the point of producing a nuclear reaction and the subsequent birth of the sun.

Theories have also been developed about the differences between the inner and outer planets. Their size appears to involve how much water is available and whether planets are far enough away from the sun for ice to form. Planets located at a far enough distance from the sun can acquire more solid mass and attract large amounts of many other elements, including the abundant elements hydrogen and helium. These larger planets formed beyond what is referred to as the "snow line." As is the case with many credible theories, there have been questions about whether or not this process is inevitable. Discoveries and observations of other solar systems, such as 51 Pegasi, indicate enough definite differences from our solar system to raise further questions about exactly how planets are formed.

Current efforts to verify or modify the body of knowledge about how planets are formed are employing many avenues for research. Some, such as Richard H. Durisen's attempt to update Laplace's theory, make use of computer simulations while still identifying dense gas rings as the mechanism of planet formation. Other research focuses on areas beyond our own solar system, such as the Hubble Space Telescope's production of images of protoplanetary disks around stars in the Orion Nebula—about 1,600 light-years away. Continuing observation by astronomers is likely to yield greater understanding of the process of planet formation.

Betty A. Gard

See also Kant, Immanuel; Laplace, Marquis Pierre-Simon de; Planets; Stars, Evolution of; Telescopes

Further Readings

Durisen, R. H. (2005). Rings of creation. *Mercury, 34*(3), 12–19.

Schilling, G. (1999). From a swirl of dust, a planet is born. *Science, 286*(5437), 66–68.

Weintraub, D. A. (2000). How do planets form? *Mercury, 29*(6), 10.

Neogene

The Neogene, a term introduced by Moritz Hörnes in the mid-19th century, is a period in the geochronological scale and a system in the chronostratigraphic scale. This dual procedure (time interval and corresponding rock record) is used by earth scientists to subdivide geologic time in deciphering the history of the earth. The Neogene is the last period/system of the Cenozoic era/erathem and, accordingly, the most recent one of the earth's history. It began 23 million years ago, at the Paleogene-Neogene boundary, and it ends at the present. Under the current proposal of the International Commission on Stratigraphy, it includes four epochs/series: Miocene, Pliocene, Pleistocene, and Holocene. The classification and interpretation of the last two epochs/series, as well as a Quaternary sub-era, have been, and still are, a matter of debate. An important consequence is that the scientific community inherited different notions for the Neogene. Thus, the end of the Neogene has been variously interpreted to be at the Pleistocene–Holocene, Pliocene–Pleistocene, and Tertiary–Quaternary boundaries.

Marine microfossils are the backbone of the subdivision of the Neogene into its constituent ages/stages. Complex mammal evolution under the influence of major continental separations and climatic change and orbital forcing cyclicity in sediments and oxygen isotopes records in the Atlantic and Mediterranean (supported by the Australian–Antarctic marine magnetic polarity scale) provide a precise and highly accurate Neogene timescale.

The Neogene Earth looked much like our own. However, the relatively similar distribution of landmass between then and now masks some dramatic changes. Some continental motion took place during the Neogene, the most significant event being the counterclockwise rotation of the Arabian Plate, connecting Africa and Eurasia and cutting off the remnants of the old Tethys. India collided with Asia, giving rise to the Himalayan Mountains and the connection between North and South America.

In the south, a continuous circumpolar current circled Antarctica, isolated from other landmasses. Thus both poles were thermally isolated from warm equatorial waters, and (perhaps for the first time since the Ordovician) both poles accumulated heavy coverings of ice. At the same time, the virtual closing of east-west circulation through the Mediterranean Sea and between the Americas changed the hot, circulating currents. Thus, during the Neogene the world became much drier and cooler, culminating in the Pleistocene ice ages and the harsh conditions of the present day.

The world dried out. Huge deserts developed in North Africa and Central Asia. Grasslands expanded and quickly replaced the thinning forests. During the Neogene, birds and mammals evolved considerably, and the dawn of the genus *Homo* occurred. However, most other animals not needing grasses were relatively unchanged. Grasses are poor fodder: tough, low in nutrients, high in tooth-destroying silicates. Consequently, herbivorous species were smashed or utterly changed. Some grazer species emerged and evolved high-crown teeth. Ruminants diversified, and cranial appendages appeared. Nevertheless, their predators followed them into extinction or transformation. The later Neogene saw the creation of an entirely new type of hunter, the pursuit predator. The pursued developed their own responses: herd behaviors, seasonal migrations, and big bodies adapted for speed and endurance in open country.

Another line of adaptation led to small-bodied generalists (rodents, raccoons, rabbits, and opossums) and their predators, the foxes, cats, dogs, and snakes. These generalists were mainly unspecialized herbivores or omnivores with partially fossorial habits, strong territoriality, and high reproductive rates. Theirs was the ability to exploit many resources within small, locally, or temporarily favorable conditions.

The Miocene epoch (23 to 5.3 million years ago [mya]) or "less recent" is so called because it contains fewer modern animals than the following, Pliocene, epoch. The Miocene is the longest epoch of the Neogene. During the late Miocene the island continent of India slammed into Asia, pushing up the Himalayas. Elsewhere, the western American cordilleras, the Alps, and the Caucasus rose as well. One of the best known events in the marine realm is the Messinian salinity crisis at the end of the Miocene. The rise of mountains in the western Mediterranean combined with the global fall of sea level due to formation of the Antarctic ice cap sealed the western end of the Mediterranean for about 600,000 years. During this time, the Mediterranean Sea virtually dried up, forming enormous evaporite deposits. When the present Strait of Gibraltar was ultimately opened, the Atlantic would have poured a vast volume of water into the Mediterranean drying basin, resulting in a giant waterfall, much higher than 1,000 meters and far more powerful than Niagara Falls. On the other side of the African continent, three major rifts opened in roughly an east to west sequence. These events were probably related to the counterclockwise rotation of the Arabian plate. The Miocene was a time of warmer global climates, but during the mid-Miocene (14 mya), a marked drop in temperatures occurred and further led to the buildup of the East Antarctic ice cap.

The Miocene was a time of huge transition, the end of the ancient world, and the birth of the more recent sort of world. Two major ecosystems first appeared during the Miocene: kelp forests and grasslands. It was also the high point of the age of mammals. Also, this period saw animals that had evolved on different continents during the Eocene and Oligocene spread via land bridges.

The Pliocene epoch (5.3 to 1.8 mya), compared to previous epochs, was a relatively brief period of only 3.5 million years. The name *Pliocene* means "more recent." During this time, the earth approached its current form, with ice caps, relatively modern geography, modern mammals, and the evolution of hominids. Continents had taken up their present positions. Both North and South America were drifting northward. However, South America was moving somewhat faster, related to a shift in the Caribbean tectonic plate. Thus, a permanent land bridge between the Americas developed in the mid-Pliocene, allowing mammals to migrate across. The closing of the Isthmus of Panama isolated the waters of the Gulf of Mexico and separated the marine biota of the east and west coasts. This tectonic episode had major consequences for global temperatures, because warm equatorial ocean currents were cut off and the climate became cooler and drier. At the same time, the Himalayan uplift accelerated the unfolding cooling process.

The Pleistocene epoch (1.8 to .011 mya) is known as the ice age, because this short epoch witnessed a dramatic, continued cooling, culminating in a series of advances and retreats of the ice as the climate fluctuated between cold (glacial) and warm (interglacial) periods at periodicities fitting Earth's orbit cycles (Milankovitch cycles). The sea level rose during the melting of the glaciers; then land bridges, created during cooler periods when glaciers sequestered more water, enabled the migration of animals and humans across continents. The term *Pleistocene* ("most recent") was coined for strata with 90% to 100% present day species. Animals and plants were basically modern species, although distributions were unusual. The great mammalian megafauna flourished. Many giant mammals evolved and lived on all continents. During the Pleistocene, the hominid tendency to increase brain size and hence intelligence continued, and finally modern man (*Homo sapiens*) emerged.

The Holocene epoch covers the last 11,500 years of the Neogene period. The term *Holocene* means "completely recent" and refers to the present geological epoch. The Holocene represents a marked climatic warming phase corresponding to the present interstadial (warm period between glaciations) phase. All other ages, epochs, and eras are represented by natural evolutionary and geological phenomena. The Holocene in contrast is distinguished by being the epoch during which there has been an exponential growth in human population and knowledge. Human activities have had a marked, and for the most part extremely detrimental, effect on the rest of the biosphere.

Beatriz Azanza

See also Chronostratigraphy; Earth, Age of; Evolution, Organic; Fossil Record; Geologic Timescale; Geology; Glaciers; Ice Ages; Paleogene; Paleontology; Plate Tectonics; Stratigraphy

Further Readings

Gould, S. J. (Ed.). (1993). *The book of life: An illustrated history of the evolution of life on Earth*. New York: Norton.

Gradstein, F. M., Ogg, J. G., & Smith, A. G. (Eds.). (2004). *A geologic time scale*. Cambridge, UK: Cambridge University Press.

Stanley, S. M. (2004). *Earth system history* (2nd ed.). New York: Freeman.

Wicander, R., & Monroe, J. S. (2003). *Historical geology: Evolution of Earth and life through time* (4th ed.). London: Brooks/Cole.

Nero, Emperor of Rome (37–68 CE)

Nero Claudius Caesar was the fifth of the five Julio-Claudian emperors and one of the most notorious. Two millennia after his death, his name continues to conjure images of a cruel, self-indulgent tyrant who "fiddled while Rome burned." He is also legendary for being one of the first rulers to order the persecution of a small religious sect known as the Christians. Despite the overwhelmingly negative views of Nero and his rule, he represents an important period in the history of Rome. Nero was the last emperor with a hereditary link to Julius Caesar. He reigned at the end of a century of peace. After his death, civil war broke out. Because Nero had ordered the death of any relative who might inherit the throne after him, when he died the throne was open to anyone with the power to claim and keep it.

Early Years

Nero was born in Antium in December, 37 CE, and was named Lucius Domitius Ahenobarbus. His father, Cnaeus Domitius Ahenobarbus, was a member of a distinguished noble family of the republic. His mother, Agrippina the younger, was the daughter of Germanicus. When Lucius was 2 years old, his father died. The reigning emperor, Gaius (Caligula), brother to Agrippina, seized his inheritance and banished mother and son to the Pontian Islands, where they lived in near poverty. Caligula and his wife and infant daughter were killed in 41 CE. His uncle Claudius, a far milder ruler, ascended to the throne and recalled his niece and her son from exile. Agrippina, a very ambitious woman, promptly arranged a proper education for her son.

In 48 CE, Claudius had his wife Messalina executed for adultery. The following year he married his niece Agrippina, and she furthered Lucius's prospects by having him betrothed to his stepsister Octavia (whom he married 4 years later). Lucius completed his education under the tutelage of the eminent Stoic philosopher Lucius Annaeus Seneca. In 50 CE, Agrippina persuaded Claudius to formally adopt her son, securing his place as heir to the throne. Lucius's name was officially changed to Nero Claudius Drusus Germanicus.

Emperor Nero

Claudius died in 54 CE—probably poisoned by his wife. Nero claimed the throne with the support of the praetorian prefect Sextus Afranius Burrus. Agrippina acted as regent to the 16-year-old emperor. Nero's first few years as ruler were stable, led by the sound guidance of Burrus and Seneca. Nero announced that he would model his rule after that of Augustus, a very prestigious and respected ancestor. Nero applied himself to his judicial duties, granting more freedom to the senate, forbidding the killing of gladiators and criminals, lessening taxes and the extortion of money by provincial governors, and making reforms to legislation.

Difficult decisions and administrative pressures eventually caused Nero to withdraw. He devoted himself to pleasures: chariot racing, singing, poetry, acting, dancing, and sexual activity. Seneca and Burrus attempted to keep his performances private and the government running smoothly. Agrippina was furious about (some say jealous of) Nero's conquests. She also deplored her son's interest in Greek art. Nero grew hostile toward his mother as news of her virulent gossip came back to him.

Nero's life reached a turning point when he took a new mistress named Poppaea Sabina. Agrippina supported his wife Octavia, who was naturally opposed to this latest affair. Nero responded by making various attempts on his mother's life. After three unsuccessful attempts to poison her, the ceiling over her bed was rigged to collapse while she slept. That also failed, so a boat was constructed that would break apart and sink in the Bay of Naples. However, Agrippina managed to swim ashore as the boat sank. An exasperated Nero finally sent an assassin who clubbed and stabbed her to death in 59 CE. Nero reported to the senate that his mother was plotting his death and he had no choice but to retaliate. The senators had never approved of Agrippina and did not question her removal.

Nero celebrated his freedom with even more contests, festivals, and orgies. He sang, acted, and played instruments in public. Performers were considered unsavory, so it was an outrage to have an emperor on stage. In 62 CE, Burrus died from an illness. He was succeeded as praetorian prefect by two senators who were corrupt and encouraged Nero in his excesses. Seneca found the situation uncontrollable and resigned. Nero's life became a series of scandals. He divorced Octavia and had her killed later that year. He then married Poppaea, who was also killed by Nero a short time later.

Despite Nero's behavior in Rome, the empire as a whole was relatively peaceful and prosperous until one of the greatest disasters in Rome's long history occurred. In July of 64 CE, the great fire of Rome ravaged the city for 6 days. When it was finally contained, 10 of the 14 districts of the city had been reduced to rubble and ashes. After the fire, Nero claimed a vast area and began construction of his "Golden Palace." Given the vast size of this complex, it could never have been built before the fire. The Roman people began to have suspicions about the source of the blaze. Nero, always desperate to be popular, looked for a scapegoat to blame. He found a new, obscure religious sect called the Christians. Many were arrested, thrown to the wild animals in the circus, burned to death, or crucified.

Beginning of the End

A large-scale conspiracy planned by a number of senators to remove Nero from the throne was discovered in 65 CE. The 27-year-old had been emperor for more than a decade, and the only positive result of his reign was the strict building codes put into place after the great fire, making Rome a safer and more attractive city. Nero's response to the conspiracy was to take an extended tour of Greece while his prefect decimated the senatorial ranks by execution or ordered suicide. In the year 68 CE, another revolt began in the provinces. Galba, an elderly provincial governor, claimed the throne and marched his troops toward Rome. Nero was abandoned by the few supporters he had remaining. The senate ordered Nero's death. Nero heard and chose to commit suicide instead, with the assistance of his secretary. He died on June 9 in the year 68 AD. Even at the very end of his life, Nero remained more concerned with his artistic pursuits than affairs of state. His last words were "*Qualis artifex pereo!*" or, "What an artist the world loses in me!"

Nero ruled when there had been over 100 years of relative peace. Despite his antics in Rome, the people in the rest of the empire lived well enough to prevent unrest. Before Nero's death, he had every relative who might ascend to the throne killed, to assure that a child with his blood would rise to power. After he died childless, civil war broke out, because the throne was open to anyone who claimed it. The last of the Caesars was succeeded by a series of provincial strongmen with personal armies.

Jill M. Church

See also Caesar, Gaius Julius; Christianity; Rome, Ancient

Further Readings

Champin, E. (2003). *Nero*. Cambridge, MA: Harvard University Press.

Grant, M. (1985). *The Roman emperors: A biographical guide to the rulers of imperial Rome 31 BC–AD 476*. New York: Charles Scribner's Sons.

Suetonius. (2003). *The twelve Caesars*. London: Penguin Classics.

NEVSKY, SAINT ALEXANDER (1220–1263)

During his short life, Saint Alexander Nevsky, born Aleksandr Yaroslavovich, made his mark in history as one of Russia's best-known Christian military commanders; he protected Russia against European invasion during the Middle Ages. He was heralded as savior of the Russian Orthodox Church.

A military strategist of the time, Nevsky's triumphant defense against the invasion of Russia by the Swedes, the Teutonic Knights, and the Lithuanians saved Russian culture. Many historians believe that, through his collaboration with the Mongols, Nevsky was able to save Russian lives and land and also saved Russia from Roman Catholic control, thus preserving the Orthodox faith. He also did much to advance the centralization of the Russian government.

Nevsky's role as defender of Russian land from the German and Swedish feudal lords began when he was at the tender age of 16, when he became the duty-bound prince of Novgorod. His legendary victory over the Swedes, who in 1240 attempted to block Russia's access to the Baltic at the Battle of Neva, earned him both the name of Nevsky and a place in history by raising him to legendary status. The military tactic of a surprise lightning attack in this battle ensured Nevsky's victory. This was an especially significant event because it prevented an all-out invasion of Russia by the Swedes. This victory further strengthened the young prince's political aspirations.

When the invasion of Russia was again at hand, Alexander Nevsky again went to war. His victorious battle with the German Knights in the Battle of the Ice in 1242 was a significant historical event of the Middle Ages, for it was in this victory that foot soldiers first defeated mounted knights, a military tactic that was to become a timeless battle strategy. This victory and the victory over the Lithuanians in 1245 established Nevsky as a one of the greatest military leaders of that time and ensured the survival of Russia.

In 1246, Nevsky faced a problem that would require his skills not on the battlefields but in diplomacy. The problem concerned a loss of Russian independence. At this time, with the Mongols' conquest of eastern Russia, Nevsky wisely cooperated with them. He was made Grand Prince of Vladimir (1252–1263), and his cooperation with the Mongols allowed him to protect the Orthodox Church from aggression, to spare Russians from further hardship, and to achieve some stability in northern Russia.

Nevsky died in 1263. The end of his leadership was a loss deeply felt by the country, but his heirs ruled Russia until 1917. With his successors and descendants, princes came to be monarchs in Moscow. In death, he continued to be an influence in Russian history. In the 14th century (1381), Nevksy was elevated to the status of a local saint, and in 1547 he was canonized by the Russian Orthodox Church, because his collaboration and intercession with the Mongols helped to maintain Russia's way of life and religious freedom and prevented much bloodshed. This endeared him to the Russian people.

The Alexander Nevsky Monastery, founded in 1710, now includes some of the oldest buildings in the city of St. Petersburg and burial places for some of the giants of Russian culture. In 1725, one of the highest Russian military decorations, the Order of Alexander Nevsky, was established to revive the memory of Alexander's struggle with the Germans, and in 1836 a triumphal arch was erected in his memory and a principal street was named for him in St. Petersburg. In 1937, Sergei Eisenstein made a classic film to promote Russian nationalism using Nevsky as the subject. The Soviet Order of Alexander Nevsky was introduced during the Great Patriotic War of 1942.

Several Russian naval vessels were named for him, including the 19th-century frigate *Alexander Neuski*. Without Nevsky's leadership the history of Eastern Europe and thus of the world might have been very different.

Joyce K. Thornton

See also Attila the Hun; Genghis Khan

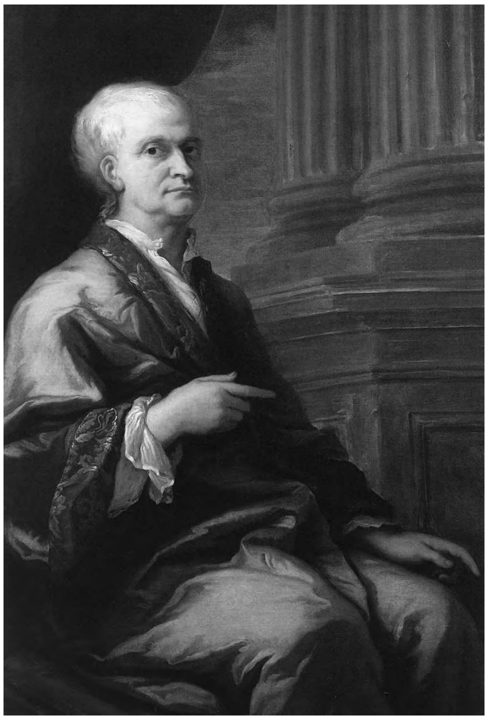
Further Readings

Christiansen, E. (1998). *The northern crusades* (2nd ed.). New York: Penguin.
Commire, A. (Ed.). (1994). *Historic world leaders* (Vol. 3). Washington, DC: Gale.
Mitchell, R., & Forbes, N. (Trans.). (1970). *The chronicle of Novgorod, 1016–1471.* New York: AMS Press.
Presniakov, A. E. (1970). *The formation of the great Russian state* (A. E. Moorehouse, Trans.). Chicago: Quadrangle Books.

NEWTON, ISAAC (1642–1727)

Sir Isaac Newton, English natural philosopher, mathematician, and physical scientist, revolutionized the theoretical concepts regarding the physical laws that govern the universe. The impact of his contributions to the understanding of the mathematical perspective of motion, space, and time provided the means to further challenge both the Aristotelian foundations of science and ecclesiastical authority over science. Additionally, Newton's metaphysical distinctions based on his theoretical principles drew criticism from many theologians and philosophers of the Enlightenment traditions, including rationalist and empiricist.

Praised as a scientist and ridiculed as a philosopher, Newton attempted to construct a metaphysical bridge in order to reconcile the mechanics of the universe with God, but his attempt was vastly underscored or dismissed. For Newton, there had been a conflict between traditional or orthodox religion and science that he now attempted to overcome in presenting his own unorthodox metaphysical approach to God and God's significance for the universe and humankind. Newton's major works include *Philosophiae Naturalis Principia Mathematica* (1687), *Opticks* (1704), and *Arithmetica Universalis* (1707).



Portrait of Sir Isaac Newton (1642–1727) by Sir James Thornhill. A mathematician, physicist, and English astronomer, Newton proposed that gravity was a universal force and that the sun's gravity was what held planets in their orbits.

Newton's scientific, albeit philosophical, explorations in the laws that govern the physical universe are steeped in cursory observations, rational speculations, and mathematical computations. Regarding the temporal nature of the universe and its relation to physical matter, the abstract notions of motion and space are irrevocably united within the conceptual framework of a theoretical and sometimes theological framework. Beyond the eternal, infinite, and geocentric concepts set forth by Aristotle (384–322 BCE), Ptolemy (c. 90–168 CE), and, theologically, Saint Thomas Aquinas (1225–1274 CE), the scientific advancements of Nicolaus Copernicus (1473–1543), Galileo Galilei (1564–1642), and Johannes Kepler (1571–1630) changed and influenced previous perceptions of space, motion, and more important, time. Newton influenced and integrated advancements in both science and philosophy within his perspective; he furthered scientific advancements by creating a mathematically systematic approach to explain the natural phenomena of the universe. These secular contributions to science and mathematics, along with a theistic cosmological perspective, had secured the separation of physics from theology. Interesting and yet obscure, the theistic tendencies within Newton's cosmology possess a confounding blend of ontology and teleology.

Newton provided a scientific explanation for the symbiotic relationship of gravitation and motion. In the explanation of the physical phenomena observed on this planet and in the universe, he calculated that gravitation had an effect on physical bodies, from earthly objects to celestial bodies. In resolving the terms of motion, Newton had stated three laws:

1. Motion is constant until an external force is applied.
2. Force can be calculated by the relationship between mass (m) and acceleration (a); thus $F = ma$.
3. Every action has an equal and opposite reaction.

These explanations in terms of motion have unique implications for the concept of time. Time and space, interrelated and reflected in Newton's established laws, are not in constant and fluid motion. Objects exist in absolute time, and absolute space is perceived in relation to motion. This would question the exact nature of space—space being a void or some reactionary force—and the conceptualization of time in terms of the interactions between the mass and velocity of bodies. Furthermore, a lack of knowledge regarding physical composition, especially of celestial bodies, and its relationship to space and motion, would have greater implications. Although Newton provided mathematical computations to support his rational speculations, his metaphysical implications drew criticisms from both philosophers and scientists with differing theological and philosophical perspectives. However, as a precursor to the work of Albert Einstein (1879–1955), these speculations would lead to monumental contributions to theoretical physics.

The concept of time and its relationship to our own species' developmental ontology and teleology are easily tracked within the historical accounting of philosophical ideals. Reflected in these ideals, self-awareness and temporal perception are uniform; some are supported in part by mathematics. Time becomes an integral part of human existence far beyond the physical mechanics of the universe. For Newton, this reality in the concept of time is often underscored. Within his theistic cosmology, Newton acknowledged that a divine power existed that was both infinite and eternal. Space, similar to this divine power, was infinite yet containing finite objects. These celestial bodies, placed within the confines of space, are not only maintained by a divine force but also explained in terms of mechanical operations of gravity within space. The necessity for a stable system, both theologically and cosmologically, became paramount. The infinity of the universe, as opposed to sidereal boundaries of space, precludes any philosophical distinction and definition of what exists beyond the boundaries of time and space. The distribution of stars and planets, albeit complete solar systems, are finite within the infinite. For Newton, the temporal nature of the material universe, involving creations, recreations, and dynamic (yet stable) changes, was beyond the depiction of time necessitated by religious scripture. The age of the solar system was steeped within the immensity of time. Regardless of the duration of time, the material universe and the mechanical operations of gravity and motion remained to be the sole factor in Newton's argumentt for the existence of God.

The cosmological ideas of Newton concerning the sensorium of God, though heretical, depicted an infinite universe governed by the mechanical operations of an intelligent and divine power. Contrary to the views of his day, the previous Aristotelian order and operation of the universe was replaced by a mathematically ordered universe that reflected this divine power. Motion was considered not as a result of the actions of an unmoved mover but of natural laws of gravity, acceleration (velocity), and space. Although Newton never attributed this design to the Greek notion of *logos,* the natural order and laws that govern the solar system and stars was reduced to a theistic "proof" of God's existence, although Newton's perspective on the basic structures of Christianity remains elusive.

Regardless of Newton's theistic beliefs, the universe, stars, solar systems (perhaps multiple systems), and planets were much older than depicted in the Bible. With the errors within scripture being pervasive, it would be interesting to speculate on Newton's own temporal view of our species. The concept of time, regardless of scientific advancements, becomes a personal and universal reality by means of which human beings are aware. Motion and its related mechanical principles illuminate this concept of time and our relation to the external world. Newton's contributions to understanding of gravity, motion, and abstract notions of time and space (finite and infinite) were critical for the foundations for modern physics.

David Alexander Lukaszek

See also Einstein, Albert; Einstein and Newton; Galilei, Galileo; God, Sensorium of; Newton and Leibniz; Space, Absolute; Time, Absolute;

Further Readings

Cohen, B. (Ed.). (1958). *Isaac Newton's papers and letters on natural philosophy and related documents.* Cambridge, MA: Harvard University Press.

Janiak, A. (Ed.). (2004). *Philosophical writings/Isaac Newton.* New York: Cambridge University Press.

McGuire, J. E. (1983). *Certain philosophical questions: Newton's Trinity notebook.* New York: Cambridge University Press.

Newton, I. (1999). *The principia: Mathematical principles of natural philosophy.* Berkeley: University of California Press. (Original work published 1686)

Newton and Leibniz

The controversy between Isaac Newton (1642–1727) and Gottfried Wilhelm von Leibniz (1646–1716) was primarily over their views of space and time. There had been some claims among Newton's followers that Leibniz had plagiarized from Newton, particularly regarding the calculus. It was later proved that there was no plagiarism, but that these two geniuses, standing on the shoulders of those (like Johannes Kepler, for example) who had preceded them, had each made the conceptual leap independently to the calculus. However, Newton (somewhat paranoid) may have retained some feelings of resentment toward Leibniz, and thus does not respond to him directly about their differing views; rather, the differences are aired primarily in the correspondence between Leibniz and Samuel Clarke, a follower of Newton.

Newton had expressed his views on space and time in his *Principia Mathematica* (1686), in the scholium following the section on definitions. He explains why he did not include in the definitions time, space, place, and motion, because they were well known to everyone. However, people commonly held prejudices regarding these concepts, so he expounds his technical definitions. "Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external." It is also called duration. Relative, or common, time is a sensible measure of duration (by means of motion). "Absolute space, in its own nature, without relation to anything external, remains always similar and immovable." Relative space is somehow a measure of this absolute space. It is important to look at both concepts together, because they share characteristics that may help in understanding what Newton means. Space (absolute space) is a kind of permanent container in which things may come and go, appear and disappear. Imagine a huge matrix on which one might move pieces (a kind of cosmological chess board); the pieces may move and change, but the board always remains. By analogy, absolute time is always flowing, and does not depend for its existence on the motion or change of bodies. Change implies a before and an after in time, which therefore presupposes time, so it must be more fundamental, an objective reality, according to Newton. He says that absolute time would exist even if there were no motion, or a lapse between motions.

Leibniz denies that space and time are absolute; he argues that they are relative, that they are relations. Space is the order of perceptions of monads (a monad is Leibniz's basic metaphysical, indivisible substance, a concentration of energy, a kind of mind) that coexist; time is the ordering of a monad's different perceptions. Because space and time depend on monadic perceptions (of the world), they are ideal (phenomenal), not real. Just as other relations (such as "smarter than") do not have an independent existence, but are dependent on the entities compared, neither do space and time have an independent existence. Time is more fundamental; for a monad, the present is represented clearly, the past and the future more obscurely. Space is then the ordering of coexisting monads (or aggregates of monads) at the same time. Leibniz argues that there is a continuum of monads in this best of all possible worlds. (God would have created nothing less; existence is maximized in the best possible world.) If there had not been a best possible world, God would not have had a sufficient reason to create anything.

A controversy between Leibniz and the Newtonians began in 1705 over these serious disagreements. It culminated in 1715–1716 with an exchange of letters between Leibniz and Samuel Clarke, a follower of Newton. It began with a criticism of Newton's position sent by Leibniz to Princess Caroline of Wales; Clarke responded on behalf of Newton, Leibniz wrote back in defense, and so on. There were five letters written by Leibniz, five replies by Clarke, and it ended without resolution, at the death of Leibniz.

Leibniz begins his first letter by attacking Newton's materialism (of atoms and void) and its implications for religion. He argues that Newton's system implies that God is a kind of unskillful watchmaker who has to fix and adjust his creation periodically and has need of space as his sense organ. Clarke responds that God needs no medium of perception, because he is omnipresent. Clarke argues that a God who does not attend to his creation would be like a king who ignores his kingdom and lets it run on its own. Leibniz responds that God, in his wisdom, foresaw everything and has made the best possible world machine, which consequently does not need his intervention; his action, as supreme ruler, is that of continually preserving his creation.

Leibniz's fundamental principle is that of sufficient reason (nothing happens without a sufficient reason why it is so and not otherwise), a rational self-evident truth. If space were a real absolute being, as Newton says, all points in space would be indistinguishable, and there would not be a sufficient reason why God placed bodies in one arrangement rather than its opposite (east instead of west, for example). Similarly with absolute time, its parts would be uniform, so there would not have been a sufficient reason why God created everything *when* he did, and not sooner or later. Clarke replies that God's will is the sufficient reason for creating how and when he did. He attacks the idea of space as relational by saying that if God reversed the position of the stars with that of the moon and Earth, on a relational account, it would be the same, which is contradictory. Or if God moved the material world in a straight line at any speed, on the relational account it would continue in the same place and time (which is absurd).

Leibniz calls Clarke's examples impossible fictions, and says that Clarke did not understand the nature of relational space, by supposing that a world would be moved against an absolute background space and time, which is what is denied. Two indiscernible states are the same state, says Leibniz, and so "'tis a change without a change." Another fiction is that God might have created the world sooner, because God does nothing without a sufficient reason. Leibniz says that the order of bodies (aggregates of monads) makes space/situation possible, just as the succession of bodily states makes time/duration possible. If there were no creatures, there would be no space and time. Clarke reiterates that there can be identical parts of space that are yet distinct, and two points in time that are identical; quantity of time can be greater or less, yet the order of temporal events could be the same. Leibniz's principle of continuity denies this; between any two states there must be another state, so greater elapsed time implies more successive, distinct states.

Clarke argues that Leibniz's universe destroys freedom; everything would be determined. Leibniz replies that he has argued at length, in his *Theodicy,* that God's foreknowledge is compatible with free choice. God, in his wisdom, simply created (thought) the one possible world full of free creatures that was the best "actualizing their free natures." What God did not create, in thinking the best world, is nevertheless possible.

Leibniz argues that absolute space and time would be infinite and eternal and so independent of God, thus possibly greater than God (which is contradictory). If being *in* space and time is necessary to God, he would then be in need of them and thus limited (but God is without limits). Motion depends on a change that can be observed. Time without things, Leibniz says, is only an ideal possibility; to say the created world might have been created sooner is not intelligible (if it *could have* been created sooner, God would have done so, because that would mean more existence). Space and matter are different, but inseparable; time and motion are distinct, but inseparable, says Leibniz.

Stacey L. Edgar

See also God and Time; Leibniz, Gottfried Wilhelm von; Newton, Isaac; Space, Absolute; Time, Absolute

Further Readings

Ariew, R. (Ed.). (2000). *Leibniz and Clarke: Correspondence*. Indianapolis, IN: Hackett.

Ariew, R., & Garber, D. (Eds. & Trans.). (1989). Monadology: Principles of nature and grace. In *Philosophical essays/G. W. Leibniz*. Indianapolis, IN: Hackett. (Original work published 1714)

Newton, I. (1934/1966). *Sir Isaac Newton's mathematical principles of natural philosophy and his system of the world* (A. Motte, Trans., 1729; F. Cajori, Rev., 1966). Berkeley: University of California Press. (Original work published 1687)

Nicholas of Cusa (Cusanus) (1401–1464)

Nicholas of Cusa (Kues), a German cardinal of the Roman Catholic Church, philosopher, jurist, mathematician, and astronomer, is widely considered as one of the greatest geniuses of the 15th century. He received a doctorate in canon law from the University of Padua in 1423. His ideas influenced philosophical, political, and scientific thought and anticipated the work of astronomers Nicolaus Copernicus and Johannes Kepler.

Generally speaking, Cusa's theory of time exemplifies a Christian Platonism whose elements already had a long tradition (in, e.g., the work of Saint Augustine of Hippo, William of Conches, Albert the Great, and Saint Thomas Aquinas). Cusa's elaborations of this material, however, are sometimes quite original. Space permits inclusion here of only a few examples from among his many discussions of the topic.

In *De venatione sapientiae* (1463), Cusa begins his exposition of the subject by dealing with eternity, the image of which is time (*imago aeternitatis*). Eternity itself (*aeternum*) has to be distinguished from "perpetuity" (*aevum et perpetuum*): Whereas eternity is a mode of duration that has absolutely no beginning and no end, such that it is the peculiar mode of being of God who can himself be called eternity (*aeternitas*), perpetuity designates a duration that has no beginning and no end within the realm of time. On the other hand, the subjects of perpetuity, like the heavenly entities (*caelestia*) and the objects of pure thought (*intelligibilia*), transcend the realm of coming-to-be and perishing. Those passages, where Cusa distinguishes two senses of eternity—the pure eternity of God and the derivative eternity of the perpetual elements of the cosmos—have to be understood according to the same passages; that is, they also reflect the distinction between eternity and perpetuity. Cusa describes eternity as the realm of things that have a being as possible things (*posse fieri*). The existence of such *possibilia* is a necessary condition for God's being able to create the sensible world. The eternal objects themselves, however, are not created, but initiated (*initiata*). In this respect, Cusa echoes the Scotistic model of eternal ideas within God, which are the elements of the world in possibility while they are necessary in their own form of existence as *possibilia*. Time, on the other hand, has the connotation of change, of coming-to-be and perishing—in other words, of the sensible world. Only in this respect, Cusa sometimes also uses the Aristotelian definition of time as a measure of motion. The creation of the sensible, or timely, world is described in Neoplatonic terms as the unfolding (*explicatio*) of that which exists not unfolded (*complicite*) in the intelligible realm of perpetuity. The intelligible world is already structured in a way that enables God to create our world in its beauty. It is probably because of this connection of both the intelligible and the sensible world that Cusa sometimes calls the world itself eternal (*aeternus*) without qualification: the world in its entirety, that is, including the intelligible world, has no beginning in time; rather, it is the realm within which time begins and ends. In the eternity of God himself, on the other hand, the difference between the two worlds of being able to coming-to-be (*posse fieri*) and existing actually (*esse actu*) is suspended, because he alone is what he can be (*possest*). It is obvious from these remarks that Cusa's theology stays fairly close to the classical Neoplatonic system from late antiquity, though he reformulates it in terms that show some traces of the earlier Christian discussions. In ancient Neoplatonism, however, these ideas about time and eternity were closely connected with the idea of an eternal cosmos, which contained only a limited number of souls that migrated from one body to another one. Thus, it is no surprise that Cusa has difficulties explaining in which way the eschatological elements of Christian thought—that is, the resurrection of the dead—can be explained as related to time. In his early work *De docta ignorantia,* he explains that at the time of resurrection we will arrive, because of the end of all motion, at a place beyond time (*supra tempus*). But this process of transcending that way of being into which we have been born cannot be explained by philosophical reasoning, and consequently Cusa in his subsequent works does not give a new treatment to this question.

In his sermon *De aequalitate* (1459), Cusa approached the problem of time from another point of view. Here, he discusses the relation between soul and world in a way that is clearly inspired by Augustine's treatment of the topic in *Confessiones XI:* The soul sees that it is "timeless time" (*anima videt se esse intemporale tempus*). This is because it apprehends time to exist only in the world of change. While the soul sees itself as an active element of this world, and consequently as an element of time, it understands too that it is in its essence separate from all temporality, because it can find in itself both the past and the future moments of time, which do not exist in the world of change. Insofar as all three stages of time are present to the soul, each of them can be called "perfect time" (*tempus perfectum*). According to Cusa, the past is the memory (*memoria*) of the soul, the present its intellect, and the future its will. All of them depend, insofar as they are in the soul, on memory as their reason of being (*quia est*), but what they are (*quid est*), they are as objects of the intellect; in the will they are like an intended goal (*in intento fine*). Though the soul can liberate through these activities the instants of time from its necessary connection with elements of the world, its own existence is still timely, because the soul itself is directed toward the moments of the successive time. In this regard, it recognizes itself as different from eternity: It is in a timely way free from corruption, but not absolutely free from it as God is. It is an analogy to eternity (*similitudo aeternitatis*), but not itself eternity.

In principle, the more perfect intelligences (which must probably be understood as the angels, but the concept clearly echoes the Neoplatonic doctrine of *nous*) are in the same situation of existing timeless in time. But while they always have an active awareness of their natural state, the human soul has to strive for such an awareness by reducing its dependence upon the timely world. The relation between time and the human soul is treated again in the second book of *De ludo globi* (1463). In this work, the timelessness of the soul is explained by its intention to reach its highest good, the science of God. In its fundamental "first intention," the soul is free of any change, but one can speak about change insofar as the soul's "second intentions"; the soul's actual strivings are subject to many changes that, however, do not infect its timeless and changeless essence. This solution reminds the reader of the theories of Albert the Great (who is the interlocutor of the cardinal at this place) and of Aquinas's theories of a natural striving for the good that cannot be lost. From Cusa's explanation of *De aequalitate,* the new account differs insofar as it presupposes a difference between timely change and substantial timelessness in the soul itself.

Matthias Perkams

See also Aquinas, Saint Thomas; Aristotle; Bruno, Giordano; Eternity; Plotinus; Teilhard de Chardin, Pierre

Further Readings

Bellitto, C. M., Izbicki, T. M., & Christianson, G. (2004). *Introducing Nicholas of Cusa: A guide to a Renaissance man.* Mahwah, NJ: Paulist Press.

Jaspers, K. (1964). *Anselm and Nicholas of Cusa* (H. Arendt, Ed.). New York: Harcourt Brace Jovanovich. (Original work published in German, 1957)

Nietzsche, Friedrich (1844–1900)

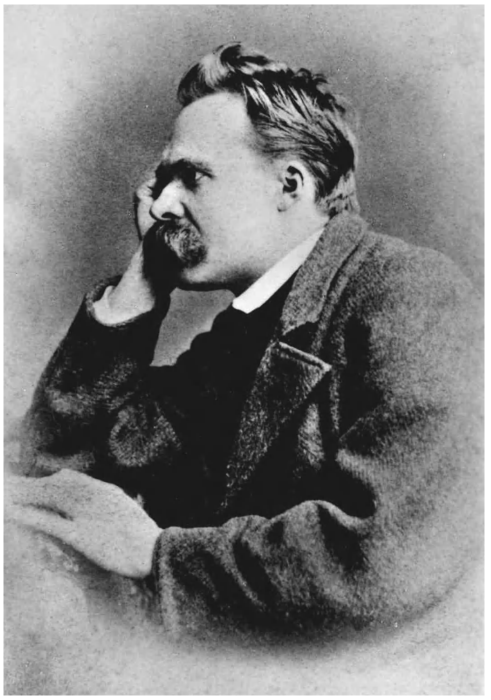
Friedrich Nietzsche has emerged as perhaps the most influential thinker of the recent past. To a significant degree, this is due to the fact that he took time seriously in terms of both cosmology and ethics. Nietzsche offered a dynamic worldview that rejected the entrenched Aristotelian philosophy and Thomistic theology of Western civilization. His provocative writings contained scathing criticisms of modern European culture, particularly its religious beliefs and social morals (all decadent values, as he saw them).

Nietzsche spent his formative years in Röcken and Naumburg, Germany, where he developed a lasting interest in music and literature. At universities, his academic concerns shifted from classical philology to ancient philosophy. He became fascinated with the early culture of Greece, especially the fundamental idea of Heraclitus, which maintained the cyclical flux of all reality. Furthermore, Nietzsche stressed the necessary value of feelings and emotions (over the use of reason) for human creativity and fulfillment. His own emerging ideas were greatly influenced by the seminal writings of the philosophers Ludwig Feuerbach and Arthur Schopenhauer.

After his studies at Bonn and Leipzig, Nietzsche became a professor at the University of Basel, Switzerland. Due to chronic illnesses, he left the university after 10 years and became a solitary wanderer in the mountains of southern Europe. The following years gave the philosopher free time to rigorously reflect on the place of our species within both Earth history and sociocultural development. He wrote a series of ingenious books, his masterpiece being the four-part poetic work *Thus Spake Zarathustra* (1883–1885).

Over time, Nietzsche wrote blistering criticisms of Christianity that dismissed all the basic beliefs of traditional theism. He boldly proclaimed that "God is dead!"—guaranteeing himself a permanent place in Western thought. He remained an unabashed atheist his entire life.

It was Charles Darwin the scientist who awoke Friedrich Nietzsche the philosopher from his dogmatic slumber. Although he benefited from reading Darwin's writings on evolution, Nietzsche's own interpretation of organic evolution offered startling philosophical speculations that were far beyond the views of his scientific naturalist contemporaries. The Darwinian struggle for survival (existence) became the Nietzschean struggle for power (creativity). The iconoclastic Nietzsche also called for a rigorous reevaluation of all values, because he saw religion, democracy, communism, and utilitarianism promoting values that were reducing human beings to a collective mediocrity. Consequently, he stressed the value of those superior individuals who are unencumbered by the vacuous ideas and false beliefs of the inferior masses.



One of Nietzsche's most important ideas, that of eternal return, is the theory that there is infinite time and a finite number of events, and eventually all events will recur again and again.

For Nietzsche, dynamic reality is essentially the will to power. As such, all the objects of this evolving universe are composed of vital energy as units of force. This is a strictly naturalistic stance that gives no credence to philosophical idealism or theological spiritualism. Throughout time, this will to power continuously creates all those objects that fill this evolving universe. If a steadfast observer with a high-powered telescope had witnessed, over billions of years, organic evolution on Earth from the surface of our moon (the process rapidly accelerated like a time-lapse film), then he or she would have experienced life forms exploding into an astonishing diversity of plant and animal species: One-celled organisms are followed by multicellular life forms, invertebrates precede vertebrates, and fossil apes give rise to human beings. Briefly, the creating universe includes creative evolution.

In terms of organic evolution, Nietzsche held that the human animal is a temporary link between the fossil apes of the remote past and the overbeings who will emerge from our species in the distant future. Moreover, in the creative sweep of biological history, he claimed that the overbeing to come will be as advanced beyond our species as the human animal of today is advanced beyond the worm! Quintessentially, this incredible progress will be made in terms of intellectual development (rather than merely temporal changes in physical characteristics). As a result, Nietzsche concluded that the overbeings to come are the meaning, purpose, aim, and goal of organic evolution on earth. These forthcoming noble beings will devote their superior intellect to creating artistic works and new values.

In early August 1881, while walking along the lake of Silvaplana near Sils-Maria in Switzerland ("6000 feet beyond man and time"), Nietzsche came upon a huge pyramid-shaped boulder. In a flash of intuition, he grasped a provocative perspective. This incident caused him to reflect upon time and, consequently, to develop his colossal idea of the eternal recurrence of this same universe. The resultant awesome temporal perspective that now occurred to him justified (so he thought) his philosophy of overcoming; the struggle for existence is worthwhile if one's personal life somehow continues to exist throughout time in this material reality. Nietzsche was delirious with joy over his immortality-granting idea. He even contemplated studying the natural sciences in order to empirically demonstrate the scientific truth of eternal recurrence.

Nietzsche argued that cosmic time is eternal, while cosmic space is finite. Moreover, he held that there is only a finite amount of matter and energy in this universe. Therefore, only a finite sequence of objects and events may take place in a cosmic cycle. But if time is eternal, then this finite cosmic cycle will repeat itself again and again. In fact, Nietzsche argued that this identical cosmic cycle has repeated itself an infinite number of times in the past, and it will repeat itself an infinite number of times in the future. Thus, material reality is the eternal recurrence of this identical universe, with no progressive evolution from cycle to cycle.

If true, then the ramifications of this cosmology are staggering for human existence. In general, it meant that everything that has ever existed will appear again in the same finite sequence throughout eternal time. In particular, it means that Nietzsche will never pass out of existence forever, since he will eternally return as the same individual living the exact life in every detail in each finite cycle. It also embraced the evolution of morality from the premorality of fossil apes to the metamorality of the future overbeings yet to emerge. In short, for our species today, eternal recurrence challenges one to seriously consider both the choices one makes and the values one holds.

Nietzsche's pervasive "Yes!" to dynamic reality, and therefore to cosmic time, is an affirmation of life with far-reaching implications for ethics, morals, and values beyond good and evil. It commands that every choice a person makes is a decision for eternity. In short, once is forever! Because an individual has no knowledge of his or her previous life, it is as if one is free to make choices, but this freedom is, in fact, an illusion. Moreover, each moment of existence has eternal value in this universal wheel of time.

Friedrich Nietzsche claimed that he wrote in blood and philosophized with a hammer. His this-worldly stance repudiated the human, all too human ideas and moralities of common life. In his dynamic viewpoint, neither species nor values are fixed in nature. Nietzsche offered an astounding interpretation of time and human existence. His optimistic philosophy is ultimately grounded in a cosmic perspective that teaches the eternal recurrence of this same universe. He held that time is an endless series of finite cycles, with each cycle being absolutely identical to all the other cycles. His extraordinary vision of cosmic time remains both a challenging and an essential frame of reference for scientists, philosophers, and theologians.

H. James Birx

See also Cosmology, Cyclic; Eternal Recurrence; Ethics; Evolution, Organic; Feuerbach, Ludwig; Heraclitus; Nietzsche and Heraclitus; Presocratic Age; Schopenhauer, Arthur; Time, Cyclical; Values and Time; Wagner, Richard

Further Readings

Klossowski, P. (1997). *Nietzsche and the vicious circle.* Chicago: University of Chicago Press.

Köhler, J. (2002). *Zarathustra's secret: The interior life of Friedrich Nietzsche.* New Haven, CT: Yale University Press.

Nietzsche, F. (1993). *Thus spake Zarathustra* (H. J. Birx, Ed., T. Common, Trans.). Amherst, NY: Prometheus. (Original work published 1883–1885)

Pearson, K. A. (1997). *Viroid life: Perspectives on Nietzsche and the transhuman condition.* London: Routledge.

Safranski, R. (2001). *Nietzsche: A philosophical biography.* New York: Norton.

Sorgner, S. L. (2007). *Metaphysics without truth: On the importance of consistency within Nietzsche's philosophy.* Milwaukee, WI: Marquette University Press.

Vaihinger, H. (1924). *The philosophy of "as if."* New York: Harcourt Brace.

NIETZSCHE AND HERACLITUS

The philosopher Friedrich Nietzsche (1844–1900), although extremely critical of many thinkers, completely accepts Heraclitus's concept of time and develops it further. When Nietzsche read Heraclitus he felt at home, because concerning the form and content of being, Heraclitus's philosophy is similar to that of Nietzsche. Concerning the content of being, both defend a natural philosophy of permanent change that leads to a never-ending process of overcoming and of creation and destruction of forms. Nietzsche specifies the content of being further by developing the metaphysics of the will-to-power. (*Metaphysics* here is understood as a description of the nature of the world, which in Nietzsche's case is monistic and this-worldly.)

Both thinkers agree, however, not only concerning the content of being but also concerning its form, which is cyclical. In Nietzsche's case this form is referred to as the *eternal recurrence,* whereas Heraclitus calls it the *great year,* which is supposed to have a (metaphorical) duration of 10,800 years. Nietzsche stresses the similarity of his concepts to Heraclitus's in various published and unpublished writings. In *Ecce Homo* he stresses that traces of his concept of the eternal recurrence can be found in Heraclitus, and in *Thus Spake Zarathustra* he himself employs the notion of the great year in order to explain his understanding of the form of being.

Eternal Recurrence, Time, and Salvation

Many Nietzsche scholars today (such as Volker Gerhardt) stress the ethical relevance of Nietzsche's concept of the eternal recurrence. However, the fact that he clearly compares his concept to Heraclitus's metaphysical one in his published writings shows that it was meant as a metaphysical one. This reading of the eternal recurrence gets further support from his plans to study physics in Paris for 10 years in order to prove his concept scientifically, as his friend Lou Andreas-Salome pointed out, and from passages in his notebooks that he did not publish himself in which he puts together arguments with which he tries to prove the eternal recurrence philosophically. All of these arguments fail or are insufficient. At the least they do not establish what they are meant to establish. From the premises he mentions, he cannot infer the eternal recurrence by necessity. This, however, does not mean that his arguments cannot be improved so that the premises actually imply the eternal recurrence of everything. In addition, current scholars who stress the ethical relevance of the eternal recurrence are surely correct in doing so. The eternal recurrence is of immense ethical importance, as it is Nietzsche's theory of salvation, and it can give meaning to people who do not believe in a Christian afterlife but rather in a this-worldly concept of existence.

Eternal recurrence implies that whatever you have done and will do will recur identically. You lived the very same life before you were born, and you will lead it again in the very same manner. This implies that your life will not be over when you die but that you will return again and again, and you will meet the very same people you know now, and you will have to go through all the pains and pleasures you have experienced and will experience. You will not remember that you have lived the very same life before, but if you hold this concept, then you can feel comfort in realizing that you will experience all the wonderful events you have experienced again and again. These events are not over and done with. On the other hand, a life might have been so terrible that the concept of eternal recurrence can be unbearable.

What is important concerning salvation on the basis of this concept is that you experience one moment that you can affirm completely. Once you have had such a moment, then all other moments before and after this one are justified by means of this one moment, because all the other moments have been and are necessary in order for that moment to occur, according to Nietzsche. By saying yes to one moment, you also affirm all the pain and suffering you have to go through to reach it. However, if you experience a moment that you can affirm completely, you are saved on the basis of this concept. Therefore, the eternal recurrence or the great year increases the importance of any single moment immensely. Scholars who focus mainly on the ethical aspect of this concept stress that it is like an existential imperative: One ought to live as if one's life were to recur forever without this actually having to be the case. This does not correspond to Nietzsche's way of thinking. He was a classical philologist who was trained to think metaphysically and ontologically and did so himself because he understood that if you wish to have the ethical side of the concept, it needs an ontological foundation. Hence, he considered proving it scientifically and attempted to argue for it philosophically.

Circular Time and Identity

Nietzsche's eternal recurrence and Heraclitus's great year, understood philosophically, have implications concerning ontology and the philosophy of time. Concerning ontology, the concept can be seen as the form of being, the circle in which all other worldly events occur. Concerning the philosophy of time, the concept implies the circularity of time. If we take the notion of the circularity of time seriously, then it does not imply that we have the *x* plus *n*th (whereby *n* has to be a natural number) circulation but only one. Hence, we cannot talk about infinite time but rather circular time, time that is in itself circular. According to this concept, everything that occurs, occurs infinitely often. However, it would be more appropriate not to say that anything occurs infinitely often but rather that the very same thing occurs again and again. In the end, it is not the same but rather the identical that happens again. The circularity of time therefore implies that there is the relation of identity in its strongest Leibnizian sense between the various circulations of the world. The qualities that are valid in one circulation are also valid for all others. Here we also have to include spatiotemporal qualities.

Nietzsche tried to prove this concept philosophically. He argued, for example, thus: The law of the conservation of energy demands eternal recurrence. However, this is clearly false. The law of the conservation of energy alone does not necessarily imply this concept. If we assume the conservation of energy but also that the amount of energy is infinite, then we have an infinite number of possible combinations. However, an infinite number of possible combinations excludes the possibility of the eternal recurrence. If we assume that energy is finite but space exists separately from energy and is infinite, then again we have an infinite amount of combinatory options. Even if it were the case that energy is finite and time and space were qualities of energy, the eternal recurrence does not follow by necessity, as it could be the case that the law that is responsible for the change of the energy is itself subject to change, which excludes the possibility of the occurrence of the eternal recurrence.

Even if we further assume that energy is finite, time and space are aspects of energy, and the law underlying the change is determined and unchanging, the eternal recurrence does not follow by necessity, as there is the option that energy can turn up in an infinite amount of sizes, which also precludes that eternal recurrence takes place. Only when we assume, in addition to the premises just mentioned, that energy can turn up only in a finite amount of sizes, eternal recurrence follows, as the law of the conservation of energy (which is already included in our premises) also entails the reversibility of all states of the world—another necessary premise. By adding the premises just listed, however, we significantly expanded the argument suggested by Nietzsche.

It has to be noted that the notions "energy" and "force" that Nietzsche employs can be substituted by the notion "substance." There is a fairly wide range of words that can be exchanged for one another. However, the meaning of the words depends on the context in which they appear. Hence, it is not usually the case that one word has only one meaning in Nietzsche's writing, which is why one must be extremely cautious when interpreting him. Nietzsche's worldview is based on one substance, to which he refers using a great variety of words. This one substance is not unified but consists of various will-to-power quanta, to which he also refers as "force" or "energy." When various will-to-power quanta are unified, will-to-power constellations come into existence. In his notebooks he tried to develop a will-to-power metaphysics. By doing so Nietzsche was the only thinker who further developed Leibniz's monadology. However, Nietzsche's was based upon only one, nonunified substance, as "will can only act upon will." Because one type of substance is all there is, time and space have to be aspects of it and cannot exist separately from it. In addition, this substance is finite, as Nietzsche tries to banish all aspects of infinity from his philosophy.

In practice, this undertaking has the following implications: An infinite force cannot exist; therefore the existing force has to be finite. Infinite divisibility cannot exist; therefore the divisibility of force has to be finite. As a further premise we thus get the following: Force is not divisible infinitely often but turns up only in certain quantities. The logic or law of change demands that it be based upon a certain, specific law, which Nietzsche described in detail in his will-to-power metaphysics. It is decisive for eternal recurrence that such a law exists and that it is unchanging. Furthermore, the reversibility of all states of the world at an instant has to be given. Nietzsche solves this problem by reference to the law of conservation of energy. All the reflections just mentioned were not made by either Nietzsche or Heraclitus. However, they correspond to Nietzsche's and Heraclitus's way of thinking. We can summarize the foregoing as follows:

1. There is only one substance.
2. Time and space are aspects of one substance but do not exist independent of it.
3. The complete amount of substance is finite.
4. The divisibility of the substance is also finite, that is, there is a minimal amount in which the substance exists that is not divisible any further, whereby the size is different from zero.
5. There is a certain law that is the basis for change of the one substance.
6. The reversibility of all states of the world at an instant has to be assumed.

Conclusion: In such a system, substance can have only a finite number of states.

Once all states are present, then, one state has to recur, as the possibility of recurrence is given. If one state of the world at an instant recurs, and if the law governing the change does not change either, all other states of the world have to recur in an identical manner. As infinity is excluded, we cannot talk about infinite time either. As time is an aspect of the one substance, it also has to be identical with the previous time. (The word "previous" here has to be understood solely as a metaphor.) Such an understanding of time can be applied only if time is circular and finite. On that basis, the objection that this cycle is different does not apply either, as it is not different. This objection goes as follows: This cycle is different from all the other cycles, for we are in this cycle and we are conscious of being within this cycle, which does not apply to the cycles *n* plus 1 or 2. Hence this cycle cannot be identified with the other cycles. However, individuals who argue in this manner do not take the notion of circularity seriously, because if they did, they would know that there is only this one cycle.

Space

The concept of eternal recurrence also has interesting implications for the concept of space. According to both Nietzsche and Heraclitus, there is only one substance, which changes on the basis of one determined law that represents one aspect of the substance. All things and qualities are aspects of the one existing substance; that is, space and time are such aspects, too. Because the amount of substance is finite, it is also limited at its end. Limitation can only come about by something other, so that substance would have to be limited by another something. If such a something limited the substance, then it would exist outside of the substance. However, there can be only one substance.

In addition, substance can interact only with itself; two absolutely different substances cannot interact. Hence, the one substance cannot be limited by another substance. It cannot be limited by a vacuum either, as this would imply that there is an empty space. However, space exists only as an aspect of the substance, so empty space cannot exist. As substance can be limited neither by another substance nor by empty space, it has to be limited by itself. If the substance is limited, and if it can be limited only by itself—the amount of substance being finite and space being one aspect of the substance, then space can only be regarded as curved. Even though the concept of curved space was developed only about 150 years ago by first Georg Friedrich Bernhard Riemann and then Einstein, it has to be implicitly included in the philosophy of all those thinkers like Heraclitus and Nietzsche who defended the great year or the eternal recurrence of everything.

Science

In addition, we can argue that even on the basis of contemporary physics, the premises necessary for the occurrence of the eternal recurrence to occur are such that corresponding premises can be found there:

1. Time and space have aspects of ones subtance: Since Einstein formed his general theory of relativity, this has been the dominant scientific paradigm.
2. Energy or substance is limited: Scientifically, this is a very probable premise. If the density of matter is sufficiently high, the Friedmann equations, which can be deduced from Einstein's equations of the general theory of relativity, demand a closed universe. If the mass of neutrinos were zero, then when they are not moving, the density of matter of the universe would be great enough for a closed universe.
3. Force is limited, which implies that it is being limited in amount and in its divisibility: Again, a comparable premise can be found in contemporary physics. Energy can turn up only as an integer multiple of the Planck constant.
4. There is a determined law responsible for change: Physicists attempt to find a grand unified theory (GUT) in which they hope to unite the four basic forces: the weak force, the strong force, the electromagnetic force, and gravitation. The GUT can be seen as the determined law demanded by eternal recurrence.
5. The reversibility of all states has to be given: The law of the conservation of energy alone might be sufficient to imply this premise. However, one can also argue against the validity of this premise by referring to the second law of thermodynamics, which implies the permanent striving for entropy. However, there are natural scientists, such as Benjamin Gal-Or, who hold that the second law of thermodynamics might just be connected to the expansion of the universe. We might have antientropy during the collapse of the universe.

Given the foregoing comparison between the premises of the eternal recurrence and of modern science, we can see that even from a scientific standpoint, eternal recurrence bears some plausibility. However, this does not mean that eternal recurrence can simply be identified with the physical theory of the big bang and the expansion and contraction of the universe, because here problems concerning the understanding of singularity come in. Stephen Hawking's and Roland Penrose's understanding of singularity is dominant today, and it causes problems for this kind of understanding of the eternal recurrence. This again does not mean that all cosmological interpretations of the eternal recurrence have to fail. With the eternal recurrence or the great year, Nietzsche and Heraclitus developed concepts of time that are very different from our everyday perception of time, but once grasped, these concepts inspire a lifelong fascination.

Stefan Lorenz Sorgner

See also Cosmology, Cyclic; Eternal Recurrence; Heraclitus; Nietzsche, Friedrich; Presocratic Age; Time, Cyclical

Further Readings

Danto, A. (1965). *Nietzsche as philosopher.* New York: Columbia University Press.

Sorgner, S. L. (2001). Heraclitus and curved space. *Proceedings of the Metaphysics for the Third Millennium conference,* Rome, September 5–8, 2000 (pp. 165–170).

Sorgner, S. L. (2007). *Metaphysics without truth—On the importance of consistency within Nietzsche's philosophy* (Rev. ed.). Milwaukee, WI: Marquette University Press.

Nirvana

Nirvana is from a Sanskrit word that means "extinguishing." It is also spelled *nibbana.* The idea of nirvana is found most prominently in Buddhism, although Hinduism alludes to the idea. Buddhist doctrine includes the idea of *karma* (one's actions), *dukkha* (suffering), and *samsara* (reincarnation). Buddhists live a life filled with karma, acquired through positive and negative actions. When a Buddhist dies, the life is continued through rebirth; the condition of the rebirth is determined by the karma acquired in previous lives. In addition, Buddhism teaches that life is filled with dukkha. The acknowledgment of dukkha ties a Buddhist to the stream of samsara. By realizing that the essence of a Buddhist is not the accumulated lives lived but instead is separate from the experiences of the past and present lives, a Buddhist experiences enlightenment, which leads to nirvana. Through a reduction in karmic actions plus an awareness that a state of being exists beyond the physical one of samsara, the Buddhist can attain nirvana.

Nirvana is neither a physical nor a spiritual place; therefore it is beyond questions of where and when. No description of nirvana has been given, although descriptions of its attributes exist. In the *Dharmapada Sutra,* the Buddha described nirvana as the highest happiness (or bliss). Yet this happiness and bliss is not to be confused with that state experienced while in the process of transmigration, but with a state of calmness that transcends the earthly experience. A Buddhist who is "in" nirvana will not "leave" nirvana; death does not again occur. Siddhartha Gautama (or Gotama; 5th century BCE) realized how to reach enlightenment without aid and so became the Buddha. Upon the death of his last life (or his "cessation") Siddhartha entered into a state of nirvana. He is currently "in" nirvana and will no longer die or return to a physical form.

Entrances into nirvana, and the definition of nirvana itself, differ between the two larger groups within Buddhism: Theravada and Mahayana. Theravada ("doctrine of the elders") Buddhism teaches that each Buddhist must attain nirvana individually. The Buddha left teachings that can guide Buddhists toward reducing suffering and negating karma, but these must be attained alone. In addition, only a monk can attain enlightenment. Upon being enlightened, that is, upon realizing that illusion of rebirths and of suffering, the Theravada Buddhist becomes an *arhat,* or one who will not be reborn and enters into nirvana. Consequently, Theravada Buddhism necessitates a long period of rebirths in which to reach nirvana. For this reason, it is also known as Hinayana, or "lesser raft" Buddhism, because of the smaller number of Buddhists who reach the state of nirvana during a set time period.

Mahayana Buddhism teaches that each Buddhist has help from those who have been enlightened and decide to remain in the physical world of rebirths in order to aid other Buddhists. These previously enlightened individuals are called *bodhisattvas* (as opposed to arhats in Theravada Buddhism.) Tibetan Buddhism, a branch of Mahayana Buddhism, gives these bodhisattvas the name of lama, with the chief lama being known as the Dalai Lama. The highest goal in Mahayana Buddhism is to reach enlightenment yet decline to enter into nirvana, instead choosing to return in future rebirths. These bodhisattvas experience death and rebirth, but it is their choice to delay entrance into nirvana in order to aid others.

Within the Mahayana Buddhism tradition exists a writing known as the *Nirvana Sutra* (or *Mahaparinirvana Sutra* or *Maha-nirvana Sutra*). Mahayana Buddhists believe this is the last teaching of the Buddha. This writing teaches a different understanding of nirvana. The *Mahaparinirvana Sutra* also draws a distinction between nirvana and mahaparinirvana. Nirvana is the realization that suffering is an illusive aspect of one's physical lives. Mahaparinirvana is the realization of one's Buddha-nature. This idea of the Buddha-nature is unique to Mahayana Buddhism. The Buddha-nature exists in everyone and is the capacity of understanding reality. Therefore, the state of Mahaparinirvana consists of realizing the true nature of suffering plus an awareness of one's Buddha-nature.

The word *nirvana* is found in Hinduism. Hinduism also teaches the doctrines of karma and rebirths. The idea of a break in the cycle of rebirths differs from Buddhism, though, for in Hinduism one is connected with Brahman, the impersonal spirit. The word *nirvana* as a Hindu idea occurs primarily in the *Mahabharata,* an epic poem within Hinduism, and specifically a writing within the *Mahabharata* called the *Bhagavad Gita.* Within the *Bhagavad Gita,* the idea is linked with the Hindu idea of moksa or "release" from the rebirths: "Only that [one] whose joy is inward, inward his peace, and his vision inward shall come to Brahman and know nirvana. All-consumed are their imperfections, doubts are dispelled, their senses mastered, their every action is wed to the welfare of fellow-creatures: Such are the [ones] who enter Brahman and know nirvana." Thus, the Hindu ideal is for liberation from the passions and acknowledgments of a physical life; when this occurs, one experiences moksha or nirvana, and is united with Brahman. Consequently, the idea of nirvana as found in Hinduism differs from the nirvana as taught in Buddhism, although both are similar in that nirvana is the experience of and result from being released or enlightened.

Buddhist doctrine also includes the concept of parinirvana. *Parinirvana* is the term given to the death of one who has been enlightened yet chooses to remain in a physical state a while longer. In Mahayana Buddhism, the day that celebrates the Buddha's final death is known and celebrated as Parinirvana (or Nirvana) Day. The Buddha died in present-day Kushinigar, India, where today exists a parinirvana temple commemorating the site where the Buddha left his last physical life (died). Inside the temple lies a statue of the Buddha at his moment of parinirvana, or moment when he ceased his earthly lives and entered into nirvana.

Mark Nickens

See also Buddhism, Mahayana; Buddhism, Theravada; Buddhism, Zen; Hinduism, Mimamsa-Vedanta; Hinduism, Nyaya-Vaisesika; Hinduism, Samkhya-Yoga; Reincarnation

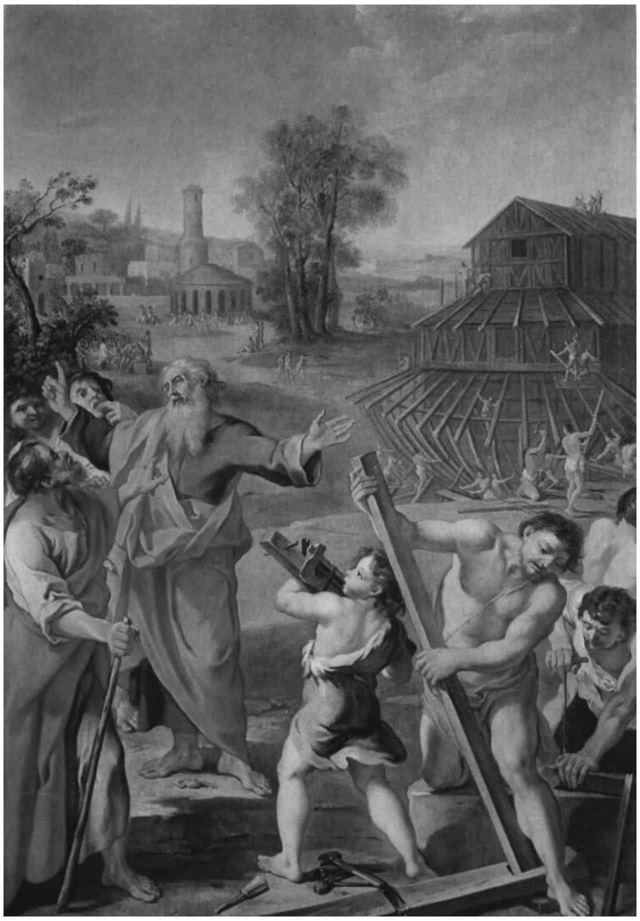
Further Readings

Harvey, P. (1990). *An introduction to Buddhism: Teachings, history and practices.* New York: Cambridge University Press.

Rahula, W. (1974). *What the Buddha taught.* New York: Grove Press.

Noah

Noah is the main character of the cataclysmic flood story told in the biblical Book of Genesis (chapters 6–9). Noah represented the last generation of the era of the antediluvian Creation and became the father of the current world order, thus a link between the ancient past and the present.



Noah's Ark, *by the Französischer Meister ("The French Master"), Magyar Szépmű́vészeti Múzeum, Budapest. c. 1675. The ark story told in Genesis has parallels in the Sumerian myth of Ziusudra, which tells how Ziusudra was warned by the gods to build a vessel in which to escape a flood that would destroy humankind. The deluge story is one of the most common folk stories throughout the world.*

According to the Book of Genesis, Noah lived nine generations past the first created humans—Adam and Eve. Adam and Eve introduced sin into the world by disobeying God when they ate from the tree of knowledge of good and evil. This sin escalated throughout Creation to the point where all humanity was wicked by Noah's time. Then God regretted he had made humanity and decided to destroy the world with a flood. However, God chose to spare Noah, the only righteous man, and his family. God ordered him to build a massive ark upon which Noah, his family, and a pair of animals representative of each species would be spared from a watery annihilation. Noah obeyed, built the ark, and survived the deluge. After the flood, the ark landed on Mt. Ararat, a mountain located somewhere in the area that is now eastern Turkey, where Noah and his family disembarked.

Noah represents the best and worst of humans. He represents the best because before the flood God deemed him alone as righteous and blameless of all the people in the world (Gen 6:9). He is the only one who deserved to be spared from destruction. However, he also represents the worst of a corrupt world. After the flood, Noah became drunk and passed out. Ham, one of Noah's sons, sinned when he "saw the nakedness of his father" (Gen 9:22). Therefore, through Noah sin carried over from the initial Creation into the postdiluvial world.

Noah is one of many heroes of ancient Near Eastern flood stories. Ziusudra, hero of the Sumerian flood story, overheard the gods plotting to wipe out humanity. He was saved from a 7-day and 7-night flood by making a boat. Afterward, he offered a large sacrifice to the gods. Being pleased, the gods gave him eternal life. Atrahasis, hero of the Akkadian flood story, is warned by the god Enki that the gods intended to flood the earth and destroy humanity. Atrahasis built a boat and escaped the flood. Utnapishtim, hero of the flood story in the Gilgamesh epic, has an experience similar to that of Atrahasis, except after the flood Utnapishtim offered a sacrifice to the gods, who were so thankful that they gave Utnapishtim and his wife eternal life and placed them in a distant location separate from the rest of humanity.

The story of Noah has two timeless elements. First, the story has a theological connection, that is, the seriousness of sin and the grace of God. This theme is the basis of the flood story and is prominent throughout the Hebrew Bible. Second, the story of Noah has inspired some people to search for the remains of the ark, in a sense to find a modern physical connection with the ancient past. Some people believe that the ark landed on the Agri Dagh peak in the Ararat mountain range. However, to date no evidence of the ark has been found.

Terry W. Eddinger

See also Adam, Creation of; Bible and Time; Genesis, Book of; Moses; Sin, Original

Further Readings

Hunt, J. H. (2003). Noah. In T. D. Alexander & D. W. Baker (Eds.), *Dictionary of the Old Testament: Pentateuch*. Downers Grove, IL: InterVarsity.

Westermann, C. (1987). *Genesis 1–11: A commentary* (J. J. Scullion, Trans.). Minneapolis, MN: Augsburg Fortress.

Nostradamus (1503–1566)

Michel de Nostredame, more commonly known as Nostradamus, is criticized by some and acclaimed by many as a seer whose 942 quatrains (poems with four lines each) transcend time and predict the future. Born on December 14, 1503, in Saint Remy de Provence in the south of France, Nostradamus was the first son and one of nine children born to Reyniere de St. Remy and grain dealer and notary Jaume de Nostredame. He is best known for his book *Les Prophecies* (1555) and *The Almanac,* a set of annual predictions published until his death on July 2, 1566.

Historically, the Nostredame and St. Remy families had strong academic ties. Several family members were doctors and scholars. Although originally of Jewish descent, the family converted to Christianity in 1502 as a consequence of the ascension of Louis XII. Starting at the age of 15, Nostradamus followed family tradition and attended the University of Avignon for more than a year. An outbreak of the black plague forced the university to close its doors, leading Nostradamus to pursue a career as an apothecary. In 1529 he entered the University of Montpelier to study for a doctorate in medicine, but upon the discovery of Nostradamus's occupation as an apothecary, he was expelled. Despite his lack of university credentials, many of his colleagues and publishers still addressed him as Doctor.

Following his expulsion, Nostradamus married and had two children, but his wife and children succumbed to the plague in 1534. Thirteen years later, in 1547, Nostradamus married a wealthy widow named Anne Ponsarde Gemelle, and the two had six children: three sons and three daughters.

In 1550, *The Almanac* was first published, and Michel de Nostredame became widely known under the name Nostradamus. *The Almanac* was so successful that he decided to publish his predictions annually.

Today, many admirers of Nostradamus believe that he accurately predicted such events as the great fire of London, the rise of Adolf Hitler, the crash of the American space shuttle *Challenger,* and the September 11, 2001, attack on the World Trade Center and the Pentagon. Overall, Nostradamus made 6,338 predictions, many of which, however, never came to fruition. In any event, skeptic and follower alike cannot contest that Nostradamus left his mark; his prophesies remain an ongoing source of speculation and debate. In the wake of the events of September 11, 2001, an Internet hoax cited a Nostradamus quatrain that, it was claimed, predicted the fiery attack. Later, to the delight of skeptics, the quatrain was proven false. As both skeptics and neutral observers have noted, Nostradamus's prophecies are ambiguous because they fail to provide specific dates; therefore these predictions are open to numerous and contradictory interpretations.

Jennifer R. Fields

See also Futurology; Prophecy; Toffler, Alvin

Further Readings

Hogue, J. (1987). *Nostradamus & the millennium: Predictions of the future.* New York: Doubleday.

Lemesurier, P. (1997). *The Nostradamus encyclopedia: The definitive reference guide to the work and world of Nostradamus.* New York: St. Martin's.

NOTHINGNESS

The term *nothingness* denotes the result of specific negation of a reality (metaphysical or ontological meaning) and/or of a value and validity of something (axiological meaning). Its content is close to the terms "nothing," "nonbeing," "emptiness," and "vanity."

As opposed to the common meaning of the word "nothing" ("nonbeing"), which relatively negates the attributes, state, or existence of a particular object (or a category of objects), *nothingness,* in its ontological meaning, is concerned with absolute negation of the whole of entities, thus of any particular object (or category of objects) at all. For example, in the sentence "Yesterday, there was a glass on the table, but today there is nothing there," by "nothing" we mean only the so-called relative nothing—the absence of the glass in the given place and not the fact that there is no other particular object in the place of the expected glass. In contrast, in the sentence "The world was created from nothing," by "nothing" we mean exactly the absence of any particular object (category of objects), absolute nothing, nothingness. In the first case, the absence (nothing) of something is the presence (existence, entity) of something else, other than the negated thing. In the second case, this does not apply: Absence (nothing) is the absolute opposite of any presence (existence, entity). Because of this negation of all that exists, the concept of nothingness is often considered the result of illegitimate abstraction and therefore unacceptable for rational thinking. To favor it during the explanation of reality is considered to be (ontological) nihilism. This applies even more so to its stronger alternative, which negates not only all reality but also possibility (so-called negative, or absolute nothingness).

Nothingness in its axiological meaning is in human experience and its reflections thematized in several ways. Depending on which aspect of a value it negates (positive, negative, or both), the basic positions of value nihilism vary from the extreme pessimistic, for example when we sigh along with the preacher, "Vanity of vanities! all is vanity"; through the more moderate one, which answers the question of what humanity is with "A Nothing in comparison with the Infinite, an All in comparison with Nothing" (Pascal); all the way to the mystic ideal of a mind emptied of values (neutral), for example in the state of nirvana. Depending on the kind of the negated value, we differentiate between ethical nihilism (negating the obligatory validity of moral values), religious nihilism (denying the existence of the sacred or gods), political nihilism (negating the obligatory validity of social order), logical nihilism (denying the existence of truth), and gnoseological nihilism (rejecting the possibility of knowledge).

The concept of nothing, or nothingness, as an ultimate explanation principle of reality and human life, played a more important role historically in Asian religious and philosophical thinking than it did in the thinking of Western civilization. It was also to a great extent particular to mystically inclined thinking rather than to rationalistic systems. For example, in the ancient Chinese doctrine of Laozi (5th century–4th century BCE), the basic principle of reality, *tao,* is empty—nameless and formless; later in the writings of Zuang-zhou (4th century BCE) it is the emptiness itself—*xu*. In ancient India, it was mainly the teaching about *nirvana* (Hinduism, Buddhism), the content of which is the emptying of the mind of an individual of partial contents and its transition into the state of "nonbeing." But most of all the doctrine of emptiness (*sunyata*), understood in an ontological as well as axiological way, developed in Mahayana Buddhism. The concept of nonbeing (*abhava*), also in absolute meaning, can be found as one of the categories even in the logically tuned system Vaisesika. Later it was Zen Buddhism that attempted a synthesis of the ways of Buddhism and Taoism, also in the area of the understanding of emptiness as a central concept. In Jewish mysticism, a similar function of holy nothingness was carried by the concept of *ein sof*.

Unlike oriental doctrines, ancient Greek philosophy was more hostile toward the concept of nothing and nonbeing (nothingness). According to Parmenides of Elea (540–450 BCE), being (*on*) is and nothing (nonbeing—*me on*) is not, because it is unthinkable, as thinking and being are the same thing. Nothing (nothingness) as the absolute opposite of being should have been excluded from the rational discourse. But already Democritus (450–370 BCE) was forced in his philosophy, in an effort to explain plurality and motion, to postulate alongside being (plenitude, atoms) also the existence of nonbeing—of empty space. Even Plato (428–348 BCE) admits in a certain way to the existence of nonbeing, in order to explain, for example, the possibility of an error in human knowledge, because an erroneous statement is a statement about the nonexistent. Nonentity (nothing), however, is not the opposite of being, as it was with Parmenides, but it's a part of it; it is not absolute nonbeing, but merely relative—it is other being, the being of other, because each determined entity, as identical with its own self (*tauton,* is also at the same time different from another determined entity (*heteron*). For example, motion *is* motion (itself), but it *is not* stability (something other). In another context, in an attempt to clarify the changeable nature of the perceptible world, Plato again admits to the existence of nonbeing (matter), in which this world participates, as being similar to being itself (ideas). Nonbeing not only *is not* any determined other, but also it is not itself; it is presented here as a generalized principle of an undetermined otherness. Later, for Aristotle, with his differentiation of matter (possibility) and form (reality) as the necessary aspects of the existence of every object, nonbeing is a not yet realized entity, *ens potentialis,* which lacks some or all attributes of a future thing; it is rid of its positive determination (lack of being, *privatio*).

Greek philosophy, despite its plurality in the understanding of nonbeing, in principle did not overstep its rationalist rule according to which "out of nothing, nothing comes" (*ex nihilo nihil fit*). On the contrary, medieval Christian thinking acknowledged the concept of the absolute nothing, nothingness as a legitimate element of discourse about reality and man, by the fact that on the basis of its credo, it explained the origin of the world as "creation from nothing" (*creatio ex nihilo*). It was mainly Saint Augustine of Hippo who, in an attempt to demonstrate the unlimited nature of God's power, theoretically justified this change, whereas he also endowed nothingness with a morally sacral dimension. Nothingness was worthless, connected to evil and sin. As a result of this, all creatures carried its dual seal—ontological as well as axiological.

A new aspect was added to meontological problematics by thinkers influenced by Neoplatonic mysticism, most of all Pseudo-Dionysios (5th century CE), Meister Eckhart (1260–1327), and Nicholas of Cusa (1401–1464), who on the grounds of negative theology applied the concept of nonbeing (nothing) through various ways even to God himself. However, in their case, it was not nothingness in the sense of absence or lack of being (or its determination), but the opposite, nothingness "resulting" from surplus of being, because the infinite and absolute God, according to them, cannot be identical with being that is specified as an entity by finite determinations. God is beyond it and above it; he is incomparably (even in terms of worth) more than being itself. If, despite all differences, this thinking was closer to

Plato's ancient message, Aristotle's reflections on lacking (*ens potentialis, ens rationis*) were developed mostly through scholastic tradition (Saint Thomas Aquinas, 1225–1274; Francisco Suarez, 1548–1617; and others). Later it was followed by the classics of modern philosophy—Baruch de Spinoza (1632–1677), G. W. Leibniz (1646–1716), and Immanuel Kant (1724–1804).

Significant for further development of these problematics were Georg Wilhelm Friedrich Hegel's reflections on nothing (and negativity as such). Hegel (1770–1831) in a quasi-rationalistic reception of mystical views, gets almost as far as negation of the logical law of contradiction through a provocative statement that "pure being and pure nothing are therefore the same," whereby their truth is becoming. Here, the negativity of nothingness becomes the driving force of dialectics. These reflections, together with his master-slave dialectic, significantly inspired existentialists (Martin Heidegger, 1889–1976; Jean-Paul Sartre, 1905–1980; Albert Camus, 1913–1960; and others), as the main successors of the meontological problematics in the 20th century. According to Heidegger, who in his ontological difference distinguishes between entity and being, nothing is the absolute negation of the whole of entities. However, one does not encounter it in thinking, but in anxiety. Nothing, nonbeing (which paradoxically is the veil of being) enables human being (*being-there, dasein*), because for one to be means to be held out into this nothing, to transcend one's self. Later, Sartre uses nothingness, as opposed to being in-itself, as being for-itself, that is, empty, contentless, and undetermined consciousness that allows human freedom, because paradoxically "it is what it is not and it is not what it is." This approach received great criticism from analytically oriented philosophy and particularly from logical empiricism. According to Rudolf Carnap (1891–1971), violation of logical rules of language lies behind Heideggerian reflections, when for example the word *nothing* is used as a name of an object, whereby it is a form of negation, used to create negative existential statements. All thoughts of a similar kind are therefore in their ultimate effects meaningless.

Marián Palenčár

See also Aquinas, Saint Thomas, Aristotle; Augustine of Hippo, Saint; Becoming and Being; Eckhart, Meister; Hegel, Georg Wilhelm Friedrich; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Metaphysics; Nicholas of Cusa; Ontology; Parmenides of Elea; Plato; Spinoza, Baruch de; Time, Nonexistence of

Further Readings

Carlson, E., & Olsson, E. J. (2001). The presumption of nothingness. *Ratio, 14,* 203–221.

Gale, R. M. (1976). *Negation and non-being.* Oxford, UK: Blackwell.

Heidegger, M. (2000). *Introduction to metaphysics* (G. Fried & R. Polt, Trans.). New Haven, CT: Yale University Press. (Original work published 1953)

Sartre, J.-P. (2003). *Being and nothingness: A phenomenological essay on ontology.* New York: Routledge. (Original work published 1943)

Novels, Historical

The historical novel is a genre of literature whose story is set during a period that predates the author's own time, often by a significant number of years. A historical novel generally involves substantial research by the author concerning details of the period. The genre became widely popular during the 19th century Romantic period, advanced by great novelists such as Sir Walter Scott.

The purpose of the historical novel extends beyond that of entertainment, though many excel at this in their own right. Authors have often intended to deliver a message, advance a cause or ideology, or popularize history and present a time period to the public; none of these intentions is necessarily exclusive of the others. Historical novels are commonly set during eventful periods in human history, depicting a conflict or a transitional moment in time. Some historical novels span a lengthy duration and may include many accurate details about the past.

A prominent example of a historical novel that deals with the notion of time is Mika Waltari's *The Egyptian,* published in 1945. First written in Finnish, *The Egyptian* is set during the reign of the pharaoh Akhenaton, more than 3,000 years ago. The novel is centered on a fictional character, Sinuhe, the personal physician to the pharaoh, who recounts the tale of the pharaoh's decline and fall. The tale also parts from Egypt and describes Sinuhe's extensive travels throughout the ancient world. Published immediately following World War II, Waltari's novel was intended to explore the violence and brutality of the human condition and to imply that this has changed little from ancient to modern times.

The legendary Greek conqueror Alexander the Great has been depicted in numerous works of literature. Nikos Kazantzakis's *Alexander the Great,* written in the 1940s, is one modern example intended primarily for a younger audience. Kazantzakis was already a prominent author and philosopher by the time he penned the novel. *Alexander the Great* is a flattering depiction of the hero from a Greek author with a sense of pride in Greek history. However, Kazantzakis does not entirely succumb to glorification of the hero, presenting his faults and human qualities as well. The modern reader can thus relate to an ancient heroic figure.

The intention of delivering a powerful message through a classic work is exemplified by Henryk Sienkiewicz's historical novel *Quo Vadis: A Narrative of the Time of Nero*. Published in 1895, *Quo Vadis* is the Polish author's most famous work. The story is centered on a romance between a Roman patrician (Marcus Vinicius) and a young Christian woman (Lygia) at a time when Christians faced violent persecution by the Roman authorities. The novel conveys a strongly Christian message, implicit in the title as well as in the vivid depictions of Christian martyrdom. Sienkiewicz received the Nobel Prize for Literature in 1905. *Quo Vadis* has withstood the test of time, having been adapted to several film interpretations.

Popular interest in the time of imperial Rome and the birth of Christianity is evident by the reception of *Ben-Hur: A Tale of the Christ* in 1880. The author, Lew Wallace, was an American Civil War general, politician, and novelist. The book has been acclaimed for its accurate descriptions of the Holy Land of 2,000 years ago, though Wallace had never set foot there. Set during the reign of Tiberius, *Ben-Hur* is a tale of a Jewish aristocratic named Judea Ben-Hur who is falsely accused of murder by a Roman officer, Messala. Like *Quo Vadis,* the story deals with a pivotal moment in time as Christianity emerges within the Roman Empire. *Ben-Hur's* exceptional popularity helped to make the historical novel a popular literary and cinematic genre in the United States.

The author of *Ivanhoe,* Sir Walter Scott, is often credited as the father of the historical novel. Scott's 27 historical novels established the standard structure of the genre and greatly influenced later writers. His interest in the European Middle Ages is reflected in *Ivanhoe,* published in 1819. The story is set in 12th-century England during the time of King John. *Ivanhoe* is not only a tale of chivalry, combining fictional characters and actual events, but also a critique of the persecution of Jews in England. *Ivanhoe* helped to rekindle popular interest in the Middle Ages during the 19th century.

Leo Tolstoy deviated from the conventional novel with *War and Peace,* published as a series between 1865 and 1869. This ambitious story is set during the Napoleonic period and specifically during the Russian campaign. The Russian author spurned the "great man" paradigm of history in favor of capturing the daily human struggles during warfare. As such a human, Napoleon does not fare well in Tolstoy's depiction, whereas the personal interactions within Russian society form the narrative. This notion of "history from below" is central to Tolstoy's understanding of time and the movement of events.

Perhaps the most significant antiwar novel written is Erich Maria Remarque's 1929 classic *All Quiet on the Western Front.* Remarque's novel was timely; it was published in German during the interwar period. The novel is set during the First World War and is narrated by a young German soldier, Paul Baumer, who is engaged in the infamous trench warfare emblematic of the conflict. Baumer experiences the horrors of war and comes to recognize the deception of blind nationalism. The novel breaks sharply from the traditional portrayal of warfare over time, in which it has generally been glamorized. So powerful is the message in *All Quiet on the Western Front* that the novel was banned as subversive by the Nazi party in 1933.

A host of other distinguished novels could be added to this list. All of the aforementioned historical novels have film adaptations, which have also contributed to the popularity of the genre. Historical novels continue to connect readers to the past and to the passage of time.

James P. Bonanno

See also Dostoevsky, Fyodor M.; Flaubert, Gustave; Novels, Time in; Tolstoy, Leo Nikolaevich

Further Readings

Buckley, J. H. (1967). *The triumph of time: A study of the Victorian concepts of time, history, progress and decadence.* Cambridge, MA: Belknap Press of Harvard University Press.

Lukacs, G. (1978). *The historical novel* (H. Mitchell & S. Mitchell, Trans.). London: Humanities Press.

McGarry, D., & White, S. H. (1963). *Historical fiction guide: Annotated chronological, geographical, and topical list of five thousand selected historical novels.* New York: Scarecrow Press.

Saintsbury, G. E. B. (1971). *The historical novel.* Folcroft, PA: Folcroft Library Editions.

Novels, Time in

Time in novels is based on a fundamental duality. Günther Müller, a German literature theorist, was the first who reflected thoroughly on this duality. In 1948 he introduced the opposition between *erzählte Zeit* (story time) and *Erzählzeit* (narrative time), a literary terminology that has gained international acceptance. *Story time* designates the chronology of the events told—that is, the time of the story—whereas *narrative time* means the time of the narrative presentation of the story; in other words, the time of the plot. The temporal complexities that result from the relation between story time and narrative time were studied in detail by Gérard Genette, a French literary theorist who is primarily associated with the structuralist movement. In his canonical work, *Narrative Discourse: An Essay in Method* (1972), Genette proposes that time in novels may be classified in terms of order, duration, and frequency. We shall follow Genette's terminology, because it fills the need for a systematic theory of time in narrative texts.

The first main category discussed by Genette is the category of *order.* It designates the discrepancies between, on the one hand, the temporal order of a series of real or fictitious events connected by a certain chronology and, on the other hand, the temporal arrangement of these events in the narrative discourse. Genette pays attention to the fact that events occur in one order but are narrated in another. This discordance between the temporal succession of events in the story and their arrangement in the plot is called *anachrony.* Anachronical relations between story and plot are realized mostly by means of analepses and prolepses. *Analepses* are narrative episodes that take place earlier than the temporal point of departure of the narrative into which they are inserted. They are narrative retrospections or backflashes. The framing narrative is the first narrative, containing the analeptic sequence as the second narrative. *Prolepses* are temporal anticipations, narrative episodes that take place later than the temporal point of departure of the narrative, into which they are inserted. The framing narrative that contains the proleptic sequence is the first narrative, whereas the framed episode is the second narrative. Yet a careful analysis of the temporal order of narrative texts is not finished with the mere identification of analepses and prolepses, which must be further specified in respect to reach and extent. *Reach* designates the temporal distance of events told in the analeptic (proleptic) sequence from the moment in the story when the narrative was interrupted to make room for the anachrony. To determine the reach of analepses (prolepses) the reader must ask, "How long is the temporal distance between first and second narrative?" *Extent* is used to describe the duration of the story that is covered by the analeptic (proleptic) sequence. In this case the reader's question is, "How long is the period of time told in the second narrative?" In addition, analepses (prolepses) may contain further anachronies. These narrative sequences already framed by an anachronic episode are analepses (prolepses) of second degree.

Duration is the second main category discussed in Genette's *Narrative Discourse.* The duality of story time and narrative time allows novelists to control precisely the speed of their narratives. Duration is defined by the relation between the length of the story (measured in seconds, minutes, days, etc.) and the length of the text used to describe it (measured in lines, pages, chapters, etc.). The discrepancies between the length of the story and the length of the text are *anisochronies* (variations in speed). Genette determines four types of speed variations: summary, scene, pause, and ellipses.

- *Summary* means that the period of time told in a story is much longer than the narrative sequence used to describe it. Summaric episodes may cover 50 years in three or four sentences. Usually they are used for the transition between two scenes; they form the background against which scenic presentations stand out.
- *Scene* designates the correspondence between the period of time told in the story and the length of the narrative that describes it. Most often scenic episodes are characterized by dialogues, they present important conversations between the protagonists as well as dramatic events in their real length.
- *Pause* means that the speed of a narrative text is remarkably slowed down. Descriptive pauses are realized by epic ecphrasis or digression. The length of the narrative discourse of a pause may cover eight or nine pages, though it tells nothing about the further development of the story. Descriptive pauses stop the temporal progression of the story while the narrative discourse moves on constantly.
- *Ellipses* are gaps in the temporal continuity of the story. The period of time left out may cover hours, days, years, and more. For a precise knowledge of ellipses, readers have to consider the elided story time. Thus, their first question is to know whether the temporal elision is explicitly announced by quick summaries of the type "some time later" (explicit ellipses) or left out without any comment (implicit ellipses). Their second question is to know whether the duration of these time gaps is indicated (definite ellipses) or not (indefinite ellipses).

Frequency is the last main category discussed by Genette to describe the complex relations between story time and narrative time. It designates the relation of repetition between the events told in the story and their presentation in the narrative discourse. The frequency of a narrative text determines its temporal rhythm. Genette works out four types of frequency: narrating once what happened once, narrating *n* times what happened *n* times, narrating *n* times what happened once, and narrating once what happened *n* times. The first two types are singular narratives. In singular narratives the number of events in the story corresponds exactly to the number of statements about these events in the narrative text: If something happens once in the story, it is mentioned once in the narrative discourse; if something happens twice in the story, it is mentioned twice in the narrative discourse, and so on. The third type of frequency is the repeating narrative. Repeating narratives are characterized by a discrepancy between the number of events told in the story and the number of statements about these events in the narrative. For example, something happened only once, yet it is mentioned two times or more in the narrative discourse. The last type of frequency is the iterative narrative. In iterative narratives regular events are reduced to one single utterance of the type "Every Monday he caught the train at 11 p.m."

Genette's *Narrative Discourse* exclusively analyzes the literary presentation of time with regard to the form of narratives. Yet time can also be the thematic center of a novel. When we study time as the theme of a narrative, we no longer refer to its form but to its content. In this respect a fundamental distinction of time is the one between objective and subjective time. *Objective time* designates the regular succession of minutes, hours, and days that is measurable with a watch or a calendar. It is a consistent kind of time without deviations. *Subjective time* is based on the perception of characters in a novel. It depends on their individual experience, capricious imagination, or rambling memory. Subjective time changes constantly; hours are stretched into months, years compressed into days.

A careful textual analysis of the duality between story time and narrative time has to consider the specific characteristics of both kinds of time, especially in their relation to form and content. In the following section (Time as Form) we shall focus on some of the most famous novels of world literature in which the literary presentation of time decisively determines the narrative form. The final section, Time as Content, discusses renowned novels in which time is a thematic center. Although the presentation of time in novels has to be considered separately in respect to form and content, the two aspects are not to be isolated from each other. It is exactly their correspondence, or their significant contrast, that constitutes the temporal complexity of a narrative piece of writing.

Time as Form

Thomas Mann's *The Magic Mountain* (1924) is one of the most prominent novels in which the presentation of time in the story is mirrored in the form of the narrative. The protagonist's subjective experience of, and his reflection on, time is formally expressed by variations in speed. Hans Castorp, an ordinary young man, takes a short break between his final examinations in engineering and his first job. He plans a 3-week visit to his cousin Joachim, who stays at a sanatorium in the Swiss mountains because he suffers from pulmonary tuberculosis. Though Hans's visit begins as a holiday trip, it turns into a stay of 7 years that is abruptly ended by the outbreak of World War I.

The spatial distance between the mountains and the so-called flatland turns the sanatorium into a hermetic place. The rhythm of time on the mountain is completely different from the rhythm of time in the plain where the young protagonist comes from. At first, Hans views life on the mountain from the perspective of the flatland. He accuses Joachim of wasting his time in the sanatorium and does not understand why for him and the other patients the smallest temporal unit is a month. Yet life in the sanatorium rapidly benumbs Hans's sense of time. Soon he has experienced all the details of clinical routine and knows by heart its daily, weekly, and even monthly rhythms. The protagonist begins to live in a perpetual present, lacking even the temporal clues of nature, because in the mountains all kinds of weather appear in disorder throughout the year. Paradoxically, the extratemporal present on the mountain inspires Hans Castorp to reflect about the essence of time and to question temporal categories he has previously taken for granted. The new patient learns by experience that time in the flatland (objective time) is completely different from the psychological experience of time on the mountain (subjective time). The protagonist's complete absorption in atemporality ends with the outbreak of the First World War: He has to do military service and dies, presumably in a battle.

Hans's subjective experience of time and his isolation in an eternal present find their formal expression in a significant acceleration of speed. The length of the text that describes the first 3 weeks on the mountain is about seven times longer than the summary of the following 3 weeks. Apart from Hans's discussion with the Italian humanist Lodovico Settembrini and his opponent Leo Naphta, the remaining time of the protagonist's stay in the sanatorium (altogether 7 years) is summarized even more briefly. Another outstanding event in respect to time is Hans Castorp's dreamlike vision of life and death in a blizzard during a solitary skiing expedition. For the presentation of this event, the narrative speed slows down again, just to accelerate even faster afterward. These variations of speed illustrate clearly that Mann tried to find a formal equivalent for the temporal experience of the protagonist.

James Joyce pursued a similar idea when he wrote *Ulysses* (1922), whose composition of time depends primarily on the author's new approach to characterization. Instead of describing the characters from outside, Joyce puts himself in their place and depicts them from inside. This radical internalization is called "stream of consciousness." It tries to present the thoughts and feelings of literary figures exactly as they pass through the characters' minds. Joyce was the first writer to use a stream-of-consciousness presentation continuously in his narratives. This new approach to characterization significantly influences the presentation of time in *Ulysses*. In respect to the story, internal characterization leads to an emphasis on subjective time. Objective time provides merely an external framework for the temporal structure of Joyce's novel. The major action takes place in the temporal experience of the main characters (Leopold Bloom, his wife Molly, and Stephen Daedalus). The intertextual references to Homer's *Odyssey* enrich the presentation of time in *Ulysses* on a symbolic level. Each episode of Joyce's novel has its parallel in the *Odyssey.* Yet the Irish author summarizes Odysseus's wanderings, which lasted around 10 years, in just 1 day: The action of *Ulysses* takes place exclusively on June 16th, 1904.

Because the story of Homer's epic poem is implicitly integrated into *Ulysses,* time in Joyce's narrative assumes a mythological quality. In respect to the form of *Ulysses,* the consequent use of the stream-of-consciousness technique provokes a deceleration of speed in the narrative discourse: Whereas the story time covers just one day, the narrative time is significantly longer. It is impossible to read Joyce's novel in precisely 24 hours, even if readers want to. The literary presentation of the character's thoughts and feelings consumes much more time than their actual succession in reality. Thus it is precisely the technique of the stream of consciousness that shapes the conception of time in *Ulysses* in respect to both form and content.

In contrast to the 1-day summary of *Ulysses,* the events in Homer's *Odyssey* (c. 700 BCE) cover a temporal period of approximately 10 years. Yet the passage of time is not reported continuously. The *Odyssey* is full of anachronic sequences that switch back to the protagonist's past or implicitly hint at his future. The anachronic presentation of time allows Homer to portray the wanderings of Odysseus exclusively in their final and decisive phase, which lasts about 40 days. All events that precede this starting point of the first narrative (from the fall of Troy until the protagonist's shipwrecking on Ogygia) are told in analeptic sequences by Odysseus himself or in the songs of a minstrel. A similar temporal order applies also to Homer's earlier work, the *Iliad* (c. 750 BCE), that centers around a quarrel between Achilles and Agamemnon. Having evoked the conflict between the characters that the narrator proclaims to be the starting point of his story, he switches back about 10 days to reveal the cause of the quarrel. The first analeptic sequence is thus inserted in the very beginning of Homer's epic poem. It reveals the cause of the conflict in about 140 retrospective lines. A closer look at Homer's epics makes clear, therefore, that the temporal structures of the *Iliad* and the *Odyssey* are based fundamentally on anachronies.

Returning to 20th-century literature, the most complex literary presentation of time can be found in Marcel Proust's *In Search of Lost Time* (also known as *Remembrance of Things Past,* 1913–1927). The reflection on time in the *Search* is exceptional in respect to form and content. As in Mann's *Magic Mountain* and Joyce's *Ulysses,* subjective time determines the story of Proust's narrative. In the *Search,* time assumes the form of involuntary memory (*mémoire involontaire*). The narrator-protagonist, Marcel, tries to remember his life. He learns that only the involuntary memory is able to bring back the complete image of the past immediately. The voluntary memory (*mémoire volontaire*) is under rational control and thus remains superficial. A canonical example of the workings of the involuntary memory is the so-called madeleine passage in the opening of the *Search*. A discrete similarity between present and past (in this case the unexpected flavor of a piece of madeleine cake that Marcel dips into a cup of tea) transports Marcel immediately back to his childhood at Combray. The involuntary memory evokes an overpowering recollection and grants Marcel a glimpse into the essence of the past.

Proust's literary presentation of the involuntary memory was significantly inspired by the philosophy of Henri Bergson. His philosophical study *Matter and Memory* (1896) appeared when Proust was 25. In the second chapter of his work, Bergson distinguishes two kinds of memory: the memory of habit and the pure or spontaneous memory. He argues that the latter is independent of our will. Proust's poetics can be called "Bergsonian" insofar as he implicitly adopts the philosopher's distinction between an intentional and an unintentional form of remembrance.

The involuntary memory also determines the narrative form of the *Search*. Although remembrance is a temporal process, the basic structure of the novel seems to be static and lifts the action out of time. The impression of atemporality is primarily evoked by the iterative character of the narrative form of the *Search:* Marcel tells us once what happened every Sunday in Aunt Léonie's household; he tells us once about the daily walks with his family. Regular repetition has turned these ordinary actions into a ritual. It is the iterative narration of ritualized events that evokes the impression of immovability and makes Marcel's remembrance of the past eternal.

The last important literary technique for the presentation of time we shall discuss is digression. The complexity of time in Laurence Sterne's *Tristram Shandy* (1759–1767) results primarily from the exuberant use of rhetorical digression. Digressions are excurses from the primary line of a narrative. They slow down the narrative speed or even cause it to stagnate. Rhetorical digressions thus traditionally assume the function of pauses: In a digressive sequence, the time of the story is stopped while the narrative discourse moves on. In *Tristram Shandy,* however, the use of digression is driven to the extreme and undermines its classical function. Digression causes an inversion of the ordinary flow of time: Having set himself the task to omit nothing of his life that is relevant, the narrator-protagonist, Tristram, has to admit its impossibility. Up to the middle of the fourth volume of the novel, he has gotten no farther than the first day of his life. The more Tristram tells about his life, the more he will have to tell. He dwells upon long excurses while his own life is constantly proceeding but remains undocumented. Sterne's exuberant use of digression turns it into progression: His novel is digressive and progressive at the same time. Sentences are interrupted abruptly and not finished until 30 pages farther on. Yet the time in between is stuffed with oddities and strange encounters that enrich the characters by adding new details of their past lives. By driving digression to the extreme, the author creates temporal paradoxes that completely suspend the linear flow of time.

Rhetorical digression also shapes the presentation of time in Herman Melville's *Moby Dick* (1851). Although *Moby Dick* is a work of fiction, Melville included chapters that are largely concerned with an almost scientific discussion of whales. These chapters are known as episodes of cetology (from the Greek nouns *cetus* "whale" and *logos* "knowledge"). They significantly slow down the narrative speed of the story that focuses on Captain Ahab's furious obsession to kill Moby Dick, the white whale, who swallowed his leg. The cetology chapters form a story of second degree that parallels Captain Ahab's obsession on a more abstract level: They present the narrator's untiring effort to bring the mythic power of Moby Dick under rational control by scientific reflection. Yet, as Ahab drowns in a fight with Moby Dick, the intention of Ishmael, the narrator, remains unfulfilled, too. All the scientific approaches fail to give him an adequate account of the white whale's ineffable mystery and strength. The conception of time in *Moby Dick* is thus determined to a significant degree by rhetorical digression. In contrast to *Tristram Shandy,* however, digression keeps its traditional function in *Moby Dick:* It does not generate the whole novel but remains a deviation from the primary line of the narrative.

Time as Content

This section discusses in chronological order certain novels in which time is a central theme of the story and thus primarily relevant in respect to the narrative's content.

The content of Ovid's *Metamorphoses* (completed in 8 CE) unites three kinds of time: primeval time, mythological time, and historical time. Ovid starts his epic poem with the story of Creation. He proceeds with a literary description of the mythological history of the world and ends his narration in his own time under the rule of Augustus. The major theme of the *Metamorphoses* is, as the title already suggests, transformation or change. Divine and human beings are physically transformed into animals or plants. The story of each single transformation is intended to give a reason for the existence of things. Metamorphosis thematically unites the loosely connected episodes. It is a process in time that demonstrates that continuous change is the fundamental principle of the mythological as well as the terrestrial world. Containing versions of many of the most famous myths of Greece and Rome, Ovid's epic poem has become one of the cornerstones of Western culture.

Dante's *Divine Comedy* (c. 1300) opposes two time schemes: the historical time of the terrestrial world on the one hand, and the time of salvation history on the other. In the middle of his life, Dante (the author, narrator, and protagonist) has lost the straightforward pathway to God. To be purified again, he has to cross the three empires of the beyond: hell, purgatory, and paradise. Dante enters the eternal sphere as an individual person, though his figure has a representative meaning, too: Dante's voyage beyond the grave is also the voyage of humankind. By assuming both an individual and a representative meaning, the figure of the narrator–protagonist unites historical time and eternity. This double meaning applies also to the voyage that is not a mere movement through time and space but a spiritual journey. We can measure Dante's travel in historical time: It lasts about 7 days. Yet, what is more important than the measurement of time in days is the traveler's process of purification during his transition from hell to paradise. This process is spiritual and thus situated outside of time, in eternity. However, the narrative discourse shows no traces of reflecting this extratemporality. The narrative form of Dante's epic poem can be described as a regular alternation between scene and summary. The *Divine Comedy* thus illustrates a strict division between the representation of time in respect to its content and the temporal conception of the narrative discourse.

Temporal paradoxes are thematically discussed in Lewis Carroll's book *Alice's Adventures in Wonderland* (1865). Following a white rabbit down a rabbit hole, Alice finds herself in a dreamlike world where the logic of reality is completely abandoned. In Wonderland even time runs differently so that Alice joins, for instance, a never-ending tea party in which it is always six o'clock. The temporal absurdities the young girl is confronted with are discussed in the story. They find, however, no corresponding expression in the narrative discourse that shows the classical alternation between scene and summary.

Gustave Flaubert's *The Temptation of Saint Anthony* (1874) is about Anthony the Great, a recluse who lives isolated on a mountain top in the Egyptian desert. The novel describes one night in the life of Anthony during which he is besieged by carnal temptation and philosophical doubt. Asceticism and meditation completely suspend the protagonist's sense of time and space. In this hallucinatory mood Anthony is confronted with the vision of a primordial earth. He witnesses the first signs of inanimate and animate nature as well as the birth of humankind. In addition, the saint is haunted by several allegorical figures (among them Lust and Death) who want to change his belief that isolation is the truest form of worship. In *The Temptation of Saint Anthony* Flaubert tried to summarize the history of the world in the visions of one night.

The discussion of time as memory is an important theme in Fyodor M. Dostoevsky's *The Brothers Karamazov* (1880). Whereas the primary line of narrative centers around the story of a parricide, the topic of memory is discussed primarily in the most important side story of Dostoevsky's novel. It focuses on a group of schoolboys throwing rocks at one of their peers, Ilyusha. In the course of the novel, however, Ilyusha dies. His funeral is discussed at length in the epilogue of *The Brothers Karamazov.* Alyosha, the youngest of the Karamazov brothers, makes a speech near the stone where Ilyusha's parents wanted to bury their son. Alyosha asks the boys to keep Ilyusha as well as the day of his funeral in their memories forever. He proclaims that especially the memory of one's childhood is the best kind of education. Memory shall unite Ilyusha, his friends, and Alyosha forever. With Alyosha's memorial speech Dostoevsky emphasizes the importance of living memory, that is, an active kind of commemoration that constantly tries to evoke the dead as companions of the living.

Time as history is the thematic center of Henryk Sienkiewicz's *Quo Vadis. A Narrative of the Time of Nero* (1895) whose story takes place in antiquity. *Quo Vadis* is the most famous historical novel of the late 19th century. It tells of a love between Lygia, a young Christian woman, and Marcus Vicinius, a Roman patrician. The action is set around 64 CE in the city of Rome under the rule of Nero. Before writing *Quo Vadis,* Sienkiewicz thoroughly studied the history of the Roman empire. He filled his novel with historical conflicts and characters to evoke the time of Nero as authentically as possible. The tradition of the historical novel experienced a great revival with Umberto Eco's *The Name of the Rose* (1980), perhaps the most famous historical novel of the 20th century.

In contrast to historical novels that deal with a distant past, science fiction novels discuss imaginary technological or scientific advances that may determine our life in the future. With *The Time Machine* (1895), H. G. Wells set the cornerstone for this literary genre. His narrative is concerned with the concept of time travel using a vehicle that brings the traveler into the past or the future. The physical constitution of time is discussed at length in the framework story of *The Time Machine:* The time traveler, a nameless amateur inventor living in London, explains to his evening guests that time is nothing but the fourth dimension of space. He is convinced of the fact that there must exist a suitable apparatus that can move back and forth in time.

Eventually the inventor constructs such a machine that takes him to the year 802701 CE, where he is faced with a society that has diverged into two branches: There are the peaceful, childlike, but unintelligent Eloi on the one hand, and the intelligent but bestial Morlocks on the other. Both species are of subhuman intelligence. Another adventure brings the time traveler to a future that is 30 million years from his own time. He sees the last traces of life on a dying Earth, where the only sign of life is a black creature with tentacles. From a last voyage in time, the inventor never returns.

The Time Machine also set the ground for the literary tradition of dystopia in the 20th century. Dystopian narratives present the picture of an imaginary society that is worse than our own that the majority of us would fear to live in. Dystopian images are for the most part visions of a future society. Wells's narrative is both a science fiction novel and a dystopian novel that presents the author's vision of a troubled future.

The basic conception of time in Arthur Conan Doyle's *The Lost World* (1912) resembles to some degree the conception of time in Mann's *The Magic Mountain*. It tells the story of an expedition to a hidden plateau in South America where dinosaurs and other extinct animals are still alive. Again it seems to be spatial isolation that provokes a significant change of time and takes the explorers back into a prehistoric past. Conan Doyle's narrative is among the first science fiction novels of the 20th century.

James Hilton's utopian novel *Lost Horizon* (1933) is a further narrative that centers on the specific conception of time in a geographically isolated place. Hugh Conway, a member of the British diplomatic service, is among four kidnap victims who are brought to Shangri-La, a lamasery in the mountains of Tibet. They receive a very friendly welcome by the monks, who firmly believe in an ethics of moderation. Like the sanatorium in *The Magic Mountain,* the valley of Shangri-La is a peaceful but isolated place that ignores the actions of the outer world. Conway and the other victims soon realize that the temporal rhythm in Shangri-La differs to a large degree from the rhythm of time outside the valley. This dichotomy is a further aspect that resembles the conception of time in *The Magic Mountain,* though a closer look reveals that time in the Tibetan lamasery also differs significantly from time in the Swiss sanatorium: Whereas Hans Castorp experiences an extreme acceleration of time, the temporal rhythm of life in Shangri-La is remarkably slowed down. This deceleration of time affects primarily the physical processes of the human body. By a combination of drugs, meditation, and a special diet, the metabolism itself is slowed. Thus the inhabitants of Shangri-La may arrive at an age of several hundred years. In contrast to the artistic masterpiece of Mann that reflects the protagonist's subjective experience of time in the form of the novel, the deceleration of time finds no corresponding expression in the narrative form of the *Lost Horizon.*

Verena Kammandel

See also Alighieri, Dante; Bradbury, Ray; Carroll, Lewis; Chronotopes; Clarke, Arthur C.; Dostoevsky, Fyodor M.; Flaubert, Gustave; Homer; Joyce, James; Mann, Thomas; Ovid; Proust, Marcel; Shangri-La, Myth of; Sterne, Laurence; Tolstoy, Leo Nikolaevich; Verne, Jules; Wells, H. G.; Woolf, Virginia

Further Readings

Bergin, T. G. (Ed.). (1967). *From time to eternity. Essays on Dante's* Divine Comedy. New Haven, CT: Yale University Press.

Fluchère, H. (1965). The mind and the clock. In H. Fluchère, *Laurence Sterne: From Tristram to Yorick* (pp. 90–129). London: Oxford University Press.

Genette, G. (1990). *Narrative discourse. An essay in method.* Ithaca, NY: Cornell University Press.

Kristeva, J. (1996). *Time and sense: Proust and the experience of literature.* New York: Columbia University Press.

Kumar, U. (1991). *The Joycean labyrinth: Repetition, time, and tradition in* Ulysses. Oxford, UK: Clarendon Press.

Nakin, P. J. (2001). *Time machines: Time travel in physics, metaphysics, and science fiction.* New York: AIP Press.

Westfahl, G. (Ed.). (2002). *Worlds enough and time: Explorations of time in science fiction and fantasy.* Westport, CT: Greenwood Press.

Now, Eternal

The eternal now is a notion often linked with the nature of God, according to Western theology and according to various mystical, Asian, and so-called New Age traditions.

Anicius Boethius (480–c. 524 CE) and Saint Thomas Aquinas (c.1225–1274 CE) conceive of God as existing outside of time. They argue that the divine essence involves a perpetual present or now, without succession of moments. God exists in a kind of unchanging specious present. Such a divine essence could not thus be described as existing "before" any event in time. It could exist, instead, as intimately present at every moment of our time, while being itself outside of time. Even Jesus, the alleged physical embodiment of God, is said to have asserted that "Before Abraham was, I am" (instead of "I was"). Paul Tillich (1886–1965) in his book *The Eternal Now* claims that a timeless eternal now is what makes possible our sense of the temporal present now. For, looked at objectively, time as a succession of moments does not exhibit any present or any now. Yet we experience a now. The experience of a present now, Tillich claims, is made possible only by the breaking through of a timeless eternal present (of God, and of our essential divine self) in the time sequence.

A much-repeated metaphor meant to shed light on the paradoxical relation between a divine eternal now and our successive time is the image of God as an immovable point at the center of a circle, a center point equally distant from every point on the circumference. The circumference represents the moving, successive, spread-out nature of time. Such a circumference would have to be imagined as infinitely long and as not necessarily returning to close upon itself. Also, in this image the distance between God, as center point, and each point on the circumference would have to be imagined as nonexistent—to establish the immediacy of God's presence in every moment of time.

Philosophical Challenges

One of the challenges for this notion of a timeless divine specious present, or eternal now, is to preclude it from being static or frozen, thus lifeless and nonconscious. Can there be nondurational, nonsuccessive consciousness? Does consciousness not require some dynamism or activity? Those who answer in the positive, like the philosopher Josiah Royce, tend to insist that our durational present should remain the model for understanding the divine consciousness and its eternal now. These critics understand the divine state as still somehow temporal, although this temporal present would be much wider in scope, perhaps infinitely wider, than our human specious present. Would such a divine durational now be a temporal flow that is parallel to our time? Or would it involve some sort of temporality, some hypertime, unknown to us? Could this divine now be, instead, some sort of nontemporal, nonsequential, dynamism? Does the latter notion make logical sense? Are we to take refuge in paradox here?

It is worth noting that 20th-century physics has also addressed the notion of time and of the present now. The theory of relativity proposed a union of space with time. According to a widespread interpretation of this union, though it is still debated, time becomes assimilated to a fourth dimension of the static continuum "spacetime." Some philosophers and scientists have objected to this static-like interpretation of time. Even Albert Einstein argued that in relativistic spacetime, the time dimension is not equivalent to the spatial dimensions. He preferred viewing space as being dynamized by this union with time, instead of time being spatialized by it. For instance, simultaneity becomes relativized in Einstein's theory. This means that the notion of "instantaneous space," that is, the notion of all events occurring at the same time across all space, becomes problematic. Such a set of "simultaneous" events cannot be extracted unambiguously from the four-dimensional world process. This is because a point-event occurring before, at the same time, or after, another point-event depends in part on the standpoint from which the sequential observation is made. (The exceptions might be cases of causally related events.) Thus in relativistic physics, unlike Newtonian physics, past and future are not separated by a durationless three-dimensional "now" instantaneously spread across the universe. Past and future are instead better viewed as separated by a four-dimensional region of "elsewhere."

Recently there has been a resurgence of nonphilosophical and nontheological experience-based claims regarding some form of timeless eternity. These accounts derive partly from the New Age movement since the 1950s—a dispersed movement characterized by eclectic nontraditional mysticism-based spirituality. Similar claims derive also from the now widespread phenomena of near-death experiences.

The former movement includes a number of alleged spirit channelers reporting on pantheistic claims to the effect that God is in everything and that by turning inward we can access God's and our own (and more real) timeless nature. This viewpoint advises that beneath our ordinary temporal realm there is another and more basic one, often characterized as a divine eternal now. The metaphysics underlying this claim seems to be that the ultimately timeless divine reality opts to manifest itself as the temporal and spatial multitude of things we call the universe (and perhaps as many other universes as well). The "Seth" books by Jane

Roberts are among the most popular examples of this New Age account of reality.

There is, in addition, an extensive recent literature regarding the *experience* of some form of timelessness during alleged "near death experiences" (experiences one has during certain traumas, and sometimes in hospitals through moments while one is mistakenly declared clinically dead). During parts of such experiences—while reviewing one's whole life "instantaneously," or while engaging in some form of "instantaneous" thought-travel—many people claim that their sense of time slows down drastically, or stops altogether, while their awareness of countless events continues. Some claim that this represents the experience of an eternal now, and they often attribute this eternal now to a feature of the postlife divine environment.

Carlo Filice

See also Aquinas, Saint Thomas; Becoming and Being; Boethius, Anicius; Einstein, Albert; Eternal Recurrence; Eternity; God and Time; Tillich, Paul; Time, Perspectives of

Further Readings

Boethius, A. (1969). *The consolation of philosophy* (V. E. Watts, Trans.). London: Penguin. (Original work c. 524 CE)

Craig, W. (2001). *Time and eternity: Exploring God's relationship to time.* Wheaton, IL: Crossway Books.

Leftow, B. (1991). *Time and eternity.* Ithaca, NY: Cornell University Press.

Roberts, J., & Butts, R. F. (1994). *Seth speaks: The eternal validity of the soul.* San Rafael, CA: Amber-Allen.

Nuclear Winter

Nuclear winter is a term used to describe the potential environmental and climate effects resulting from a large-scale nuclear war. On December 23, 1983, five scientists, Richard P. Turco, Owen B. Toon, Thomas P. Ackerman, James B. Pollack, and Carl Sagan, published a paper in the journal *Science* that has come to be known as the TTAPS Study. The paper raised concern over the short-term and long-term consequences of dust, smoke, radioactivity, and toxic vapors that would be generated by a nuclear war. Although with the end of the Cold War in the 1980s, the threat of nuclear war has subsided, it should never be dismissed completely.

In the article, the five scientists concluded that exploding just one half of the combined nuclear weapons of the United States and the former Soviet Union would throw billions of metric tons of dust, soot, smoke, and ash into the atmosphere. In each explosion, most of this dust would be carried up by the nuclear fireball itself, and some of it would be sucked up the stem of the mushroom cloud. Even a more modest explosion on or above cities would produce massive fires like those in Hiroshima and Nagasaki at the end of World War II. These fires would consume wood, natural gas, and a wide variety of combustibles. The resulting smoke would be far more dangerous to the earth's climate than the dust; the smoke, the scientists argued, could produce a blanket of air pollution so thick that it would have the potential to block more than 80% of the sunlight that would otherwise reach the northern hemisphere.

As a result, they claimed, severe worldwide climate changes could occur, including prolonged periods of darkness and below-freezing temperatures, making the average land cool to 10°C to 20°C; continental interiors could cool by up to 20°C to 40°C, with subzero temperatures possible even in summer. There would also be the potential for violent windstorms. The combination of cold temperatures, dryness, and lack of sunlight would also cripple agricultural production and destroy ecosystems, putting most of the world's population at risk of starvation, according to the 1985 report by the International Council of Scientific Unions. Other studies suggest that even a small nuclear war would devastate the earth.

Severe climate change may have been a factor in the demise of the dinosaurs toward the end of the Mesozoic era. There is evidence that the end of the Mesozoic era saw changes in climate resulting in a pronounced drop in temperatures, similar to a nuclear winter. Major volcanic eruptions may have produced enormous quantities of smoke and ash that blocked the sunlight over major portions of the earth's land mass; alternatively, as some geological evidence suggests, an extraterrestrial object, most likely a meteor or asteroid, may have struck the earth, throwing up huge quantities of debris into the atmosphere and blocking out sunlight for a time. Such an event would have created a winter condition that killed plants and larger animals. This scenario is similar to that of a nuclear winter that could follow a major nuclear war.

The nuclear winter theory has been the subject of some controversy. Efforts were made by government and military scientists to play down the possible consequences. They argued that the effects would not be nearly so severe and began talking of a "nuclear autumn." In 1984, the U.S. National Research Council publicly stated that it agreed with the ideas advanced in the *Science* article; however, in 1985, the U.S. Department of Defense issued a report saying that while the nuclear winter theory might be valid, it would not change defense policies.

Today, although the threat of nuclear war has receded somewhat, the continued existence of nuclear weapons is a reminder that the possibility of a nuclear winter cannot be entirely dismissed.

Patricia Sedor

See also Dinosaurs; Ecology; Extinction, Mass; Extinction and Evolution; Sagan, Carl

Further Readings

Fisher, D. E. (1990). *Fire and ice: The greenhouse effect, ozone depletion and nuclear winter.* New York: HarperCollins.

Grinspoon, L. (1986). *The long darkness: Psychological and moral perspectives on nuclear winter.* New Haven, CT: Yale University Press.

Rowan-Robinson, M. (1985). *Fire and ice: The nuclear winter.* New York: Longman.

Sagan, C., & Turco, R. (1990). *A path where no man thought.* New York: Random House.

O

Observatories

Throughout history, humans have watched the stars in the night sky. Observatories were built to aid in the study of celestial objects as a means of measuring time. Many calendars are based upon the information gathered through these observations, including the Julian and Gregorian calendars. Different cultures and countries built observatories of different kinds to study the skies and track their calendars.

Prehistoric and Early Observatories

Arguably the most well-known prehistoric observatory is Stonehenge in Wiltshire, England, a circle of massive stones arranged to align with certain celestial events. Stonehenge was used as a way of tracking the moon, stars, and eclipses. There are a number of other Neolithic structures throughout Europe similar to Stonehenge in design and serving a similar purpose.

Native Americans built rock pattern structures called medicine wheels, or spiritual healing sites, that are strongly connected to the night skies. The three most notable medicine wheels are located at Big Horn, Wyoming, in the United States and at Moose Mountain in central Saskatchewan and east of Calgary in Majorville, Alberta, Canada. Most medicine wheels are created of stones located on top of hills or mountains, and they consist of a central stone from which spokes radiate toward a rim.

The Mayans have written records of astronomical observations, and several of the Mayan buildings were architecturally designed around the heavens or for the purpose of observing the skies. One such building is the Caracol Tower in Chichen Itza, which has three windows used by Mayan astronomers for observations. The Mayan people used the information gathered through these observations as a source for creating the Mayan calendar.

Muslim Observatories

In medieval Islam, there existed a desire to retain and elaborate upon the knowledge created by the ancient Greeks. Constructed in Baghdad, in what is now Iraq, during the Abbasid era of Islam, the House of Wisdom, a research center with observatory, enabled astronomers to create updated charts of planetary motion based on Ptolemy's research.

Many observatories were destroyed or abandoned due to superstition or political conflict. One such research facility, also known as the House of Wisdom, was constructed in Cairo, Egypt early in the 11th century CE. The observatory was destroyed 100 years later due to the superstition held by the populace toward planetary observation and political strife. The Istanbul Observatory, built 500 years after the Egyptian House of Wisdom, met a similar fate for similar reasons.

Not all Islamic observatories met such ill-fated demise. The two most successful observatories in the Islamic world were located at Maragha, in modern-day Iran; and at Samarkand, in modern-day

El Caracól observatory at Chichen Itza, dedicated to the study of astronomy, consists of a tower erected on two rectangular platforms.
Source: Kristine Kisky/Morguefile.

Uzbekistan. The Maragha observatory was originally constructed with astrological, rather than astronomical, intent. The major accomplishment associated with the Maragha observatory is the Ilkhanic tables charting the motion of the planets, the moon, and the sun. Fifteenth century astronomer Ulugh Beg used the ruins of the Maragha observatory as a model for the observatory at Samarkand built in the 15th century CE, where a sextant with a 120-foot radius was constructed. This instrument allowed for a resolution of arc seconds in its measurements, which was not to be surpassed until the invention of the telescope 200 years later. Astronomers at the Samarkand observatory recorded a list of nearly 1,000 stars visible from their location. Today, a crater on the moon is named after Ulugh Beg.

Asian Observatories

The Beijing observatory, built in the 15th century CE, was occupied by astronomers charged with watching the night skies. Over the course of 3,000 years, these astronomers had recorded data on hundreds of astronomical activities, including lunar and solar eclipses, meteor showers, and comets. The Chinese, in the 1st century CE, were the first to build automated instruments to measure celestial objects. The Chinese used a water clock as the timer for these devices, creating the first known clock drive. In the 1670s, Jesuits convinced Chinese astronomers to add Western instruments to the Beijing observatory. Observational activities were limited due to a conflict of interests. The Chinese astronomers' interests in observations were only in revising the current calendar. The church's stance against any activities associated with heliocentric ideas, and the Jesuits' strict adherence to this position, also prevented further contribution.

India's most notable observatories were constructed in the 18th century under the direction of the Hindu prince Jai Singh. He constructed the largest instruments he could to increase accuracy. One tool he commissioned to be built was an 88-foot-tall sundial. Updating Ulugh Beg's star data, Singh added 4 degrees, 8 arc minutes to the ecliptic longitudinal measurements to accommodate the earth's precession for the past 300 years.

European Observatories

Bernard Walther built the first notable European observatory in Nuremberg, Germany, in the mid-1470s CE. Observational data collected at this observatory noted a slight discrepancy in the Alfonso Tables, the most popular star tables in Europe from 1300–1500.

Galileo is often credited with inventing the telescope, which was in fact created in 1608 by the Danish spectacle maker Hans Lippershey. Galileo, however, was the first, in 1609, to turn the device to the skies, using the invention as an astronomical observational device and making a number of improvements to Lippershey's model. Galileo's observations through the telescope changed the study of astronomy. Galileo's most notable observations include the surface features of Earth's moon and four of the moons of Jupiter. Galileo noted the surface of Earth's moon was abundant with mountains and dark spots believed to be large bodies of water, which he named *maria,* or seas. Galileo also observed the phases of Earth's moon and those of Venus.

Tycho Brahe's 16th century observatory, built on the Danish island of Hven, was named Uraniborg and housed a number of instruments used in observations. Brahe is credited with recording the most accurate observational data of his time, prior to the invention of the telescope. Johannes Kepler assisted Brahe, and after Brahe's death, Kepler used the data gathered by Brahe to create his laws of planetary motion.

The Paris Observatory, built in 1667, became a model for national observatories. National observatories, such as the Paris and Greenwich observatories, were dedicated to gathering observational data for national interests, including improving navigation and calendars. By creating accurate tables of star positions, and with the invention of the chronometer, seafaring vessels were capable of determining their geographical location at sea.

Private observatories were also constructed, usually by wealthy individuals or organizations. In 1781, William Herschel's discovery of Uranus won favor with King George III, and Herschel was soon appointed as the king's astronomer. Herschel built his own telescopes, creating them with a high-enough resolution to open the field to galactic astronomy. Inspired by Herschel, Johann Schröter built the largest observatory of its time in Europe in the small town of Lilienthal, Germany. Schröter sketched the surfaces of the moon and of Mars, creating an interest in the studies of planetary astronomy.

Lowell Observatory, Clark Dome, in Flagstaff, Arizona. The observatory's stated mission is to pursue the study of our solar system and its evolution; to conduct pure research in astronomical phenomena; and to maintain public education and outreach programs to bring the results of astronomical research to the public.

Source: Library of Congress, Prints & Photograph Division.

American Observatories

Following in the footsteps of early national observatories, younger nations also built their own modern observatories, some shaped by the field of astrophysics. One such nation, the United States, erected the United States Naval Observatory in 1839.

While attending the Massachusetts Institute of Technology, George Hale invented a device known as a spectroheliograph, which is capable of photographing the sun. Hale built a solar observatory in his parents' backyard, located in a Chicago suburb. Hale accepted a position at the University of Chicago, and the construction of the university's Yerkes Observatory in Wisconsin was completed in 1897. The Yerkes Observatory was one of the first observatories constructed for the purpose of studying astrophysics rather than average celestial observations. Hale also planned the construction of the Mt. Wilson Observatory in California in 1904.

Conclusion

After the success of the Mt. Wilson Observatory and the Palomar Observatory in California, it was recognized that mountaintop locations near the ocean were ideal for observatories. Most observatories are now constructed upon higher elevations in an attempt to observe above, rather than through, the atmospheric interference. Today, observatories use not only optical telescopes but also radio telescopes and X-ray and gamma-ray telescopes. These telescopes allow us to "see" wavelegths outside of visible light. While radio telescopes can be used on Earth, most X-ray, gamma-ray, infrared, and ultraviolet *wavelengths* are blocked by the atmosphere and are best observed from space, through space-based observatories such as the Hubble Space

Telescope. Optical telescopes also capture their best images from space, due to the lack of interference from the atmosphere.

Mat T. Wilson

See also Calendar, Gregorian; Calendar, Julian; Galilei, Galileo; Light, Speed of; Planetariums; Sundials; Telescopes

Further Readings

Aveni, A. F. (1977). *Native American astronomy.* Austin: University of Texas Press.
Heilbron, J. L. (1999). *The sun in the church.* Cambridge, MA: Harvard University Press.
North, J., & Porter, R. (1995). *Norton history of astronomy and cosmology.* New York: Norton.

Old Faithful

Nathaniel P. Langford and Gustavus C. Doane, of the 1870 Washburn Expedition, coined the name Old Faithful to testify to this geyser's punctual regularity. Old Faithful is one of thousands of thermal features in Yellowstone National Park that result from a subterranean magma spike—where magma rises to within 40 miles of the earth's surface, compared to an average distance of 90 miles. This unique feature accounts for the park's Upper Geyser Basin, which contains nearly one quarter of Earth's geysers.

Old Faithful Geyser, Yellowstone National Park, erupting.
Source: Photo by Ansel Adams, 1941, courtesy of the National Park Service.

Predicting Eruption Time

Yellowstone boasts six grand geysers, each ejecting water spouts exceeding 100 feet. One of these giants, Old Faithful, ranges in height from 105 to 185 feet. It is a popular attraction; crowds flock to see it year round. For visitors to better understand the geyser, general rules have been devised to help predict eruption times.

Joseph Le Conte's claim that Old Faithful erupted hourly became replaced by a generalization saying eruptions lasting under 4 minutes are followed by another in 40 to 60 minutes, and eruptions over 4 minutes are followed in 75 to 100 minutes. Over time, more detailed studies yielded more specific rules. In general, an eruption of 1.5 minutes will be followed in 45 minutes. Approximately 65 minutes of rest follow a 3-minute eruption, and it takes 86 minutes to rebuild after a 5-minute eruption. Old Faithful's eruptions, on average, last 4 minutes.

Many factors upset the balance of geysers over time. People can cause immense damage. Even within two years, from the 1870 expedition to a formal survey in 1872, noticeable damage had been done to Old Faithful's cone by specimen collectors. More damage has ensued as the geyser sees 3 million visitors yearly. A 1980s cleanup project removed debris from the geyser itself, as visitors sometimes throw coins and other objects in. These activities all affect a geyser's stability.

Earthquakes serve as an additional factor that could contribute to lessening the reliability of Old Faithful. Seismographs record up to 215 tremors on the Yellowstone Plateau each year. Large earthquakes noticeably affect the balance of geysers. Before a 1959 quake, eruptions occurred at an average 65-minute interval. This quake and another in 1975 lengthened intervals, and a 1983 quake increased the average to 78 minutes.

Although geysers come and go, one should not prematurely conclude Old Faithful has yet become less predictable. Correlations and frequent observation continue to yield reliable estimates even as rest intervals increase. Though Old Faithful now erupts less often, it still maintains an uncannily consistent schedule.

Jared Nathaniel Peer

See also Geology; Plate Tectonics; Wegener, Alfred

Further Readings.

Bryan, T. S. (1995). *The geysers of Yellowstone.* Niwot: University Press of Colorado.

Bryan, T. S. (2005). *Geysers: What they are and how they work.* Missoula, MT: Mountain Press.

Schreier, C. (1992). *A field guide to Yellowstone's geysers, hot springs and fumaroles.* Moose, WY: Homestead.

Olduvai Gorge

Olduvai Gorge remains one of the most recognized archaeological sites in the world. It has provided, and continues to provide, vital information to researchers seeking answers about the origins of humanity and its evolution through time.

Wilhelm Kattwinkel, a German entomologist, stumbled across Olduvai Gorge in 1911 in northern Tanzania. The location is a canyon approximately 40 kilometers long with walls standing nearly 100 meters high that showcase nearly 2 million years of history. Extensive investigations at Olduvai Gorge began shortly afterward, yielding an array of lithic tools and fossilized animal remains amongst which were the remains of early hominids, including those of *Australopithecine* (*boisei*) and *Homo habilis* specimens. The variety of nonhominid remains discovered at Olduvai Gorge, found both separate from and amongst those of hominids, includes giraffe, antelope, and elephant. Collectively, the remains and associated tools continue to provide researchers with crucial data regarding the activities of early hominids and the overall development of humanity through time. For the latter issue, Olduvai Gorge helped put Africa in the forefront of human origins research, leading to other significant finds within the region. This includes Mary D. Leakey's 1979 discovery of *Australopithecus afarensis* footprints in Laetoli, Tanzania, which provided evidence of bipedalism approximately 3.6 million years before the present (BP).

A host of researchers investigated Olduvai Gorge's assemblages after Kattwinkel's discovery in 1911. However, it is the Leakey family of researchers in particular who are most noted for their excavation of and reporting on Olduvai Gorge. The Leakeys, particularly Louis, Mary, and Richard, are a multigenerational family of scholars who continue to spearhead human origin investigations as they did throughout the 20th century. Although their fieldwork has been curtailed in recent years, the Leakey family's collective impact on our understanding of the development of the human species through time is still strong. As for their collection and analysis of fossil and lithic material recovered from Olduvai Gorge, it was the parents, Louis and Mary, who initiated their activities throughout the early and middle portions of the 20th century. With the help of their children, the Leakeys uncovered evidence of early hominids evolving within Africa, including *Australopithecines* and *Homo habilis,* and of changes in lithic technology over time. Ultimately, the Leakey family's impact on the study of human origins and time itself is unparalleled. Through their examination of Olduvai Gorge and its various sites, the Leakeys helped determine multiple stages of hominid evolution and expand our contemplation of human evolution to accept the long duration of time through which humanity changed from early hominids to humankind's present form.

The finding of Olduvai Gorge was in and of itself an important discovery for archaeologists, paleontologists, and other researchers interested in the evolution of species and the changes of technologies developed by hominids. Specifically,

Olduvai Gorge is an archaeological site located in the eastern Serengeti Plains, northern Tanzania. Some of the oldest remains of early hominids have been found in this ancient gorge.

Source: Chris Crafter/iStockphoto.

however, there are a few discoveries in particular that set Olduvai Gorge apart from other archaeological sites pertaining to prehistoric populations. The first such find was uncovered in 1959.

After years of excavating in Olduvai Gorge, Mary Leakey uncovered the remains of an early hominid, which was later designated as *Zinjanthropus boisei.* These thick-boned and almost complete skeletal remains, discovered in 1959, were later dated to 1.8 millions years BP and ultimately classified as *Australopithecus boisei.* As stated earlier, this discovery not only provided a broader understanding of the development of the human species from earlier primate forms, it also provided an impetus for investigating Africa for evidence of human origins and evolution. That fact alone is grounds for securing Olduvai Gorge's place among the most important archaeological sites throughout the world, although it also provided other landmark discoveries.

Decades of excavation, analysis, and interpretation on the part of the Leakey family helped direct the attention of researchers toward Africa in the quest to unravel the mysteries of human evolution. The Leakeys' reputation, which was enhanced by the uncovering of *Zinjanthropus boisei,* was further cemented by the early 1970s discovery of human remains that were eventually classified *Homo habilis.* It was the first set of *Homo habilis* remains to be discovered and further hinted at Africa's being the location where humanity developed.

A final Olduvai Gorge discovery that requires mentioning is the Oldowan Tradition. With all the early hominid remains and ancient tools recovered from the gorge, it ultimately became possible for researchers to determine stages of technological development on the part of hominids along with the stages of biological development that humanity endured. The Oldowan Tradition, a term coined by the Leakey family, included lithic tool forms resembling rocks with flakes removed to create a cutting or puncturing edge; this tool kit included cores and flakes, both possibly used as tools and weaponry. While rudimentary in design, the Oldowan Tradition showed a propensity toward technology on the part of early hominids unmatched by other organisms. As for Olduvai Gorge's temporal significance as related to this technology, the gorge provided researchers with an idea of when the technology surfaced and for how long it survived.

Additional evidence of early hominids has been discovered elsewhere, including Laetoli (Tanzania), Ethiopia, and South Africa. Yet Olduvai Gorge, which continues to yield data regarding human evolution, retains lasting significance. By helping to guide researchers toward Africa in their efforts to ascertain how modern human beings evolved from earlier hominids, the discoveries at Olduvai Gorge were crucial in helping to provide a foundation for the study of humanity's development through time.

Neil Patrick O'Donnell

See also Anthropology; Archaeology; Fossils and Artifacts; Geology; Paleontology

Further Readings

Fagan, B. M., & DeCourse, C. R. (2005). *In the beginning: An introduction to archaeology.* Upper Saddle River, NJ: Pearson Prentice Hall.

Leaky, L. S. B. (1951). *Olduvai Gorge: A report on the evolution of the hand-axe culture in beds I–IV.* Cambridge, UK: Cambridge University Press.

McCarthy, P. (2006). Olduvai Gorge. In H. James Birx (Ed.), *Encyclopedia of anthropology* (pp. 1451–1452). Thousand Oaks, CA: Sage.

Price, D. T., & Feinman, G. M. (1993). *Images of the past.* Mountain View, CA: Mayfield.

Omega Point

See Teilhard de Chardin, Pierre

Omens

An omen, also known as a portent, is a sign that is believed to foretell a future event, which may or may not be supernatural in nature. From earliest times, omens have been given credence in the world's cultures and folklore. Although usually classified according to the generic terms "good" and "bad," an omen is more likely referred to in the foreboding sense, to indicate something sinister that has yet to occur.

The first recorded omens are those of the ancient Babylonians and Assyrians. Both of these cultures believed that the future could be foretold and controlled. Because religion was integral in these ancients' lives, and the omens were thought to be directly from the gods, appeasements could be made in an attempt to stave off the impending calamity. Priests skilled in the arts of omen reading and divination, known as *baratu,* would interpret the portents. These portents could be found in the sky, in animal entrails (known as extispicy), and in the weather, among other sources. The omen could be as simple as a lightning bolt hitting a tree or as complex as a pregnant snake circling a statue, laying her eggs, and dying right after. Each of these meant something different and required the baratu to interpret them, though the meaning may have been explicitly clear.

Ancient Greece and Rome also were filled with omens. In ancient Rome, before official state business was conducted, omens or the auspices (special omens observed in birds, either involving their flight in the sky or observations of the bird in general) were taken. One such auspice involved the observation of a sacred chicken's choice of whether or not it would eat food placed in front of it by an augur (a priest specially trained in auspicy). The chicken would even accompany armies to battle in a cage and the auspices would be taken before battle. A famous omen from ancient Rome involves the consul Publius Claudius Pulcher before his attack against the Carthaginians. The chicken refused to eat the grain laid before it, which was interpreted as a bad omen, and consequently as it being an inopportune time to attack the Carthaginians. Knowing his crew would find this an unfavorable omen, Claudius threw the chicken overboard. Subsequently, the Romans suffered a terrible defeat, with almost all the ships under Pulcher's command sunk.

A more popular category of omens are those concerning the weather. One such modern omen of this type is observed every year in the United States and Canada on February 2nd. It is colloquially known as "Groundhog Day" and involves the observation of a groundhog's shadow. If the groundhog fails to see his shadow because it isn't a bright day, winter will end very soon. If in fact, he does see his shadow, due to the sun being out in that particular moment, then the groundhog will be frightened, run back into his hole, and winter will continue for at least 6 more weeks. Although more of a tradition now than an actual example of a prophecy, it remains classified as a bad omen if the groundhog sees his shadow and a good one if he does not.

Supernatural and paranormal omens exist as well. These may be in the form of dreams, visions, or apparitions. One particularly frightening omen, found in the folklore of Ireland, involves the spectral banshee, or "otherworld woman," that appears before certain Irish families, then weeps and wails to portend the impending death of one of the family members. Another popular omen in this category is visions seen in the sky. One such example of this is Constantine I's legendary vision, in which he observed the Christian cross along with the words "by this sign you will be the victor." Whether or not this truly happened is subject to debate, though it is interesting to note Constantine's devotion to the Christian religion after his victory.

Another interesting omen category involves the appearance of astronomical occurrences that include, but are not limited to, comets, eclipses, and shooting stars. These particular omens sometimes signify notable births, deaths, and other significant events. A shooting star after a funeral may be confirmation that the deceased will be warmly accepted into an afterlife. A famous example, often referred to by astrologers, is the astrological chart of Princess Diana. She was married to Prince Charles on a solar eclipse date, and the day before her death was another day when a solar eclipse occurred.

Among the most frightening types of omens are those that are believed to signify the apocalypse, or the end of the world. Every culture seems to have some notion of this, and it usually has religious connotations. For example, in Christian literature, one is expected to see the sun go dark and the moon to not give off light. Another popular omen considered to foretell the end of the world, successfully adapted into the aptly named film *The Omen,* is the appearance of the Antichrist. The Y2K bug was the source of some fear for a while also, some believing it would result in a technological catastrophe that would ultimately lead to the end of the world.

It is important to note that omens can be culture dependent and not universal. For example, in the United States, it is considered that one will have bad luck if a black cat crosses his path, but in the United Kingdom, the effect is good luck. Likewise, there are certain omens that do seem to be universal. Omens that fall into the supernatural and paranormal category are almost always considered bad omens. Appearances of spectral warnings seem to be viewed with much anxiety and are considered to be signs of impending disaster.

Omens continue to be read and misread by people all over the world, in accordance with local traditions. The continuing fascination with omens may lie in humankind's uneasiness with what is yet to come. Whereas skeptics will attribute to chance any bad events that may follow the appearance of an omen, others continue to view them with fear and dread.

Dustin B. Hummel

See also Apocalypse; Nostradamus; Prophecy

Further Readings

Buckland, R. (2003). *Signs, symbols and omens: An illustrated guide to magical and spiritual symbolism.* St. Paul, MN: Llewellyn.

Waring, P. (1998). *A dictionary of omens and superstitions* (New ed.). London: Souvenir Press.

Ontology

The term *ontology* (from Greek *to on, ontos*—being, entity; *logos*—concept, science) usually denotes: (a) a philosophical discipline that studies being (entity) as being (entity), that is, being in general; (b) the ontology of a theory: the kind of entities that should exist if the given theory is true. One of the fundamental problems of ontology (particularly in its first meaning) is the question about the relation between being and becoming and thus the question about the place and role of time in the explanation of reality.

As a philosophical discipline, ontology has existed at least since the time of Aristotle (384–322 BCE), who in his *Metaphysics* claims that one of its tasks is to investigate "being as being and the attributes that belong to this in virtue of its own nature." While the investigation itself is old, the name is relatively new. It was not created until the 17th century as a result of the efforts of ontology to emancipate itself as an element of metaphysics in relation to its other disciplines, most of all however in relation to (rational) theology. The first to have used it was the German scholastic Rudolf Goclenius (1547–1628) in his work *Lexicon Philosophicum* dated 1613, but it was Christian Wolff (1679–1754) who definitively introduced it into philosophical terminology and thus the period's intellectual awareness. In his work *Philosophia Prima Sive Ontologia* from 1730, he identified ontology as a fundamental philosophical discipline within general metaphysics. While the latter describes being (entity) in general, the disciplines of specific metaphysics are concerned with its partial domains, such as God, soul (humanity), and nature.

Historically, there are three basic and interconnected areas of problems that differentiate themselves within ontology, and these may be briefly delimited by these three questions: (1) *What is being?* (2) *What really exists?* (3) *What exists?*

What Is Being, or, What Does It Mean to Be, to Exist?

Although it may seem that this question would be central to ontology, most philosophers gave up on any serious research in this direction as something problematic, perhaps even impossible. Already Aristotle, in his polemics with Parmenides (540–450 BCE), considered it disputable to think of being as such—that is, as the most general concept in a single meaning, and he emphasized its polysemic nature. Blaise Pascal (1623–1662), for example, pointed out the danger of circular definition (*circulus in definiendo*) in such generally understood being (as it can only be determined with the help of the word "is"). Immanuel Kant (1724–1804) argued that being, or existence, is not an attribute (predicate). There is no empirical attribute within the concept of an existing object by which it would differ from the concept of a similar, but nonexisting, object. With similar intentions, modern logic solves the problem of statements about existence; for example, it transforms the statement *Man is* into a formally correct form of the statement with an existential quantifier, that is, *There exists a thing that is a man.*

Despite difficulties in thinking about being (existence), Martin Heidegger (1889–1976) attempted early in the 20th century to build a fundamental ontology, the main aim of which is exactly to seek the meaning of being. As opposed to the previous philosophy (ontotheology), which forgot about being, replaced it with entity, and would explain one entity with the help of another (even divine) entity, it is necessary to clearly distinguish an entity from the being of this entity (*ontological difference*). The key to the understanding of the meaning of being is the analytics of a particular type of entity—human being, being-there (*dasein*), through the medium of objectless forms of thinking—existentials. The project of fundamental ontology remained unfinished, but it inspired phenomenological, existentialist, and hermeneutical thinking in the given field (Jean-Paul Sartre, 1905–1980; Maurice Merleau-Ponty, 1980–1961; and others).

What Really Exists, or, Which Things Do Really Exist?

Although the question "What does really, therefore truly, ultimately, exist?" is logically a version of the question "What exists?" it is historically older and it has been perhaps the most typical of ontological questions in traditional metaphysics since its beginnings. It presumes a split of reality into two ontologically as well as axiologically unequal fields: (a) a privileged, true reality (*noumenon,* substance) which exists in-itself, as a autonomous, changeless, and independent of all else, and (b) a secondary, ontologically less valuable phenomenon (*fainomenon, akcidencia*), which, as nonautonomous and changeable, is derived from the first. It is mainly the ontology of middle-period Plato (428–348 BCE) that is paradigmatically known in this sense, with his differentiation of a perfect world of intelligible ideas and an imperfect world of empirical particulars, which have reality only to that extent to which they have a part in the former.

It is the same with time as a movable and imperfect picture of eternity. In his understanding of the *first philosophy* as a teaching about a divine substance, Aristotle supported such a model of an axiologically saturated ontology when he placed against each other the perfect entity of an unmoved first mover and the hierarchically lower, by their form dependent, and derived entities. Unlike the first one, their characteristic is time as a number of movement with regard to before and after.

The dispute between idealism and materialism also became classic in this sense. Idealism considered matter as merely a manifestation (other-being) of an absolute spirit, and time as intuitive becoming was the essential but imperfect and temporary manifestation of this spirit (G. W. F. Hegel 1770–1830), or a bundle of perceptions (ideas) of the human mind (G. Berkeley, 1685–1753). Materialism considered consciousness, mind, and spirit as merely a product, an attribute or a function of matter. This traditional, substantialist ontology model dominated until the times of René Descartes (1596–1650), or Kant, after which it became the subject of perennial criticism. In the 20th century, this criticism came mainly from analytical philosophy, but also from Heidegger, Alfred North Whitehead's (1861–1947) process philosophy, Nicolai Hartmann's (1882–1950) critical ontology, and others.

What Exists, or, Which Kinds of Things Do Exist?

At the beginning of this investigation, more neutral and unreductionist—compared with the previous one—was Aristotle, with his understanding of ontology as teaching about categories, that is, about the most general kinds (predicates) of things. Categorical analysis has been a component of philosophy until the present day, but historically, both the understanding of the nature of categories and their selection have changed within it. While Aristotle understands them first and foremost realistically (they are the attributes of things themselves), and he lists 10 of these—substance, quality, quantity, etc.,—Kant understands them transcendentally, as fundamental forms of our cognition of things, so far as is possible a priori, and there are 12 of these—unity, plurality, totality, etc. Time too is a priori transcendental and does not belong to things in themselves but is one of two principles of pure intuition (the second one being space) that allow humans' inner experience and vicariously an experience of external phenomena. Similar thoughts are those of Edmund Husserl (1859–1938) in his ontology, as an eidetic science about intentional objects in general with time as "world horizon" that allows a contact between humans and the whole of existence, whereas Bertrand Russell (1872–1970) as an analytic philosopher presumes that the structure of the world (atomistic facts) exposes itself to us through the structure and categories of language (atomistic propositions).

A stimulating conception of so-called critical ontology—realistically understood categorical analysis that investigates the forms of being gained by observation of reality and the relations between them—was created by Hartmann in the 20th century. Hartmann understands reality in its gradual unfolding from an inorganic level through organic and psychic levels to a spiritual level, whereby he presumes that these levels are categorically heterogeneous. Every one has specific categories that cannot be reduced to categories of other levels, neither downwards (criticism of materialism) nor upwards (criticism of idealism). All beings are understood to be dynamic as becoming; time is a more fundamental determination of reality than space.

The development of linguistically and mainly analytically orientated philosophy in the 20th century has led to specific reasonings about the ontological implications of language, which in the second half of the century resulted in discussions about so-called ontological commitments. According to the protagonist of this discussion and the author of the term, Willard van Orman Quine (1908–2000), the answer to the ancient ontological question "*What exists?*" does not come from philosophy but from science. Because acceptance of a scientific theory always presumes some ontology, it also therefore postulates some kind of entities that should exist if the theory is true. Quine also formulates a concrete criterion for specification of thus-formed ontological commitments of theories. If the theories are formulated in a standard language of first-order predicate logic, then for them "to be means to be the value of a bound variable." However, as he points out, this criterion is not absolute—the given theory can be satisfied by several different ontologies, and it is not possible to definitely decide which one of them is valid (the principle of ontological relativity). Quine holds a perdurantist understanding of persistence of things in time, according to which a concrete particular is an aggregation of its temporal parts. Such an understanding is anchored in an eternalist conception of time that (unlike the presentist one) supposes that all time dimensions, not only the present, are ontologically real.

Marian Palenčár

See also Aristotle; Bergson, Henri; Descartes, René; Heidegger, Martin; Hegel, Georg Wilhelm Friedrich; Husserl, Edmund; Idealism; Kant, Immanuel; Materialism; Merleau-Ponty, Maurice; Metaphysics; Nietzsche, Friedrich; Parmenides; Plato; Plotinus; Presocratic Age; Russell, Bertrand; Schopenhauer, Arthur; Spinoza, Baruch de; Whitehead, Alfred North

Further Readings

Aristotle. (1993). *Metaphysics*. New York: Oxford University Press. (Original work 1st century CE)

Hartmann, N. (1953). *New ways of ontology.* Chicago: Regnery.

Heidegger, M. (1996). *Being and time.* Albany: State University of New York Press.

Inwagen, P. van. (2001). *Ontology, identity, and modality: Essays in metaphysics.* Cambridge, UK: Cambridge University Press.

Quine, W. V. O. (1964). On what there is. In W. V. O. Quine, *From a logical point of view.* Cambridge, MA: Harvard University Press.

Oparin, A. I. (1894–1980)

Aleksandr Ivanovich Oparin, a Russian biochemist, was noted for his contributions to the explanation for the origin of life. Profoundly influenced by Charles Darwin (1809–1882), Oparin presented a theoretical foundation that stressed both a materialistic and mechanistic explanation for both planetary formation and the evolution of life on this planet. His understanding of astronomy, chemistry, geology, biology, and philosophy had allowed for a comprehensive view of a temporally evolving world and humankind's place within it. Oparin's underlying principles encompassed not only the chemical processes that constituted the precursors to and the emergence of life but also the immense evolutionary time that was necessary for its formation. Oparin is best known for his major works *The Origin of Life* (1938) and *Genesis and Evolutionary Development of Life* (1968).

The biological history of this planet could be found within its remote geological history. Against prevailing philosophies and theologies, Oparin viewed the emergence of life as a result of chemical synthesis and external influences of our planet's developing environment. Acknowledging and encompassing the universe in its totality, this chemical synthesis and development of cellular organisms are unique to this planet within the cosmos. In terms of theoretical or cosmological origin paradigms, Oparin rejected the concepts of autogeneration, cosmozoa, spontaneous generation, panspermia, and vitalism as possible explanations. For Oparin, only inorganic matter existed in the beginning of Earth's development. This evolving matter would later emerge as organic. The implications are certain: life emerged from inorganic matter. The saga of symbiotic relationships between and among organic and environmental (inorganic) matter is as complex as life itself. Nevertheless, the origin of life evolved from simple beginnings.

According to Oparin, the evolution of carbon compounds, especially hydrocarbons, was necessary for a biogenic synthesis of organic substances. The formation of proteins and the development of amphoteric electrolytes allowed for multiple reactions with water. The subsequent complexity of protein and protein molecules allowed for greater organization and even greater complexity. This billon-year process resulted in the primordial "soup" by which greater complexity would slowly evolve. Although it would be over 2 billion years before the earth would attain single-celled life, the protobionts stage encompassed the emergence of coacervates, coenzymes, enzymes (including genetic information), and anaerobes. Additionally, changes in atmospheric conditions allowed for further evolution and emergence of aerobes. Over this span of nearly a billion years developed greater complexity and symbiotic relationships that resulted in multicellular life.

Oparin's speculations offered a unique perspective on the relationships within the inorganic matter from which life itself emerged. Stressing chemical action and reaction, the chance "environment" in which greater organization and complexity took place makes life unique within a highly improbable universe containing life. This point has two implications. First, the idea that life emerged from inorganic matter over billions of years implies a rejection of anthropocentric philosophies and theologies. Second, it answers the question, "Are we alone in the universe?" with a degree of implausibility. Today, design theories and the "God gene" are alternative explanations for the philosophical questions of human existence. There is very little doubt that Oparin would reject any version of these ideas and their manipulation of science. The principles set forth by Darwin, when applied in a comprehensive manner, would exclude these assertions. Oparin, a Darwinian evolutionist, understood both the temporal nature of organic and inorganic processes and their implication for humankind. From inorganic to organic, life, especially human life, is distinctive but not necessarily unique within this dynamic material universe.

David Alexander Lukaszek

See also Darwin, Charles; DNA; Evolution, Chemical; Evolution, Organic; Life, Origin of; Materialism

Further Readings

Oparin, A. I. (1953). *Origin of life.* New York: Dover Press.

Oparin, A. I. (1968). *Genesis and evolutionary development of life.* New York: Academic Press.

Orwell, George (1903–1950)

George Orwell was the pen name of Eric Arthur Blair, an English novelist and journalist. He is best known for his political satires *Animal Farm* (1945) and *Nineteen Eighty-Four* (1949). The two novels criticize totalitarianism and social injustice.

Nineteen Eighty-Four was one of the most popular and widely quoted novels of the 20th century. It describes a bleak picture of a future world ruled by totalitarian regimes. Individual freedom and privacy are suppressed in the tightly controlled society described by Orwell. "Big brother is watching" is one of the many famous lines that have been frequently quoted from the book. The Stalinist regime of the Soviet Union was the real-life archetype for Orwell's idea.

George Orwell was born in Motihari, Bengal, India, on June 25, 1903, into a lower-middle-class family. He attended the prestigious Eton School in London. In 1922 he returned to India and joined the British imperial police. In India and in Burma Orwell developed a strong antipathy toward imperialism and class division. He resigned from the imperial police and returned to Europe, where he moved between England and France, living a life of poverty. This experience gave him the material to write the memoir *Down and Out in Paris and London* (1933). His other works of the period include *A Clergyman's Daughter* (1935), and *The Road to Wigan Pier* (1937), in which Orwell describes his strong socialist sympathies. In 1936 he traveled to Spain and fought alongside the Republicans in the Spanish Civil War. He also became highly critical of communism during this period, expressing these sentiments in *Homage to Catalonia* (1938).

Orwell returned to England in 1937 and became a productive journalist, writing numerous articles and essays before and during World War II. He denounced Nazism but opposed war with Germany. In 1944 he completed *Animal Farm,* a brilliant satire in which barnyard animals overthrow their oppressive human master, only to divide into a new social order thereafter. The pigs assume power over the other animals and establish privileges for themselves. Orwell wrote *Animal Farm* to parody the Russian Revolution and the dishonesty of leaders such as Joseph Stalin. Orwell's book was especially relevant during a time in human history marked by ideological struggles and totalitarian regimes. He believed that fascism and communism were not inevitable outcomes in time, but were dangerous ideas that should be resisted. Many lines from the book continue to be quoted in popular culture, including "All animals are equal, but some are more equal than others." Government's actions hostile to a free society are often referred to as "Orwellian."

Orwell was married twice and had one adopted son. He suffered from tuberculosis during the later years of his life. He died in a London hospital on January 21, 1950.

James P. Bonanno

See also Bradbury, Ray; Clarke, Arthur C.; Futurology; Novels, Time in; Toffler, Alvin; Verne, Jules; Wells, H. G.

Further Readings

Bowker, G. (2003). *George Orwell.* London: Little, Brown.

Davidson, P. (1996). *George Orwell: A literary life.* New York: St. Martin's.

Shelden, M. (1991). *Orwell: The authorized biography.* New York: HarperCollins.

Ovid (43 BCE–17 CE)

The poet Ovid lived in Rome under the reign of the Emperor Augustus in the 1st century BCE. He is best known for the *Metamorphoses,* an epic poem chronicling the history of the cosmos from creation to his own era. He incorporated many ancient myths and legends into this work, many of which had never been recorded. In doing this he preserved centuries of oral history for future generations to enjoy.

Ovid was born in 43 BCE in central Italy near the Abruzzi Mountains. At age 16 he left for Rome to study rhetoric. By 18 he had become a judge but was unsatisfied with a career in law. While in Rome he developed a passion for poetry and decided to make his living as a writer. He also found happiness with Fabia, his third wife, with whom he had one daughter.

Ovid began his career by writing love poems, and his first public work was titled *Amore*. His works were very popular, because they referred to the daily activities of "modern" young people. This was very unusual for poets of his time. As his career progressed, Ovid began writing more erotic poems. He considered himself an instructor for young lovers. This sometimes explicit poetry got him into trouble with the law. To counteract the amoral trend of Roman society, Augustus created new morality laws to help reinstate family structures. On hearing of these laws, Ovid decided to write a poem based on mythological stories he had enjoyed as a child.

The *Metamorphoses* was completed in 8 CE and consists of 15 books, 12,000 verses, and 246 legends. The poem's title comes from the focus on transformation stories in which gods and spirits are changed into plants and animals. The first transformation story is the changing of Earth into Man, and the work ends with the story of Julius Caesar becoming a star. Ovid wrote it in dactylic hexameter, the meter closely associated with epics and the poets Virgil and Homer. However, the content is not that of a traditional epic. Instead of chronicling the story of a single protagonist, it spans all time, from Earth's creation from chaos right up to the reign of Augustus. The theme is the same as in all of Ovid's poems, love. Each story seems to glorify love—the emotion or the god Amor (Cupid).

Ovid's attempt to evade punishment for his early risqué poetry was in vain. He was exiled to Romania, where he is still considered a national hero. Because of his immense popularity with the Roman public, he was allowed to keep his fortune and continued to write and publish until he died in Tomis, now Constanța, in 17 CE.

Ovid's greatest work influenced many of the writers that would follow him. Dante mentions him twice in his great *Divine Comedy.* Many scholars believe that Shakespeare's famous *Romeo and Juliet* was based on *Pyramus and Thisbe,* which also features in *A Midsummer Night's Dream.*

Jessica M. Masciello

See also Caesar, Gaius Julius; Lucretius; Poetry; Rome, Ancient

Further Readings

Ovid. (2005). *The metamorphoses* (F. J. Miller, Trans.). New York: Barnes and Noble Classics. (Original work c. 8 CE)

Rădulescu, A. (2002). *Ovid in exile.* Iași, Romania: Center for Romanian Studies.

P

Paleogene

The Paleogene is a geochronological and chronostratigraphic unit of the Cenozoic era/erathem. It is a period in the geochronological scale and a system in the chronostratigraphic scale, and it is placed between the Cretaceous and Neogene periods. It began 65 million years ago, at the Cretaceous-Paleogene (K-Pg or K-T) boundary, and ended 23 million years ago, at the Oligocene-Miocene (O-M) boundary; thus, the Paleogene lasted 42 million years. It consists of three epochs and/or series: Paleocene, Eocene, and Oligocene.

The Paleogene followed the Cretaceous period and began with the Cretaceous-Paleogene mass extinction event. There is paleontological evidence of abrupt changes in flora and fauna in this event (most often referred to as the K-T boundary mass extinction), including the total extinction of dinosaurs, ammonites, belemnites, cephalopods, and rudist molluscs; and the catastrophic mass extinction of planktic foraminifers, calcareous nannofossils, corals, bivalves, brachiopods, fishes, mammals, and other reptile groups. The Paleogene is most notable as being the period in which mammals and birds were diversified, exploiting ecological niches untouched by the previously extinct dinosaurs. Both groups evolved and came to dominate the land. Mammals evolved considerably into large forms in terrestrial and marine environments; birds evolved into roughly modern forms in an airborne environment.

During the Paleogene, global tectonic processes continued that had begun during the Mesozoic era, with the continents drifting toward their present positions. Although these were gradual processes, the drifting of the continents caused significant paleoclimatic and paleoceanographic turnovers during the Paleogene. The former components of the old supercontinent Gondwana continued to split apart, with South America, Africa, and Antarctica-Australia pulling away from each other. Africa moved north toward Europe, slowly closing the occidental Tethys Ocean until it disappeared during the Eocene, and uplifting the Alps during the Oligocene. Similarly, India initiated its rapid migration toward the north, until it collided with Asia, narrowing the oriental Tethys Ocean, folding the Himalayas, and forming the Indian Ocean. The Tethys Ocean vanished during the Paleogene, becoming today's Mediterranean Sea, the remnant of that old ocean. The northern supercontinent Laurasia began to break up during the Eocene, with Europe, Greenland, and North America drifting apart. The tectonic splitting of the Greenland and Norwegian seas increased the submarine volcanic and hydrothermal activity (North Atlantic flood basalts) during the Paleocene-Eocene transition. Antarctica and Australia began to split in the late Eocene, and South America and Antarctica in the Oligocene, which allowed the formation of the circumantarctic current.

The climate of the earliest Paleogene was slightly cooler than that of the preceding Cretaceous. Nevertheless, the temperature rose again in the late Paleocene, reaching its highest point at the Paleocene-Eocene (P-E) boundary. A sudden and extreme global warming event occurred in the P-E boundary, 55.8 million years ago, called the Paleocene-Eocene Thermal Maximum (PETM). It was an episode that lasted less than 100,000 years, very rapid in geologic terms, and it caused an intense warming of the high latitudes (up to 7° C) and a mass extinction in the benthonic fauna of the bathyal and abyssal oceanic environments (mainly benthic foraminifera). It is hypothesized that PETM was caused by runaway greenhouse effect due to a sudden release of methane from oceanic hydrates. This methane flux and its oxidation product carbon dioxide could be of a magnitude similar to that from present-day anthropogenic sources, creating the sudden increase of greenhouse warming. The main cause of this short-term change may be related to the reorganization of tectonic plates that produced an increase of volcanic activity (mainly in the North Atlantic) as well as significant paleogeographic and paleoceanographic turnovers. Among these last, the most important was the closing of the Tethys Ocean with the formation of vast areas of shallow epicontinental seas. This may have been responsible for the shift in the locus of ongoing deep-water formation from cold and nutrient-depleted deep waters produced in the polar (Artic and Antarctic) regions to warm, saline, and oxygen-deficient deep waters formed in Tethyan evaporative basins. The stability of these methane hydrates depends on temperature, and, therefore, it is possible that the abrupt deep sea warming induced a shift in sediment geotherms.

The climate continued to be warm and humid worldwide during the early and middle Eocene, with tropical-subtropical deciduous forest covering nearly the entire globe (even in Greenland and Patagonia) and ice-free polar regions covered with coniferous and deciduous trees in a temperate environment. The equatorial areas, including the Tethys Ocean region, were characterized by a tropical, hot, and arid climate. The Eocene global climate was the warmest and most homogeneous of the Cenozoic, but the climatic conditions began to change in the late Eocene. A global cooling, initiated toward the end of the Eocene, occurred during the Oligocene. This cooling caused gradual extinctions along the Eocene-Oligocene (E-O) transition, between 39 and 33 million years ago, that drastically affected land mammals and vegetation. Tropical areas, such as jungles and rainforests, were replaced by more temperate savannahs and grasslands. The E-O cooling episode was the most recent transition from a greenhouse (Cretaceous to Eocene) to an icehouse (Oligocene to present-day) climate mode. The cause of this climatic cooling was the establishment of the circumantarctic current that isolated the Antarctic. Feedback mechanisms, such as the formation of the Antarctic icecap, a substantial drop in sea level, and an increase in the earth's albedo, drove rapid climate change, which eventually led to the Pleistocene glaciations.

During the first epoch of the Paleogene, the Paleocene, the flora are marked by the development of modern plant species, including the appearance of cacti and palms. The flowering plants or angiosperms, which first appeared in the beginning of the Cretaceous, continued their development and proliferation. Along with them evolved the insects that fed on these plants and pollinated them. During the PETM and Eocene, the high temperatures and warm oceans created a tropical, humid environment, with forests spreading throughout the globe from pole to pole. By the time of the climatic cooling of the late Eocene and Oligocene, deciduous forests covered large parts of the northern continents (North America and Eurasia, including the Arctic areas), and tropical rainforests held on only in equatorial South America, Africa, India, and Australia. The tundra stretched out over vast areas of Antarctica, and open plains and deserts became more common.

Because of the dinosaur extinction at the K-T boundary, the reptiles were reduced to palaeophid snakes, soft-shelled turtles, varanid lizards, and crocodilia. With the extinction of marine plesiosaurs and ichthyosaurs, sharks became the chief ocean predators. Birds began to diversify during the Paleocene, but the most modern bird groups appeared during the Eocene and Oligocene, including hawks, owls, pelicans, loons, and pigeons, among others. The fossil mammal evidence from the Paleocene is scarce, but it is characterized by an evolutionary radiation of small mammals, mainly insectivorous species, including monotremes, marsupials, multituberculates, and primitive placentals, such as the mesonychid. The most important radiation of mammals occurred during the climatic optimum of the Eocene, when there appeared new and modern groups such as artidactyls and perissodactyls. Early forms of many other mammalian orders also appeared, including primates, bats, proboscidians, rodents, and cetaceans. Several mammal groups were extinguished during the cooling episode of the E-O transition, including mesonychids and creodonts.

Ignacio Arenillas

See also Cretaceous; Fossil Record; Geologic Timescale; Geology; K-T Boundary; Neogene; Paleontology

Further Readings

De Graciansky, P. C., Hardenbol, J., Jacquin, T., & Vail, P. R. (Eds.). (1998). *Mesozoic and Cenozoic sequence stratigraphy of European basins.* Tulsa, OK: Society for Sedimentary Geology (SEPM).

Gradstein, F. M., Ogg, J. G., & Smith, A. G. (Eds.). (2004). *A geologic time scale 2004.* Cambridge, UK: Cambridge University Press.

PALEONTOLOGY

Paleontology (from Greek: *palaeo,* "old, ancient"; *on,* "being"; and *logos,* "speech, thought") is the study of ancient life. Life appeared on Earth about 3,550 million years ago in the oceans, subsequently evolved from simple bacteria-like cells to complex multicellular forms, and colonized the land. Countless adaptations resulted in a great diversity of biological forms and in addition changed the planet itself. We have learned about extinct organisms through the examination of fossils, the visible evidences left behind by them and preserved in rocks and sediments. Fossils include mineralized, carbonized, mummified, and frozen remains of bodies after death, or of cast-off parts, normally of the skeleton or portions, such as teeth, that became partially mineralized during life; the preservation of soft tissues, however, is extremely rare. Many other fossils consist of casts or impressions, tracks, burrows, fossilized feces (coprolites), as well as chemical residues.

People have collected fossils ever since recorded history began, and probably before that, but the nature of fossils and their relationship to life in the past became better understood during the modern era as a part of the changes in natural philosophy that occurred during the 17th and 18th centuries. The emergence of paleontology, in association with comparative anatomy, as a scientific discipline occurred at the end of the 18th century, when Georges Cuvier clearly demonstrated that fossils were left behind by species that had become extinct. Paleontology therefore is the study of fossils throughout geological time. The totality of fossils, both discovered and undiscovered, and their placement in sedimentary layers or strata is known as the *fossil record.* The fossil record ranges in age from the Holocene, the most recent geological epoch that began 12,000 years ago and continues until present, to the Archean eon, which extends from about 3.8 to 2.5 billion years ago.

Fossils vary in size from the microscopic (microfossils), such as fossilized shells of unicellular organisms, to those of gigantic proportions, such as the fossil bones of dinosaurs. Micropaleontology studies microscopic fossils, including organic-walled microfossils, the study of which is called *palynology.* The study of microfossils requires a variety of physical and chemical laboratory techniques to extract them from rocks and the use of light or electron microscopy to observe them. Macrofossils are usually studied with the naked eye or under low-power magnification, but the observation of fine skeletal details often needs high-powered magnification.

The study of macrofossils is undertaken by several specialties. Invertebrate paleontology deals with fossils of animals with no vertebral column, while vertebrate paleontology deals with those of animals with a vertebral column, including fossil hominids (paleoanthropology). Paleobotany undertakes the study of macrofossils of plants. There are many developing specialties, such as paleoichnology (the study of trace fossils), molecular paleontology (the study of chemical fossils or biomarkers), and isotope paleontology (the study of the isotopic composition of fossils).

Two of the most important portions of knowledge that paleontologists obtain from fossils include first how they were formed (taphonomy), that is, the process of fossilization through which some material or information was incorporated from the biosphere to the lithosphere; and second, what the organisms were that produced them (paleobiology), as well as how and where they lived and what their evolutionary history was. The source information for this purpose is the biology and ecology of present-day organisms, applying the uniformitarian principle. Fossils usually contain morphological information that allows us to recognize most of them as living organisms and then to identify and classify them according to the Linnaean taxonomy, as well as to study their relationships to other taxa.

Fossils are generally found in sedimentary rock with differentiated strata representing a succession of deposited material. To place the fossils in context in terms of the time, setting, and surroundings in which the organisms lived, paleontologists require knowledge of the precise geological location where the fossils were found and details of their source rock strata. Paleontology has provided important tools for both geologists and biologists.

In geology, fossils are important in the analysis of the order and relative position of strata and their relationship to the geologic timescale, and also in correlating successions of rock strata from the same time interval across the globe. The deep time of Earth's past has been organized into a timescale composed of various units that are usually delimited by major geological or paleontological events, such as mass extinctions. In a pioneering application of stratigraphy, at the end of the 18th century, William Smith in England and Georges Cuvier and Alexandre Brongniart in France made extensive use of fossils to help correlate rock strata in different locations. They observed that sedimentary rock strata contain particular assemblages of fossilized flora and fauna and that these assemblages succeed each other vertically in a specific, reliable order that can be recognized even in widely separated geologic formations (principle of faunal succession). Later, Darwin's theory of evolution closely described the causal mechanism of the observed faunal and floral succession preserved in rocks.

This principle is of great importance in determining the relative age of rocks and strata by using the fossils contained within them (biostratigraphy). As the distribution and diversity of living organisms are limited by environmental factors, and as vestiges of biochemistry of the original organism and isotopic signatures of ancient environments are preserved on fossilized skeletal remains, fossils provide an insight into the environment once inhabited by living organisms (paleoecology) and help in the interpretation of the nature of ancient sedimentary environments and the diagenetic processes undergone by the rocks that contained them. The primary economic importance of paleontology lies in both applications to geology. The study of the fossils, especially microfossils, contained in a rock remains one of the fastest, cheapest, and most accurate means to determine the age and nature of the rocks that contain them or the layers above or below. This information is vital to the mining industry and especially the petroleum industry.

In biology, fossils are the most direct evidence of the evolution of life on Earth; they have helped to establish evolutionary relationships and to date the divergences between taxa (phylogeny). An expanding knowledge of the fossil record encouraged the formulation of early evolutionary theories. In fact, Darwin himself collected and studied South American fossils during his trip on the H.M.S. *Beagle*. After Darwin's evolutionary theory was published in 1859, much of the focus of paleontology shifted to understanding lineage evolution, including human evolution. George Gaylord Simpson and, later, Stephen J. Gould played a crucial role in incorporating ideas from paleontology to evolutionary theory.

Fossils indicate long-term patterns of biodiversity in the geological past. The story of the development of life on Earth, of the biosphere, forms the subject of paleontology. Modern paleontology sets ancient life in its context by studying how, over this vast time span, life has adapted to a changing world; this change is barely discernible during a single human lifetime. Long-term physical changes of global geography (continents and oceans pushed by plate tectonics, mountains formed and eroded) and long-term fluctuations between hot and cold climates (ice ages driven by orbital factors, warm periods in response to rapid increases in atmospheric carbon dioxide) triggered changes in living things: Populations, species, and whole lineages disappeared, and new ones emerged. Ecosystems have responded to these changes and have adapted to the planetary environment in turn. These processes continue, and today's biodiversity is affected by these mutual responses.

Very few species, known as living fossils, survive virtually unchanged for tens or hundreds of millions of years. Most species today appeared very recently in geological terms. It has been estimated that more than 95% of species that ever lived have become extinct. Paleontology has shown that extinction is a natural process that generally happens at a continuously low rate. Throughout geologic history, very few mass-extinction events have occurred in which many species have disappeared in a relatively short period of geological time. Thus, paleontology evidences the fragility of the world. Humans appeared only about 2.5 million years ago, and several human species have become extinct. Modern man appeared very recently in geological terms, no more than 200,000 years ago. At the end of the last glacial period, around 12,000 years ago, many mammals weighing more than 40 kilograms (megafauna) disappeared. There is a debate as to the extent to which this extinction event can be attributed to environmental and ecological factors, to the onset of warmer climates, or to human activities, directly by overkilling megafauna or indirectly. Megafaunal extinctions continue to the present day, and this deteriorating situation is being referred to as "the sixth mass-extinction."

The present biodiversity of an area is the consequence of the natural evolution of the species in its dating back to more than 3 million years ago. This evolution has been conditioned, in many ways, by geological history and certain other natural phenomena. But for the first time, a single species—ours—appears to be almost wholly responsible for an extinction crisis. Natural environments are now so degraded that we must go back in time to true known natural environments to understand natural processes. Paleontology furnishes an extensive database that, when integrated with neontological data, allows us to define models that explain better the past and present biodiversity and that would be useful in prospective studies.

As a consequence, the strategies aimed at the protection of biodiversity should also take into account the preservation of paleobiodiversity (paleontological heritage) and of geological materials (geological heritage and geodiversity), which constitute proof of past natural processes. Although fossils are also preserved in museums and private collections, the paleontological heritage exists in the natural environment as fossil sites. These sites compose an irreplaceable and finite resource for science, education, and recreation. Paleotourism, as part of adventure tourism, is poised for dramatic growth in the decades ahead, a fact directly related to the demography of wealthy nations. As this industry grows in years to come, it will be important for scientists and government officials to work together with the local inhabitants of the fossiliferous regions to create effective partnerships to educate the public and to protect and develop our paleontological heritage. This element of natural and cultural heritage is vulnerable to abuse and damage and therefore needs safeguarding and management to ensure its survival for future generations.

Beatriz Azanza

See also *Archaeopteryx;* Dating Techniques; Dinosaurs; Fossil Record; Fossils, Interpretations of; Geology; Stromatolites; Trilobites

Further Readings

Briggs, D., & Crowther, P. R. (2001). *Palaeobiology II.* Osney Meads, Oxford, UK: Blackwell Science.

Foote, M., & Miller, A. I. (2007). *Principles of paleontology* (3rd ed.). New York: Freeman.

Gould, S. J. (Ed.). (1993). *The book of life: An illustrated history of the evolution of life on earth.* New York: Norton.

Prothero, D. R. (2004). *Bringing fossils to life: An introduction to paleobiology.* Boston: McGraw-Hill.

Prothero, D. R. (2007). *Evolution: What the fossils say and why it matters.* New York: Columbia University Press.

Paley, William (1743–1805)

William Paley, English churchman, theologian, moral philosopher, and apologist, is best known for his "watchmaker analogy," a classic argument for the existence of God, the Creator. From its publication in 1802, Archdeacon Paley's famous book, *Natural Theology,* influenced the Creation/evolution debate, which became especially lively from Darwin's era until the present. Few issues related to the study of time hold more significance.

Paley was born in Peterborough in 1743, the son of a vicar and schoolmaster. To prepare himself for the ministry, Paley enrolled in Christ's

College, Cambridge, in 1758, from which he graduated and where he later became a fellow and tutor. (Nearly 70 years later, Charles Darwin also enrolled in Christ's College, lived in rooms formerly occupied by Paley, and studied—and admired—the latter's writings.) Ordained in 1767 and married in 1776, William Paley advanced through clerical ranks and held various appointments. In 1782, he became archdeacon in Carlisle. There he began the process of expanding his Cambridge lectures on apologetics and ethics for publication.

Though he published several other books, Paley's fame rests on four works, all of which exerted considerable influence in his lifetime—and beyond. His first study, *The Principles of Moral and Political Philosophy* (1785) became a standard textbook at Cambridge. He taught a form of ethical utilitarianism and opposed the slave trade. In 1790, Paley published his second book, *Horae Paulinae, or the Truth of the Scripture History of St. Paul,* a defense of the Bible's historical nature. The third book, *A View of the Evidences of Christianity* (1794), another study on Christian apologetics, sorted and updated important material from earlier authors and achieved wide acclaim. In contrast to Hume, he supported the historicity of biblical miracles.

He published a fourth volume in 1802 under the title *Natural Theology, or Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature.* Paley regarded this last book as the most important, a logical predecessor to the rest. Through an orderly arrangement and readable style, Paley—like his predecessors who advanced the cause of natural theology (e.g., John Ray, William Derham)—compiled a series of case studies to support the teleological argument for the existence of God, also known as the argument from design. In his *Natural Theology,* still in print after more than two centuries, Paley pointed primarily to complex parts and systems of human anatomy as arguments in favor of "intelligent design." As a watch's functioning components imply the existence of a watchmaker, he suggested, the biological realm reflects the work of a purposeful designer.

Critics point to various flaws in this famous analogy (e.g., it begs the question by assuming that the watchmaker must be the God of the Bible) and claim that Darwin's conclusions have obviated the need for an external, divine artificer. Others still find Paley's simple premise compelling. As the church reacted to intellectual challenges of that era (e.g., deism; Enlightenment writers such as Hume and Kant), Paley offered hope to readers who believed in a Creator with a personal interest in the universe.

Gerald L. Mattingly

See also Bible and Time; Creationism; Darwin, Charles; God and Time; Gosse, Philip Henry; Scopes "Monkey Trial" of 1925; Teleology; Watchmaker, God as

Further Readings

Brooke, J. H. (1991). *Science and religion: Some historical perspectives.* New York: Cambridge University Press.

Dillenberger, J. (1960). *Protestant thought and natural science: A historical interpretation.* Nashville, TN: Abingdon Press.

Eddy, M. D. (2004). Science and rhetoric of Paley's *Natural Theology. Literature and Theology, 18,* 1–22.

Fyfe, A. (2002). Publishing and the classics: Paley's *Natural Theology* and the nineteenth-century scientific canon. *Studies in History and Philosophy of Science, 33,* 729–751.

LeMahieu, D. L. (1976). *The mind of William Paley: A philosopher and his age.* Lincoln: University of Nebraska Press.

McGrath, A. E. (1999). *Science & religion: An introduction.* Malden, MA: Blackwell Science.

Nuovo, V. (1992). Rethinking Paley. *Synthese, 91,* 29–51.

Paley, W. (2006). *Natural theology.* New York: Oxford University Press. (Original work published 1802)

Panbiogeography

In 1964 the biogeographer and evolutionist Leon Croizat published a book titled *Space, Time, Form: The Evolutionary Synthesis.* The title of the book presented a renewed emphasis on the role and significance of space and time in the evolutionary process and in understanding evolutionary history. Many representations of the theory of evolution from the time of Darwin's *On the Origin of Species* (1859) assumed that space and time together constituted a separate environmental container through which organisms moved and evolved. Croizat pointed out that this perspective resulted in an erroneous understanding of the evolutionary process.

For most people, time is perhaps the most compelling element of evolution that directly links the present with the past, principally through the geological fossil record. Fossilized organisms are identifiably related to those of the living world, either at a general level of organization or at more specialized levels such as those of genera and species. These fossils have contributed to the idea that living species have a history of ancestral species, some of which are preserved in the fossil record. However, this record alone was not necessarily enough to convince everyone of evolution by descent with modification—including Darwin himself. But it was during his world voyage on H.M.S. *Beagle* that Darwin found that some fossils in Argentina were more closely related to organisms currently living in that region than to those of other areas. This geographic juxtaposition of temporal records and biological relationships provided Darwin with a critical insight that helped lead him from a creationist to an evolutionary perspective. So it is no surprise that the very first sentence in Darwin's 1859 book began with the observation that the distribution of organisms and the geological relationships of the present to the past inhabitants of South America "seemed to throw some light on the origin of species."

Darwin's discovery pointed to a key aspect of evolution, that time and space are causally interrelated. But this interrelationship was taken largely for granted in much of evolutionary theory until nearly a century later, when Leon Croizat developed his unique approach to evolution called panbiogeography. In this approach Croizat did what no one else had ever done before. He tested Darwin's theory of evolution through the comparative study of animal and plant distributions, whether living or fossil. Animal and plant distributions provide a direct representation of time and space in evolution. The spatial component is represented by their location, while the temporal component is represented by their differentiation or divergence as well as the spatial correlation of distributions with tectonic features associated with earth history.

In recognizing the integral relationship of time with geographic location and the evolution of biological form, Croizat proposed the representation of evolution as the summation of their individual and combined effects by the following equation: Evolution = space + time + form. This formulation showed that the study of evolution was effectively the study of how all three elements are interrelated and affect each other, rather than just the study of a purely physical (biological) process. Time now becomes part of the evolutionary process rather than just a temporal record of evolutionary events. Because of this integral relationship, Croizat regarded the process of biological evolution (which he referred to as "form-making") in space over time as fundamental for the whole of biology in both its theoretical and practical aspects.

Croizat's approach to time as an aspect of space has its historical background in new ways of thinking about time and space that were developing at the transition between the 19th and 20th centuries, particular in Italy where Croizat was born and spent his formative years concurrently with the emergence of the Italian futurist movement. Futurists challenged the conventional assumptions of space and time as absolute categories by developing space and time as relational concepts with physical form. This was further developed in challenging presence and absence as independent and localized concepts. Croizat's panbiogeography showed that the full meaning of an organism at any one place and time is always permeated by a phylogenetic, morphological, ecological, or biogeographic counterpart or complement that is located somewhere else in space and time. The trace of this vicariant counterpart is represented graphically as a line or track that shows the connection of organisms in space and time. In this context, organism and environments are not absolute entities, but biogeographic and ecological relationships where spacing and temporalization are the ways in which replication of the past in the present influences the future.

By comparing the geographic distributions of animal and plant species, Croizat concluded that evolutionary differentiation of biological form (e.g., speciation) results in related taxa (species, genera, families, etc.) occupying different geographic sectors without any of these taxa having individually moved to those locations. This process was made possible by their common ancestor already having a distribution range that encompassed all the descendant locations. Each descendant came to occupy different areas through their biological divergence over different parts of the ancestral range. Croizat called this process *vicariant form-making*. These various taxa may be assigned any one of a number of different taxonomic ranks (species, genus, family, etc.), but Croizat was adamant that time in evolution is not tantamount to age as expressed in any particular taxonomic group. He argued, for example, that even though one might assume that a genus comes before a species because the genus is made up of species, in reality a genus could hardly exist independently from at least some of its species, so that the two ranks are effectively contemporary in origin. In this way Croizat attempted to distinguish between absolute time as an overall process inherent to the spatial evolution and differentiation of taxa, and relative time as the relationship between a specific taxonomic rank and its place in evolutionary rather than absolute time, so a species in one group may be as old as a genus or family in another group.

Key questions of time in evolution include the estimation of evolutionary rates of differentiation and the provision of a temporal scale for divergence between lineages. To address these questions, evolutionists often refer to the fossil record. The fossil record provides a general geological timescale for the first appearance of various lineages in the fossil record. Fossils can represent only the minimal age of fossilization for a recognized group of organisms. Fossils contain no information on whether or how long a group existed before the appearance of their earliest fossil. For example, the earliest known bird fossil, dated at about 150 million years old, may show that birds had evolved by this time, but the fossil contains no information as to how much earlier birds originated or the age of the common ancestor of birds and their nearest dinosaurian relatives. The fossil record is replete with examples of organisms for which the fossil record extends the organism's history tens of millions of years further than previously existing records did.

Method

Panbiogeography provides a spatial method for estimating temporal divergence and understanding evolutionary rates by correlating animal and plant distributions with tectonic features involved with geological history. Tectonic formations such as spreading ridges, plate boundaries, transform faults, and zones of uplift or subsidence are all indicators of geological process that underlie the geological topography now occupied by plant and animal distributions. These features can be geologically dated through radioactive decay rates to provide a geological timescale for their formation. A temporal correlation is often made for fossils that are imbedded in dated geological strata, but this approach may also be used for living taxa. This geological correlation technique may have significant implications for dating the origin of taxa where the fossil record is sparse or lacking altogether, and it may even lead to controversial challenges to accepted ages of origin based on the fossil record.

The possible temporal implications for evolutionary rates and age of origin may be illustrated by the spatial correlation between the 200-million-year-old Triassic fossil mollusk *Monotis* and the modern flowering plant genus *Coriaria*. The fossil distribution of *Monotis* overlaps with extensive circum-Pacific geological terranes (geological strata that have a different origin than other strata immediately adjacent) as well as a series of terranes extending through central Asia to Europe. This fossil range is spatially comparable with the modern distribution of *Coriaria* with the exception of western North America, where the plant is absent and no fossil representatives are known. The overall spatial correlation with circum-Pacific terranes may suggest that the modern distribution of Coriaria is as old as the Triassic, or it may have a more recent origin that was still affected by the subsequent geological history of those terrains that previously influenced the Triassic distribution of *Monotis*. The controversial aspect of this spatial correlation between geology and biology is that it suggests the genus *Coriaria* may be older than the earliest known fossil flowering plants recorded from the early Cretaceous (125–130 million years ago). Although some interpretations of the fossil record allow for an earlier origin for the evolution of flowering plants, the idea that some modern genera may also be this old would be widely viewed as problematic if not impossible.

Croizat's Mesozoic Theory

Spatial correlations between modern distributions and the earth's tectonic features (including spreading ridges, faults, and ocean basins) led Croizat to conclude in the 1950s that the origin of most groups of plants and animals distributed between continents originated in the Mesozoic. He proposed that their ancestors were already widely distributed before the Mesozoic, and so they are now isolated between continents, because these land areas have since become isolated. Croizat argued that some modern plant groups may have originated within the Jurassic, while others originated later in the Cretaceous. Even within continents he suggested that many groups originated in the Tertiary and survived the Pleistocene glaciations, an evolutionary model that was later to gain greater support from researchers but at the time was rarely considered.

The Mesozoic theory was strongly opposed by the influential theorists of Croizat's time, such as George Gaylord Simpson and Ernst Mayr, who looked to a much more recent origin of modern life and therefore had to appeal to theoretical migrations, whereby a vast range of animals and plants had to embark on a globetrotting series of migrations in different directions all over the globe to establish themselves on the different continents. Over the last 3 decades, Croizat's model has become widely accepted, although it remains controversial for many groups where other biogeographers believe that the plants or animals in question are of recent origin. A Mesozoic origin for modern life also has critical implications for understanding the mass extinction of dinosaurs and other groups at the end of the Cretaceous that has been attributed to a comet impact. The correlation of modern plant and animal distributions with Mesozoic tectonic structures may suggest that the ancestors of these groups survived the extinction event.

The expanded biogeographic timescale for plant and animal evolution was even proposed for the origin of animals and plants on oceanic islands such as Hawai'i and the Galapagos. Even though these islands were only a few million years old, Croizat argued that they inherited life that occupied earlier islands or island groups that no longer existed in the immediate vicinity. This model was later corroborated by the discovery that the Galapagos and Hawai'i, for example, are the latest formations in a series of volcanoes generated at a stable hotspot, and that both hot spots have a history of volcanic eruption extending back at least 90 to 100 million years. If these hot spots came into contact with mobile island arcs or microcontinents, some of their inhabitants may have colonized the volcanoes and continued to persist at the hot spots by sequentially migrating onto new volcanoes as they appeared, while the older islands were moved away by plate transport and as they eroded finally submerged beneath the sea. Because life is able to colonize new landscapes, it is possible for a young geological surface to support a very ancient biota, whether in reference to recent volcanic islands, volcanoes within a continent, or newly emergent land covered by recent oceanic sediments (e.g., mudstone, limestone).

The Mesozoic model and extended timescale for evolution has recently come into conflict with the popular application of molecular clocks. Molecular clock methods rely on the establishment of a temporal rate of molecular difference between related organisms as a function of time. In order to link a divergence rate to a particular temporal difference, it is necessary for the molecular divergence to be calibrated against a known geological age. This is most often accomplished by using a fossil representative and then extrapolating the relative age for those species for which there is no fossil representative. This method has resulted in the divergence of many groups being calculated as later than a particular geological event (such as the separation of continents occupied by the group), with the conclusion that the origin of the divergence postdated the earlier geological connection, so the current disjunction (such as between different continents) must be the result of recent dispersal or migration. This line of reasoning has been shown to be erroneous, because the molecular divergence date is calibrated by a fossil that can only provide a minimal divergence date. Any molecular dates applied by extrapolation to other taxa must, therefore, also represent minimal, not maximal, divergence estimates. Molecular divergence estimates that postdate a geological event do not, therefore, falsify the possibility that the geological event was actually involved with a divergence that was underestimated by the molecular clock. Molecular clock divergence dates may, however, provide potential falsification of a later geological event. The widespread reference to molecular clock divergence estimates as a falsification of Croizat's biogeographic model is, therefore, unfounded.

Panbiogeography and Theories of Divergence

As a final example of the panbiogeographic perspective on time and molecular approaches to evolution, one may contrast the chimpanzee and orangutan theories of divergence between humans and their nearest living great ape relatives. According to molecular similarity, chimpanzees are our nearest living relatives. Based on the molecular clock theory calibrated by the fossil orangutan relative *Sivapithecus* at about 13 million years, or by other primate fossils, the divergence between humans and chimpanzees has been estimated from as little as 4 million years to as much as 10, with 6 to 8 million years being often favored. In the absence of a fossil record for chimpanzees or gorillas, there is no other corroboration of this divergence estimate. The orangutan theory of relationship would establish an entirely different timescale, with divergence between orangutans and humans occurring at least 13 million years ago. This temporal alternative is also supported spatially with fossil orangutan relatives being distributed around parts of the Mediterranean, central Asia, and eastern Asia. These distributions, along with that of the fossil hominids of East Africa, are largely vicariant, and this would suggest that the temporal differentiation of hominids, the fossil apes, and the orangutans all occurred in their respective areas from a common ancestor that was already widely distributed over all localities. Subsequent extinction of many of these lineages by about 9 million years ago (some apparently the result of climate change and loss of forested environments) resulted in the apparent discrepancy between the origin of hominids in Africa and the origin of modern orangutans in southeastern Asia. It is only through the triple consideration of biological affinity (the evolutionary relationships), the temporal history (in the fossil record), and the spatial distribution of living and fossil taxa that the modern geographic disconnection can be understood as a spatial artifact resulting from the extinction of geographically intermediate forms.

John Grehan

See also Darwin, Charles; Evolution, Organic; Extinction and Evolution; Fossil Record; Fossils, Interpretations of; Phylogeny

Further Readings

Craw, R. C., Grehan, J. R., & Heads, M. J. (1999). *Panbiogeography: Tracking the history of life.* New York: Oxford University Press.

Croizat, L. (1958). *Panbiogeography.* Caracas, Venezuela: Author.

Croizat, L. (1964). *Space, time, form: The biological synthesis.* Caracas, Venezuela: Author.

Matthews, C. (1990). Panbiogeography [Special issue]. *New Zealand Journal of Zoology, 16.*

Sermonti, G. (1988). Panbiogeography [Special issue]. *Rivista di Biologia Biology Forum, 81.*

Pangea

Pangea (Greek for "all earth") was a supercontinent that gradually formed during the early Paleozoic era (beginning approximately 450 million years ago) and broke apart beginning in the Middle Jurassic era (approximately 180 million years ago). At its most complete state in the Early Jurassic, Pangea consisted of nearly all of the world's continental crust sutured together into a single giant landmass. This landmass was C-shaped, centered on the equator, and surrounded by a single giant ocean, termed Panthalassa. Pangea enclosed an eastward-facing body of water called the Tethys Sea, of which the modern Mediterranean is a much-reduced remnant, and was home to vast subtropical deserts. The existence of a single giant continent had profound effects on life, and many important evolutionary events occurred on Pangea, including the radiation of the dinosaurs and the early evolution of birds and mammals.

During the early history of geology it was thought that Earth was a static, stable planet whose surface remained largely unchanged through time. However, beginning in the early 1900s, German meteorologist Alfred Wegener accumulated substantial evidence showing that the continents had not always occupied their present positions. Wegener discovered that South America, Africa, India, Australia, and Antarctica shared a suite of unique Mesozoic fossils, including a tropical plant flora characterized by the fern *Glossopteris* and a reptile fauna that included the tusked, pig-like *Lystrosaurus*. Because modern animals do not range across all continents, owing to the existence of oceans, mountain ranges, and other barriers, Wegener hypothesized that these landmasses must have been linked during the Mesozoic era (225–65 million years ago), and have since moved to their present, widely divergent positions. Additionally, Wegener chronicled closely matching rock units shared by Africa and South America, as well as evidence of former equatorial climate belts and glaciations shared between now divergent continents. Taken together, these facts suggested to Wegener that all of the continents had once been joined together into a supercontinent, which he named Pangea. Initially Wegener's ideas were controversial, as he could provide no plausible mechanism for continental motion. However, further research in the years after World War II roundly supported Wegener's observations and firmly established the existence of a Paleozoic-Mesozoic supercontinent. Today, many geologists believe that Earth is characterized by a supercontinent cycle, in which these giant landmasses form and disintegrate roughly every 500 million years.

The formation of Pangea was gradual and can be traced to the breakup of a previous supercontinent, Pannotia, approximately 750 million years ago. Pannotia split into three large landmasses, including a large southern platform called Gondwana and the more northern Proto-Laurasia, which subsequently split into several smaller landmasses. Two of these smaller landmasses, termed Laurentia and Baltica, collided in the Late Ordovician (about 450 million years ago) and were joined several million years later by Avalonia, a slice of crust comprising present-day New England, Nova Scotia, and Great Britain. Meanwhile, Gondwana was fragmenting into many small landmasses that periodically collided with the Laurentia-Baltica-Avalonia landmass, known as Euramerica. These smaller collisions occurred throughout the Devonian, Mississippian, Pennsylvanian, Permian, and Triassic periods (about 420–200 million years ago), until nearly all of the world's continental crust was completely sutured together during the Early Jurassic.

The breakup of Pangea began during the Middle Jurassic, approximately 180 million years ago. During this time North America moved to the northwest away from Africa and South America, opening the central Atlantic Ocean. North America remained connected to Europe and Asia, and together the land that is now these continents composed the landmass of Laurasia. Laurasia rotated clockwise and completely split from the southern expanse of Pangea, now termed Gondwana and composed of present-day South America, Africa, India, Australia, Antarctica, and Madagascar. Further disintegration of these two large landmasses occurred during the Cretaceous period (about 145–65 million years ago). South America split from Africa to form the south Atlantic Ocean, with the two continents gradually separating from south to north. There is some controversy about the timing of this separation, as most geophysical models place the breakup at about 100 million years ago, but recently published reconstructions suggest it may have occurred much earlier, perhaps up to 140 million years ago. Around the same time as the South America–Africa split, India and Madagascar rifted away from Antarctica and Australia, forming the eastern Indian Ocean. India separated from Madagascar about 95 million years ago and moved rapidly northeastward before colliding with Asia near the end of the Cretaceous. In the Late Cretaceous, North America and Europe rifted apart, forming the North Atlantic Ocean, and Australia and Antarctica separated. Further motion during the Cenozoic brought the continents to their modern positions.

The existence of a single large landmass had profound effects on geography, climate, and life. The numerous continental collisions that built Pangea produced many mountain ranges, including the Appalachians, which were formed by the Silurian collision between Laurentia and Avalonia and subsequently raised by the Mississippian collision between northwest Africa and Euramerica. Alteration in wind and precipitation patterns led to vast inland subtropical deserts. These deserts, along with an extensive central Pangean mountain range, formed substantial barriers for floral and faunal migration. On the whole, however, the presence of a single landmass allowed for easy dispersal of organisms, and many plant and animal species (including Wegener's *Glossopteris* and *Lystrosaurus*) had a cosmopolitan distribution during the Mesozoic.

Many important evolutionary events also happened on Pangea. Dinosaurs first evolved as small, swift predators during the Late Triassic (about 225 million years ago), and the key to their subsequent rise to dominance may have been their ability to thrive in the dry interior of Pangea. The first mammals and birds also arose during the Late Triassic and Early Jurassic, and the early evolutionary history of both groups played out on Pangea. Furthermore, two major extinctions occurred during the existence of Pangea: the Permo-Triassic mass extinction, history's largest mass die-off in which perhaps 95% of all marine species were killed; and the end of Triassic extinction, which decimated both marine and terrestrial communities. Although several different hypotheses have attempted to explain these events (including extraterrestrial impact for the Permo-Triassic), it is possible that the altered climate regimes and ease of migration on Pangea were contributing factors, at least for terrestrial extinctions.

Stephen L. Brusatte

See also Catastrophism; Extinctions, Mass; Geology; Paleontology; Plate Tectonics; Uniformitarianism; Wegener, Alfred

Further Readings

Scotese, C. R. (2004). Cenozoic and Mesozoic paleogeography: Changing terrestrial biogeographic pathways. In M. V. Lomolino & L. R. Heaney (Eds.), *Frontiers of biogeography.* Sunderland, MA: Sinauer.

Smith, A. G., Smith, D. G., & Funnell, B. M. (1994). *Atlas of Mesozoic and Cenozoic coastlines.* Cambridge, UK: Cambridge University Press.

Wegener, A. L. (1924). *The origin of continents and oceans.* New York: Dutton.

Ziegler, A. M., Scotese, C. R., & Barrett, S. F. (1983). Mesozoic and Cenozoic paleogeographic maps. In P. Broche & J. Sundermann (Eds.), *Tidal friction and the earth's rotation II.* Berlin: Springer-Verlag.

PANTHEISM

See BRUNO, GIORDANO

PARACELSUS (1493–1541)

Philippus Theophrastus Aureolus Bombastus von Hohenheim, otherwise less exhaustively known as Paracelsus, was a medieval alchemist, astrologer, occultist, and physician who was well ahead of his time. The title Paracelsus, literally meaning "greater than or equal to Celsus," pays homage to the Roman encyclopedist Aulus Cornelis Celsus (25 BCE–50 CE), whose only extant work, *De Medicina,* deals largely with archaic medical practices. Stories of Paracelsus's ego and arrogance would lead one to believe that Paracelsus accepted this title readily. His interest in time is evident in his numerous prophecies.

Born in Switzerland some time in late 1493 (conflicting accounts exist as to whether the month was November or December), Paracelsus was the son of a German physician and chemist and a Swiss mother. In fact, his earliest medical training was likely with his father, until more formal arrangements were made later on at the University of Vienna, where he graduated with a bachelor's degree in 1510. A doctorate was later procured, but the university he received it from is unknown, although some believe it to be the University of Ferrara.

After completing his research, Paracelsus adopted a wanderer's life for some 10-odd years. His journeys took him across Europe and landed him in Russia, where he was taken prisoner by the Tartars. Gaining the favor of the ruler of the Tartars, Paracelsus eventually was enlisted to escort the ruler's son to Constantinople.

It was in Constantinople that Paracelsus's latent quest for hermetic knowledge was nourished by Arabian adepts, although Paracelsus was a devout Catholic. Perhaps this was his first encounter with the mentioning of *alkahest,* the universal element and solvent that Paracelsus believed to be the philosopher's stone, the pursuit of all alchemists. It was the belief of many alchemists that the philosopher's stone, in addition to being able to transmute other metals into gold, was also the key to immortality.

After returning to Europe, Paracelsus began his practice of medicine as an army surgeon. His contempt for contemporary medical tradition would become apparent after his witnessing of many amputations. Paracelsus's approach to medicine was all natural, similar to some homeopathic practices that exist today. His knowledge of alchemy allowed him to clean wounds with chemicals rather than allowing them to become gangrenous and require amputation. In fact, he would become the first to name the element zinc in 1526, after the German word for pointed: *zinke*. This combination of alchemical knowledge with medicinal practice would become the precursor to the modern discipline of pharmacy.

Also, like many other physicians and alchemists of the time, Paracelsus consulted astrology to help treat various ailments that he encountered in his practice. He believed in the idea that humankind was governed by the movement of celestial bodies. A medical astrologist, Paracelsus would base diagnoses on natal charts and Zodiac signs, with the understanding that each of the 12 signs of the Zodiac corresponded to various regions of the body.

Paracelsus's background in alchemy and astrology would allow him to become acquainted with much mystical knowledge. This is confirmed by an account of Paracelsus mentioning that he had created a homunculus, the so-called little man. This artificially created human was purportedly one foot tall and carried out menial tasks for its creator. As unbelievable as this may sound, humankind's current preoccupations with creating robots and other artificial intelligence show similar pursuits.

Perhaps the most striking of all of Paracelsus's mystical cornerstones are his prophecies. Like the more popular prophecies of Nostradamus, Paracelsus's prophecies seem to be heavily abstracted. A majority of them seem to hint at the course of the Reformation and other ecclesiastical affairs. One particular prophecy seems to predict Napoleon Bonaparte's imprisonment on Saint Helena.

Scholarly dispute exists as to whether Paracelsus's prophecies are prognostications of future historical events or whether they are merely a collection of allegories pertaining to the evolution and development of the human soul. The human soul and its relation to the cosmos was certainly an essential part of Paracelsus's teachings. Most likely both of these arguments have some foundation, as many seers of the time cloaked their messages in layers of symbolism to escape religious persecution.

Paracelsus, however, was one who was constantly plagued with persecution, and even his vast mystical and medical knowledge could not cure this malady. After being threatened with imprisonment for fining a clergyman with a medical fee, Paracelsus abandoned his post at the University of Basel and returned to his former nomadic lifestyle. His dedication to his medical practices and pursuit of hermetic knowledge continued. Years later, in 1536, his *Die Grosse Wundartzney* ("The Great Surgery Book") would be published, thereby enhancing his reputation.

On September 24, 1541, Paracelsus died in Salzburg. His wish to be buried at St. Sebastian Church in Salzburg was honored. After his death, his work continued to be studied for its remarkable value in medicine and other areas. Almost 4 centuries later, the psychiatrist Carl Jung praised Paracelsus for his bombastic nature. Without Paracelsus's stubbornness, he said, it is unlikely that the practice of medicine would have progressed as fast as it did.

Dustin B. Hummel

See also Healing; Medicine, History of; Philosopher's Stone; Prophecy; Zodiac

Further Readings

Bale, P. (2006). *The devil's doctor: Paracelsus and the world of Renaissance magic and science.* New York: Farrar, Straus, & Giroux.

Goodrich-Clarke, N. (Ed.). (1999). *Paracelsus: Essential readings.* Berkeley, CA: North Atlantic Books.

Haarman, F. (1993). *Paracelsus: Life and prophecies.* Whitefish, MT: Kessinger.

Paradigm Shifts

See Darwin and Aristotle

Parmenides of Elea (c. 500 BCE)

Parmenides of Elea was one of the most influential of the Presocratic philosophers. He was born before 500 BCE in Elea, a Hellenic city on the southern coast of Italy where he founded the School of Elea. Unfortunately, his only known work, the didactic poem later titled "On Nature," written in hexameter verse, is extant only in fragments totaling approximately 150 of what were originally around 3,000 lines. It deals with the topic of time indirectly by separating real being from the influences of time.

The poem was divided into an introduction and two main sections about "the way of truth" (*aletheia*) and "the way of opinion" (*doxa*). In the proem the narrator describes his ascent to the home of an unnamed goddess from night to day, unusual for human beings. With the help of the sun maidens, he passes the gates of night and day and meets the goddess, who reveals to him the natures of truth and opinion, that is that which "is" and that which "is not." According to her instruction, real inquiry via pure reason (*logos*) is only possible concerning that which "is," because it is a true, real, unchanging, ungenerated, imperishable, indestructible, continuous whole that keeps remaining in being. But one cannot know or name that which "is not," because it is the opposite of that which "is." Ordinary human beings believe that which "is not," namely, the physical cosmos including sun, moon, earth, and the stars, to be real. But they are mistaken, due to their using deceptive sense perception. They trust the illusion that perceived or imagined things actually "are," and even give them names.

Although Parmenides does not explicitly lay down a philosophy of time, the characterization of that which "is" and which "is not" indicates his point of view. Scholars have different opinions on this subject, but they agree that according to Parmenides, unchanging being is never affected by time, because it has neither a "before" nor an "after," both of which are indissolubly linked with change and process. Because the "is" has no duration, but is "now," the question arises if being should be adequately described as atemporal or even atemporal eternity. Surely one is not allowed to identify the "now" of being with the "now" in the realm of opinion that is embedded in the process of coming-to-be and passing away. Whereas the latter "now" is changing all the time, the "now" of being remains always the same without lasting in time. Because being is free from doxical time, it seems correct to understand it as atemporal. It can also be addressed as eternal, insofar as being eternal is usually characteristic of the revered realm that has neither beginning nor end, and insofar as eternity is not meant as everlastingness here but as a continuous present beyond ordinary time.

The Parmenidean duality of appearance and reality as well as the connotations for a philosophy of time considerably influenced Plato and Neoplatonic thinkers, as is apparent in Plato's *Sophist* and *Parmenides,* as well as in Proclus's commentary on the latter dialogue. Both philosophers treated Parmenides' work with extreme respect and saw themselves as adherents of his ontology, but they introduced further differentiations, such as the ontological comparative and the explicit distinction between real eternity, everlastingness, and time.

Anja Heilmann

See also Anaximander; Anaximines; Becoming and Being; Empedocles; Heraclitus; Presocratic Age; Pythagoras of Samos; Thales; Xenophanes

Further Readings

Meijer, P. A. (1997). *Parmenides beyond the gates: The divine revelation on being, thinking and the doxa.* Amsterdam: J. C. Gieben.

Mourelatos, A. P. D. (1970). *The route of Parmenides: A study of word, image, and argument in the fragments.* New Haven, CT: Yale University Press.

Tarán, L. (1971). *Parmenides: A text with translation, commentary, and critical essays.* Princeton, NJ: Princeton University Press.

Parousia

The word *parousia* is borrowed from the Greek; it means "presence" or "arrival." It is used in Christianity to refer to the coming of Jesus; the word is also commonly used in the Christian Bible.

In I Corinthians 16:17, Paul writes of the parousia of several Christians to Corinth. In II Corinthians 7:6, Paul writes of the parousia of Titus to Corinth. These two passages refer to people who are coming to Corinth. But the word is also used to denote a time in the future when Jesus will come back to earth, as in Matthew 24:27, 37, and 39 and I Thessalonians 2:19, for example.

The timing of Jesus's parousia has caused debate. Christians who lived soon after Jesus believed that his parousia was imminent. I John, which many scholars believe was written in the 90s CE, states, "Dear children, this is the last hour." Revelation 1:3, also written in the 90s, states: "Blessed are those who hear it and take to heart what is written in it, because the time is near." As time passed and Jesus did not return, Christians nevertheless continued to anticipate his arrival. Among the most famous of the predictors was William Miller, who predicted that Jesus would return in 1844. Many Christians in the 19th century believed him. After Jesus failed to return, some formed the Christian denomination the Seventh-Day Adventists. Currently, some Christians believe that the parousia of Jesus will occur in their lifetimes.

Over time, Christians have debated the nature of Jesus's coming: Some link it with the "rapture," or Second Coming of Jesus. These events are not synonymous. The rapture is best described in I Thessalonians 4:16, 17: "For the Lord himself will come down from heaven . . . and the dead in Christ will rise first. After that, we who are still alive and are left will be caught up together with them in the clouds to meet the Lord in the air. And so we will be with the Lord forever." At this parousia, Jesus will not come to earth but will call Christians to him while suspended in the air.

The Second Coming of Jesus is recorded in Matthew 24 and Revelation 19:11ff. This event forecasts Jesus's coming to earth with a resultant battle against the forces of evil. The result of this battle will be a victory for Jesus, and Christians will rule in peace with Jesus. The amount of time that Christians will spend in peace with Jesus is debated, with some believing that this will last forever and others believing it will last for 1,000 years (Revelation 20:4).

Not all Christians believe that the parousia of Jesus will be a physical one, or even one in some future time. Some Christians believe that the events spoken of in Matthew 24 and the Book of Revelation have already occurred, that they were referring to persecutions meted out by the Romans. Others believe that these events are not meant to be taken literally but refer instead to spiritual phenomena and situations.

Mark Nickens

See also Apocalypse; Ecclesiastes, Book of; End-Time, Beliefs in; God and Time; Last Judgment; Religions and Time; Teilhard de Chardin, Pierre; Time, Sacred

Further Readings

Frykholm, A. J. (2007). *Rapture culture: Left behind in evangelical America.* New York: Oxford University Press.

McGinn, B. (1998). *Visions of the end.* New York: Columbia University Press.

Peloponnesian War

The Peloponnesian War (431–404 BCE) was more than a classic conflict between two Greek city-states and their allies; it was also a clash of ideologies—a democracy (Athens) and an oligarchy (Sparta)—and of opposing views on the nature of the world. This war is an example of conflict between two militaries with very different and incompatible styles of fighting; thus, it serves as an example of adaptation (or the lack of it). A large volume of information, including contemporary accounts of the war, has survived, providing greater detail than is known about any other ancient war. Because of the opponents' political and military differences and the amount of information available, modern war colleges study the Peloponnesian War in terms of strategies, consequences of actions, and politics.

History of the War

The cause of the Peloponnesian War dates back to the time of the Greek wars with the Persians in the early 5th century BCE. Sparta, with its totally land-based military, had taken command of the Hellenic League. The seafaring powers resented

Sparta's leadership, especially over naval forces. Athens, a sea power, accepted leadership of a new league of sea-power states called the Delian League in 479–478 BCE. Sparta remained the leader of the land-power states called the Peloponnesian League. Tension mounted between Athens and Sparta until war broke out in 460 BCE. The causes of the conflict, sometimes called the First Peloponnesian War, include Spartan suspicion of the growing Athenian empire, the defection of the city of Megara to Athens, and the Athenian construction of a long wall to the sea. The war continued until the both sides ratified the Thirty Years' Peace in 445 BCE.

The conflict restarted in 431 BCE, beginning the Peloponnesian War. Historians divide the war into three phases: the Archidamian war (431–421), the Sicilian campaigns (420–413), and the Decelean war (413–404). In the Archidamian war, Sparta launched brief land invasions into Attica in hopes of scaring Athens into capitulation. This strategy did not work, for two reasons. First, Sparta was far from home, which made sustaining operations difficult. Second, Sparta's slave class, the Helots, was always at risk of revolting when the army was away. Therefore, the Spartan army tended to keep excursions brief in order to prevent a Helot uprising. Athens, following the advice of their army general, Pericles, chose to fight a passive war, to remain behind her strong city walls, and to avoid a direct land battle. Athens did raid the Peloponnesian coast using her superior navy. Their aim was to harass Sparta and her allies in the hope that the Spartans would withdraw to Peloponnesus and sue for peace. Neither strategy worked nor could one side exploit the other side's weakness in order to win a decisive battle. This period concluded with the Peace of Nicias in 421 BCE.

The peace reflected poorly on Sparta in that its allies thought Sparta had sold them out; however, it gave the Athenians time to rest, rearm, and reevaluate their strategy. Athens, with a new general named Alcibiades, a new fleet, a replenished treasury, and a pacified empire, decided to take the offensive. Athens convinced Argos, Sparta's greatest rival, to join the alliance. Athens sent troops to Argos for a battle with Sparta, but they were too few in number. Sparta won the battle and regained the momentum; Athens had lost an opportunity to win the war.

Next, Athens chose to attack Sparta's supply lines from the west. This move began the Sicilian campaigns. Syracuse, an ally of Sparta, posed a threat to Athenian allies on Sicily. Athens sent a fleet to destroy Syracuse; however, poor decisions on strategy and slow movement to action gave Syracuse time to prepare its defenses and cost the Athenians their opportunity to achieve their goal. This campaign, far from home, ended disastrously for Athens. Athens tried to fight a land battle instead of relying on her strength—the fleet. This led to the destruction of the Athenian fleet, the capture of almost the entire army, and the defection of her enthusiastic general, Alcibiades, to the Spartans.

The Decelean phase of the war was a time of desperate strategy for both sides. Sparta made an unlikely alliance with the Persians, while the Athenians reverted to a defensive strategy. Furthermore, Sparta took to the seas, an unusual strategy for a land-based army, to cut off the Athens supply lines at the Hellespont. The Athenian fleet, once again under the command of Alcibiades, was able to put together a string of victories, but none of them was decisive. Finally, in 405 BCE, the Spartan general Lysander caught the Athenian fleet on shore. He knew not to face the Athenian fleet head on but chose to fight Athens on Spartan terms, that is, to battle a moored Athenian fleet. Lysander won a decisive victory, destroyed 168 ships of the Athenian fleet, and captured over 3,000 sailors. This, the Battle of Aegospotami, probably is the best example in the war of perfectly using one's strength against another's strength. This battle effectively ended the war.

The Peloponnesian War devastated Greece, from which she would never recover. Not only did the war bring an end to her Golden Age, a time when she was the cultural and intellectual center of the world, but it also left the countryside ravaged and the general populace struggling for survival. The Greeks lost their place as a regional power and, in 371 BCE, lost their independence to the Macedon king Philip II.

The War's Lessons

The Peloponnesian War has timeless elements that are relevant to the modern world. First, the war represents a battle between vastly differing political ideologies—a democracy versus an oligarchy. This political difference bred distrust, which led to alliance building and then to war and destruction. Because these same political differences exist in modern times, the Peloponnesian War serves as a paradigm and an example of what can go wrong.

Second, the mismatch between the two sides' military capabilities—with Sparta strong on land and Athens strong at sea—resulted in two phenomena that still have relevance in the 21st century. First, because neither alliance could effectively attack the other's center of gravity, each initially opted for a war of attrition that sapped resources without essentially harming the opponent in any serious way. Second, the opponents clearly saw the need for joint or coordinated operations, that is, operations on land and sea simultaneously. The Spartans ultimately succeeded in joint operations, while the Athenians failed. This concept of joint operations has become fully ingrained in the Western military system, especially since the rise of the European navies in the 16th century. In addition to the areas of land and sea, modern warfare adds air, space, and the cybernetic world to the arena of joint operations.

Terry W. Eddinger

See also Alexander the Great; Plutarch; Thucydides; Weapons

Further Readings

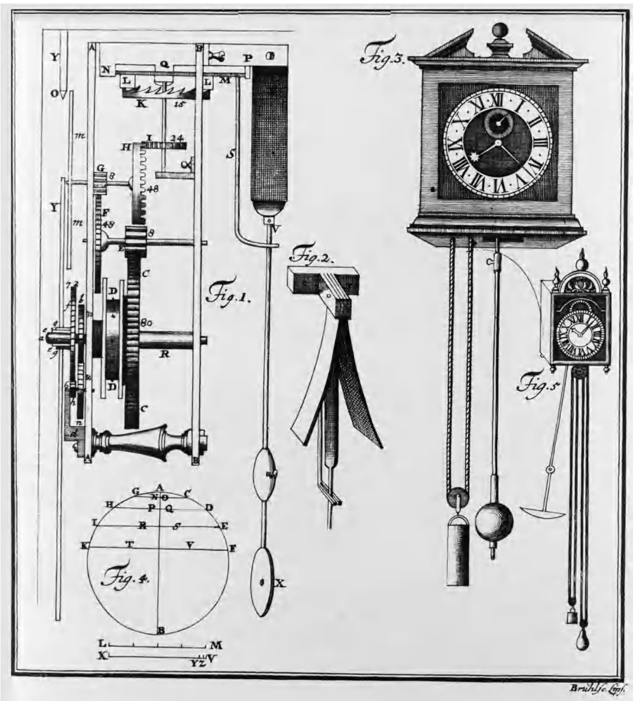
Bagnall, N. (2006). *The Peloponnesian War: Athens, Sparta, and the struggle for Greece.* New York: St. Martin's Press.

Strassler, R. (Ed.). (1998). *The landmark Thucydides: A comprehensive guide to the Peloponnesian War* (R. Crawley, Trans.). New York: Touchstone.

Pendulums

A pendulum is a suspended body that swings back and forth or oscillates about a fixed point. The simple pendulum consists of a heavy object called a bob suspended from a string, rope, wire, or light cord that, when given an initial push, will swing back and forth under the influence of gravity over its central or lowest point. Its swing or oscillation is regular and periodic. It is believed that the famous scientist Galileo Galilei (1564–1642) observed the regularity and periodicity of the pendulum's motion as early as 1583 by comparing the movement of a swinging lamp in a cathedral in Pisa, Italy, with his pulse rate.

Pendulums have made a valuable contribution to our understanding and appreciation of the concept of time since Galileo's observations and subsequent analysis of their motion led to the utilization of pendulums in clockwork, providing the world's first accurate measure of time. Prior to the advent of the pendulum, time was measured by the use of natural periodic phenomena, which appeared to be steadily rhythmic but varied widely from system to system and place to place. For example, use was made of the sun (sundials), flowing water (water clocks or clepsydra), flowing sand (sand clock or hourglass), burning candles and incense, and then early mechanical clocks in which weights would slowly drop, turning a gear



The mechanical system of a clock driven by weights and pendulum (1725). The Dutch mathematician and astronomer Christiaan Huygens was the first to successfully produce the first pendulum clock in 1656.

Source: Library of Congress, Prints & Photographs Division.

to move the clock's hand and display the time. Before the pendulum, these early mechanical clocks were probably the most accurate, and yet it was not unusual for these clocks to be off by as much as 2 hours per day! It is easy to imagine the colossal negative effects of this on society as a whole, particularly on work practices and on scientific investigations.

Within 30 years of the first use of pendulums in clocks, the average error of measuring time went from about 15 minutes a day to less than 10 seconds. By the early 1900s, time could be measured to within a hundredth of a second a day because of the pendulum. The implications of this ability to accurately measure time for the first time in history were significant, resulting in considerable technical, social, cultural, and scientific advances. Indeed, some believe that it is this (which was facilitated by the pendulum) which ushered in the scientific revolution, so creating the foundations of modern science and society. Rapid advances in our knowledge about ourselves, nature, the earth, and the entire universe would have been impossible without accurate time measurement (and therefore the pendulum).

The time required for a pendulum to swing back and forth (one complete oscillation) is called the *period* of the pendulum. This time is constant at a fixed location on earth. It does not depend on the weight of the bob or on the size of the swing (for small swings). It is dependent only on the length of the pendulum. It is this invariant time for one oscillation that makes pendulums useful for regulating the action of several devices, especially clocks. For example, one well-known use of the pendulum is as a metronome to aid musical students to keep time.

The motion of the idealized so-called simple pendulum with a light string and frictionless system is referred to as simple harmonic motion, because it is continuous and repetitive, oscillating in such a way that it swings out an equal distance on either side of a central point, with its acceleration toward the central point proportional to the distance of the pendulum from it.

The term *pendulum* is often used outside of timekeeping and science to describe systems or situations where anything undergoes regular shifts or reversals in value, direction, attitude, opinion, or state. For example, one may hear about the "pendulum of public opinion" spinning from one extreme to the next. It is also used to describe systems that use any kind of "to and fro" process. For example, *pendulum arbitration* is a method of arbitration where one side makes a proposal, and then the other suggests their proposal, with the arbitrator finally choosing one of the proposals, which then becomes binding on both sides. A technique for delivering supplies or for rescue using a helicopter, where a rope or hoist cable is set swinging by rocking the helicopter or pushing and pulling the rope, is called a *pendulum maneuver.*

The Period of a Simple Pendulum

The simple pendulum is an idealized or mathematical model of a practical pendulum for which it is assumed that the

- ring, cord, rope, wire, or rod from which the bob is suspended is so light that it is considered massless.
- string, cord, rope, wire, or rod from which the bob is suspended is inextensible; that is, of unvarying length; in simple terms, it must not stretch.
- bob is a point mass (i.e., its mass must be concentrated at a point).
- amplitude of the swing, that is, the angular displacement, is small (less than about 10 degrees) and thus the motion is simple harmonic (see θ in Figure 1).
- pendulum swings only in the vertical plane.
- effects of the air in which it moves are negligible.
- effects of the pivot or point of suspension are negligible.

In the simple idealized pendulum, when it is displaced from its rest position, only two forces act on the pendulum as shown in Figure 1. The first force is the tension in the cord acting upward along the cord, and the second force is the weight of the bob acting directly downward. The weight is given by mg, where m is the mass of the bob and g is the acceleration due to gravity. The weight consists of the two components, F_1 which balances the tension in the cord and F_2 which acts along the path of the pendulum. The force F_2, acting to restore the pendulum to its original position is equal to $-mgx/L$, where x is the displacement and

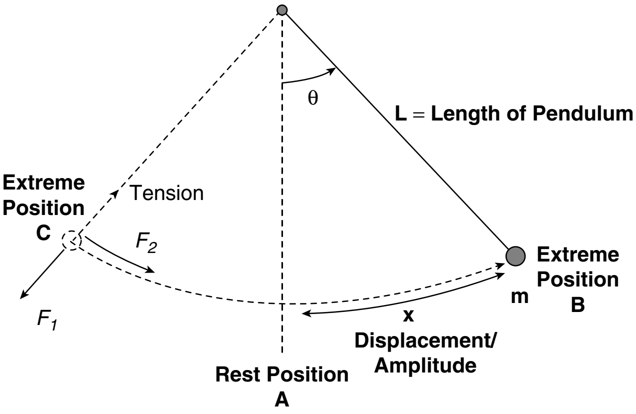


Figure 1 Principle of the simple pendulum

L is the length of the cord. The value of F_2 is always negative since it acts in the opposite direction to the displacement.

The law governing the motion of the idealized simple pendulum was discovered in the late 1500s by Galileo and states mathematically that the period of oscillation of a pendulum varies directly with the square root of the length of the pendulum and inversely with the force of gravity (acceleration due to gravity). The time, T, required for a complete swing (the period) is described as follows:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where L is the length of the pendulum and g is the acceleration due to gravity. Because π is a constant and g is a constant at a fixed location, the period of the pendulum varies only with its length. In other words for a pendulum of constant length, at a fixed location, the period is constant. Much more sophisticated mathematics is required to describe the motion of an actual physical or complex compound pendulum.

History of Pendulums

By some reports, the pendulum was used as early as 132 CE in a seismoscope or earthquake recording instrument invented by a Chinese philosopher named Chang Heng. Thus, almost certainly, people have been using pendulums for thousands of years in devices and possibly looking at swinging pendulums. Indeed, the notebooks of Leonardo da Vinci (1452–1519) include a theoretical design of a silent pendulum mechanism that could be used to regulate the motion of a clock.

Yet, the first detailed studies of the motion of the pendulum were reported only in the 17th century, by some leading scientists of the time. These included Galileo Galilei, Christiaan Huygens (1629–1695), Isaac Newton (1643–1727), and Robert Hooke (1635–1703). Although the extent of the contributions to pendulum theory and clock making of the various scientists, particularly Galileo and Huygens, is sometimes the subject of debate, it is generally accepted that it was Galileo who, at different times, made four entirely new claims about pendulum motion, as follows:

1. The period varies with the length of the pendulum (and later with the square root of length—the *law of length*).
2. The period is independent of the size of the swing or amplitude (the *law of amplitude independence*). (Huygens and Mersenne later showed this to be true only for pendulums with small amplitudes.)
3. The period is independent of the weight of the bob (the *law of weight independence*).
4. For a given pendulum length, all periods are the same (*Law of Isochrony*).

Christiaan Huygens's Contribution

It is thought that the ideas of Galileo inspired the Dutch scientist Christiaan Huygens to patent a mechanical clock in 1656 that employed a pendulum to regulate its movement. Others believe that it was the theologian and mathematician Marin Mersenne (1588–1648) who gave Huygens the idea to use the pendulum as a timing device. Whatever his inspiration, Huygens is credited with making the first pendulum clock, and after this invention, he continued to work on increasing the precision and stability of these clocks. He also devoted much time to the construction of pendulum clocks for use on ships in the open sea. The construction and use of pendulum clocks quickly spread. Indeed, in 1658, only 2 years after Huygens obtained the patent for the first pendulum clock, a clock maker from Utrecht named Samuel Coster built a church pendulum clock with a guaranteed accuracy. Indeed, by then most major towns in Holland had pendulum tower clocks.

In Huygens's memoirs, published in 1673 and entitled *Horologium Oscillatorium,* he gave a detailed description of pendulum clocks and their theory. There, he confirmed the earlier observation by Marin Mersenne that the period of a pendulum does vary with the size of the swing, and that Galileo's observation of amplitude independence was accurate only for small swings or amplitudes.

Much later, around 1675, Christiaan Huygens (with Robert Hooke) invented the coiled balance spring to make clocks more mobile. The modern version is now sometimes called the hairspring, and it is still found in some of today's wristwatches. Although this mechanism depends on the elastic properties of a spring and not a pendulum, the underlying physics of the device is the same as that of the pendulum.

Huygens has also been credited with being the first scientist who observed and described the "synchronization phenomenon." In 1665, he noticed, while lying in bed sick observing two clocks hanging on a wall in his room, that the pair of pendulum clocks that hung from a common support had synchronized: Their oscillations coincided perfectly, and they moved always in opposite directions. He described this synchronization as the "sympathy of two clocks."

This discovery was probably just as important as his invention of the first pendulum clock, because synchronization phenomena are frequently found in engineering, nature, science, and everyday life. Systems as varied as recurrent viral epidemics (e.g., childhood infections), orbits of celestial bodies, singing crickets, flashing fireflies, and applauding audiences display synchronization. Synchronization has today become a popular research topic.

Other Scientists' Contributions

Apart from Huygens and Galileo, several other scientists of the time used pendulums to increase our knowledge of the earth and to construct useful devices. The English scientist Robert Hooke was responsible for suggesting (as early as 1666) that the pendulum could be used to measure the force of gravity. He was also the inventor of the conical pendulum, consisting of a weight attached to a light rod, which was made to execute circular motion. He applied his observations of this pendulum to his study of orbital planetary motion. His observations of the conical pendulum and its application to planetary motion were also thought to have influenced the development of Newton's laws of motion.

In 1671, during an expedition to Cayenne, French Guyana, Jean Richer demonstrated the variation in the force of gravity with location on the earth by observing that the period of a pendulum was slower at Cayenne than it was at Paris.

For pendulums that used metal wire or rods to suspend the bob, it was observed that the length of the pendulum changed with temperature due to expansion of the metal with increased temperature. This, of course, caused the period to vary and was to be avoided in making an accurate clock. George Graham in 1726 designed a type of "compensated" pendulum having a glass hollow bob filled with mercury suspended by a steel pendulum rod. In his design, the thermal expansion of the mercury balanced or compensated for the thermal expansion of the pendulum rod. This came to be known as Graham's pendulum.

John Harrison, a British clockmaker, expanded on this idea of compensation for changes in the length of pendulums due to temperature changes by inventing a pendulum with up to nine alternating steel and brass rods that was known as the gridiron pendulum.

An experiment with an unusual pendulum has been credited with contributing to the popularization of pendulums and science in the early 19th and 20th centuries. This experiment was also used to demonstrate, for the first time in a simple way, that the earth indeed rotated on its axis. In 1851, Jean Bernard Léon Foucault suspended a pendulum (later named the Foucault pendulum) from the dome of the Panthéon in Paris. The bob of the pendulum was a 62-pound iron ball suspended from an iron wire 220 feet long. Foucault set it in motion, causing it to rock slowly back and forth. To record the swing of the pendulum, he attached a pointer to the ball and placed a ring of damp sand on the floor. From the patterns in the sand, the pendulum appeared to rotate, leaving a slightly different trace with each swing, thus illustrating that the earth rotated on its axis.

There were many more developments in pendulum clocks over the next century, and these led in 1889 to Siegmund Riefler's invention of a clock made with a nearly free pendulum, which attained an accuracy of a hundredth of a second a day, becoming the standard in many astronomical observatories. A more accurate free pendulum clock was later invented by W. H. Shortt in 1921. Interestingly, the Shortt clock contained two pendulums, one called the master and the other the slave. The National Institute of Standards and Technology (NIST) based in the United States had used the Riefler clock from 1904 until 1929 as the national time standard. It was briefly replaced by the Shortt double pendulum clock before the NIST finally switched to an electronic timekeeping system.

Types of Pendulums

Following Galileo's analysis and Huygens's work, several different types of pendulums were designed and constructed for use in timekeeping and in other applications. Indeed, Newton's pendulum (sometimes called Newton's cradle) survives today as a very popular desk and table ornament. It consists of five metal spheres as bobs suspended, so they all touch one another along the same line. One or more of the metal bobs are drawn back and released, causing the released spheres to swing and collide with the remaining spheres. Other types of pendulums include these:

- *Astatic pendulum:* a pendulum that is not restricted to swinging in a plane.
- *Ballistic pendulum:* a device consisting of a heavy block suspended by rods that measures the velocity of a projectile, such as a bullet, by calculating the angle of the pendulum's swing.
- *Barton's pendulum:* in its simplest construction, a device that uses approximately 10 different pendulums hung from one common string.
- *Compensated pendulum:* a clock pendulum that has mechanisms that are designed to maintain constant pendulum length in spite of temperature changes. One example of this type of pendulum using zinc and steel was used in the Big Ben clock of London, England.
- *Cycloidal pendulum:* a device that consists of a heavy weight suspended by a cord that hangs between two cycloid-shaped metal constraints.
- *Double pendulum:* a pendulum that has been attached to the end of another pendulum to make what is often called a chaotic pendulum.
- *Galitzin pendulum:* a very large horizontal pendulum that is used to measure changes in the direction of the force of gravity with time, serving as the basis of a seismograph.
- *Horizontal pendulum:* a pendulum that moves in a horizontal plane, such as a compass needle turning on its pivot.
- *Kater's (reversible) pendulum:* a pendulum that can be supported from either of two movable knife edges that is used to accurately measure the acceleration of gravity.
- *Long period pendulum:* a pendulum used for measurements of gravity, in seismometers, and for vibration isolation. In 1901, one such pendulum, 4,440 feet long and with a period of 70 seconds, was made by the faculty of the Michigan Technological University.
- *Magnetic pendulum:* consists of a permanent magnet that is suspended and free to turn in a horizontal plane in a magnetic field with a horizontal component.
- *Torsional/torsion pendulum:* This consists of a horizontal disk suspended by a wire attached to its center. When the disk is twisted and released, it returns to its original position. The disk continues to spin first one way and then the other.

Other Uses of Pendulums

Child Development/Cognitive Development

The pendulum was used by the Swiss psychologist Jean Piaget in investigations of the cognitive development of children. This involved testing the children's knowledge of the physical world by observing their understanding of the laws governing the motion of a simple pendulum. The pendulum test has been used in several investigations to identify the onset of formal operational thinking in children.

Divination

Pendulums are often used as a so-called divination device or tool in unscientific methods of searching for subsurface water, minerals, or other hidden materials. In a process sometimes known as dowsing, a forked twig or pendulum is often used as the "dowser" or "divining rod." Reportedly, this was first practiced in Europe during the Middle Ages. Although it is not widely recognized by science, dowsing has been used commercially and in archaeology. In particular, dowsing with a pendulum is sometimes called *radiesthesia* and is used in many fields, including alternative medical diagnosis, and in the location of missing persons or objects.

Hypnosis

Pendulums are sometimes used as tools to induce the so-called altered state of consciousness characteristic of the hypnotized subject. The use of a swinging pendulum to bring about a trancelike state is well known in popular culture.

Impact of Pendulums

The pendulum has played an important role in the development of science, culture, and society. Indeed, the developments in timekeeping and watchmaking that were made possible by the pendulum were so significant that the century from 1660 to 1760 is referred to as the British horological revolution. The pendulum provided the world with the first accurate measure of time. The accuracy of mechanical clocks went from within half an hour a day to a few seconds per day in just a few years. This dramatic increase in the accuracy of measuring time enabled new types of accurate measurements in fields as diverse as astronomy, navigation, and mechanics. Certainly, accurate measurement of time led to the determination of longitude. Because latitude was already known, the accurate mapping of the earth was made possible. Some believe that the British horological revolution, which began with Huygens's invention of the pendulum clock, played a major role in Britain's supremacy at sea and may have led to the industrial revolution in Britain.

The pendulum also played a key role in establishing many laws of motion in physics, including the collision laws. It was used to determine the value of the acceleration due to gravity *(g)*. By using the pendulum to determine the variation in g at different parts of the earth (specifically at the poles and equator), it was possible to deduce the earth's shape. This led to the creation of the science of geodesy.

Foucault's pendulum provided evidence for the rotation of the earth on its axis and also played a role in the popularization of science in the 19th and early 20th centuries. The many significant scientific and social developments that occurred because of the accurate measurement of time that became possible with the advent of pendulum clocks are the subject of several published works.

Jennifer Papin-Ramcharan

See also Clocks, Mechanical; Divination; Earth, Rotation of; Experiments, Thought; Galilei, Galileo; Harrison, John; Longitude; Newton, Isaac; Time, Cyclical; Time, Measurements of; Watches

Further Readings

Aczel, A. D. (2003). *Pendulum: Léon Foucault and the triumph of science.* New York: Atria Books.

Baker, G. L., & Blackburn, J. A. (2005). *The pendulum: A case study in physics.* Oxford, UK: Oxford University Press.

Barnett, J. E. (1998). *Time's pendulum: The quest to capture time—from sundials to atomic clocks.* New York: Plenum.

International Society for the Study of Time, Fraser, J. T., Lawrence, N. M., & Haber, F. C. (1986). *Time, science, and society in China and the West* [The Study of Time V]. Amherst: University of Massachusetts Press.

Macey, S. L. (1980). *Clocks and the cosmos: Time in Western life and thought.* Hamden, CT: Archon.

Matthews, M. R., Gauld, C. F., & Stinner, A. (2005). *The pendulum: Scientific, historical, philosophical and educational perspectives.* Dordrecht, The Netherlands: Springer.

Matthys, R. J. (2004). *Accurate clock pendulums.* Oxford, UK: Oxford University Press.

Newton, R. G. (2004). *Galileo's pendulum: From the rhythm of time to the making of matter.* Cambridge, MA: Harvard University Press.

Pikovsky, A., Rosenblum, M., & Kurths, J. (2001). *Synchronization: A universal concept in nonlinear sciences* [Cambridge Nonlinear Science Series, No. 12]. Cambridge, UK: Cambridge University Press.

Roberts, D. (2003). *Precision pendulum clocks: The quest for accurate timekeeping.* Atglen, PA: Schiffer.

Perception

When considering the concept of time perception, we must first ask the following question: Is it right to talk about perception when dealing with time? We must, in this context, remember James J. Gibson's remark to the effect that time, as such, is not a distinct stimulus and note that no one has so far discovered a sense or sensory organs that function directly to process time-related stimuli, nor do we know much about the information we use in the process that eventually generates a sense of duration. We know that there is a relationship between certain hormones, such as melatonin and dopamine, and the activities of some biological pacemakers, but this does not by a long stretch amount to a definition of *time perception.* Strange as this hiatus in our knowledge may seem given the crucial role of time in the adaptation of any living organism, we cannot as a result talk about time as we do about visual, auditory, or tactile stimuli, for instance.

Let us remember that the term *perception* refers to the process whereby a stimulus in some form of physical energy reaches dedicated sensory organs, in which, then, a process takes place that translates the energy into neural signals. These signals, in turn, reach a certain brain area via the nervous system in which they are decoded in order to create a sensory experience. Even though brain research has been making progress in the identification of brain areas associated with time-related processes, it is still wholly impossible to describe a perceptual track for the creation of time-related experience. So far, the research for a clear, stable, and meaningful connection between the pace of activity of any type of biological pacemakers or of any cyclical biological activity such as, for example, daily temperature fluctuations, on the one hand, and the properties of duration estimations of events, on the other, has been in vain. Thus for instance, research conducted in "time-free" environments, where individuals are located in deep caves or isolated bunkers without any connection to the world and with no way of obtaining external information so that, in estimating duration, they have to rely exclusively on their internal senses, did not succeed to find a significant relationship between, say, the circadian rhythm and duration estimations. Given this situation, many researchers tend to assume that the sense of time is a product of information processing or a cognitive process that utilizes information from various sources, at least while speaking of humans. If this, indeed, is the case, then it would be more adequate to talk in terms of a process of time estimation or judgment rather than of "time perception." We will, nevertheless, continue using the latter notion, but taking account of its above explained meaning.

We should also remember that the experience of time has a number of dimensions, the most prominent of which is that of duration, but which also include the order of events in time, simultaneity of events as opposed to successiveness, perception of rhythm, and more. Most of the research is concerned with duration, and hence we shall focus on it below and more particularly on prospective time judgment of short—seconds or minutes long—durations in humans. The reason for this focus is that prospective duration judgments of short intervals resemble the "perception" notion much more than duration judgments of long intervals or perception of other temporal dimensions. Temporal order perception, for example, is not determined solely by the discriminability of two events' duration but, to a large extent, by the meaning of the stimuli. Long durations, unlike short ones, are related to long series of events that are not simply an integral property of a single event, and the processes involved in experiencing and remembering the duration of a series of events are probably consciously controlled. This is not the case regarding brief durations, where duration information may be assumed to be an integral part of the experience of a single event

Psychophysical Properties and Sensitivity of Time Perception

Due to the high dependency of time perception on contextual factors and on stimuli's parameters, it is not easy to portray a clear-cut and simple picture of the psychophysical properties or of the sensitivity of time perception. Hence, only a general description is outlined in this section.

If an event lasts for less than a few milliseconds, it is perceived as instantaneous and without duration, but if, for example, two auditory stimuli are presented dichotically with an interval greater than several milliseconds between onset times, successiveness will be experienced. This is the case regarding the auditory modality, which is the most sensitive of all modalities to time. The sensitivity to time is lower in the visual modality. For example, if two binocularly presented stimuli occur with an interval of about 44 milliseconds or less between the onset times of the two, they are perceived as a single stimulus. However, if two 100-millisecond visual stimuli strike spatially adjacent receptors on the retina, an apparent movement from one position to the other will be experienced when the interval between the onsets of the two stimuli is as short as 3 to 10 milliseconds. A different experience of a flicker will be reported if the two stimuli strike the same retinal receptor. Successiveness will be experienced, in dependence on stimuli's parameters, only when the interval between the onsets of two 100-millisecond stimuli is longer than 120 milliseconds. This indicates that two successive stimuli can be discriminated reliably as separate events only if they are at least 20 to 25 milliseconds apart. Stroud (1995) suggested that psychological time is not a continuous dimension but rather consists of discrete chunks, called "perceptual moments," that are the psychological units of time. He estimated that the duration of a psychological moment is about 100 milliseconds. Other researchers estimate this duration to be 30, or 60 to 70, milliseconds in length. In any case, the psychological moment notion suggests that its duration should be the shortest possible perceived duration, an idea supported by the visual masking phenomenon. Most studies report that only beyond the range of 100 to 150 milliseconds will people be able to discriminate time intervals as being of different durations.

Judgments of time periods in the range from about 500 milliseconds to a few minutes tend to be monotonously and linearly related to objective durations with a slope of about 1.0, or in other words, duration estimates are a power function of actual duration with an exponent slightly less than 1.0.

Judgments of duration usually vary approximately up to 10 percent around the mean. However, it was found that accuracy can be significantly improved by extended practice.

The Impact of Sensory Modality

Psychophysical studies demonstrate modality differences in time perception. In both absolute judgments and discrimination tasks, people typically estimate auditory stimuli as longer than visual ones. Evidence from electrophysiological studies revealed greater sensitivity to duration in the auditory than in the visual modality.

The Impact of Contextual Factors

Duration estimations involve processes that are highly sensitive to contextual factors. A major contextual factor is the duration estimation paradigm. Estimating short durations is called *prospective* if a person knows before the beginning of a target interval that its duration should be estimated, and *retrospective* if a person is not aware of the need to estimate duration until the target interval has ended. Block differentiated between *experienced* and *remembered* time in relation to the two paradigms, respectively.

It was J. J. James who asserted that duration in passing lengthens when one pays attention to the passage of time itself, but duration in retrospect lengthens as a function of the complexity of the memories that the time affords.

Indeed, the ability to pay attention to the passage of time under prospective conditions is a major distinction between the processes that underlie timing in the two paradigms. A 1997 meta-analytic study revealed that there are some fundamental differences between duration estimations under prospective and retrospective conditions. For example, prospective judgments are longer than respective retrospective judgments in about 16% of all cases and tend to be more accurate. In both cases the judgments tend to be underestimates of objective durations. A major difference between the two paradigms is revealed when the nontemporal information processing load is manipulated during a target interval. Whereas retrospective estimates lengthen as the amount of nontemporal information increases, prospective estimates shorten as the nontemporal information processing load increases. Such fundamental differences imply that somewhat different mechanisms subserve duration judgments under prospective and retrospective conditions.

Models of Time Perception

Models of time perception vary according to the type of timing mechanism suggested.

Whereas time perception of very brief durations is grounded primarily in models of biopsychological and sensory-perceptual processes, the experience of time regarding periods in the range of seconds and minutes seems to be a manifestation of temporal information processing. This realization occurred only after it was recognized that the experience of time cannot be explained solely in terms of biological pacemakers.

Types of Duration Judgment Models

Models of duration judgment can be classified as models with and without an internal clock mechanism. Models that do not incorporate the notion of an internal clock are based on some sort of a neural or cognitive mechanism that is able to represent the passage of time. Neural-network models are one example. These models do not assume any dedicated circuit or area for encoding duration. Rather they rely on de facto neural activation responding to stimuli in order to represent its temporal features.

Some of these models assume that the activity of some neural nets in the brain can represent a certain time interval by the state of the neural net itself. This time interval can later on be reproduced by reactivating the net until it reaches the former state. Other models propose that timing is based on the detection of simultaneous activity across multiple neural inputs or the detection of patterns of neural activity associated with a specific time interval.

Despite the appealing nature of neural-net and brain models, many researchers believe that models that do not include a timer of any sort are unable, at the present time, to account for many of the characteristics of temporal behavior, like its scalar properties.

Clock models assume the existence of a biological clock, a pacemaker, or a cognitive mechanism with the characteristics of a physical clock such as the regular and constant emittance of a pulse of signals in a constant pace.

Scalar Timing Theory (SET)

Scalar timing or scalar expectancy theory (SET) is usually considered to be the most completely developed model of timing. It was originally developed by behavioral psychologists like Gibbon and Church in order to account for animals' timing behavior, which is characterized by the ability to exhibit temporal judgments of a wide range of durations, as in the case of time-based schedules of reinforcement.

SET postulates an internal clock, a memory store, and a decision mechanism. The clock itself consists of a pacemaker, a switch, and an accumulator. The pacemaker produces pulses at regular intervals. The switch acts as a gate to the pulses and either passes them or blocks them from arriving at the accumulator, in which the pulses are counted. The operation of the switch can start and stop the timing of an event. Because the pacemaker produces pulses at a regular pace, the animal's internal clock measures time along a scale that is linear with objective time, and perceived duration is a monotonic function of the total number of pulses that were counted in the accumulator.

The two major properties of scalar timing are

1. mean accuracy, which implies that mean measures of time behavior vary linearly with respective objective time intervals, and
2. scalar property of variance, which implies that timing sensitivity remains constant as duration timed vary. This property can be considered to be a form of Weber's law.

Indeed, it was found that animal timing behavior reflects these properties.

Recently, some researchers, like Wearden, found evidence for both scalar properties in human adults and in children. The internal clock notion can also provide an explanation for the auditory modality dominance over the visual modality in temporal processing. It was assumed that the internal clock is running faster for auditory than for visual stimuli, and as a result more pulses are accumulated for similar objective durations in the auditory accumulator, and for this reason subjective time is perceived as longer in the auditory modality.

Cognitive Models of Retrospective Time Judgments

Most models of retrospective duration judgments are cognitive ones and do not incorporate a notion of an internal clock. These models are confined to memory processes. The basic idea behind such models is that retrospective duration judgment relies on retrieval of information, believed to represent the target interval, from memory. The models differ in the definition of the nature of that information, but all of them assume that retrospective duration judgments are a function of the amount of relevant information that was successfully retrieved. While Ornstein's storage size model does not specify the type of information, the contextual change model (Block) claims that estimates of durations are based on the number of changes observed during an interval, or in Fraisse's words, "Psychological duration is composed of psychological changes." The model assumes that alternating cognitive operations increases the sense of subjectively experienced change and in consequence increases the subjective experience of duration. An elaboration of the contextual change model is the segmentation model introduced by Poynter. The assumption here is that contextual changes are coded as significant markers that segment experience and provide subjective referents for the estimation of the passage of time. As a result, the more an interval is segmented by meaningful stimuli, the more its retrospective duration estimates increase.

The weakness of cognitive models of retrospective duration judgment without an internal clock is rooted in its inability to provide an explanation for empirical findings, which show that under constant conditions, retrospective duration estimates are linearly correlated with objective durations. Note that even a completely "empty" interval will not be retrospectively estimated as a "duration-less" interval. In order to account for this property of retrospective duration estimates, Zakay suggested that retrospective duration experiences reflect some sort of an integration between the output of the memory retrieval process with the output of some internal clock mechanism.

Cognitive Models of Prospective Duration Judgment

Under prospective conditions, a person may intentionally encode temporal information as an integral part of the experience of the time period. Due to this characteristic, most models are relying on some sort of an attentional process in order to account for prospective duration judgments.

Models that do not assume the existence of an internal clock posit the existence of a cognitive counter that may be viewed as a processor of temporal information. The counter is incremented as a function of the amount of temporal information being processed, which depends on the amount of attentional resources allocated to it. The more attentional resources allocated for timing, the more units of temporal information are being processed and the higher the experience of prospective duration will be. Because timing competes constantly with current nontemporal tasks for attentional resources, the end result is that when one has to prospectively judge the duration of an interval during which an easy nontemporal task has to be performed, the prospective duration estimate will be higher as compared with a similar interval during which the performance of a difficult nontemporal task is required (see Time, Illusion of). The weakness of attentional models without an internal clock is that the definition of temporal information and the meaning of allocating attentional resources for temporal information processing are vague and unclear. These models are also unable to provide strong support for scalar properties of prospective duration judgments. In order to cure this situation, Zakay and Block introduced the attentional gate model (AGM), which is an elaboration of SET.

What is added to the components of SET is an attentional gate, which is a unit that enables more pulses from the pacemaker to pass through to the counter when more attentional resources are allocated for timing and that reduces the number of passing pulses when the amount of attentional resources is reduced. Thus, according to the AGM, allocating attention for temporal information processing means opening the attentional gate wider, and temporal information processing consists of accumulating and counting the number of pulses emitted by the pacemaker.

Thus, the AGM provides an explanation for scalar properties of prospective duration judgments while enabling us to take an evolutionary perspective on the development of timing mechanisms in humans.

Conclusions

It can be concluded that time perception in humans is a complex cognitive activity rather than a real perceptual process, except for very brief durations of less than 1 second. Subjective time in the context of intervals longer than 1 second can be understood only by taking into account complex interactions among all the relevant contextual factors in both the internal and in the external environments within which duration is being judged.

At the moment it seems that models that incorporate the notion of an internal clock poses better explanatory power regarding the variety of timing phenomena, in both animals and humans, as compared with models without an internal clock.

It is plausible, however, that models based on brain mechanisms that do not operate in a clock-like manner will be able, in the future, to surpass the former type of models and will have higher explanatory power.

Dan Zakay

See also Cognition; Consciousness; Memory; Psychology and Time; Time, Phenomenology of; Time, Subjective Flow of

Further Readings

Block, R. A. (Ed.). (1990). *Cognitive models of psychological time.* Hillsdale, NJ: Lawrence Erlbaum.

Grondin, S. (2001). From physical time to the first and second moments of psychological time. *Psychological Bulletin, 127*(1), 22–44.

Wearden, J. H. (1991). Do humans possess an internal clock with scalar timing properties? *Learning and Motivation, 22,* 59–83.

Zakay, D. (2005). Attention and duration judgment. *Psychologie Bulletin Francaise, 50,* 65–79.

Zakay, D., & Block, R. A. (1997). Temporal cognition. *Current Direction in Psychological Science, 6,* 12–16.

Permian Extinction

After more than 100 million years of relative stability during the Carboniferous and the Permian eras, this last period ended 251 million years ago with the largest extinction event in the Earth's history. This biotic crisis is known in paleontology as the Permian-Triassic (P-T) boundary extinction event, sometimes popularly called the Great Dying. It was more devastating than the much more famous K-T boundary extinction event, when the dinosaurs were extinguished. It has been estimated that as many as 52% of families and 90% to 95% of species were lost, far more than were lost in the K-T extinction, in which 11% of families and 75% to 80% of species were extinguished. Some authors have considered that perhaps 99.5% of individuals died as a result of the event. The primary marine and terrestrial victims included the fusulinid foraminifera, trilobites, rugose and tabulate corals, blastoid echinoderms, acanthodians, placoderms, and pelycosaurs, which did not survive beyond the P-T boundary. Other groups that were substantially reduced include the bryozoans, brachiopods, nautiloids, ammonites, sharks, bony fish, crinoids, eurypterid arthropods, ostracodes, and echinoderms. Terrestrial fauna affected included insects, amphibians, reptiles, as well as the dominant terrestrial group, the therapsids (mammal-like reptiles).

During the Carboniferous and Permian, life flourished with crinoids, nautiloids, and ammonites. Corals and fishes dominated the oceans, and amphibians and reptiles progressively invaded the terrestrial environment. This scenario changed in the end of the Permian due to causes that still are under debate. Many causes have been proposed, including meteorite impacts, volcanic activity, glaciations, and fluctuations in sea level. It is known that the formation of the supercontinent Pangea occurred in the Permian, collecting all the earth's major landmasses; that it extended from the North to South poles, and that it caused an effect on ocean currents. These large continental landmasses created climates with extreme variations of heat and cold (continental climates), and the deserts were widespread on Pangea. One of the first scenarios proposed for explaining the Late Permian extinctions was the reduction of shallow continental shelves as a result of the formation of this supercontinent. Such reduction would cause an ecological competition for space, acting as an agent for extinction. In fact, it is suggested that the marine environment was more affected than the terrestrial one, estimating that more than 95% of marine species and only 70% of land species became extinguished. Although this is a viable hypothesis, it is known as the formation of Pangea and the putative destruction of the continental shelves occurred in the Early and Middle Permian—that is, unrelated to the Late Permian mass extinction.

A second possible mechanism for the Permian extinction was severe climatic fluctuations produced by concurrent glaciation events on the North and South poles, and subsequent sea level changes. There is sedimentological evidence of significant cooling and drying in temperate latitudes, such as thick sequences of dune sands and evaporites, and prominent glaciation in the polar latitudes, such as glacial tillites.

The hypothesis for the Permian extinction most broadly accepted by paleontologists posits an increase in volcanic activity. There is abundant evidence that massive flood basalts from magma output contributed to rapid climatic turnovers and environmental stress. A massive eruptive event spanning the Permian-Triassic transition, about 252 to 250 million years ago, formed the famous Siberian Traps, a large igneous province in Siberia that covered over 200,000 square kilometers. Extensive pyroclastic deposits suggest that numerous large explosive eruptions occurred during or before the eruptions of basaltic lavas. The combination of a worldwide ash cloud and sulphates in the atmosphere might have initiated sudden climatic changes. Dust clouds and acid rain might have disrupted photosynthesis and caused the collapse of the food chains, triggering the P-T mass extinction. Later, the carbon dioxide emitted by the Siberian Traps eruptions caused the possibly cyclical climatic warming (greenhouse effect).

The main challenge to this hypothesis is the need to prove that the emissions of dust and aerosols were enough to explain the extinction event. Estimations suggest that the Siberian Traps eruptions occurred within a period of no less than 200,000 years, doubling the atmosphere's carbon dioxide content and raising global temperatures by 1.5° C to 4.5° C. This seems to be insufficient to explain the P-T extinction, but the greenhouse effect might have exponentially increased due to the release of methane from oceanic methane hydrates trapped in deep-sea sediments. Carbon isotopic analyses suggest giant methane hydrate gasification across the P-T boundary, and oxygen isotopic analyses indicate that global temperatures increased by about 6 °C near the equator and therefore by more at higher latitudes. Methane is a greenhouse gas about 62 times as powerful as carbon dioxide. Because the stability of the methane hydrates depends on temperature, it is possible that a light deep-sea warming caused a giant transfer of methane from oceanic hydrates to the atmosphere, increasing the greenhouse effect and triggering the P-T extinction event.

There are questions as to the velocity of the extinctions during the Late Permian event, because some specialists consider that those extinctions were compatible with a more gradual mass extinction model and with the gradual volcanic theories. However, other studies indicate that the extinctions occurred very abruptly, consistent with a catastrophic, possibly extraterrestrial, cause. These data suggest that an impact event (asteroidal or cometary) accompanied the P-T extinction event, as was the case for the K-T boundary event. P-T boundary impact evidence has been reported, including chondritic fragments in Antarctica, shocked quartz, fullerenes trapping extraterrestrial noble gases, and several potential impact craters: the 120-kilometer-diameter Woodleigh crater (western Australia), the 250-kilometer-diameter Bedout crater (northeastern coast of Australia), and even the giant 500-kilometer-diameter Wilkes Land crater (Wilkes Land, Antarctica). It has been suggested that the large-scale volcanism in the Siberian Traps was triggered by some of these impacts. Nevertheless, for all proposed craters, the size, impact origin, and precise age of the impacting object have not been yet completely demonstrated.

Therefore, the real initial cause for the Permian mass extinction event is under debate. At present, the most broadly accepted hypothesis considers a multicausal scenario including climatic cycles between glacial and greenhouse conditions, volcanic eruptions, dissociations of methane hydrate, and probable meteoritic impacts.

José Antonio Arz

See also Armageddon; Catastrophism; Extinction; Extinction and Evolution; Extinctions, Mass; Fossil Record; Geology; Glaciers; Global Warming; K-T Boundary; Meteors and Meteorites; Paleontology; Pangea; Uniformitarianism

Further Readings

Becker, L., Poreda, R. J., Basu, A. R., Pope, K. O., Harrison, T. M., Nicholson, C., et al. (2004). Bedout: A possible end-Permian impact crater offshore of northwestern Australia. *Science, 304,* 1469–1476.

Erwin, D. H. (1993). *The great Paleozoic crisis: Life and death in the Permian.* New York: Columbia University Press.

Ward, P. D., Botha, J., Buick, R., De Kock, M. O., Erwin, D. H., Garrison, G. H., et al. (2005). Abrupt and gradual extinction among Late Permian land vertebrates in the Karoo Basin, South Africa." *Science, 307,* 709–713.

Petrarch, Francesco (1304–1374)

Francesco Petrarch (Petracco) was an Italian poet and scholar widely recognized as the "father of humanism." He revived European interest in the knowledge of antiquity through his writings and collection of ancient texts.

Petrarch marks a transition in time from the Middle Ages to the Renaissance. Deeply critical of the neglect that ancient texts received in Europe during the Middle Ages, he sought to personally collect and translate ancient writings, visiting monasteries and churches around Europe. Were it not for his work, the Latin writing of ancient historians such as Cicero might be largely unknown today. Petrarch thus preserved the historical record for future generations. He referred to the centuries after the fall of Rome as the Dark Ages and personally laid the foundation for the rebirth of learning now known as the Renaissance.

Petrarch was born in Arezzo, Italy, on July 20, 1304. His family moved to Avignon in 1309 in support of Pope Clement V and the Avignon papacy. Petrarch studied at Montpellier and Bologna where he developed an interest in Latin literature. Following his studies he held various clerical posts and devoted much time to writing. His first major work, *Africa,* is a Latin epic about the Roman general Scipio Africanus. Petrarch considered this his greatest work, revising it throughout his life. His other Latin works include *De Contemptu Mundi,* an imaginary dialogue between the author and Saint Augustine, and *Itinerarium* (1358), a guide to the Holy Land. Petrarch saw no contradiction between humanism and faith, expressing his own religious faith in *De Vita Solitaria,* in praise of monastic life.

Petrarch wrote hundreds of poems in Italian. Most of these are compiled in his famous *Canzioniere,* a book of songs. In these poems, which consist primarily of sonnets and odes, Petrarch expresses his devotion to a beloved woman named Laura. He pursued Laura until her death and afterward wrote of her as a guide to God. Petrarch achieved great fame with his *Canzioniere.* In 1341 he was crowned as poet laureate in Rome. This tribute is often cited as marking the transition to the beginning of the Renaissance period, as Petrarch was the first poet in centuries to have received the honor. He traveled widely throughout Europe on diplomatic missions, befriending both Dante Alighieri, author of the *Divine Comedy,* and Giovanni Boccaccio, author of the *Decameron.* Together with the writings of these two prominent authors, Petrarch's writing helped to render the Tuscan dialect as the standard Italian language. He also maintained a wide correspondence, exchanging numerous letters with scholars around Europe. By his role in initiating the Italian Renaissance, Petrarch set in motion a series of revolutions over time that changed the course of world history. He has often been referred to as the first modern man.

Petrarch died on July 19, 1374, a day short of his 70th birthday. He is buried in Padua.

James P. Bonanno

See also Alighieri, Dante; Augustine of Hippo, Saint; Christianity; Humanism; Poetry

Further Readings

Bergin, T. G. (1970). *Petrarch.* New York: Twayne.

Bishop, M. (1963). *Petrarch and his world.* Bloomington: Indiana University Press.

Philo Judeaus (c. 20 BCE–c. 50 CE)

Philo Judeaus, also known as Philo of Alexandria, was a Jewish philosopher born in Hellenic Alexandria, Egypt. His writings are a unique blend of Greek philosophy and Jewish teachings and are the only surviving manuscripts from the culture of Hellenistic Judaism. Philo's work reflects a deep concern with time and the meaning of life.

Philo's writing gives much insight into the experience of the Jews within the Roman world. He was a contemporary of Jesus of Nazareth but makes no mention of Jesus in his work. Philo does discuss Pontius Pilate, the Roman governor of Judea, as well as the Roman emperors Augustus, Tiberius, Gaius Caligula, and Claudius. Around 40 CE Philo was chosen by the Jews of Alexandria to lead a delegation to Rome to protest injustices committed against them. Philo was highly regarded within his community because of the wisdom and knowledge, as expressed in his extensive philosophical writings.

Little is known about the private life of Philo. Scholars believe he was born around 20 BCE to a wealthy and influential family in Alexandria. He later wrote negatively about affluence. Philo most likely received a traditional Jewish education as well as schooling in the writings of the Greeks. His writing shows the influences of Plato, Aristotle, and the philosophies of stoicism and cynicism. Philo's work can be divided into three general categories: (1) discussions of Jewish law, (2) popular works, and (3) philosophical essays. The discussions of Jewish law include Philo's *Allegorical Commentary on Genesis,* an interpretation of the Ten Commandments and the lives of the prophets. Popular works include the *Life of Moses,* intended for a wider audience. Philosophical essays consist of treatises on a variety of issues, such as *On Providence* and *On Animals.* Philo believed that the Torah contains both literal and allegorical meaning.

The Temple of Jerusalem still stood during Philo's lifetime and had great meaning to him. He made at least one pilgrimage there. He believed that Gentiles could not be excluded from Judaism and that Jewish teachings had universal application. Philo never departed from his strongly held Jewish beliefs, and he often serves as a bridge between the ideas of the Jews and the Greeks. Clearly the teachings of both the Jews and the Greeks have had a profound impact on the development of knowledge over time. Both schools of thought deal with the nature of humankind and its place in the universe. Philo's work stands as the most important link between the two.

The Jewish historian Josephus wrote an account of the delegation to Rome led by Philo. The emperor Caligula had ordered statues of himself as a god erected in the Jewish temples of Alexandria. The Jews naturally viewed this as a deliberate provocation. Philo met with Caligula directly, but the two did not find common ground. Scholars place the date of Philo's death around 50 CE.

James P. Bonanno

See also Christianity; Egypt, Ancient; Judaism; Law; Rome, Ancient

Further Readings

Bentwich, N. (1910). *Philo-Judaeus of Alexandria.* Philadelphia: Jewish Publication Society of America.
Sandmel, S. (1979). *Philo of Alexandria: An introduction.* New York: Oxford University Press.
Williamson, R. (1989). *Jews in the Hellenistic world: Philo.* Cambridge, UK: Cambridge University Press.

Philoponus and Simplicius

The beginning or the eternity of the world and infinity or finitude of time is a central topic in the philosophy of late antiquity, especially in the debate between Christians and pagans. This quarrel started for the first time in the Neoplatonic school of Alexandria in the 6th century CE between John Philoponus and Simplicius, who were the philosophically most talented pupils of Ammonius Hermeiou. Simplicius preserved the orthodox Neoplatonic doctrine (Ammonius and his master Proclus always held to the eternity of the world), whereas the Christian Philoponus opposed this view. It is astonishing that the grammarian Philoponus (he called himself John the Grammarian and edited most of Ammonius's lectures on Aristotle's writings) argued without Christian presuppositions and personal disparagement; Simplicius, however, usually a very modest and well-educated philosopher, very rudely called Philoponus's arguments "rubbish" and accused him of "bragging and contentiousness." Obviously, they had never met personally (most probably, Simplicius had been working in Athens long before 529 CE, when the academy was closed by Justinian; Philoponus apparently never left Alexandria). Philoponus argued against the eternity of the world in his commentaries on Aristotle's *Physics* (probably written in 517 CE) and *Meteorology,* then in *On the Eternity of the World, Against Proclus* (*De aeternitate mundi contra Proclum,* written in 529 CE; this treatise refutes 18 arguments from a lost treatise written by Proclus about the eternity of the world). The writing *Against Aristotle* (*Contra Aristotelem*), which can be dated between approximately 530 CE and 534 CE, is preserved only in fragments. The first five books contained Philoponus's criticism of Aristotle's theory of the fifth element, the sixth book his criticism of Aristotle's theory of eternal movement, and at least two further books contained reflections about a Christian theory of divine creation. Simplicius's answer to Philoponus can be found mainly in his commentary on Aristotle's *De caelo I* and *Physics VIII.*

Philoponus attacks the eternity of the world by demonstrating inner contradictions in Aristotle's theory of time and eternity and by refuting Aristotle through Aristotle himself. One argument goes as follows: The eternity of the world is incompatible with Aristotle's definition of movement, because movement is the act of what is movable in potency, that is, the movable in potency exists prior to the movement. This implies that the eternal movements (e.g., the heavens' circular movements) have some movable in potency prior to them (e.g., the heavens), if the movable in potency is always anterior to the movement. Philoponus concludes that the Aristotelian definition of movement is not universal. Simplicius defends the universality of Aristotle's definition of movement by making a difference between infinite and finite movement: In the case of finite movement, the movable is still there, if the movement has finished; in the case of infinite, eternal movement, only one state of movement is prior to another state. For instance, if the sun is in Aries, then it is the movable, which is potentially in Taurus.

Further, if any first movement is excluded, Philoponus argues that all present movements become unintelligible, because every movement presupposes an infinite number of previous movements; we could not avoid a *regressus in infinitum*. Moreover, all present movements are added to those of the past; that leads to the evidently absurd notion of an infinite constantly increasing. The same problem arises concerning the future: If time and movement infinitely continue in the future, there would be an infinite body with infinite power. But that is not possible, so the world could not exist indefinitely in the future. The core of this argument is Philoponus's attack on Aristotle's notion of infinity: Aristotle contends that infinity is merely potential and never actual. For if you divide a line or a duration, you can actually mark off only a finite number of divisions, either physically or mentally. There is only a potential infinity of divisions, inasmuch as infinity exists through a process of dividing one point (or one now) after another; it is the same with the infinity of numbers.

Philoponus attacks this notion of infinity by several arguments. First, the universe must have had a beginning, or it would by now have traversed an actual infinity of years. The second argument is this: If you suppose an actual infinite number of years up to this year, next year will be an infinity plus one year. So the infinity is increasing. Simplicius says Aristotle had already anticipated Philoponus's objections, for he had pointed out that the past years have finished, so you do not get an actual infinity of them existing. That implies that time and movement are not an actually infinite quantity, but their infinity means there is a possibility of transcending every given limitation. The most fundamental difference between Philoponus and Simplicius is this: Whereas, Simplicius's infinite time is a circular indefinite repetition of finite times, Philoponus's notion of time is linear. However, the rejection of Philoponus's argument appears difficult in the context of Aristotle's philosophy of nature if you want to preserve the singularity of the individual parts of time, for instance, days or hours.

Philoponus's arguments against the eternity of the world were repeated by Bonaventure in the 13th century, after the arguments had been elaborated by Islamic philosophers. Finally, the dispute between Philoponus and Simplicius has an equivalent in Kant's doctrine of the "antinomy of pure reason" in his *Critique of Pure Reason,* especially the "first conflict of transcendental ideas." One branch of the antinomy is equivalent to Philoponus's argument (in Kant's words, "The world has a beginning in time"); this and the opposite argument ("the world has no beginning in time") is equivalent to Simplicius. Probably, there is not any "immediate effective historical connection" between the Alexandrian school quarrel and Kant's cosmological antinomy, but it shows that in this quarrel, "Greek thinking comes to the limits of its own presuppositions."

Michael Schramm

See also Aristotle; Christianity; Eternity; Infinity; Kant, Immanuel; Time, Cyclical; Time, Linear

Further Readings

Sorabji, R. (1987). Infinity and the creation. In R. Sorabji (Ed.), *Philoponus and the rejection of Aristotelian science* (pp. 164–178). London: Duckworth.

Verbeke, G. (1982). Some later Neoplatonic views on divine creation and the eternity of the world. In D. O'Meara (Ed.), *Neoplatonism and Christian thought* (pp. 45–53). Norfolk, VA: International Society for Neoplatonic Studies.

Philosopher's Stone

The philosopher's stone is a substance, tincture, or item created through alchemy that is supposed to change base metals into more precious ones and has the ability to extend one's life, cure sickness, and even grant immortality. Western traditions of alchemy are more closely associated with the concept of the philosopher's stone; the Eastern traditions of alchemy were more closely associated with the concept of the elixir of life.

Europeans probably discovered Islamic alchemy following the influence brought about by the Crusades. Islamic alchemy has its roots in Alexandria, which combined various traditions of both Greece and Egypt. The Western traditions were much more involved with the idea of changing base metals into higher or noble metals (gold or silver from lead) with longevity as a secondary effect. That is not to say that there was no interest in longevity, but that wealth was the primary motivator for many alchemists in Western Europe.

There were some European alchemists, however, who pursued the aspects of longevity as well as those of healing. Paracelsus (1493–1541) was both a physician and alchemist, using alchemy to cure the sick and pursuing the art in a different manner than others before him. He was one of the first to separate the pursuit of transmuting metals (*alchemia transmutatoria*) from that of healing (*alchemia medica*). Paracelsus is also considered the founder of toxicology. He died at the age of 48, possibly of cancer, somewhat young for one devoted to pursuing longevity and healing.

Another well-known alchemist associated with the philosopher's stone is Nicolas Flamel (1330–1418). He began a career as a scrivener but found a small book on alchemy that he wanted to understand and began his career as an alchemist. Several books are attributed to him and describe his pursuit of the philosopher's stone, but many scholars now believe that some of these works were written later by others to lend legitimacy to the field of alchemy and the pursuit of longevity. There are myths surrounding the death of Flamel and his wife; notably, the legend that he did not die but faked his death and is still living today on his discovery of the philosopher's stone. Again, these legends are attributed to those who want to add to the legitimacy of the field of alchemy.

As with the Eastern tradition of alchemy, the Western tradition became more and more philosophical or transcendental. The idea that the transmutation of a human was less a physical process and more of a spiritual exercise, and not achievable through any physical process, became important as the role of science became more prevalent. Scientists continued to make discoveries regarding the immutability of metals and, by extension, humans also could not physically transmute. Therefore, they had to do so internally, through mysticism, philosophy, or some other transcendental means.

In one respect, Nicolas Flamel and others have achieved a kind of immortality. As seen in some of today's popular media (e.g., the *Harry Potter* movies, and the *Da Vinci Code* novel by Dan Brown), Flamel has lived on, although not in the way he intended.

Timothy Binga

See also Elixir of Life; Longevity; Paracelsus; Shangri-La, Myth of; Youth, Fountain of

Further Readings

Franklyn, J. (1935). *A survey of the occult.* London: Arthur Barker.
Holmyard, E. J. (1957). *Alchemy.* Baltimore, MD: Penguin Books.
Thorndike, L. (1923–1958). *A history of magic and experimental science.* New York: Columbia University Press.

PHILOSOPHY, PROCESS

See WHITEHEAD, ALFRED NORTH

PHI PHENOMENON

The phi phenomenon is a type of apparent movement or an illusion of movement. It is also known as *stroboscopic movement.* In fact the phi phenomenon consists of three types of apparent movement: beta, gamma, and delta movements. For reasons of space, we shall elaborate only on the first, the beta movement. As in the case of the tau and kappa illusions, the phi phenomenon illustrates the complex nature of the interrelations between the perceptions of movement, distance, and time.

The apparent movement occurs when two physically distinct stimuli—say, two light points—are alternately displayed at a frequency that exceeds a certain threshold value. Under such conditions, a continuous movement from one stimulus to the other is perceived. The apparent movement's characteristics depend on a number of factors: the physical spatial distance between the two stimuli; the physical intensity of the stimuli, which determines the amount of energy reaching the relevant sensory apparatus in the perceiver; and the duration or time span between appearance of one stimulus and the next. If the distance and intensity factors are kept constant, then when the time span between the first stimulus and the second is approximately 20 milliseconds, this will result in a perceptual experience of simultaneity. When the time span is increased to approximately 60 milliseconds, this will result in a perception of continuous movement between the two stimuli. At approximately 200 milliseconds, the resulting perception will be of one stimulus followed by the next, without any movement between them.

By 1915, the psychologist A. Korte had defined the conditions for apparent movement as follows:

- If the intensity of stimuli is kept constant, then the time span needed for optimal apparent movement changes in direct proportion to the changes in distance between the stimuli.
- If the time span between stimuli is kept constant, then the required distance between them in order to generate optimal apparent movement changes in direct proportion to stimuli intensity.
- If the distance between stimuli is kept constant, then the stimulus intensity required for optimal apparent movement is inversely proportionate to the time span between the first stimulus and the second one.

Some researchers, however, have questioned the relevance of light intensity—in the visual case—for apparent movement.

Beta movement is a continuous apparent movement between two, closely adjacent static light points that alternate lighting up. Continuous movement is perceived when the frequency at which the lights go on and off exceeds a certain threshold value, which depends on the distance between the two light points. Some researchers believe that light intensity is a significant factor here as well.

Beta movement is used, for instance, on billboards that are actually made up out of tiny static light points: Each couple of adjacent light points switches on and off at an appropriate frequency and thus the flowing effect we are all familiar with is created.

Cinema is the ultimate application of the beta phenomenon. The audience is presented with projections of static images at a frequency that ranges between 12 and 24 images per second, and this is what creates the experience of continuous movement.

Another manifestation of beta movement is its tactile variant: This occurs when an apparent sense of movement is experienced between two adjacent locations on the skin when they receive alternating stimulations. Here, too, the felt quality of the resulting apparent movement will depend on factors of distance between the two locations, the time span between one stimulus and the next, and—according to some researchers—on stimulus intensity. The existence of the tactile phenomenon indicates that the phi phenomenon is a fundamental physical principle that is not specific to one sensory modality.

The first to describe the phi phenomenon was Max Wertheimer (1912), a Gestalt psychologist. The phenomenon served as early empirical evidence for Gestaltist psychologists' claim that perceptual experience cannot be explained by means of a one-to-one relation between proximal stimulus and sensory process. There is no fit, in the case of the phi phenomenon, between the perceived movement and the external physical stimuli, which are actually static. In the visual case, even though there is no motion of a retinal image, there is a perceptual experience of movement. And so, the basic argument of the Gestaltists is that a perceptual experience does not constitute a simple mapping of the external stimulus. Perceptual processes, in fact, reflect rules of perceptual organization that the perceptual system imposes on the external stimulus.

The phi phenomenon has not been fully and exactly explained to date. Explanations relating to the visual variant refer to the persistence of vision and to the existence of a degree of temporal overlap in the activity of adjacent receptors on the retina.

Persistence of vision occurs as a retinal image continues to exist for one sixteenth of a second after the disappearance of an external stimulus. Hence, if a second stimulus occurs, creating a retinal image on an adjacent receptor within that time span (i.e., within less than one sixteenth of a second), what emerges is a temporal overlap between the activities of the two receptors. This then leads to the emergence of the perception of apparent movement.

Dan Zakay

See also Film and Photography; Memory; Perception; Psychology and Time; Time, Illusion of

Further Readings

Sekuler, T. R. (1996). Motion perception: A modern view of Wertheimer's 1912 monograph. *Perception, 25,* 1243–1258.

Steinman, R. M., Zygmunt, P., & Pizlo, F. J. (2000). Phi is not beta, and why Wertheimer's discovery launched the gestalt revolution. *Vision Research, 40,* 2257–2264.

Photography, Time-Lapse

The purpose of using time-lapse photography is to speed up events that normally take considerable time. A simple example is the opening of a flower. In a sense, it is just the opposite of the process used in creating slow-motion pictures. Both processes involve a technique for intentionally altering a normal duration of time in order to learn more about the subject by closer examination. But, whereas slow-motion focuses only on the specific subject being filmed at the time, time-lapse photography can record processes that in real time take or months or years to be completed. With both techniques, humans are able to effectively manipulate time for their own practical or artistic purposes.

In time-lapse photography, the photographer takes a sequence of pictures at a slower rate than the standard 24 frames per second used by the movie industry. The special skills needed to perform time-lapse photography include being able to discern how much time should be allowed to lapse between each photograph being taken, so as to record discernable changes that are occurring. Time intervals may need to be adjusted depending on the particular changes the subject is undergoing, but the process will usually involve taking individual pictures over 24-hour periods for as long as is needed to record the entire process. The effects of both temperature and light must also always be considered.

John Ott is generally considered a pioneer in time-lapse photography. What began as a hobby in his high school days in the late 1920s developed into a career in which his skills became influential. Because this type of photography was relatively unexplored, he had to use whatever equipment was available and to devise improved equipment himself until he was satisfied that he was photographing subjects in their most realistic setting. Starting with a Brownie camera and a timer made from kitchen clock works, he eventually built an automatic plastic greenhouse. He developed the ability to take microscopic pictures, as well as a process known as "total spectrum lighting."

Ott witnessed growing interest in uses of time-lapse photography beyond entertainment and advertising, such as applications in horticulture and medicine. He received numerous honors, including an honorary degree from Loyola University, and eventually became a faculty member in the Department of Horticulture at Michigan State University. He worked as a researcher for various companies, including Quaker Oats and General Electric.

In working with Walt Disney on the film *Secrets of Life,* which was to include a segment on the growth of an apple, Ott discovered that ordinary glass would not transmit all the ultraviolet and shorter wavelengths needed to accurately record the normal process. He was finally able to complete the assignment by substituting special plastic materials.

In his film *Our Changing World,* he wanted to depict the orderly progressions of earth and the creation of life and its development. The power of the single cell had always impressed him. He noted that humankind has been on earth a much shorter time than plants and that plants and animals tend to respond similarly to light.

Though Ott had said that his work was often slow and discouraging, his pioneering efforts were very impressive. His advances encouraged others to devise and use more sophisticated techniques and equipment. Those working with the process continued to emphasize the importance of correct lighting and determining the most appropriate time intervals between pictures.

Time-lapse photography has been used in many scientific studies, such as research on glacier motion in Glacier National Park, studies of sleep patterns, studies of slow-acting geologic processes in natural settings, studies of movement in plants, and studies of weather phenomena. In addition to exploring the natural world, there are also many other potential applications of time-lapse photography with respect to human activities, such as monitoring business projects and procedures, and studying the urban environment and urban renewal. An example of a successful project related to the urban landscape can be found in the work of Camilio Jose Vergara, a photographer, sociologist, and ethnographer. For 30 years he recorded the changes in inner-city neighborhoods in New York, Newark, Chicago, Detroit, and Los Angeles.

Perhaps one of the most dramatic uses has occurred at Ground Zero, the site of the World Trade Center disaster. Documentary filmmaker Jim Whitaker initiated Project Rebirth in the spring of 2002, with the goal of recording what was happening in this area. As the project continued, cameras were installed at all four corners and at ground level. Some results of the ongoing process are available on the Project Rebirth Web site. The process involves taking one frame every 5 minutes for 7 days a week; the final result will be viewable within a span of 20 minutes.

Betty A. Gard

See also Film and Photography; Perception; Time, Illusion of

Further Readings

Abeid, J., & Arditi, D. (2002). Time-lapse digital photography applied to project management. *Journal of Construction Engineering and Management, 128*(6), 530–535.

Kinsman, E. M. (2006). *The time-lapse photography FAQ: An introduction to time-lapse photography.* Retrieved June 7, 2007, from http://www.sciencephotography.com/how2d02.shtml

Ott, J. (1958). *My ivory cellar: The story of time-lapse photography* (3rd ed.). Winnetka, IL: Twentieth Century Press.

PHOTOSYNTHESIS

Photosynthesis is the process by which organisms convert light energy into chemical energy in the form of carbohydrates. The inputs of the chemical reaction are light energy, carbon dioxide, and water; the outputs are carbohydrates and oxygen.

The overall reaction, which has many intermediate steps, is written as follows:

$$\text{Light energy} + CO_2 + H_2O => (CH_2O) + O_2$$

The sun is the main source of light for the process. Photosynthetic organisms break down the bonds in the resulting carbohydrates to obtain the necessary energy for life-sustaining functions. Plants, algae, and some bacteria are the known organisms capable of photosynthetic activity. They all produce pigments, specialized proteins that capture energy when exposed to light. Numerous photosynthetic organisms have developed adaptations to regulate the timing of photosynthesis. By lengthening the time spent in photosynthesis per day or changing the time of day when photosynthesis occurs, organisms improve the efficiency of photosynthesis and their ability to survive.

Locations and Functions of Pigments

The location of pigments in photosynthetic organisms depends on whether the organism is prokaryotic (does not have a cell nucleus or organelles) or eukaryotic (has cell nucleus and organelles). The prokaryote *Halobacterium halobium* and other photosynthetic bacteria have pigments embedded in their cell membranes. Prokaryotic blue-green alga has pigment proteins inserted in a more complicated system of stacked membranes interior to the cell wall. Higher plants, such as needle-leaved plants and flowering plants, have a specialized organelle for photosynthesis within the plant cell, the chloroplast. The double-membraned organelle contains photosynthetic membranes that are embedded most commonly with the pigments, chlorophyll-a and chlorophyll-b.

Pigments are essential to photosynthesis, because they can absorb energy from photons, the units of light energy. Each pigment absorbs a characteristic wavelength, which is a stream of photons. For example, chlorophyll-a absorbs wavelengths in the range between 550 and 700 nanometers (nm, 1×10^{-9} meter), and bacteriochlorophyll-a in bacteria absorbs wavelengths between 470 and 750 nanometers.

Pigments efficiently absorb energy because they contain chemical bonds that accommodate fluctuating levels of energy. The characteristic carbon rings in pigments include many double bonds. Carbon atoms joined by double bonds share their electrons; thus the electrons are not strongly attracted to a particular carbon nucleus and move in a loose cloud around the entire molecule. When photons strike a pigment, their energy is accepted by the pigment's electrons, which can easily move from a lower energy level to a higher one in the cloud of electrons. Chlorophyll-a has five carbon rings with a total of 10 double bonds, making it an excellent acceptor of energy from light. The pigment can either donate the energized electrons to other molecules or release the energy from the electrons as longer wavelengths than those the pigment absorbed.

Structures in Photosynthesis

Organisms have structures in their photosynthetic membranes called *reaction centers* and *antennae,* respectively, both of which are necessary for photosynthesis to occur. The reaction center is composed of the unique pigments capable of initiating the chemical reactions of photosynthesis by donating electrons to molecules within cells; the pigments are bacteriochlorophyll-*a* in bacteria and chlorophyll-*a* in algae and plants. Scientists have identified special forms of these chlorophylls that are responsible for the actual work of changing light energy into chemical energy in the reaction centers. The chlorophylls are P870 in bacteria and P700 and P680 in algae and plants, where P stands for pigment and the number refers to an absorption wavelength. However, the specialized chlorophylls cannot absorb enough light energy on their own to drive photosynthesis; they are fed energy by the antennae.

The antenna structure in membranes is the locus of light energy absorption and concentration. It is composed of accessory pigments that generally can absorb shorter wavelengths than P680, P700, and P870 can. Examples of accessory pigments are bacteriochlorophyll-*b* (absorbs 400 nm–1020 nm wavelengths) in purple bacteria and chlorophyll-*b* (absorbs 454 nm–670 nm wavelengths) in higher plants. Accessory pigments capture light energy and then release it to other accessory pigments or chlorophylls in the antennae as longer wavelengths, but these accessory pigments are not capable of donating electrons to other molecules. The accessory pigments pass along longer wavelengths to each other until the waves reach a length that can be absorbed by the specialized chlorophylls in the reaction center.

A substantial number of accessory pigment proteins are needed to feed a reaction center with enough light energy to drive photosynthesis. Over 300 molecules of chlorophyll-*b* are needed to funnel enough light energy to activate one molecule of chlorophyll-*a* in the reaction center of a typical higher plant.

Adaptations in Photosynthesis

Photosynthetic organisms are capable of making photosynthesis more efficient by regulating the time spent in photosynthesis per day or changing the time of day when photosynthesis occurs. Some higher plants can change their leaf position over the course of a day to track the sun's movement. This adaptation allows the plants to increase the number of hours per day spent in direct sunlight and maximum light absorption. Experiments have confirmed that this behavior, called *diaheliotropism,* increases the efficiency of photosynthesis.

Plants that live in hot, dry climates, such as cacti, have developed an adaptation of photosynthesis that allows parts of the process to occur at a different time of day than in the majority of plants. Generally, all steps of photosynthesis occur during daylight, including the intake of carbon dioxide through stomata, which are openings in the leaves of plants. The majority of plants take in carbon dioxide and initially fix the carbon into a compound called 3-phosphoglycerate. However, plants in hot, arid regions lose water at a high rate when the stomata are open, so many have developed crassulacean acid metabolism (CAM) to avoid dehydration. CAM plants open their stomata only at night, initially fix carbon dioxide into malic acid, and then store the acid. During the day, CAM plants close their stomata, break down the malic acid to release the carbon dioxide, and then proceed with photosynthesis. The CAM adaptation makes it possible for plants to withstand long periods of drought.

Erin M. O'Toole

See also Chemical Reactions; Chemistry; Ecology; Global Warming; Seasons, Change of; Trees

Further Readings

Das, V. S. R. (2004). *Photosynthesis: Regulation under varying light regimes.* Enfield, NH: Science Publishers.

Heldt, H.-W. (2005). *Plant biochemistry* (3rd ed.). Burlington, MA: Elsevier Academic Press.

Lawlor, D. W. (2004). *Photosynthesis* (3rd ed.). Oxford, UK: Taylor and Francis.

Phylogeny

A phylogeny is an evolutionary history of an organism or group of organisms; it may be interpreted as a genealogical tree, an ancestor and descendant lineage, or as systematic relationships of form within a classification scheme. Phylogenies are studied principally in the fields of phylogenetics and systematics.

History of Phylogenetics

Phylogeny was discussed in detail by the 19th-century German morphologist Ernst Haeckel, who proposed a biogenetic law (or the law of recapitulation). The biogenetic law states that phylogeny, or the evolutionary history of an organism, is recapitulated through its ontogeny, or the development of an individual organism in embryo. The subsequent rejection of Haeckel's law was a significant move away from using mechanical explanations or causes, such as embryonic development, to explain the relationship between organisms. Haeckel's most significant contribution was that of the phylogenetic tree (*Phylogenetisches Stambaum*), the now universally accepted way to depict genealogical relationships.

A phylogenetic tree may depict hypothetical ancestor-descendant relationships, sometimes called a *transformation series,* between groups of organisms (species, genera, and families) or their characteristics, through time. Such phylogenetic trees have been popular tools of paleontologists who use them to establish so-called ghost lineages between similar-looking fossils throughout the stratigraphic record. Phylogenetic trees were challenged in the early 20th century by the German-speaking systematic morphologists, led by Adolf Naef. The evolutionary relationships that phylogenetic trees were claimed to depict were based on linking similar-looking organisms that overlapped through time, rather than considering relationships of form.

The systematic morphologists considered *homologues* (different manifestations of the same morphological structure) to be a sounder basis for the discovery of relationship than the assembly of ghost lineages. If organisms are related, their characters are homologous, that is, the same; as opposed to analogous, that is, similar but not the same. Naef's trees related organisms only at the terminal branches, rather than depicting hypothetical lineages, with organisms (hypothetical or real) at both the nodes and tips. Homologous organisms belonged to "natural groups or classifications" that share a greater relationship among themselves than they do to any other group.

The rejection of phylogenetic trees and the concomitant support for natural groups was criticized by Anglo American phylogeneticists such as George Gaylord Simpson and Ernst Mayr, who defended the depiction of lineages in phylogenetic trees rather than the discovery of natural groups, which challenged some traditional taxonomic groups. Anglo American phylogenetics, however, changed considerably in the latter half of the 20th century when the work of Willi Hennig, a German entomologist, was translated into English.

Phylogenetic Systematics

Hennig's *Phylogenetic Systematics* attempted to resurrect Haeckel's systematic phylogenetics by reintroducing the causal mechanisms that had been rejected by Adolf Naef. Hennig's phylogenetic systematics combined Haeckel's transformational viewpoint—but at the level of character rather than taxon—with Naef's trees of relationships to form ancestor-descendant schemes of relationship with organisms only at the tips, and character transformations leading from the nodes to the tips. The resulting trees attempted to group homologous organisms into "natural" or monophyletic classifications based on a causal mechanism, thus combining Haeckel's phylogenetic tree with Naef's systematic morphology.

Phylogenetic systematics developed into a numerical method by incorporating the principal notion of *phenetics,* that is, similarity concepts, with a causal mechanism to find optimal trees.

Phylogenetic systematics, later referred to as *cladistics,* underwent a revolution in the work of Gareth Nelson by returning to systematic morphology. Pattern cladistics rejected causal homologies and ancestor-descendant relationships as uninformative and misleading, because they introduced bias into phylogenetics. The pattern cladists, led by Ronald Brady and Gareth Nelson, considered monophyly to indicate "natural groups," which can be used to test existing taxonomies rather than to identify causal relationships (a common ancestor). The resulting diagrams, called cladograms, could represent numerous lineages but only a single classification. Hennig's elimination of paraphyly and its connection made with ancestry by cladists such as Colin Patterson helped to define phylogenetics as a science of classification based on the relationships of form.

Molecular Phylogenetics

Molecular phylogenetics is the study of amino acid or DNA sequences and how they may be related among different organisms. The field has grown exponentially and amassed a significant volume of data. Unlike phylogenetic systematics, molecular phylogenies tend to consist of individual character trees (relationships between organisms based on a single character) and are used to hypothesize recent genealogies in populations as well as ancestor-descendant relationships in species. Despite its popularity, very little theoretical work has been done on the relevance of homology of DNA sequences. Molecular phylogenetics, however, has progressed methodologically and technologically in such issues as alignment of sequences and in mapping the similarity distances in phenetic methods.

Phylogenetic Classification

Phylogenies may be interpreted as explicit evolutionary pathways, natural groups (classifications), or a combination of both. The latter has caused the most controversy in its claim for phylogenetic classifications. Recent debate has focused on defending lineages rather than classifications in taxonomy. A *nonmonophyletic* group (also known as a *paraphyletic* or *polyphyletic* group) is an artificial or incongruous set that shares greater relationship to other groups than to its own. A proposed lineage may be paraphyletic and therefore contradict any given natural classification. Reptiles are an example of a paraphyletic group that exists in name only, not within a natural classification. The defense of paraphyletic groups in classification reflects the battle between the Anglo American paleontologists and systematic morphologists in the early 20th century, during which classification and hypothetical lineages were confused.

Phylogenetic Biogeography

Phylogenies have been used in biogeography (the study of biotic distributions) during three periods: in the late 19th century, with the advent of natural selection as a viable mechanism for species evolution (e.g., Haeckel); in the 1960s, with the onset of Hennig's phylogenetic systematics; and in the late 20th century, with the use of molecular phylogenies. The same method has been used in each of these periods, namely that of proposing a center of origin and drawing the direction of dispersal and/or vicariance events (allopatry) on a phylogenetic tree.

Since the late 19th century, fossils were used to date such events within any given phylogenetic tree. The method is still widely practiced today (i.e., using a molecular clock). The only difference between these periods is the data used. Nineteenth-century phylogeneticists relied on fossils, mid-20th-century phylogeneticists on the morphology of extant taxa, and 21st-century molecular systematists on molecular data.

Malte C. Ebach

See also Cybertaxonomy; Darwin, Charles; DNA; Evolution, Organic; Haeckel, Ernst; Huxley, Thomas Henry

Further Readings

Kitching, I., Forey, P. L., Humphries, C. J., & Williams, D. M. (1998). *Cladistics: The theory and practice of parsimony analysis* (Systematics Association Publications No. 11). Oxford, UK: Oxford University Press.

Nelson, G., & Platnick, N. I. (1981). *Systematics and biogeography: Cladistics and vicariance.* New York: Columbia University Press.

Williams, D. M., & Ebach, M. C. (2008). *Foundations of systematics and biogeography.* New York: Springer.

Piaget, Jean (1896–1980)

Jean Piaget was a Swiss philosopher and psychologist whose principal research interests were in epistemology and developmental psychology. He believed that to understand knowledge, one must look at its psychological origins and how it evolves as children become adults. His research led him to the epistemological stance he deemed *constructivism*—the position that knowledge is constructed from experience over time.

During work in Alfred Binet's lab at the Sorbonne, Piaget noticed that children of the same age consistently made the same mistakes on intelligence tests. Later, after very careful observations of children during which he would ask questions or assign tasks to elicit behaviors that would give him insight, Piaget noted that children were organizing and reorganizing the world as they gained more experience. He concluded that children were not simply imitating or regurgitating what they were told or observed; they were creatively interpreting the world based on their past experiences at a fairly constant rate, which could be organized into stages.

According to Piaget, children proceed with this process of interpretation by constructing and revising gestalt-type schema, which allow for future recognition of patterns that have been experienced. With this view in mind, Piaget conducted experiments to determine specifically how the knowledge of time is constructed in children. His results are outlined primarily in *The Construction of Reality in the Child* (1937) and *The Child's Conception of Time* (1946).

These experiments led Piaget to conclude that children begin with an egocentric conception of time where duration (number of minutes, years, etc.) depends on speed of action—the faster one goes the less time one spends on an action.

Eventually children develop a distinction between duration and succession (past, present, future; before and after), which allows them to see that the flow of time is constant. For Piaget, the fact that children seem to move from special relations constituting the concept of time to the more complex notion of independent time flow showed that space was a more basic concept from which the concept of time is constructed.

Many have criticized Piaget's epistemology and conception of time. J. T. Fraser, a prominent author on time who debated Piaget, held that there must be some intuition of time in children. Later, other prominent authors critiqued Piaget for unwarranted generalizations and other experimental problems. However, his importance to the progression toward understanding time in psychology and philosophy is evident in his influence on such thinkers as Jürgen Habermas, Thomas S. Kuhn, and contemporary constructivist epistemologists, as well as reactions from such prominent thinkers as Noam Chomsky and Hilary Putnam.

Kyle Walker

See also Cognition; Consciousness; Education and Time; Epistemology; Kuhn, Thomas S.; Language; Memory; Psychology and Time; Time, Teaching

Further Readings

Cohen, D. (1983). *Piaget: Critique and reassessment.* New York: St. Martin's Press.

Singer, D. G., & Revenson, T. A. (1997). *A Piaget primer: How a child thinks* (Rev. ed.). Madison, CT: International Universities Press.

Piltdown Man Hoax

In 1912, fragments of a skull and jawbone were found in a gravel pit at Piltdown, a village in East Sussex, England. When assembled, scientists believed the specimen to be the "missing link" between ape and human, providing solid proof of the theory of evolution. Forty years after its discovery, Piltdown man became exposed as the Piltdown hoax, one of the most notorious frauds in the history of science.

The Find

A laborer working in the Piltdown gravel pit in the early 1900s claimed to have found a piece of a skull. He passed it on to Charles Dawson, a local solicitor and well-known amateur archaeologist. Dawson found additional fragments at the site in 1911, and presented them to Sir Arthur Smith Woodward, keeper of geology at the British Museum. Interested in the finds, Woodward returned to the site with Dawson, where they recovered additional skull fragments and half of a lower jawbone. The same pit also produced a few fossil animal bones and a tooth. In December 1912, they presented their reconstructed skull to the Geological Society of London as a new type of early human, *Eoanthropus dawsoni,* or "Dawson's Dawn Man." The bone of the skull was unusually thick and stained with age, implying primitiveness, while having the shape and larger size of a modern braincase. However, the mandible associated with it was far more simian than human. This apparent ape-man found with the bones of extinct mammals in a Pleistocene gravel bed was exciting news for English paleontologists. Until that point, all fossil human remains had been found in various locations on the Continent, especially Germany and France. England could now claim a place on the evolutionary tree even earlier than these other hominids.

Additional finds were made at Piltdown through 1915, including additional animal bones, stone tools, and a second skull (also found by Dawson) 2 miles away from the original site. Interestingly, no more finds were made after Dawson's death in 1916.

The reconstruction of Piltdown man was challenged from its introduction. The hinge joining the jaw to the skull was conveniently missing, causing some experts to doubt that the skull and jaw were from the same individual. Others developed a completely different model from the pieces. In the 1920s, Franz Weidenreich, an anatomist, examined the specimen and reported that it was a modern human cranium and an orangutan jaw with filed teeth. He was correct, but it took 30 years for paleontologists to admit it. As more and more hominid finds were made around the world in the following years, including *Homo erectus* and *Australopithecus, Eoanthropus* was pushed aside.

Not only did it not fit into the increasingly clear evolutionary tree, but also no other specimen was ever found resembling it.

Exposure of the Hoax

Joseph Weiner, an anthropology professor at Oxford University, has been given credit for exposing the hoax. In the early 1950s, he attended a paleontology congress in London. Piltdown man was hardly mentioned once again, for not "fitting in." The possibility of fraud dawned on him. After meticulously gathering evidence, conducting interviews, and using recently developed tests on the bones themselves, he exposed the forgery in 1953. A new dating technique, the fluorine absorption test, was developed to determine age and had been applied to the Piltdown fossils in 1949. The results established that the remains were, in fact, relatively modern, but they were still assumed to be genuine. In 1953, with the fluorine test more advanced, the Piltdown remains were retested. It was determined that the cranium was from the Upper Pleistocene and approximately 50,000 years old, while the mandible and tooth were modern. Another new test devised by American scientists analyzed nitrogen content to determine age and corroborated these results. In 1959, however, the recently discovered carbon-14 dating technique was applied to the bones. The skull was shown to be between 520 and 720 years old, and the jawbone a bit younger.

Eventually it was proven that the Piltdown site had been salted with bones and artifacts from a variety of sources. The hoax had succeeded for 40 years due to a variety of circumstances. The find gave experts evidence supporting a theory they believed to be true at the time. The scientists closest to Piltdown were experts, but not in hominid evolution. In the early 20th century, there were no chemical tests or dating techniques. Analytical tools were primitive by today's standards. At the time of the find, there were no hominid fossils other than the earliest Neanderthal remains for comparison. Finally, the Piltdown bones were kept locked away in the British Museum as valuables, so most scientists wishing to study them had to rely on pictures, sketches, or poor-quality X-rays.

Identity of the Forger

The identity of the perpetrator has never been proven. The reason for the entire hoax is also debated. This hoax was deliberately and systematically carried out over a number of years with no obvious motive. About two dozen suspects have been suggested over the intervening years, and there is plenty of circumstantial evidence implicating several of them.

The most obvious suspect is Dawson himself. He had no formal training but a lot of luck at finding unique artifacts. He was present at Piltdown when all the major finds were made. Once Piltdown was exposed, scientists reexamined his other finds, and 46 objects credited to him turned out to have questionable backgrounds or were outright forgeries. He appears to have appropriated the finds of others as his own, and many of his writings were plagiarized. Most people agree he was involved, but question the presence of an accomplice. Woodward is also suspect. He was Piltdown's strongest supporter and refused to allow some of the simplest scientific tests to be given to the specimens, which would have exposed the forgery immediately. Sir Arthur Conan Doyle, author of the Sherlock Holmes stories, is often presented as a suspect. He was a neighbor of Dawson, an amateur fossil hunter, and a participant in the digs at Piltdown. It has been argued that his novel, *The Lost World,* has clues referring to the hoax. Pierre Teilhard de Chardin has also been accused. He was a Jesuit, a theologian, and an anthropologist. As Dawson's friend, he participated in the work and was present for many of the key discoveries. He had traveled to locations in Africa where some of the frauds originated, and his later recollections of the events at Piltdown were very vague.

The most recent accusations, however, have been against Martin Hinton, zoology curator at the Natural History Museum in London. He worked under Woodward at the time of the hoax and had a public conflict with him over salary. There was also professional rivalry between the two, and Hinton may have perpetrated the hoax to embarrass his colleague. He was known for creating elaborate practical jokes. In the mid-1970s a trunk was found in a loft of the museum with Hinton's initials on the lid. Among other things, there were a variety of bones and teeth stained with chemicals identical to those used on the Piltdown finds. The chemical recipe was apparently created by Hinton and presented in an 1899 scientific paper.

The identity of the culprit and the reasons for creating such an elaborate scheme may never be proven, but there is an important lesson to be learned. The hoax was successful for decades, owing to inconsistent examination and analysis. Once an expert had established the importance of the find, it was accepted uncritically. Scientists embraced the Piltdown find because it supported the prevailing beliefs of the time. Scientists are still human, and ambition, pride, and rivalry can all come into play.

Jill M. Church

See also Anthropology; Dating Techniques; Evidence of Human Evolution, Interpreting; Hominid-Pongid Split; Teilhard de Chardin, Pierre

Further Readings

Millar, R. (1972). *The Piltdown man.* New York: St. Martin's Press.

Russell, M. (2003). *Piltdown man: The secret life of Charles Dawson and the world's greatest archaeological hoax.* Stroud, Gloucestershire, UK: Tempus.

Walsh, J. E. (1996). *Unraveling Piltdown: The science fraud of the century and its solution.* New York: Random House.

Werner, J., & Stringer, C. (2003). *The Piltdown forgery* (50th anniversary ed.). Oxford, UK: Oxford University Press.

PLANCK TIME

The *Planck time* has a value of 5.39121×10^{-44} second (current uncertainty 40×10^{-44}). It is the smallest time that can be operationally defined, that is, measured even in principle. The *Planck length* has a value of 1.61624×10^{-35} (current uncertainty 12×10^{-35}) meter and represents the smallest length that can be operationally defined.

By international agreement, the distance or length, L, between two points in space is defined as the time, t, it takes for light to travel between the points in a vacuum, multiplied by a constant, c

$$L = ct, \tag{1}$$

where c = 299,792,458 meters per second is the speed of light in a vacuum. (This number is exact by definition.) In order to measure t, and thus L, we need a clock with an uncertainty Δt no larger than t. The time-energy uncertainty principle says that the product of Δt and the uncertainty in a measurement of energy in that time interval, ΔE, can be no less than $\hbar/2$, where $\hbar = h/2\pi$ and $h = 6.6260693 \times 10^{-34}$ joule-second (current uncertainty 11×10^{-34}) is Planck's constant. That is,

$$\Delta E t \geq \Delta E \Delta t \geq \frac{\hbar}{2}\ . \tag{2}$$

Thus,

$$\Delta E \geq \frac{\hbar}{2t} \geq \frac{\hbar c}{2L}\ . \tag{3}$$

This energy is equivalent to the rest energy of a body of mass m,

$$\Delta E = mc^2. \tag{4}$$

Equation 5 implies that within a spherical region of space of radius L, we cannot determine, by any measurement, that it contains a mass less than

$$m = \frac{\hbar}{2cL}\ . \tag{5}$$

Now, a spherical body of mass M will be a black hole if its radius R is less than or equal to

$$R = \frac{2GM}{c^2}, \tag{6}$$

where $G = 6.6742 \times 10^{-11}$ cubic meters per kilogram per square second (current uncertainty 10×10^{-11}) is Newton's gravitational constant. This is called the *Schwarzschild radius.*

Consider a body of mass m given in Equation 5. Its Schwarzschild radius will be

$$L_{PL} = \left(\frac{\hbar G}{c^3}\right)^{\frac{1}{2}}, \tag{7}$$

which is called the Planck length. Notice it is simply the length formed from the three basic constants in physics, $\hbar$, c, and G. It represents the smallest length that can be operationally defined, that is, defined in terms of measurements that can be made by any instrument. If we tried to measure a smaller distance, the time interval would be smaller, the uncertainty in rest energy larger, the uncertainty in mass larger, and the region of space would be experimentally indistinguishable from a black hole. Because nothing inside a black hole can climb outside its gravitational field, we cannot see inside and thus cannot make a smaller measurement of distance.

Similarly, we can make no smaller measurement of time than the Planck time,

$$t_{PL} = \frac{L_{PL}}{c} = \left(\frac{hG}{c^5}\right)^{\frac{1}{2}}. \quad (8)$$

The Planck time and Planck length are the most basic units of time and space. Although distance and time are assumed continuous variables, they are fundamentally discrete. However, because physics experiments have not yet even come close to probing space and time on the Planck scale, treating them as continuous remains a good approximation.

General relativity, the theory of gravity introduced by Albert Einstein in 1915, has so far passed every empirical test to high precision. However, not being a quantum theory, it can be expected to break down at the Planck scale, where it will have to be replaced by a quantum theory of gravity, still not developed.

The Planck time represents the earliest time that can be operationally defined for our universe on the positive side of the time axis. However, this does not mean that "time began" at that moment. Nothing forbids, and time symmetry implies, another universe at earlier times, on the negative side of our time axis.

Victor J. Stenger

See also Attosecond and Nanosecond; Einstein, Albert; Light, Speed of; Newton, Isaac; Quantum Mechanics; Time, Measurements of; Time, Operational Definition of; Time, Symmetry of; Time, Units of

Further Readings

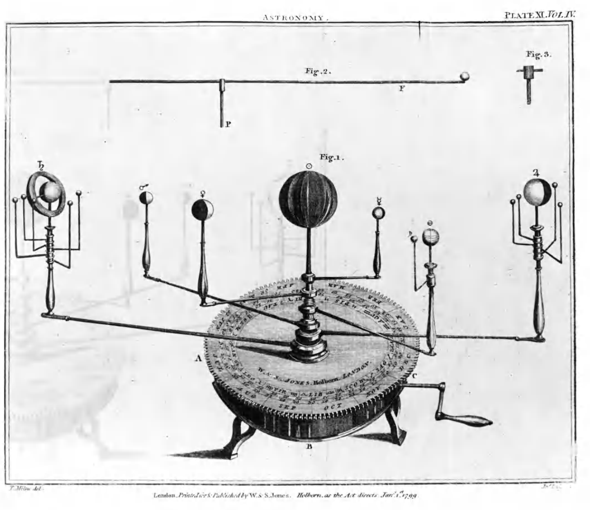
Stenger, V. J. (2006). *The comprehensible cosmos: Where do the laws of physics come from?* Amherst, NY: Prometheus.

Planetariums

A planetarium is a device for artificially depicting the night sky, showing the relative positions and motions of the sun, moon, and planets. Modern planetariums are theaters, usually dome shaped, that employ elaborate equipment, including projector systems and lasers, for educating and entertaining the public about astronomy and for training nautical and military personnel in celestial navigation.

The lineage of the planetarium can be traced back to ancient Greece. An ancient mechanical calculator used to accurately determine astronomical positions was found in 1900 by sponge divers in what is now referred to as the "Antikythera wreck," off the Greek island of the same name (located between Kythera and Crete) and has been dated to about 150–100 BCE. This technology was extraordinarily complex for the time, and it has no known precursor and no successor or equivalent until the 18th century CE. This movement, or one similar, with its high level of sophistication for that and most other eras, is widely believed to have been used in Archimedes' construction of a primitive equivalent to the modern planetarium. Rather than providing public entertainment or instruction to navigators in training, the creation of Archimedes was used to predict the movements of the sun, moon, and planets as known at that time and also to approximate their relation to each other at various phases and points in time.

Giovanni Campano, more readily identified as Johannes Campanus, was an Italian astrologer, mathematician, and astronomer of the 13th century. In his *Theorica Planetarum,* Campano describes, and, more importantly, provides direction on how to assemble, a planetarium incorporating the astronomical knowledge at that time. Given the instructions left on how to build this piece, it can be stated that there is a very high correlation between the "planetarium" of Campano and the orrery of today. (The orrery is so named for the Earl of Orrery; Orrery is a location within Ireland, and an 18th-century Earl of Orrery had one constructed.) An orrery is a three-dimensional mechanical device that depicts the relative positions and motions of the planets and moons in the solar system, as well as their relation to each other,



An orrery or planetarium designed by George Adams showing the relative positions of the planets in relation to the sun (1799).

Source: Library of Congress, Prints & Photographs Division.

as based upon the presumption of Copernican heliocentrism. These pieces usually owe their movement to a large clockwork mechanism with a sphere (representing the sun) at its core and with a distinct and specific representation of a particular planet at the end of each of its arms. Given the small size of orreries as constructed by Campano and his predecessors, it appears that these devices were mostly used for personal curiosity, knowledge, and recreation, as they were not large enough to be of any true service to a crowd. One obvious limitation of this form of representation is its complete inability to replicate or depict the backdrop of stars and constellations.

Early 19th-century England provided the backdrop for Adam Walker and his Eidouranion, the name given his very large orrery, approximately 20 to 25 feet in height, with a proportionate width. Walker's Eidouranion provides the first documented usage of an orrery for either educational or entertainment purposes, with his lecture incorporating both facets into a simulated presentation on the heavens. While not extremely precise in its representation, this show provided the audience an opportunity to encounter elements of time beyond an immediate number, day, and date. In relaying the parallels of heavenly occurrences such as a lunar phase, or planetary alignment, with definite cycles and events (e.g., seasonal change resulting from the earth's positioning and alignment in relation to the sun), Walker can be seen as one of many to have helped establish the depth and permanence of events of this world by incorporating the heavens as support. As Walker's popularity, and presumably wealth, began to grow, others such as William Kitchener and his Ouranologia began to take their rather inaccurate orreries on the road, forgoing scientific display for sensationalism and the awe of large crowds.

The preeminent German optics firm of Carl Zeiss found itself in a unique situation at the turn of the 20th century. Working within the firm's compound in Jena, Germany, were astronomer Max Wolf, former director of Heidelberg's Baden Observatory, and Franz Meyer, chief engineer of optical works for Zeiss. Both men, in conjunction with Oskar von Miller of Munich's Deutsches Museum, looked to create a representation of the night sky free of movement created by overt force (e.g., the mechanically driven arms of an orrery). The result of their ingenuity and labor was a projector that produced the movements of planets and stars, without aid from bulky and visually obtrusive rails, supports, and the like. Instead, once centrally mounted, their optical projector was capable of projecting images upon the surface of a hemispherical ceiling, and in 1923 the first modern-day planetarium projected its representation of the heavens upon the inside of a dome erected on the roof of the Zeiss building. Given the complexities associated with production of a planetarium (named for the device used to project images, and not necessarily the hemispherical room or building in which the projector is housed; commonly the entire unit—projector[s]— and dome, are referred to as a planetarium) and the sterling reputation of Carl Zeiss, most every planetarium produced or in use upon the globe prior to World War II could be directly traced to the Zeiss factory of Jena.

Projectors such as those introduced by Zeiss use a hollow sphere with a light contained within as their primary means of projecting the appearance of the heavens. This "ball of stars" contains a tiny hole for each star being represented, with the location and relation of "star holes" being computed to near perfection when compared with their authentic form in the true night sky. To simulate the planets and their movements, another projector is commonly used to superimpose these images upon the starry backdrop.

Currently, digital projectors are beginning to appear in more and more planetarium settings. The cost of upkeep is considerably less than that of the traditional "star ball" models, and synchronization of various projectors (e.g., a star projector and a separate planet projector) is not required, as all solar/celestial data are stored and represented by one computer and its corresponding digital projector. Much like digital projectors in a lecture hall or elsewhere, images of the night sky are displayed as pixels, with higher pixilation resulting in a better viewing accuracy.

Daniel J. Michalek

See also Galilei, Galileo; Observatories; Telescopes

Further Readings

King, H. C., & Millburn, J. R. (1978). *Geared to the stars: The evolution of planetariums, orreries and astronomical clocks.* Toronto, ON, Canada: University of Toronto Press.

Marche, J. D. (2005). *Theaters of time and space: American planetaria, 1930–1970.* New Brunswick, NJ: Rutgers University Press.

Planets

Astronomy, one of the oldest sciences of humankind, always provided orientation in space and time: Cardinal directions (east, north, west, south) are defined and obtained by basic astronomical measurements. Time and calendar issues are also definable and measurable by astronomical observations: One "year" is the period the earth needs for one full revolution around the sun (originally, before the Copernican revolution, it was seen the other way around), and one "month" is roughly the time our moon needs to orbit the earth. The currently most widely used calendar system, the Christian calendar in use in Europe, North and South America, and many other parts of the earth, is based mainly on the motion of the earth with respect to the sun. Other cultures have developed slightly different calendars based either on the moon (e.g., the Moslem calendar) or a combination of sun and moon (e.g., the Jewish calendar).

We count seven days per week because, a long time ago, people considered "seven" objects as "planets" or "planet-like objects," namely the real planets, which could be observed by the naked eye before the invention of the astronomical telescopes: Mercury, Venus, Mars, Jupiter, and Saturn, as well as the other two large visible bodies in the solar system, the sun and our moon, together seven objects, hence also the names of the seven days of the week:

Sunday, as the original first day of the week, is the day of the sun, the brightest object in the sky, often even worshipped as a god in several ancient cultures.

The word *Monday* obviously refers to the moon.

Tuesday is named after Mars, the god of War (notice in French, Italian, and Spanish, the words for Tuesday are still close to that for the Roman God Martius (for Mars), namely *Mardi, Martedi,* and *Martes,* respectively) and it originally comes from *Tiwes dag* or *Tyr dag,* from the old Teutonic word *Tyr* for Mars.

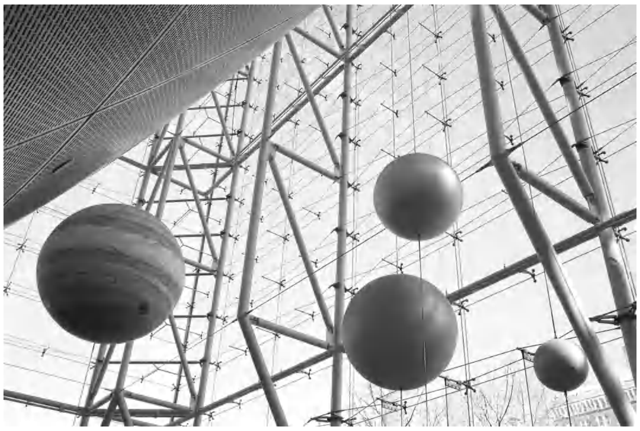
Wednesday is named after the Roman God Mercury (in Romanian, the day is still known as *Miercuri),* and the word Wednesday itself comes from *Wodan dag* for the Teutonic god Wodan.

In Roman times, the fifth day of the week (*Thursday*) was known as *dies Jovis,* after their god of thunder and chief of the gods, Jupiter, where Thursday itself comes from *Thunor dag,* the day of the Teutonic God Thor.

The Romans named another day after their goddess of beauty, Venus, and called it *dies Veneris* (still similar in French). When Germanic tribes invaded England more than 500 years ago, they imposed their goddess upon that day and called it *Frigedaeg,* now Friday.

And finally, *Saturday* is obviously called after Saturn.

Nowadays, both time and the unit *second* are defined by the speed of light. Previously, a second was defined by the atomic clocks, and also earlier as one certain small part of a day, that is, one small part of a revolution of the earth. Still, astronomical observations are important for fixing "time": Due to tidal interaction among the sun, earth, and



An upright shot of the planets at Hayden Planetarium in New York City. Since February 2000, the planetarium has been one of the two main attractions within the Rose Center for Earth and Space.

Source: Daria Peleg/iStockphoto.

moon, the rotation period of the earth is very gradually slowing down.

Historical Background

The definition of a planet has changed over the centuries, always following new astronomical observations and new understanding. The word *planet* comes from the Greek word for wanderer, meaning a wandering or fast-moving starlike object (e.g., the old Arabic name for the Egyptian capital Cairo is "Al Qahira" for "the backwards wandering," meaning Mars). As mentioned above, a few hundred to 3,000 years ago, people could see, by the naked eye, seven objects apparently moving fast in the sky (compared to the "fixed stars"), incorrectly thought to orbit around the earth in the center, namely the sun, Mercury, Venus, the moon, Mars, Jupiter, and Saturn. The next planet known today behind Saturn, called Uranus, is also visible to the naked eye during clear and dark nights, and may be visible when Uranus is close to the sun and the earth is roughly in between the sun and Uranus. This is called *opposition:* when an outer planet like Uranus is brightest as seen from the inner planet like Earth, but no such reports are known so far, possibly because Uranus moves only slowly and is quite faint.

During the Renaissance period in general and the so-called Copernican revolution in particular, it became clear, through a number of new observations, that the old theory placing the earth in the center of the universe was not perfect. Those observations became possible with the invention of the astronomical telescope. In 1609, Galileo Galilei observed the phases of Venus and craters on our moon and discovered moons around Jupiter (first called "Medici planets" or "Medici stars" after his supporters of the Italian Medici family, and now known as "Galileian moons"). All this together favored an alternative explanation, putting the sun in the center of our solar system and having the planets orbiting around the sun. At this moment, it also became clear that the earth is orbiting the sun and, hence, was now seen as a planet. Later, two more planets were discovered beyond Saturn, namely Uranus and Neptune.

While it was always possible to estimate the orbital periods of planets around the sun by their periodic appearance and disappearance in the sky, it was originally difficult to measure distances between the planets, or from Earth to either its moon or the sun. The distance between Earth and the sun is now called the *astronomical unit,* which is about 150 million kilometers. The first good estimates of such distances were obtained a few centuries ago by observing eclipses of the sun by the inner planets Venus and Mercury, which happen only very rarely (usually only once or a few times per century): One has to measure exactly either the angular distance between the apparent path of the planet across the solar disk, as seen from two different locations on Earth, or the exact times of ingress and egress of the planet moving in front of the sun. These four so-called contacts must be observed and measured from different locations on Earth with as large as possible a distance in between them, for example from South Africa and Europe. A few centuries ago, it was still difficult to coordinate such efforts and also to run precise clocks. A first observation was done in 1639, a Venus transit. After several attempts, the first good values for the distance between Earth and the sun were obtained in 1761 and 1769—these values also giving evidence about the size of the sun. Together with the laws of gravity just determined by Isaac Newton and their application to the solar system by Johannes Kepler, these values immediately yielded all distances between each of the planets and the sun.

Toward the end of the 18th century, the so-called Titius-Bode law was found and discussed: According to this law, the distance from planet to planet roughly doubles with each planet reached as one moves further away from the sun; for example, Saturn is roughly twice as distant from the sun as Jupiter, Uranus is roughly twice as distant as Saturn, and so on.

However, from Mars to Jupiter, the distance increases roughly by a factor of four, so that there would be space for one more planet. Even the famous philosopher G. W. F. Hegel wrote his dissertation about this problem at the University of Jena in Germany. Many astronomers were already hunting for this new planet. Then, in January 1801, an object was found at the expected distance from the sun, called Ceres, and celebrated as a new planet. However, soon afterward, more similar objects were found, all at a similar distance; a few decades later, the solar system had more than 20 "planets." It was also found that these new objects were smaller than all other previous planets, so it was decided to call them "minor planets" (a new class of objects). Hence, objects celebrated and counted as planets were removed from the list of planets by a new definition.

Early in the 20th century, another new object was discovered and celebrated as a new, ninth planet, called Pluto, located most of the time beyond Neptune, but sometimes crossing its orbit.

Planet Redefined

In August 2006, the general assembly of the International Astronomical Union (recognized by the UN as the international body to define and name celestial objects) discussed, among many other issues, the definition of "planet" again. The definition was prompted by two new discoveries in the 1990s: (1) Minor bodies like Pluto were discovered near and beyond Pluto; and (2) planets around other stars, so-called extrasolar planets or exoplanets, were discovered, and they were apparently different in many respects from the solar system planets, so that a new definition seemed necessary.

After lengthy and heated debates, a new definition was confirmed by a majority vote. This definition reads as follows:

> The IAU resolves that planets and other bodies (except moons) in our solar system be defined into three distinct categories. A "planet" (see note 1, below) is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces, so that it assumes a hydrostatic equilibrium (nearly round) shape (see note 2, below), and (c) has cleared the neighborhood around its orbit.
>
> A "dwarf planet" is a celestial body that (a) is in orbit around the Sun, (b) has sufficient mass for its self-gravity to overcome rigid body forces, so that it assumes a hydrostatic equilibrium (nearly round) shape (see note 2, below), (c) has not cleared the neighborhood around its orbit, and (d) is not a moon. All other objects (see note 3, below)—except moons—orbiting the Sun shall be referred to collectively as "Small Solar System Bodies."
>
> Note 1: The eight planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune.
>
> Note 2: An IAU process will be established to assign borderline objects into either dwarf planets or other categories.
>
> Note 3: These objects include asteroids, trans-Neptunian objects, comets, and other small bodies.

This says mainly that objects that (a) are in orbit around the sun (i.e., not being moons of planets), (b) have at least a certain mass (to be round by gravitational effects), and (c) have maintained their orbits by their own gravitational forces are the "planets" of our solar system. According to this definition, Pluto is not a planet (anymore). However, this was not the first time that an object was deleted from the list of planets (see above regarding Ceres and the other "minor planets"). This effect, however, is highly controversial, and it is very well possible that the definition will be changed again soon.

The Solar System

There are now eight planets in the solar system.

Mercury, the innermost known planet, is also the smallest known planet in our solar system with a diameter of less than 5,000 kilometers. (Pluto is smaller, but it is not a planet anymore according to the new definition.) It has a rotation period of 59 days, which is about two thirds of its orbital period around the sun (88 days); hence one "Mercury-day" is equal to two "Mercury-years." Mercury does not have an atmosphere that is comparable to that of Earth, and its surface is similar to that of the moon. Two thirds of its material and mass is made of iron. According to Einstein's general theory of relativity, the orbit of Mercury should change slowly: The location of the perihelion (the point in the planet's orbit at which it is the smallest distance from the sun) moves by a small angle of 43 seconds or arc per century, which has been confirmed observationally.

Venus needs 225 days for orbiting the sun (compared to 365 days for one Earth orbit around the sun). The rotation of Venus around its own axis is retrograde, that is, in the rotational direction opposite to the direction in which it revolves around the sun, and one such "Venus-day" lasts 243 days; that is, it is longer than one "Venus-year." Venus has a dense atmosphere consisting mostly of carbon dioxide and nitrogen, and it has strong pressure on the surface, from where one would never be able to see the stars in the night sky through the dense clouds.

Mercury and Venus, as planets inside the earth's orbit, orbit the sun faster than the earth does and are often close to the sun, as seen from Earth. Hence, they are observable either in the evening sky just after sunset or in the morning sky just before sunrise; that is, Venus is also called the "morning star" or the "evening star." The Greeks called Mercury "Hermes" when it appeared as the evening star and "Apollo" when it appeared as the morning star; Venus was similarly called either "Hesperus" or "Phosphorus," respectively.

Earth is the third planet from the sun; it needs 365 days for a complete orbit around the central star and 24 hours for one rotation. Its atmosphere consists mainly of oxygen and nitrogen. This planet is the only one known so far to harbor living beings like plants, animals, and intelligent life.

The fourth planet is called Mars. It has an orbital period of 687 days and a rotation period of 24.6 hours, so that a "Mars-day" is only slightly longer than a day on Earth. Its thin atmosphere consists mostly of carbon dioxide and nitrogen, but this atmosphere is not identical to that of Earth. There is frozen carbon dioxide and water ice at the poles, but no fluid water has yet been detected. However, some surface structures look like dry river beds and may indicate that fluid water was present some billions of years ago. It is not impossible that life has formed on Mars, too, but no clear evidence for life on Mars has been found yet. Mars is orbited by two small moons, called Phobos and Deimos, with 8-hour and 30-hour orbital periods, respectively. Like the moon of Earth, their rotation is bound: Their orbital period equals their rotational period; they are rotating around themselves only by orbiting their planet and always show the same side to their planet.

The innermost four planets are also called terrestrial planets, as they are all made mostly of solid material like Earth (*terra*). Between Mars, the fourth planet, and Jupiter, the fifth planet, there is a large gap where many small bodies are orbiting the sun. These are called minor planets or sometimes *planetoids,* because they are physically like terrestrial planets; that is, they are rocky objects. They are also called *asteroids,* because in the sky they look like the stars looked when they were discovered, namely pointlike (as opposed to the planets of our solar system, which appeared to be extended on the sky even in naked-eye observations, because of their larger size and smaller distance from observers).

The four outermost known planets (Jupiter, Saturn, Uranus, and Neptune) all are larger in size than the terrestrial planets, mostly because of their large atmospheres and only small solid or fluid cores. (In the case of Jupiter, there may not even be a core at all.) Hence, they are called the "gaseous giant planets."

Jupiter is the largest planet in our solar system; it has a diameter of 143,000 kilometers and a mass of 318 times the mass of Earth. It needs almost 12 years for one orbit around the sun, but only 10 hours for a rotation around itself, as can be observed with even a small telescope because of the moving large red spot in its outer atmosphere. Given its diameter, mass, and composition (mostly molecular hydrogen), it is not absolutely clear whether it has a solid or fluid core or possibly even no core, that is, no solid surface. If it has a core, the core could have a mass of a few or maybe 10 Earth masses. Due to contraction, Jupiter is still radiating more energy to outer space than it is receiving from the sun. This giant planet also has a small ring system and a large number of moons, probably a few dozen; new small moons are still being discovered. The four largest moons were originally discovered by Galileo, when he observed Jupiter for the first time with a telescope. These four moons (Io, Europa, Ganymede, and Callisto) are called the Galileian satellites.

Saturn is twice as far from the sun as Jupiter is. Saturn is known mostly for its large ring system. It also has a large number of moons. Saturn needs 29.5 years to orbit the sun and has a rotation period of 10 hours and 40 minutes. It has a solid core of a few Earth masses and a large atmosphere made mostly of molecular hydrogen gas. Saturn is the second largest planet (120,000 kilometers in diameter) and the second most massive (95 times the mass of Earth) in our solar system.

All planets from Mercury to Saturn (including Earth) have been known for several thousand years to most cultures on Earth, because they can be observed by the naked eye. The outermost planets, Uranus and Neptune (as well as Pluto), were discovered after the invention of the telescope. While Jupiter and Saturn are called "gas giants," Uranus and Neptune are also gaseous planets that can be seen as "ice giants."

Uranus was discovered (and recognized as a planet) in 1781 by William Herschel. Others had observed it before but did not recognize that it as a planet. Uranus is also a gaseous planet with a central solid core, but in total it is only 15 times as massive as Earth. Uranus needs 84 years to circle around the sun, and one "day" on Uranus lasts around 17 hours. Uranus's atmosphere consists of 83% hydrogen, 15% helium, and 2% methane. So far, 21 moons have been discovered (and astronomers are still counting). Uranus also has a small ring system as discovered by the Voyager satellites.

Neptune is the outermost known (and accepted) planet. It was observed by Galileo in 1612, but he did not recognize it as a planet. Because of apparent deviations in the orbit of Uranus, both John Couch Adams and Urbain Le Verrier predicted the existence of another planet theoretically and tried to forecast its rough location in the sky. Later, in 1846, the observer Johann Gottfried Galle in Berlin, Germany, searched that area of the sky for a small moving object and discovered Neptune within a few hours. Neptune needs 165 years for one full circle around the sun. One "day" on Neptune lasts 16 hours. Neptune has a small solid core, a large gaseous atmosphere composed mostly of molecular hydrogen, and a total mass of 17 times the mass of Earth. Neptune, like all gaseous planets in our solar system, has moons and rings.

The object Pluto was discovered in 1930 and celebrated as a new planet, but it was deleted from the list of planets in the 2006 definition of *planet* by the International Astronomical Union.

The new definition of *planet* is formulated for the solar system, but it can and should be applied analogously to other planetary systems around other stars. However, there is as yet no consensus or definition for the upper mass limit of planets. Such an upper mass limit, however, would be very important for extrasolar planets, to be able to decide whether they are planets or so-called brown dwarfs.

In history, the two definitions for a planet worked for about 200 years: The first definition worked from the Copernican revolution to the discovery of Ceres and other minor planets (which now form the asteroid belt between Mars and Jupiter); the second definition, excluding the minor planets, was in effect again for about 200 years until 2006.

Both the problem regarding Pluto and the missing upper mass limit for planets may very well lead to a new definition at one of the next meetings of the International Astronomical Society, which holds a general assembly every three years.

Ralph Neuhäuser

See also Copernicus, Nicolaus; Earth, Revolution of; Earth, Rotation of; Laplace, Marquis Pierre-Simon de; Nebular Hypothesis; Planets, Extrasolar; Planets, Motion of; Relativity, General Theory of; Time, Relativity of

Further Readings

Corfield, R. (2007). *Lives of the planets: A natural history of the solar system.* Cambridge, MA: Basic Books.

Encrenaz T., Bibring, K.-P., Blanc, M., & Barucci, M.-A. (2002). *The solar system* (3rd ed., S. Donlop, Trans.). Berlin: Springer-Verlag.

Karttunen, H., Kröger, P., Oja, H., Poutanen, M., & Donner, K. J. (Eds.). (2007). *Fundamental astronomy.* Berlin: Springer-Verlag.

Maunder, M., & Moore, P. (1999). *Transit: When planets cross the sun.* (Patrick Moore's practical astronomy series). London: Springer-Verlag.

PLANETS, EXTRASOLAR

The term *extrasolar planets* or *exoplanets* stands for planets outside our solar system—that is, planets that orbit other stars, not our sun. Planets in our solar system are defined as objects with enough mass to be spherical and round by their own gravity and to be alone on their orbit around the sun; in other words, to be the dominant object in a particular orbit and not to be a moon or asteroid

Most exoplanets are discovered by observing the stellar motion around the common center of mass of the combined star-and-planet system, that is, by observing somehow the motion of the objects in orbit around each other. This is typically done by measuring precisely the periodic variation of certain values, such as radial velocity or brightness, with time. For example, the first extrasolar planets were found with this timing technique around a pulsating neutron star.

The recent definition of "planets of our solar system" by the International Astronomical Union deals mainly with the question of the minimum mass for an object to qualify as planet and excludes Pluto. This matter was raised by the fact that more and more objects similar to Pluto were discovered by larger and larger telescopes. The questions of maximum mass and formation of planets were left out in this new definition, possibly partly because there is not yet a consensus in the international community. For a discussion of extrasolar planets, however, the maximum mass is very important in order to classify an object as planet or nonplanet and to distinguish between planets and brown dwarfs.

Both planets and brown dwarfs are substellar objects in the sense that they are less massive than stars so that they cannot fuse normal hydrogen (as stars do to produce energy and to shine for a long time). Brown dwarfs, while they cannot fuse normal hydrogen (which has an atomic nucleus of just one proton), can burn deuterium (heavy hydrogen, which has an atomic nucleus of a proton plus a neutron) so that they are self-luminous for a few millions of years until the original deuterium content is depleted.

The upper mass limit of planets can be defined either through the lower mass limit for deuterium fusion, which is around 13 times the mass of Jupiter (depending slightly on the chemical composition) or by the mass range of the so-called brown dwarf desert (as discussed in the following paragraphs).

We will next discuss the different exoplanet discovery techniques by chronological order of success and thereby also discuss the properties of objects found so far.

Radial Velocity

For a few thousand years, speculations have existed as to whether other stars can have their own planets. Both Giordano Bruno and Nicholas of Cusa answered this question positively a few hundred years ago. However, not until 1989 was the first object discovered that could really be an extrasolar planet and that is today still regarded as planet candidate. This first extrasolar planet candidate was discovered serendipitously by the so-called radial velocity technique: The velocity of the motion of an object directly toward us or away from us (in one dimension) is called *radial velocity* and can be measured by the so-called Doppler shift of spectral lines. Atoms in the atmosphere of stars can absorb light coming from the interior of the star at a certain energy, frequency, or wavelength for each kind of atom or ion, producing absorption lines in the spectrum of the star. If the star moves away from us, such lines are said to be *red-shifted;* if the star is approaching us, they are called *blue-shifted;* in either case, their wavelength is different from the normal wavelength (larger for red-shifted).

When a second object, like a planet, orbits around a star, actually both objects orbit around their common center of mass. Hence, also, the star wobbles: It sometimes approaches us, sometimes flies away from us. This can be observed as periodically changing radial velocity. The period of the variation gives the orbital period, and the amplitude of the change in radial velocity yields the mass of the companion. However, because the inclination between the orbital plane and our line of sight is normally not known, only a lower mass limit is known. Therefore, such low-mass companions detected by the radial velocity technique are to be seen as planet candidates; they could have a mass above the maximum mass for planets, making them perhaps brown dwarfs or even low-mass stars. The first such case was published in 1989 by Latham, Stefanik, Mazeh, Mayor, and Burki, namely a companion with minimum mass of 11 Jupiter masses around the star HD 114762. This planet is called HD 114762 b, following the convention that the first planet found around a star is called by the name of the star plus a lowercase *b* behind the star name (thus, a lowercase *c* for the next planet, etc.). This planet may very well have a true mass above 13 Jupiter masses, in which case it could be regarded as brown dwarf.

The first object discovered around a sunlike normal star, which is almost certainly a planet, is called 51 Peg b and is a planet with about half the mass of Jupiter as minimum mass found by Mayor and Queloz around the star 51 Peg in 1995.

The radial velocity can nowadays be measured with an accuracy of about 1 meter per second, so that planets with minimum mass of a few Earth masses can be detected by the wobble they produce on a low-mass star. In the time of one Jupiter orbit, that is, 12 years, since the important discovery of 51 Peg b, about 250 planet candidates have been discovered. In some cases, several planet candidates are orbiting a single star, in some other cases, individual planet candidates are found in binary stars. Because the high precision of the radial velocity technique has been available only since about the early 1990s, planets with more than 20 years of orbital period have not yet been discovered; one needs to observe at least one orbital period. Many planet candidates found so far orbit their stars within only a few days, which is quite different from our solar system, where the innermost planet Mercury needs several months to orbit the sun. The high number of planet candidates with short orbital period, however, can be seen as observational bias, because such planets also introduce a larger wobble on their stars due to Johannes Kepler's and Isaac Newton's laws of gravity.

The mass range of all these planet candidates shows a strong peak at about one Jupiter mass and a strong dip at around 20 to 30 Jupiter masses, even though this method would be biased toward more massive companions, because they have a stronger effect on their central star. Across the range of planet candidates, there are about 250 planet candidates all with masses below about 20 Jupiter masses, then almost no objects with minimum mass between about 20 and 70 Jupiter masses (that is, there are only a few brown dwarfs), and then again a large number of stellar companions with minimum mass above 70 Jupiter masses. This paucity of brown dwarfs identified with the radial velocity technique is called the *brown dwarf desert,* and the dip in the mass spectrum is deepest at around 20 to 30 Jupiter masses. Either the lower mass range of the brown dwarf desert or the minimum mass for deuterium burning can be used as an upper mass limit for planets, if one would define the upper mass limit for planets.

Pulsar Timing

At the end of the lifetime of a massive star, after most of the material is burned by fusion, the star collapses due to its own gravity, then forms a very dense and compact object made up mostly by neutrons, called a *neutron star,* while the rest explodes due to a rebound as supernova. A neutron star typically has about 1.4 times the mass of our sun but a diameter of only 20 to 30 kilometers. Such neutron stars rotate very fast, sometimes even about 100 times per second, sometimes once in few seconds. Most known neutron stars emit strong radio emission along their rotation axes (beams), which appear pulsed due to the fast rotation. Such objects are called *pulsars.* We should keep in mind that so-called pulsars are not pulsating, but rotating fast. One can measure the rotation period with both high precision and high accuracy. In the case of the pulsar called PSR1257, Wolszczan and Frail discovered sinusoidal variations of the millisecond pulses in 1992 and interpreted these variations to be caused by low-mass objects in orbit around the neutron star, each with a mass equivalent only to about that of Earth. This discovery of pulsar planets (by pulsar timing) came as a big surprise, because planets were not expected around neutron stars; it is still dubious as to whether planets can survive the supernova explosion, and it is unknown whether the objects found around PSR1257 are remnants of the explosion or were formed afterwards.

In the case of planets or planet candidates discovered by the radial velocity technique, the inclination of the orbit of the planet around the star in not known. One way to determine this inclination would be to use a transit. A transit occurs when the planet orbits around the star into our line of sight; the planet moves in front of the star once per orbit (and behind the star also once per orbit). When the planet is in front of the star (that is, in front of the spatially unresolved stellar disk), a small part of the stellar light is blocked by the planet. This event is called *transit* or *eclipse.* Such events also happen in our solar system; for example, as seen from Earth, the inner planets Mercury and Venus can follow a path directly in front of the sun, which can even be observed as spatially resolved. The transit light curve enables observers on Earth to measure the inclination of the orbit and also the radii of stars and planets. Then, one can determine not only the true mass of the companion (planet or brown dwarf), but also, from mass and radius, its density.

The first case for which this was successfully observed was HD 209458 in the year 2000, the first radial-velocity planet candidate confirmed to be a true planet (and found to be a gas giant planet with low density like Jupiter). About one Jupiter orbit after the discovery of 51 Peg b, about 33 transiting planets are known (as of November 2007), most of which have also been discovered first by the transit, then confirmed as planets by radial velocity. In a few cases, also the secondary transit is detected; this is a small decrease in the total combined brightness of star plus planet (one should keep in mind that in all such cases, the planet is not seen directly) when the planet is behind the star. From the difference in brightness between the time of secondary transit and the time immediately before and/or after the transit, one can indirectly determine the brightness of the planet.

Astrometry

Whereas the radial velocity technique measures the wobble of the star due to the orbiting planet in just one dimension (radial), one can measure the wobble in the two other dimensions by *astrometry,* very accurate and/or precise determination of the position of a star on the sky. Our sun as seen from about 30 light years' distance also moves slightly in the sky due to Jupiter orbiting it, but this is a very small effect, less than .001 of an arc second (the moon has a diameter of 1,800 arc seconds). The star GJ 876 was the first for which this wobble was detected, using the fine guidance sensor of the Hubble Space Telescope, confirming the radial velocity planet candidate GJ 876 b to be a real planet with just about two Jupiter masses. In the meantime, a few more planet candidates were confirmed by astrometry, and also one radial velocity planet candidate was found to be a low-mass star. Other observing programs have started, using both ground-based and space-borne telescopes, wherein one tries to discover such a wobble in stars where no planets or candidates have been found by other techniques.

Direct Detection

All previous techniques—radial velocity, astrometry, and transits—cannot determine which photons are coming from the stars and which photons from the planet; that is, they cannot directly detect (or see) the planet. While stars are bright and self-luminous due to fusion, planets are very faint, mostly shining only due to reflected light, and they are also very close to their respective stars so that they cannot be detected or seen next to the much brighter star. Young planets, which are still contracting and/or accreting matter, are self-luminous and, hence, not that faint, so that it could be less difficult to directly detect a young planet next to a young star. Several observational campaigns were started around the turn of the millennium in 2000 with the Hubble Space Telescope and ground-based 8- to 10-meter telescopes.

In the case of the ground-based observations, the earth's atmosphere is another problem, leading to the twinkling of stars, so that we obtain images lacking the best possible image quality. With the new technique of so-called adaptive optics, one can de-twinkle the stars: flatten the disturbed wave front with a deformable mirror in the telescope. With such a technique used at the 8-meter Very Large Telescope of the European Southern Observatory in Chile, a few companions to young stars have been found since 2004 that could really be young planets detected directly. The first such case was the star GQ Lupi with its companion GQ Lupi b detected by Neuhäuser, Guenther, Wuchterl, Mugrauer, Bedalov, and Hauschildt. In such cases, it is more difficult to be sure about the exact mass of the companion, because the orbital period is several hundreds of years, so that these few objects could also be low-mass brown dwarfs.

Microlensing

According to Albert Einstein's theory of general relativity, mass or matter deforms space, so that a light ray moving close to matter would be diverted. One would see a ring of light (Einstein ring) around the object. If such an Einstein ring is not resolved spatially due to small mass and/or small angular resolution, one would still see the background object being brightened by the foreground object, the gravitational lens. Such an event is called *microlensing*. If a binary lens (a star plus a planet) were to move—as seen from Earth—directly in front of a background single star, one would observe a double-peaked light curve, one brightening due to the star and one brightening due to the planet. This way, one also can detect planets at great distances—thousands of light years away. There are a few cases where such a double-peaked light curve has been observed that could possibly be due to a planet. However, in all such cases, due to the large distance and hence small brightness, the nature, mass, and distance of neither the lens (or the primary object in the double lens, the star) nor of the lensed background object are known, so that the mass of the secondary object in the lens (possibly a planet) cannot be determined without great uncertainty. The mass of the companion is determined from the mass of the primary (unknown) and the brightness ratio of the two peaks. Practically, such events can never be observed again nor confirmed.

Timing of Pulsating Stars

Some stars toward the end of their normal lifespan (i.e., after most of the light material is burned) are pulsating: They periodically increase and decrease their volume and, hence, brightness. Such a pulsation is observable as periodic brightness change. With precise observations, one can detect a small periodic variation in the pulsations, which can be explained by a wobble of the star due to an orbiting low-mass object. This is very similar to the pulsar timing and radial velocity technique. In the case of the pulsating star V391 Peg, such a variation was detected recently that can best be explained by a planet candidate with three Jupiter masses as minimum mass. This star has burned all its hydrogen already, has expanded to the red giant phase, has lost large amounts of its material, and is now again contracted to become a so-called white dwarf. This is the first time that a planet candidate has been detected in a star after the red giant phase (except for the pulsar planets). This case shows that planets can survive the red giant phase. Our sun will undergo this red giant phase in a few billion years, when it will then expand enough to swallow Mercury and Venus. It is not yet clear what effects this will have on the earth, but it is likely that all life will be extinguished.

All these different techniques to discover planets have resulted in several hundred planets and planet candidates, including some planetary systems, where several planets orbit the same star. (Updates on planet discoveries can be found on www.exoplanets.org.) Planetary systems consist not only of the planets and their host star but also of minor bodies like asteroids, comets, and moons, and often if not always also of a circumstellar disk with dust remaining from the formation phase. This is also the case in our solar system, where dust in the so-called zodiacal disk can be observed on dark moonless nights due to reflection of sunlight on dust particles; such dust debris disks can also observed around other stars, with or without planets.

All the planets discovered so far have masses of at least several Earth masses and are much different from Earth. It is not yet possible to detect earthlike planets. Such discoveries may be possible in the future, either by the use of larger telescopes or by ground- or space-based interferometry, using a combination of several telesopes.

Another eminent question is the habitability of exoplanets. So far, no signs of life have been found on other planets, neither in our solar system nor elsewhere. It is difficult not only to define life, but also to detect earthlike planets—to say nothing of earthlike or even nonearthlike life on distant planets. However, it may well be that life could form either on some already detected planets or on their moons, if these exist.

Ralph Neuhäuser

See also Bruno, Giordano; Laplace, Marques Pierre-Simon de; Nebular Hypothesis; Nicholas of Cusa (Cusanus); Planets, Extrasolar; Planets, Motion of; Pulsars and Quasars; Telescopes; Time, Planetary

Further Readings

Boss, A. (1998). *Looking for earths: The race to find new solar systems.* New York: Wiley.

Clark, S. (1998). *Extrasolar planets.* New York: Wiley.

Cole, G. H. A. (2006). *Wandering stars: About planets and exo-planets: An introductory notebook.* London: Imperial College Press.

Dvorak, R. (2007). *Extrasolar planets: Formation, detection, and dynamics.* New York: Wiley.

Latham, D. W., Stefanik, R. P., Mazeh, T., Mayor, M., & Burki, G. (1989). The unseen companion of HD114762—A probable brown dwarf. *Nature, 339,* L38.

Mason, J. (2007). *Exoplanets: Detection, formation, properties, habitability.* New York: Springer.

Mayor, M., & Queloz, D. (1995). A Jupiter-mass companion to a solar-type star. *Nature, 378,* 355.

Neuhäuser, R., Guenther, E. W., Wuchterl, G., Mugrauer, M., Bedalov, A., & Hauschildt, P. H. (2005). Evidence for a co-moving sub-stellar companion of GQ Lup. *Astronomy and Astrophysics, 435,* L13.

Wolszczan, A., & Frail, D. (1992). A planetary system around the millisecond pulsar PSR1257+12. *Nature, 355,* L145.

Planets, Motion of

As viewed from Earth, the other planets in our solar system exhibit some apparent motional changes as each revolves around the sun. These oddities long puzzled a succession of civilizations as observers contemplated the structure of the universe. For thousands of years, it was common belief that the earth was the center of the universe, around which all other objects revolved. Many times, planets were seen as omens, not necessarily benevolent ones; they could also represent destructive prophecies. Most times, this led to self-fulfilling prophecies, but through time humankind has finally come to better understand the position of celestial objects.

The inferior planets (Mercury and Venus) obey a different set of observational parameters than do superior planets (those outside the earth's orbit). Inferior planets pass from inferior conjunction counterclockwise to greatest western elongation (GWE), superior conjunction and greatest eastern elongation (GEE). Superior planets, on the other hand, have no inferior conjunction, but rather a point of opposition. Additionally, they have observational points called eastern and western quadratures. In the sky of the observer, planets move regularly from west to east against the background of stars; this is called *prograde motion.* As part of orbital mechanics, this direct motion reverses as an inner body catches up to, and surpasses, the outer one. This is called *retrograde motion* (see Figure 1).

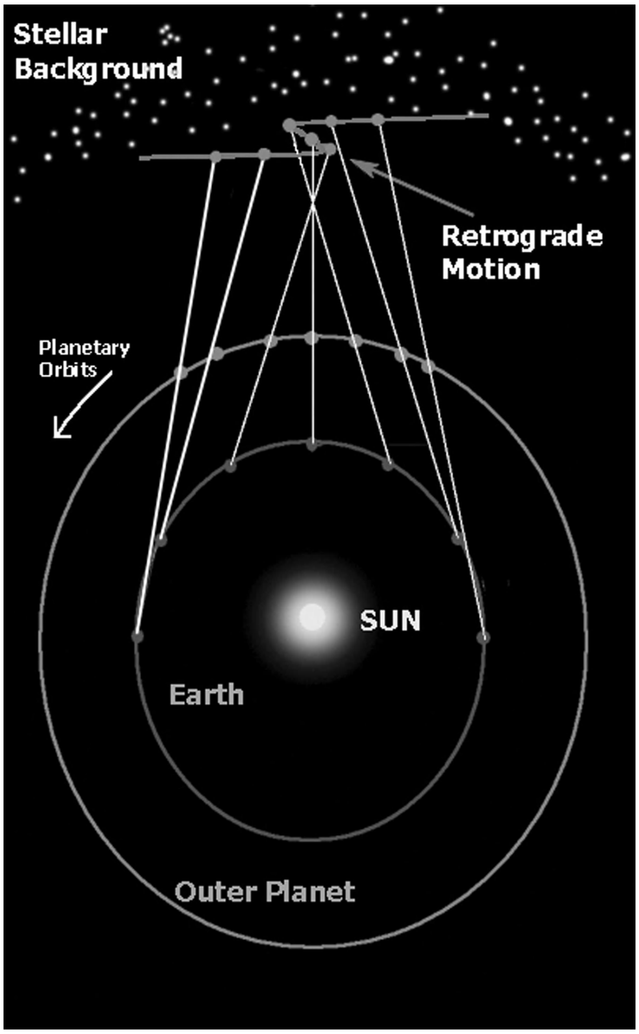


Figure 1 Retrograde motion of a superior planet

Note: Prograde motion stops midcycle, reverses, then resumes.

Inferior Planets

Every planet exhibits a consistent orbital behavior. A planetary conjunction occurs when two or more planets are in the same or opposite orbital location with respect to each other and the sun (see Figures 2a and 2b). Assuming a level plane of orbit, the sun and conjunctive planets would be in a straight line.

Inferior conjunction occurs when the inferior planet passes between Earth and the sun. In Figure 2a, the inferior planet enters into inferior conjunction with Earth. As it surpasses Earth, it will be lost in the glare of the sun. On rare occasions, the inferior planet will appear from Earth to transit the sun. At GEE, the motion of the inner planet will appear to slow, and then it will begin retrograde motion and pass behind the sun to superior conjunction. Once beyond GWE, the inferior planet will return to prograde motion. If this trajectory were seen from a location in space near Earth (which would remove the effects of Earth's daily motion), the observer would view the entire motion of the inferior planet around the sun. Note that a conjunction can occur when the two planets are at any point in their orbits; it is not necessary for them to be at perihelion or aphelion.

The inferior planets are visible between their conjunctions, but at the conjunctions they are lost in the solar glare of daylight. Each of the elongation points is related to the terrestrial cardinal direction that the planet is located in relative to the sun. As a result, observing an inner planet as a morning star prior to sunrise means that the inferior planet is in proximity to GEE. As it emerges from behind the sun, it becomes an evening star after sunset, moving toward greatest western elongation (GWE).

It is noteworthy to remember that none of these objects is fixed, including Earth. Another terrestrial observational feature is that inferior planets go through phasing similar to that of the moon. The full phase is superior conjunction, and the new phase is inferior conjunction, at which neither point can the planet be seen unaided.

Superior Planets

The outer planets, however, have a slightly different set of observational characteristics (see Figure 2b). At conjunction, the outer planet appears to pass behind the sun, while at opposition it will rise at sunset, similar to a full moon. These points are called quadratures, and they are the points where the superior planet forms a right angle with the earth and sun. At eastern quadrature, prograde motion continues but in decreasing angular measurements. Terrestrially, the superior planet sets 6 hours after the sun. As Earth approaches eastern

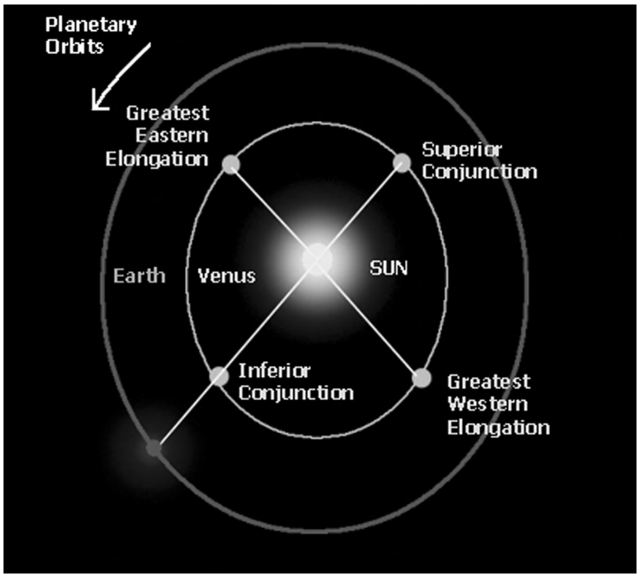


Figure 2a Inferior planetary motion

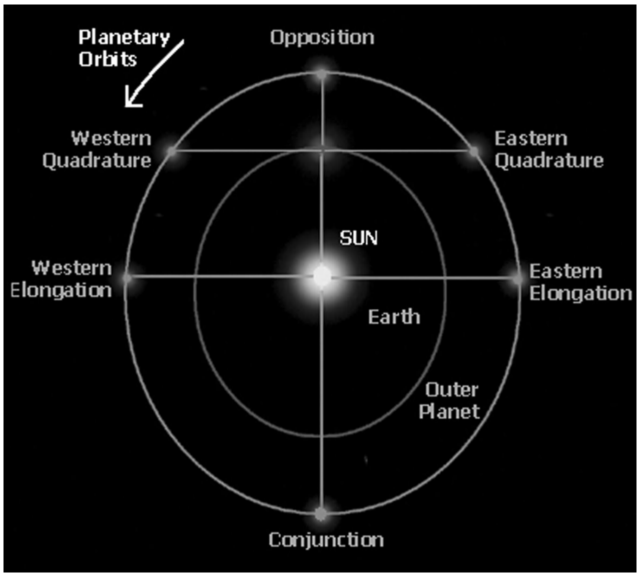


Figure 2b Superior planetary motion

quadrature, the magnitudes of prograde measurements decrease until the daily progression of the outer planet motion apparently stops and reverses into an east-to-west direction (see Figure 1). Retrograde motion continues through opposition but returns to prograde motion shortly after Earth has passed the superior planet, and the prograde distances appear to increase. Earth then continues to western quadrature, where the planet appears due south in the dawn sky. Finally, Earth returns to conjunction with the superior planet and the sun.

Predictability

A planetary alignment occurs when planets visibly cluster in the terrestrial sky. Although it is common for people to call these planetary groupings conjunctions, this is a slight misnomer. There are many planetary motions that occur, and are all part of nominal orbital mechanics. Because all planetary orbits are consistent, it is possible to predict alignments accurately. Computer-driven applet models present a three-dimensional look at when a conjunction or opposition will occur, as well as various alignments, and make it possible to predict similar occurrences in our solar system. These models are located on several Web sites on the Internet and located by utilizing a search engine.

Throughout history, planetary alignments have been blamed for the start of many wars and have been the cause for mass hysteria. In May 2000, Mercury, Venus, Mars, Earth, the moon, Jupiter, and Saturn aligned together in the western sky. News agencies reported several concerns regarding the coming tectonic, magnetic, radioactivity, and tidal catastrophes that were going to occur as a result. Over time, this has always been the case when such alignments occur. In the modern technological era, panic and hysteria is even more apt to spread with the usage of the Internet, rather than word of mouth, to carry the message. Furthermore, the enhanced ability of predicting such events gives hoaxers time to prepare their allegations. Since 2003, the Mars hoax occurs every August as Earth nears opposition with Mars; spreading mostly by e-mail to millions of people, the message claims that Mars will appear in the sky as large as the moon.

In 1974, John Gribbin misused the term *planetary alignment,* in the book *The Jupiter Effect.* The book was about the rare grouping of all nine planets being on the same side of the sun. (This actually occurs once about every 200 years.) The result would be that their combined gravitational effect would cause chaos with the sun and create massive earthquakes and floods on Earth. After reading the book, many people believed the hypothesis, and a great panic ensued. Gribbin tried to publicly quell the panic and reinforce the fictional nature of the book.

Despite the attempt to attribute terrestrial destructive forces to predictable solar system events, they simply occur as a result of the physics of motion around the sun. As each planet orbits the sun, the optical illusions of prograde and retrograde motion will be seen relative to the planetary location of the observer. Future alignments of planets will occur because they are mathematically connected, not as a precursor to chaos. Each planet takes a specific period of time to complete a solar revolution that will remain relatively constant throughout the life cycle of the solar system.

Timothy D. Collins

See also Copernicus, Nicolaus; Galilei, Galileo; Planetariums; Planets; Planets, Extrasolar; Telescopes; Time, Planetary

Further Readings

Gribbin, J., & Plagemann, S. H. (1974). *The Jupiter effect: The planets as triggers of devastating earthquakes.* New York: Macmillan.

Guest, J. (1971). *The earth and its satellite.* London: Hart-Davis.

Hetherington, N. S. (2006). *Planetary motions: A historical perspective* Westport, CT: Greenwood Press.

Karttunen, H., Kroeger, P., Oja, H., Pouanen, M., & Donner, K. J. (Eds.). (2003). *Fundamental astronomy* (4th ed.). Berlin: Springer.

Plate Tectonics

From the beginnings of science, it was thought that Earth was a static, stable planet whose surface remained largely unchanged through time. This view radically changed during the 1960s, as an array of improved analytical techniques and an influx of new observations revealed that Earth's surface is in a state of constant change. This new approach to understanding the earth is known as plate tectonics, and it holds that the outer skin of our planet is divided into several plates whose motion results in mountain building, earthquakes, volcanism, and other geological events. Understanding the processes of plate tectonics has allowed scientists to systematically explain the history and structure of the earth and to study both past and modern geological events in a unified and rigorous fashion. The philosophical shift from viewing Earth as static to viewing it as a dynamic planet governed by plate tectonics is also regarded as a prime example of a paradigm shift in science.

Early Speculation

The first recorded suggestions of a dynamic and changing Earth were offered by 16th-century philosophers and geographers, who noted the congruence between the Atlantic coastlines of Africa and South America. In 1596 the geographer Abraham Ortelius argued that the Americas were once conjoined with Europe and Asia, but later "torn away" by earthquakes and other catastrophes. In recent years, historians of science have discovered nascent hints of plate tectonics in the writings of Francis Bacon, Scottish philosopher Thomas Dick, noted French scientist Comte de Buffon, German explorer Alexander von Humboldt, and Benjamin Franklin. However, it wasn't until the early 20th century that scientists began to assemble strong evidence that the surface of the earth has changed over time, as well as a coherent hypothesis to explain how. Much of this data set was articulated by Alfred Lothar Wegener, a German meteorologist who assembled widely divergent lines of evidence into an understandable theory of continental motion.

Wegener and Continental Drift

Like the early geographers before him, Wegener was intrigued by the closely matching Atlantic coasts of South America and Africa. After reading a paper describing similar Paleozoic fossils from these two continents, Wegener launched a massive literature search in the hopes of finding additional data to support the concept of continental drift. The data he uncovered were varied and wide ranging. Not only did the coastlines of South America and Africa match, but so too did the coasts of Newfoundland, England, parts of Greenland, and Scandinavia, especially when the outlines of the continental shelf were taken into account. Additionally, Wegener discovered that South America, Africa, India, Australia, and Antarctica shared a suite of unique Mesozoic fossils, including a tropical plant flora characterized by the fern *Glossopteris* and a reptile fauna that included the tusked, piglike *Lystrosaurus*. Modern animals do not range across all continents, because it is often impossible to disperse across oceans and other barriers. This suggested to Wegener that these continents were linked during the Mesozoic era (225–65 million years ago), and have since moved to their present, widely divergent positions. Furthermore, the presence of tropical fern fossils in Antarctica makes no sense if the continent has always occupied a polar position.

Wegener supported these observations with several additional lines of evidence. This included closely matching rock units shared by Africa and South America, the distributions of former equatorial climate belts (as shown by coals and fossil reefs shared by the five aforementioned lands), and the locations of past Paleozoic glaciations. Taken together, these facts suggested to Wegener that all of the continents had once been joined into a supercontinent (which he named Pangea) that later split into two larger fragments. The first fragment, termed Laurasia, included North America, Europe, and Asia, while the second landmass, called Gondwana, consisted of Africa, South America, India, Madagascar, Australia, and Antarctica. Over time these two fragments further split into the individual continents recognized today.

Wegener presented his hypothesis of continental motion in a series of lectures and journal articles in 1912. Three years later he outlined his ideas in a short, 94-page book, *Die Entstehung der Kontinente und Ozeane,* which was subsequently revised three times and translated into English as *The Origin of Continents and Oceans*. The notion of continental drift, which overturned much of the conventional geological wisdom of the day, was initially dismissed by critics as untenable, largely because Wegener could provide no plausible mechanism for continental motion. In his book, Wegener suggested that the centrifugal force resulting from the Earth's rotation, or possibly the pull of gravity from the moon, drove the lighter, granite-rich continents through the denser, basalt-rich oceanic crust like a ship plowing through water. However, eminent Cambridge geologist Harold Jeffreys, one of the most respected scientists of his time, did the calculations and found these forces insufficient to move something as large as a continent. In response to Wegener's evidence, many in the scientific establishment suggested that now-sunken land bridges allowed for floral and faunal interchange between separate continents, and shifts in climate regimes explained the locations of past glaciations and similar rock units between South America and Africa.

At the time of Wegener's death during a 1930 expedition to Greenland, his hypothesis was openly ridiculed and his scientific credibility scorned. However, although Wegener would never know it, his hypothesis was later verified as a new age of science dawned in the shadow of World War II. Over the course of the 1960s a handful of earth scientists from across the globe instituted a scientific "revolution" that molded Wegener's observations into the theory of plate tectonics. Today, plate tectonics is regarded as the grand unifying theory of geology, and it helps to explain everything from animal dispersal and mountain building to volcanism and earthquakes.

Supporting Data

Important data supporting Wegener's evidence for continental motion came from studies of paleomagnetism. As lava cools into solid rock, tiny crystals of the magnetic mineral magnetite are "locked" into position, thereby recording the direction of Earth's magnetic field at the time of the rock's formation. Using trigonometric equations, geologists can take these data and determine the latitude at which a certain rock formed. This procedure was applied to igneous rocks across the globe, and it was discovered that the latitudes at which the rocks formed were usually different from the latitudes they occupy today. At first it was thought that the earth's magnetic pole simply wandered over time, thus causing the discrepancy in paleolatitude measurements. To test this hypothesis, scientists began compiling "polar wandering curves," charts of a continent's latitudinal position over time (enabled by recent advances in radioactive dating of rocks).

If the continents were fixed and the magnetic pole was actually wandering, the curves of different continents should match throughout geological history. However, extensive data sets showed the opposite to be the case: Each continent had its own unique polar wandering curve, which indicated that the magnetic pole is essentially fixed and the continents have drifted relative to each other. Interestingly, the polar wandering curves of North America and Europe were found to align during the early Mesozoic, indicating that these continents were moving together. Similar matches for other continents during this time support the existence of a supercontinent, as originally suggested by Wegener.

Paleomagnetic data strongly supported the reality of continental motion, but several questions about the form and cause of such motion still remained. Many of these questions were capriciously answered during the era of undersea exploration immediately after World War II. Leading this research was Princeton geologist Harry Hess, who discreetly took measurements with a fathometer while captaining a Navy transport ship in the Pacific during the war. Hess's surveys detailed the topography of the seafloor, and revealed that a series of long mountain ranges, deep trenches, and extinct volcanoes littered the deep abyss. Later evidence suggested that a large percentage of the world's earthquakes were occurring in these submerged mountains, hinting that the ocean bottom was a dynamic place.

Over time Hess became convinced that new seafloor was currently being formed in the mid-ocean mountain ridges that occurred in the centers of the Atlantic and Pacific, as well as other oceans and seas. In a landmark 1962 paper, Hess suggested that new basaltic seafloor was produced at the ridges and spread away symmetrically in both directions, a process called "seafloor spreading" by geologist Robert Dietz. This process was soon supported by a slew of additional observations. Magnetometers deployed by the Allies during the war had revealed strange magnetic patterns on the ocean floor, namely, the strength and direction of the magnetic field followed zebra-striped patterns that not only paralleled the midocean ridges, but also were symmetrically the same on both sides of the ridges. This pattern puzzled scientists until Cambridge geologists Drummond Matthews and Fred Vine directly dated much of the seafloor, and found that the absolute dates were also symmetrical about the ridges, with rocks becoming older with increased distance. Additionally, the amount of sedimentary cover and degree of erosion of extinct volcanoes increased systematically and symmetrically away from the ridge, as would be expected if the seafloor gradually increased in age. These and other observations only confirmed what Hess, Matthews, and Vine suspected: that new seafloor was created in midocean ridges and gradually spread outward in both directions.

The Theory Outlined

The coherent theory of plate tectonics, a unification of Wegener's continental drift and Hess's seafloor spreading, was largely pieced together during an 8-year period in the 1960s. Today, geologists view the earth as composed of two principal layers: the brittle, outer lithosphere (composed of the crust and upper mantle) and the denser, warmer asthenosphere (composed of the lower mantle and core). The lithosphere, akin to the fragile shell of an egg, is broken into some 20 distinct plates, which are rigid but deformable at their edges. These plates can contain both dense oceanic crust, which is rich in magnesium and iron, and lighter continental crust, which is enriched in silicon and aluminum. The interaction of plates produces many characteristic geological phenomena and is the subject of intense study by geologists and geophysicists.

When two plates meet, one of three general interactions occurs: They can move away from each other (divergent), move toward each other (convergent), or slide past each other (transform). When plates move away from each other at divergent boundaries, seafloor spreading takes place, and new oceanic crust is formed. Midocean ridges are an example of a divergent boundary, as are the rift zones of continental interiors (such as the present East African Rift). If a rift is successful and a piece of continuous continental crust is split in two, seafloor spreading commences and further pushes apart the continents. This process explains the mechanism of continental breakup, such as the splitting of the Mesozoic supercontinent Pangea into the seven main continents of today.

When plates come together at a convergent boundary, the result is more complicated. If denser oceanic crust meets lighter continental crust, the oceanic crust is subducted beneath the continent, often giving rise to volcanism. This process explains the so-called Ring of Fire, which follows many prominent subduction zones along the Pacific Rim. The subduction of oceanic crust is often associated with mountain building, most prominently the formation of the Andes of South America, which have resulted from the subduction of the Nazca Plate under the South American Plate. Additionally, subduction zones are frequently regions of deep and powerful earthquakes and are the source of the recurrent large tremors that rock Alaska and the northern Pacific. On the other hand, since continental crust is too buoyant to be subducted, the collision of two continents results in intense crustal wrinkling and thickening, producing mountains. Continental collision formed the Appalachians during the Paleozoic and today is responsible for the continuing uplift of the Tibetan Plateau, which formed via the collision of India and Asia during the Late Cretaceous and Early Tertiary.

Finally, when two plates slide past each other, earthquakes frequently occur, as manifested by the San Andreas Fault of California and the Anatolian Fault of Turkey. Such boundaries are among the most seismically active regions on Earth.

Despite this understanding of plate interactions, the exact driving force of plate tectonics is still poorly understood. Wegener originally proposed several possible mechanisms for continental motion, most of which were dismissed by critics as untenable. Years after Wegener's death, noted British geologist and physicist Arthur Holmes resurrected Wegener's suggestion that convective currents in the waxlike asthenosphere drive the motion of the overriding lithosphere, a hypothesis widely supported today. More recent research has added further details, and suggests that gravitational and frictional forces on subducting plates, as well as "push" from new extruded material at midocean ridges, also contribute to plate motion.

The ultimate driver of many of these forces is radioactive decay in the earth's core.

The "revolution" of plate tectonics, occurring between the first publication of Wegener's heretic views in 1912 and the accumulation of convincing paleomagnetic and oceanic data in the 1960s, is a prime example of a paradigm shift in science. When Wegener first proposed his theory of continental drift, nearly the entire geological community regarded Earth as static and unchanging, with current landmasses occupying the same position throughout the entirety of geological history. As would be expected, Wegener's views caused quite a stir in scientific circles, inspiring several symposia and publications that roundly criticized and dismissed continental drift. Respected geologist R. T. Chamberlin ridiculed the theory as being "of the foot-loose type," while Edward Berry bluntly labeled Wegener's method as "unscientific." Some of this criticism was pure obstinacy, but the majority of geologists chastised Wegener's failure to provide a plausible mechanism for continental motion. It was only several decades later, after new instruments and techniques revealed irrefutable evidence from paleomagnetism and oceanic surveys, that the scientific community accepted the reality of mobile continents. By this time, an increased understanding of radioactivity allowed for a plausible driving force: mantle convection. With the acceptance of plate tectonics came a new and open opportunity for understanding the processes and history of the earth, and it finally allowed for reasonable explanations of mountain building, volcanism, and earthquakes—geological phenomena that had puzzled geologists of the "static Earth" camp.

Conclusion

The theory of plate tectonics is the grand unifying theory of geology, a complete, understandable, working theory of the earth. Unlike most traditional sciences, geology deals with large-scale patterns and processes that operate over unthinkable lengths of time. Early geologists found it necessary to describe the geological history and processes of Earth based on events that occur in the present. Although intuitively rational, this "uniformitarianist" method of thinking prevented many geologists from recognizing complex processes that are difficult to observe, such as mountain building and earthquakes. An understanding of plate tectonics allows modern geologists to place volcanism, earthquakes, rifting, and other phenomena into a rigorous theoretical framework. The surface of the earth is divided into several plates that constantly move as new crust is generated at midocean ridges, driven by convective currents in the mantle. This basic set of processes has defined Earth for millions of years, differentiates our planet from other bodies in the solar system, and has governed both the physical and biological evolution of our world throughout geological history.

Stephen L. Brusatte

See also Catastrophism; Geology; Pangea; Stratigraphy; Uniformitarianism; Wegener, Alfred

Further Readings

Hallam, A. (1973). *A revolution in the earth sciences*. Oxford, UK: Oxford University Press.

Hess, H. H. (1962). History of ocean basins. In A. E. J. Engel, H. L. James, & B. F. Leonard (Eds.), *Petrologic studies: A volume to honor A. F. Buddington* (pp. 599–620). New York: Geological Society of America.

Oreskes, N. (2003). *Plate tectonics: An insider's history of the modern theory of the earth*. New York: Westview.

Sullivan. W. (1974). *Continents in motion: The new earth debate*. New York: McGraw-Hill.

Wegener, A. L. (1924). *The origin of continents and oceans*. New York: Dutton.

Plato (c. 427–c. 347 BCE)

Along with his teacher Socrates and his pupil Aristotle, Plato is recognized as one of the most influential thinkers in ancient philosophy. Plato deals with the notion of time in different contexts. He describes time as "a moving image of eternity" in his philosophy of nature (in his *Timaeus*, 37c–47c): the temporal structure of the cosmic universe aims at imitating the unchangeable eternal realm of the ideas, of which the real world is a reflection. Plato also develops (in the dialogue the

Statesman / the *Politikos,* 268d–274d) the idea of a cyclic dimension of the historical time, which consists of two "world ages" that alternate for eternity. The two ages have different characteristics and are seen as a result of a change of the overall inner motion of the cosmos. Finally, Plato aims at a deeper understanding of the paradoxes of movement that are linked to temporal becoming (in the dialogue *Parmenides,* 151e–157b). The main background for Plato's understanding of time is his doctrine of ideas, according to which the temporal world is in constant change; but "behind" this change lies the realm of unchangeable ideas, which exists outside of space and time.

Born in Athens, Greece, into an old aristocratic family, Plato was hindered in his pursuit of a political career by the turbulent politics of his times. In his youth he was a pupil of Socrates for 8 years, until Socrates' trial and execution in 399 BCE. After the death of Socrates, Plato's extended travels led him to Cyrene and Egypt and thus to Euclid of Megara, then to lower Italy, and to the Pythagoreans. In 385 Plato founded his famous school, the academy in Athens (which was only to be closed in 529 CE). He traveled several times to Sicily, where he attempted to put his political ideas into practice. He discarded this, however, after he fell into disgrace, became enslaved, and had to be redeemed by his pupils.

The platonic works that are preserved—besides the letters and the *Apology*—are all written in the form of dialogues, most of which depict Socrates debating with his interlocutors to seek the truth. Socrates' quest for a deeper understanding of the virtues and the nature of the good is presented as an antidote to the relativism and the empty rhetoric of the Sophists. In *Epistemology,* Plato aims thus at a distinction between true knowledge (*episteme*) and mere belief (*doxa*). In his political works he depicts a perfect state that is described as a corporate state, in which the people with the highest wisdom—the philosophers—should rule. Most influential for western metaphysics was Plato's doctrine of ideas, which also serves as a background for his cosmological notion of time.

Plato's Notion of Time

Plato develops his cosmological ideas in the dialogue *Timaeus* in the form of a mythical explanation of the creation of the universe. To understand this myth, one needs to look at Plato's doctrine of ideas. The core of this doctrine is the distinction between the realm of individual entities, which can be perceived by the senses and are in a constant state of change, and the eternal realm of unchanging ideas, which can only be perceived by reason. The constant change and motion of the elements of the empirical world make it impossible to secure general knowledge about them. In contrast, the eternal ideas form the realm of proper being, about which knowledge of mathematical certainty is possible. Ideas and individual entities are connected through a relation of "participation": An individual thing is only cognizable and has "being" to the degree in which it participates in a timeless idea. Something can for example be considered beautiful only if it participates at the idea of the beauty, if it is an instantiation of the general concept of beauty.

This distinction between ideas and the realm of real objects signifies on the one hand a relation of hierarchy: The archetype is more real and perfect than the image. On the other hand: the image resembles the archetype: Individual things can thus be regarded to be concrete instantiations of abstract ideas in space and time. It becomes clear that the distinction between unchanging ideas and the realm of the empirical world by Plato is also often regarded as a distinction between the timeless realm of eternal truth (like mathematical truth), in which no movement or change in time occurs, and the empirical world, in which no individual object remains the same, and a change over a period of time affects each of them.

The creation of time itself as a part of the visible universe is depicted in a myth told by Timaeus about the creation of the world. According to this myth, the godlike "demiurge" (craftsman) formed the cosmos out of preexisting matter guided by the unchangeable eternal ideas. He attempts thus to create an image of these ideas that is as nearly perfect as possible. The cosmos as a whole is seen as one perfect living being containing an invisible spirit and the visible parts of the universe (its body). The cosmos is created in the image of the perfect living creature (*zoon*) out of previously unstructured elements in a way that nothing is left outside of it. Because there is thus no exchange of matter or forces between an "outside" and an "inside," modes of spatial or temporal change cannot be attributed to the cosmos as a whole. The universe is thus eternal and does not grow in shape or size, and in this sense it also does not grow older (*Parmenides,* 33b). In the same line of argument also, the soul of the cosmos is declared to have an endless intelligent life for all times (ibid., 36e).

In order to make this image as perfect as possible, the demiurge creates "time" as a moving picture of eternity. The main idea here is that the cosmos cannot (as being created) be "eternal" in the same sense that the realm of the ideas is eternal (i.e., not affected by time), but it can mirror the idea of eternity through a cyclical periodical movement according to mathematical proportions. This movement is what we call time. One can illustrate this idea by comparing it to a thought we find in the *Symposium:* Individual living creatures are mortal and cannot be eternal, but they imitate the eternal idea through reproduction as a periodic act of the recreation of their species. Even though the individual is mortal and affected by time, the species—as the more general concept—is eternal and unchangeable.

Time is furthermore for Plato linked very closely to the realm of astronomy. It is created together with the heavens, and it finds its perfect expression in the periodic movements of the planets. The parts of time are therefore defined through astronomical relations: Days, months, and years are the natural elements of time, which are themselves determined by the movement of the earth, the moon, and the sun. In addition to this, Plato points out that there are numerous other parts of time, related to the movements of the other planets, that are—though often unknown to men—of equal importance and beauty. The most perfect cosmological "year" is completed when all planets have the same position again and the movement starts anew.

We can thus see that time aims at depicting eternity in the form of a periodic and cyclic movement, in the same sense as the circle is considered to be the perfect shape and circular movement as the most perfect type of movement. This cyclical understanding of time is characteristic of ancient Greek thought. Only in later periods (e.g., in early Christianity) did the idea of an overall direction of history culminating in salvation become important, eventually replacing the idea of an eternal return of everything by the notion of a clearly defined "progress."

Besides the parts of time (the days, months, years, etc.), Plato also discusses the modes of time, the past (the "it was"), the present (the "it is") and the future (the "it will be"). He insists that the "it was" and the "it will be" can only be applied to things within the world and not to the eternal realm of the idea, of which only the "it is" is an appropriate formulation. Linked to this idea is Plato's struggle to understand the processes of "becoming" and "changing" in general that all lead to logical paradoxes, discussed already in the Presocratic philosophy. In this context the Eleatic philosophy is very relevant, ascribing real being only to the things that "are" and remain always the same and thus denying the possibility of change. Change is thus seen as an illusion. We can see how Plato on the one hand replicates elements of this idea in his dualistic doctrine of ideas, but how he tries, on the other hand, to reconcile abstract dualism by depicting time itself as a "moving image of eternity" that itself tries to some extent to bridge the gap between the atemporal world of ideas and the temporal world of finite objects.

Cyclical Nature of History

In the *Politikos,* the question of the ideal statesman is discussed. In this context a myth of two world ages is reported by the "stranger," who takes the lead in this dialogue. Because the cosmos has a visible bodily part, it is submitted to forms of movement. Because there cannot be a movement to another place—as there is no "place" outside the cosmos—this movement takes the form of an inner rotation of the whole cosmos. This rotation is set by the gods in one direction at the beginning of the universe. In this age, determined by the overall direction of the rotation, men were born from earth and lived under the guidance of gods a pleasurable life dedicated to philosophy. This period is called the age of *Kronos* (time). (Kronos is in the Greek mythology the father of Zeus.)

After a long period of time, this age comes to its natural end when the cosmos has finished its movement in one direction. Now the gods release the cosmos to start spinning in the opposite direction: The planets and the sun move "backwards." In this second world age, the age of Zeus, nature is left to its own guidance. Men are born from men and will be buried in earth when they die. The further away this period moves from the first age, the more knowledge about the Good gets lost. Eventually this period will again come to its end, and the direction of rotation will change once more. This cyclic alteration keeps continuing for eternity. According to this myth, it is important to know in which of the two periods one is living, as the definition of the good statesman differs for both ages.

Again it can be seen that a cyclical understanding of time is prominent in Greek tradition, although Plato combines this thought with a specific direction for each age. The age we humans currently live in—the age of Zeus—is depicted as an age of decay that on the one hand moves further and further away from the golden age of the past. On the other hand—due to the eternal alternation—this age, like others, will come to an end and will be replaced by a new period "under the guidance of gods."

Logical Paradoxes of Motion and Time

In the *Parmenides,* Plato discusses central aspects of his doctrine of ideas. The main character is the aged Eleatic philosopher Parmenides, who explains to the very young Socrates his doctrine of the one being. In the first part of the dialogue, the doctrine of ideas is discussed; in the second part, several dialectical exercises are carried out by Parmenides that contain logical analyses and problems of the "one."

In this dialectical exercise, opposing theses are discussed and developed out of each other. Different interpretations have been suggested for these difficult passages; the main purpose is very likely to reject the radical dualism of the Eleatic opposition of the "unchangeable, atemporal one" and the moving unstable empirical world of changes of the other side: Zeno (the second Eleatic philosopher in this dialog, who represents this strict opposition) is becoming more and more a side-figure of the dialogue, as the main attempt seems to be to try to bridge those two realms and come to a more concrete understanding of the ontological principles of being (the ideas) and the changes happening in reality.

While the "one of being" is shown to be atemporal, every individual thing is said to have some relation to time. In this context, "existence" is identified as "being present" at a certain time: Everything that exists in time is, however, also capable of "becoming" or—more generally—of changing, especially, of course, of growing older. "Being" is thus deeply linked to time, as "is" means that something exists in the now, while "has been" means something existed in the past; "will be" finally refers to some existence in the future. Plato discusses the apparent paradox that things can thus grow older than they were while at the same time being younger than what they will be in the future.

Plato's notion of time was very influential in ancient philosophy. Its cosmological explanation (in the *Timaeus*) was adopted by Plotinus in later Neoplatonism, though in his explanation of time the relation to astronomy and mathematics gets more and more lost. Christian thought reinterpreted the myth of the *Timaeus* as a myth of creation, understanding the "timeless ideas" as a part of God's eternal mind. Aristotle's theory of "dynamis," and his distinction between the "actual" and the "potential," respectively, between the "substance" and his "attributes," can be seen as an attempt to solve some of the paradoxes linked to the question of how things can change in time and still remain the same (so that Socrates can grow older and still be "Socrates").

Andreas Spahn

See also Aristotle; Aristotle and Plato; Becoming and Being; Cosmogony; Demiurge; Idealism; Paremenides of Elea; Plotinus; Presocratic Age; Zeno of Elea

Further Readings

Brumbaugh, R. S. (1990). *Plato on the one.* New Haven, CT: Yale University Press.

Cooper, J. M., & Hutchinson, D. S. (Eds.). (1997). *Plato: Complete works.* Indianapolis, IN: Hackett.

Cornford, F. M. (1997). *Plato's cosmology: The* Timaeus *of Plato.* Indianapolis, IN: Hackett.

Kraut, R. (1992). *The Cambridge companion to Plato.* Cambridge, UK: Cambridge University Press.

Wright, M. R. (Ed.). (2001). *Reason and necessity: Essays on Plato's* Timaeus. Swansea, UK: Classical Press of Wales.

Plotinus (c. 205–270 ce)

Plotinus was born in the Nile Delta region of Egypt; he studied philosophy in Alexandria and later, Rome. He did not see himself as an original philosopher in the modern sense, but rather as interpreter of the truth that was first elucidated by Plato. Thus he became the founder of Greek Neoplatonism. Central issues of Plotinus's thinking are these: The first principle is the one; that is identical with the good; from the one, the intellect proceeds, which can be identified with being, and from the intellect proceeds the soul. These are the three principles or hypostases of reality.

In his treatise on eternity and time (*Enneade* III 7), Plato's theory of time developed in the *Timaeus* is the framework for Plotinus's own inquiry, but Aristotle's views intensively stimulate his notion of time in this world. Plato's definition of time as the "moving image of eternity" indicates that time can be described only in the context of eternity. Aristotle's definition of time as the "number of motion" shows that time is something closely linked to movement and to the counting soul. Plotinus's main thesis is this: Eternity is the life of the intellect, and time is the life of the soul.

His treatise on eternity and time starts with the presupposition that eternity (*aion*) is linked to the intelligible world of eternal being and time (*chronos*) to our sensible world of becoming. Eternity and intellect both include the same, because both are "most venerable" (*semnotaton*). While the intelligible includes everything just as a whole includes its parts, eternity includes the whole all at once (*homou*), that is, simultaneously and not as parts. Although rest corresponds to eternity as motion does to time, eternity is not identical with rest; otherwise the intelligible world would be limited to only one of the five concepts in Plato's *Sophist;* the other four (substance, motion, the other, the same) would be excluded. The first definition of eternity is this: "Eternity is the life, which belongs to that which exists and is in being, all together and full, completely without extension or interval" (all translations by Armstrong). This definition is founded on Plato's "living being" in the *Timaeus,* which is contemplated by the demiurge. This is described as "eternal" and as "always existing in the same state."

For Plotinus, eternity is not to be identified with the intellect or the intelligible world but it is related to the totality of the intelligible life. This life that is eternity is not identical with the intelligible, but is a manifestation of it: "Eternity is not the substrate but something which, as it were, shines out from the substrate itself." Eternity does not come to the intelligible from outside but it is from it and with it; that is, "The nature of eternity is contemplated in the intelligible nature existing in it as originated from it." So eternity is an aspect of the intelligible as much as beauty or truth and is very close to being like a Plotinian intelligible form. It is a true whole in such a way that it is deficient in nothing, with neither past nor future.

Whereas the universe has a future and hastens by its everlasting circular movement to everlasting existence by means of what is going to be, the complete and whole substance of reality is something that is always existing—from "always existing" (*aeion*) is derived eternity (*aion*). Eternity is described as "state [*diathesis*] and nature [*physis*]" of complete reality, so Plotinus held the thin line between giving eternity a precise ontological status and seeing it as a quality. The difference between "everlastingness" and "eternity" is as follows: Eternity is the substrate from which everlastingness manifests itself, but eternity is the substrate with the corresponding condition manifested. So the final definition of eternity is this: "And if someone were in this way to speak of eternity as a life which is here and now endless because it is total and expends nothing of itself, since it has no past or future . . . he would be near to defining it."

Plotinus's examination of time is based on other philosophers' theories of time, namely these: (a) Time is *movement* (e.g., Plato interpreted by Eudemus, Theophrastus, and Alexander as identifying time with the movement of the heavens); (b) time is *what is moved* (the heavens themselves); and (c) time is *something belonging to movement* (e.g., the Stoic view of time as extension of motion, the Epicurean definition of time as accompaniment of motion, or the Aristotelian definition of time as number of motion). For Plotinus, time proceeds from the transcendence of the intellect. As eternity is the life of the intellect (*nous*), time is the life of the soul, which is to be identified with discursive reason (*dianoia*) and which descends from the hypostasis of the intellect. "Before" the descent of the soul, time was "at rest with eternity." By "a restless active nature which wanted to control itself and be on its own," the soul "transferred what it saw to something else" and "moved on to the 'next' and the 'after.'"

Just as soul constitutes itself as an image of the intellect and then produces the physical world as an image of itself, therefore also soul constitutes time, which is its own life as an image of eternity, and then creates as an image of itself the sensible world in time. Time then exists on two levels: First, "time is the life of soul in a movement of passage from one way of life to another." Second, it is the measured time in the physical world. The life of soul is discursive reason; that is, the movement from one idea to another. Therefore, the notions of "before" and "after" are present even in the intellect, so that "before" and "after" signify the order of causality, not the temporal sequence. Therefore, Plotinus's theory of time connects Plato's definition of time as "moving image of eternity" with Aristotle's definition of time as "number or measure of motion."

According to Plotinus, Aristotle failed to explain the nature and origin of the preexistent measuring number. Plotinus was far from suggesting an exhaustive rejection of Aristotle; instead he only complained that Aristotle's writings lacked sufficient clarity, because they were addressed to an internal school audience. With regard to Plato, Plotinus only wanted to correct misinterpretations: Instead of equating the heavens with time, Plato means that the sphere and the planets "manifest" time. Thus, time as a distinct interval measured by the movement of the heavens could be used as a measure, but time itself is not a measure; it should rather be called what is measured. By integrating Plato's and Aristotle's theories of time in his own system of hypostases, Plotinus succeeded in explaining the substantial nature of time and in differentiating between the metaphysical notion of time itself and the physical measurement of time.

Michael Schramm

See also Aristotle; Becoming and Being; Bruno, Giordano; Cosmogony; Eternity; Lucretius; Nicholas of Cusa (Cusanus); Plato; Rome, Ancient; Teilhard de Chardin, Pierre

Further Readings

Smith, A. (1996). Eternity and time. In L. P. Gerson (Ed.), *The Cambridge companion to Plotinus* (pp. 196–216). Cambridge, UK: Cambridge University Press.

Strange, S. K. (1994). Plotinus on the nature of eternity and time. In L. P. Schrenk (Ed.), *Aristotle in late antiquity* (pp. 22–53). Washington, DC: Catholic University of America Press.

Plutarch (c. 46–c. 120)

Plutarch, a classical Greek writer, lived during the period when the Roman Empire ruled the Mediterranean region, including Greece. Born into an aristocratic and influential family, Plutarch spent much of his life in Chaeronea, his birthplace in Boeotia. In his travels he visited Athens, Egypt, and Italy, often teaching and lecturing in Rome. Later in life, he would found an academy before joining the priesthood of the Oracle at Delphi, as he was a devout believer in the ancient pieties as well as an astute student of antiquity. Plutarch received his education in Athens, where he composed many essays and dialogues and became a writer and thinker versed not only in philosophy but also in science and literature. His works have greatly influenced Western understanding of classical culture, especially in comparing and contrasting exceptional individuals who lived in ancient Greece and ancient Rome.

Plutarch is most renowned for his historical works, which focus on the heroic lives of those who shaped both the classical and Hellenistic ages in Greece. His *The Rise and Fall of Athens: Nine Greek Lives,* and *The Age of Alexander* and *Makers of Rome: Nine Lives* remain widely read as staples of a classical education, although they are sometimes viewed as flawed in their historical methodology. Plutarch often includes what some historians regard as an excess of critical commentary in his accounts; moreover, Plutarch was not a contemporary of many of his subjects and thus relied on secondary sources who did not necessarily witness the events they recorded, so his historical accuracy is sometimes questionable. His style of weaving into his stories a great deal of legend or myth can confound the modern reader seeking detailed historical explanations. Consequently, Plutarch's chief value may lie not in his fidelity to historical detail but in his embodiment of the spirit of the classical Greek and Roman ages.

A philosopher by trade, Plutarch habitually made moral judgments about the character of his subjects on the basis of their deeds; thus, his historical accounts were perhaps secondary to the moral example they provide the reader. Of special interest to Plutarch was the comparison between the great lives of classical Greece and those of his contemporary Romans. His *Parallel Lives* illustrates similarities in excellence of character, or lack thereof, for the purposes of providing social commentary and in a way acting as a moral compass to the leaders of his time.

For his efforts as both biographer and philosopher, Plutarch was honored by Emperor Hadrian with a government appointment in Greece. Until his death, Plutarch continued to travel between Greece, Rome, and Egypt.

Garrick Loveria

See also Alexander the Great; Aristotle; Caesar, Gaius Julius; Peloponnesian War; Rome, Ancient

Further Readings

Lamberton, R. (2001). *Plutarch.* New Haven, CT: Yale University Press.

North, T., & Mossman, J. (Trans.). (1999). *Plutarch: Selected lives.* Ware, UK: Wordsworth.

Poetry

The inexorable passage of time and corollary facets of change, mortality, memory, and nostalgia are rich themes in literature and, particularly, in poetry. Poetry, in the Aristotelian sense, seeks to recreate human experience and capture both its sensory and abstract essence. Unlike prose, poetry relies on a separate set of conventions emphasizing rhythm and sound patterns as well as figurative language and symbolism to achieve a multilayered effect. Common symbols evoking associations with time include references to the phases of the moon and tides, the rising and setting of the sun, the cycle of seasons, and shifting sand in its natural state or as a calculation of time through an hourglass. Such concrete references intensify awareness of the inevitable passage of time, which, although an abstract concept, is measured concretely through human constructs.

A common theme in Western poetry is *carpe diem,* or "seize the day." This metaphor is derived from the Latin *carpere,* "to pluck or grab," and *die,* meaning "day." The phrase is generally attributed to the Roman lyric poet Horace (65 BCE–8 BCE) also known as Quintus Horatius Flaccus. Horace used metaphors from nature to advise against procrastination and urged his readers to enjoy the present, "Be wise, strain the wine; and since life is brief, prune back far-reaching hopes! Even while we speak, envious time has passed: Pluck the day, putting as little trust as possible in tomorrow" ("*carpe diem, quam minimum credula postero*"). This view focuses on the present and encourages making the most of each day and stage of life. The adage has often been extended to embody a hedonistic sense of enjoying pleasure without concern for the future, because time, and ultimately death, are destroyers of life's joys.

The *carpe diem* theme was popularized during the European Renaissance (14th to 17th centuries), which saw a rebirth in learning and emphasis on humanism. This intellectual revolution was marked with great achievement in art, music, and literature. It also followed the devastating Black Plague of the 14th century, which wiped out at least one third of the population of Europe from Italy to Norway. The suffering and fragility of human life, as well as its potential for great accomplishment, made *carpe diem* an anthem to life and living it fully.

English poet and playwright William Shakespeare (1564–1616), long considered one of the greatest writers in the English language, often reflected on mortality and the overarching power of time in his sonnets and plays. His 38 plays were written predominantly in iambic pentameter, or blank verse, as were his 154 sonnets. In Sonnet 18, Shakespeare uses his pen to defy time and bring immortality to his love: "So long as men can breathe or eyes can see,/So long lives this, and this gives life to thee." In Sonnet 30, Shakespeare expresses remorse over wasted time: "When to the sessions of sweet silent thought/I summon up remembrance of things past,/I sigh the lack of many a thing I sought,/And with old woes new wail my dear time's waste." But knowledge of mortality can even intensify love, as in Sonnet 73: "This thou perceivest, which makes thy love more strong,/To love that well which thou must leave ere long." And Sonnet 45 expresses human resistance, as well as powerlessness, against the ravages of time: "And nothing 'gainst Time's scythe can make defence/Save breed, to brave him when he takes thee hence."

Shakespeare also made numerous references to time in his plays, both comic and tragic, as illustrated by the clown's refrain in *Twelfth Night:* "What is love? 'Tis not hereafter;/Present mirth has present laughter, What's to come is still unsure:/ In delay there lies no plenty" (act 3, scene 2). A darker reference is made in *The Tragedy of King Richard II* when Richard laments: "I wasted time, and now doth time waste me:/For now hath time made me his numbering clock" (act 5, scene 5). Whether expressing hope, defiance, regret, or stoicism, Shakespeare grappled frequently with the relentless nature of time and its effect on the human condition.

Other 16th- and 17th-century English poets also addressed the *carpe diem* theme, particularly the Cavalier poet Robert Herrick (1591–1674) and the metaphysical poet Andrew Marvell (1621–1678). In "To the Virgins, Make Much of Time" Herrick urges, "Gather ye rosebuds while ye may,/Old time is still a-flying,/And this same flower that smiles today,/To-morrow will be dying." In "To His Coy Mistress," Marvell pleads, "Now let us sport us while we may,/And now like amorous birds of prey, Rather at once our time devour/Than languish in his slow-chapped power." These works impart a sense of immediacy and become an argument for satisfying desire in the moment. This sentiment was frequently expressed by 20th-century poet Edna St. Vincent Millay (1892–1950) who recognized the short lifespan of passionate love, as in sonnet "XI": "I shall forget you presently, my dear,/So make the most of this, your little day,/Your little month, your little half a year."

Regret over wasted time recurs frequently in the works of modern and contemporary poets looking back on misspent youth or oblivious to the passage of time until it is too late. British writer Christina Rossetti (1830–1894) in "A Daughter of Eve" laments: "A fool I was to sleep at noon,/And wake when night is chilly . . . /Oh it was summer when I slept,/It's winter now I waken." A profound sense of loss is conveyed by 20th-century Welsh writer Dylan Thomas (1914–1953) when he writes powerfully of his youth and disregard for the power of time. In "Fern Hill," Thomas recreates the idealized rural paradise of his early life, which he describes as "green and golden" while "Time let me play and be/Golden in the mercy of his means." But as an adult he realizes, "Time held me green and dying/Though I sang in my chains like the sea." Another of Thomas's poems, "Do Not Go Gentle Into That Good Night," pleads to his dying father, "Do not go gentle into that good night./ Rage, rage against the dying of the light." Thomas's tone conveys not an acceptance of the inevitability of time and death but, rather, resistance even against an insurmountable power.

American writers Archibald MacLeish (1892–1982) and Emily Dickinson (1830–1886), although separated by almost a century, both pondered the unfathomable concept of eternity. Dickinson, who led a most private and solitary life, often grappled with time as an abstract and her own place in the continuum, as in "Behind Me Dips Eternity": "Behind Me—dips Eternity—/ Before Me—immortality—/Myself—the Term between." Her use of punctuation to create pauses reminds the reader of the subtle transition by which past, present, and future flow into one. Archibald MacLeish, a more public figure who was artistically and politically active, echoed a similar voice in "An Eternity": "There is no dusk to be,/There is no dawn that was,/Only there's now, and now,/ And the wind in the grass." Both poems reinforce the significance of being fully alive in the moment and the realization that humans can comprehend the universe only through sensory experience in the present.

Walt Whitman (1819–1892), influential and iconoclastic American writer, applied his theory of an "Oversoul" to create a vision of the interconnectedness of human life and the natural world, which flow as one through time. In his masterwork, "Crossing Brooklyn Ferry," Whitman uses the movement of the river, clouds, and sunlight descriptively and metaphorically, as the ferry and its passengers flow together, not only through physical space, but also through time: "Others will enter the gates of the ferry, and cross from shore to shore . . . /A hundred years hence, or ever so many hundred years hence, others will see them,/Will enjoy the sunset the pouring in of the flood-tide, the rolling back to the sea of the ebb-tide." In Whitman's interpretation, the oneness of humanity is manifest through shared experience over time; therefore, time and the cycles of nature become unifying, rather than separating, elements.

The 19th-century American transcendental movement protested reliance on the empirical world and promoted intuition and spiritualiy over doctrine and pure reason. A leading writer and thinker in this movement, Ralph Waldo Emerson (1803–1882) personifies time in his poem "Days": "Daughters of Time, the hypocritic Days, . . . /Bring diadems and fagots in their hands/To each they offer gifts, after his will,—" This verse ponders how time brings new days that can be wasted or fulfilled, either through chance or the exercise of free will. Emerson juxtaposed the lasting quality and value of a jeweled crown with the ephemeral bundle of sticks that offer a brief light before turning to ashes. Transcendentalists encouraged close observation of nature, as expressed in Emerson's essay: "To the attentive eye, each moment of the year has its own beauty, and in the same field, it beholds, every hour, a picture which was never seen before, and which shall never be seen again." Time, then, creates an ever-changing, but impermanent, beauty.

American transcendentalism is strikingly similar to Eastern views of nature as expressed in traditional Japanese haiku, a 300-year-old classical form that embodies the awareness of time by capturing the moment, particularly the transition of seasons. This traditional form, whose structure is based on elements of sound in Japanese, has been adapted in English to 17 syllables arranged in three lines of 5, 7, and 5 syllables each, respectively. It is one of the shortest but most effective forms of verse and focuses on a fleeting moment or, otherwise, unnoticed event. One of the revered writers of haiku was Basho, born Matsu Kinsaku (1644–1694), a poet, teacher, and Zen philosopher. His poetry compresses time, observing the human life span as reflected in microcosms of nature and the significance of events that mark the transition from one season to another: "The first soft snow!/Enough to bend the leaves/Of the jonquil low." The reader may extend the metaphor, complete the chain of events, and transfer the meaning to human experience.

The concise, but powerful, form of haiku has been adapted to other languages and cultures as a means of escaping time-bound expression and characterizing time as a continuum, or what theologian Paul Tillich (1886–1965) has referred to as "The Eternal Now." Poetry serves as a bridge, transcending time and space and reaching back to the past and forward to the future. As renowned Japanese writer Natsume Soseki (1867–1916) expresses in his haiku: "On New Year's Day/I long to meet my parents/as they were before my birth." Imaginative time travel is also suggested by British poet T. E. Hulme (1883–1917) in "Image": "Old houses were scaffolding once/and workmen whistling." And British poet James Elroy Flecker (1884–1915) projects his greeting forward in his six-stanza quatrain "To a Poet a Thousand Years Hence": "Since I can never see your face,/And never shake you by the hand,/I send my soul through time and space/To greet you. You will understand."

As a literary form, poetry exposes the human mind and heart grappling with the concept of time by recreating the past, capturing the present, and imagining the future. American-born writer T. S. Eliot (1888–1965) considers the nature of time in *Four Quartets,* which poses the possibility of alternate realities, or "What might have been and what has been/Point to one end, which is always present." Each section of the Quartets is related to one of the four basic elements of air, earth, water, and fire, and in "Burnt Norton" (No. 1 of *Four Quartets*), Eliot frames the conundrum powerfully: "Time present and time past/Are both perhaps present in time future,/And time future contained in time past. If all is eternally present/All time is unredeemable."

Linda Mohr Iwamoto

See also Alighieri, Dante; Chaucer, Geoffrey; Donne, John; Eliot, T. S.; Lucretius; Shakespeare's Sonnets

Further Readings

Bevington, D. (2003). *The complete works of Shakespeare* (5th ed.). New York: Longman.

Ferguson, M., Salter, M. J., & Stallworthy, J. (Eds.). (1996). *The Norton anthology of poetry* (4th ed.). New York: Norton.

Poincaré, Henri (1854–1912)

Henri Poincaré belongs to a small group of brilliant scientists who, living at the turn of the 20th century, made fundamental contributions to mathematics, physics, and philosophy. It has been said that Poincaré's mathematical knowledge comprised the whole mathematics of his time, and his lectures on theoretical physics show that he also had an encyclopedic overview of this field. Poincaré began his career as an engineer, but he quickly became famous for his great discoveries in mathematics, particularly in geometry and topology. Poincaré's results had a great impact on the history of mathematics and theoretical physics. For example, his consideration of the mechanical stability of systems composed of three bodies that attract each other by gravity led to the development of chaos theory. Poincaré's views of philosophical aspects of science, which he never presented in a systematic fashion, cannot be easily categorized as belonging to one of the main philosophical schools. This is also true of his idea of the relativity of time, which must be reconstructed from some of his papers collected in *Science and Hypothesis* (1902), *The Value of Science* (1906), *Science and Method* (1908), and the posthumous *Last Essays* (1913).

Jules Henri Poincaré was born on April 29, 1854, in Nancy, France. He was an outstanding pupil and made a very successful career in the French system of elite universities. His first academic degree was in mining engineering, and he worked for a short time as a coal-mining inspector. Yet after receiving his doctorate in mathematical sciences from the University of Paris in 1879, Poincaré began swiftly to publish important mathematical results, which brought him renowned chairs, particularly in mathematical physics, at different universities in Paris beginning in the mid-1880s. Besides being admitted to countless French and international scientific academies and societies, Poincaré was also an important member of the Bureau des Longitudes in Paris that organized the global coordination of clocks necessary for the production of precise maps. When he died prematurely in Paris on July 17, 1912, Poincaré was hailed as one of the most renowned researchers of his time. His fame as one of the last scientists who could make most important discoveries in different fields of research and reflect on his research philosophically continues to the present day.

Poincaré's consideration of time starts, like that of Einstein, with a seemingly innocent question: How can we judge objectively that two events are happening simultaneously? Any answer presupposes that it is possible to objectify the flow of time that our consciousness experiences qualitatively. Poincaré denies that human beings, scientists included, have access to some kind of absolute time beyond the scientific means of quantifying time by measurement instruments. If every process in nature were to be equally slowed down, we could not detect this deceleration, because the processes in the instruments for measuring time would also be slowed down.

Poincaré's criticism of the idea of absolute time exemplifies his philosophical stance on fundamental problems of science. He is convinced that the conceptual system by which we describe, analyze, and explain natural phenomena is a convention in the following sense: It is always possible to use, instead of the given conceptual system, other ones that can fulfill the same task. What convention we choose depends on pragmatic criteria, particularly on how simple it is to apply a conceptual system to the phenomena we want to understand. So conventions are neither true nor false; they are disguised definitions that prove to be more or less convenient for certain purposes.

To measure time, a periodic process in nature, such as the rotation of the earth on its axis, is needed whose cycles we suppose to be of the same duration. Yet this is only approximately true: The rotation of the earth, for example, is very gradually slowing down due to the friction caused by the tides. To explain this slowing down, and to detect it empirically, science presupposes the validity of well-known physical theories, namely thermodynamics and Newtonian mechanics. Their validity must not be affected however we define our measure of time, because we rely on these theories in the very act of defining. When we conventionally select one among the possible measures of time, we do this in such a way that the fundamental laws of nature can be mathematically formulated as simply as possible. As scientists, we ought not to say that one clock is right and the other one wrong; instead, we should say that it is more convenient to use this clock and not that one.

What events we suppose to be synchronous is also a matter of convenience. We choose such criteria of synchronicity as will allow the simplest formulation of the laws of nature we are using when we explain the physical processes by which we make local time measurements and by which we communicate the results of these measurements. Exploring the physics of time means, according to Poincaré, to investigate measurement processes in order to establish conventions that we can use both for an understanding of time and for an explanation of how our clocks would behave if they were perfect measuring instruments.

So far we have discussed only the philosophical sense of the relativity of time in Poincaré's thought. The question of whether Poincaré should be regarded, together with Einstein, as the discoverer of the special theory of the relativity of time and space has been intensely debated. The historical evidence seems to weigh against Poincaré: He relied too much on physical concepts (like the ether) that stood in the way of understanding Einstein's new conception of time and space. For Poincaré, the physical principle of the relativity of time is also a matter of convention, because it makes, for the sake of convenience, the following assumption that turns out to be only approximatively true: Two bodies that are very far away from each other can be described in different frames of reference, because they do not influence each other.

Stefan Artmann

See also Einstein, Albert; Einstein and Newton; Newton, Isaac; Time, Measurements of; Time, Relativity of

Further Readings

Galison, P. (2003). *Einstein's clocks, Poincaré's maps: Empires of time.* London: Hodder and Stoughton.

Greffe, J.-L., Heinzmann, G., & Lorenz, K. (Eds.). (1996). *Henri Poincaré: Science and philosophy.* Berlin and Paris: Akademie Verlag and Albert Blanchard.

Zahar, E. (2001). *Poincaré's philosophy: From conventionalism to phenomenology.* Chicago and La Salle, IL: Open Court.

Polo, Marco (1254–1324)

Marco Polo was a Venetian traveler and merchant who traveled to China at a time when Europeans knew little about Asia. Polo served the Mongol Emperor Kublai Khan for 24 years before returning to Venice. He attained great fame with the publication of his account of the journey, *Il Milione*. This book helped to inspire Europe's Age of Exploration.

Marco Polo was born in Venice, Italy, into a family of merchants. Venice was an important center of trade in the medieval world. Venetian merchants maintained trading posts as far away as the Black Sea, where goods arrived along the ancient trade route known as the Silk Road. Marco's father, Nicolo Polo, and uncle, Maffeo Polo, had traveled across Asia on a trade expedition around the time of Marco's birth. They traveled deep into China, which Europeans called *Cathay,* and they met the Mongol ruler Kublai Khan. The Khan received them very courteously and invited them to return again with Western scholars who could teach Christianity to his people. Nicolo and Maffeo Polo returned to Venice in 1269 and prepared for a second expedition that would include Marco.

In 1271, the Polos began the long journey to the Far East along with two Christian missionaries. The two missionaries became frightened while passing through Armenia and abandoned the mission. Seventeen-year-old Marco Polo, along with his father and uncle, continued the trip alone. It took more than 3 years of travel before the Polos again met Kublai Khan, after traveling much of the way on camels. Marco Polo, with his knowledge of four languages, became a valuable diplomat in the service of the Khan. He traveled on missions throughout Asia, and for 3 years served as a government official in the Chinese city of Yanh-Chow (Janguy). After 24 years away from Venice, the Polos finally decided to return home. The Khan was very reluctant to let them go.

The Polos arrived in Venice in 1295 and were scarcely recognized. They returned to a Venice that was at war with the rival city of Genoa. Marco Polo commanded a Venetian galley during the conflict but was taken prisoner by Genoa following a naval defeat. In prison, Polo wrote an account of his travels across Asia and his relationship with the great Khan. With the help of Rustichello of Pisa, Polo's story was translated into French and completed in 1298. Polo called his book *The Description of the World,* but the name *Il Milione* was more commonly applied. The book became very popular and widely distributed in a time before the advent of the printing press. The Polos were not the first Europeans to travel across Asia, but they became the most well known. By the time the Polos returned to Venice, the advance of the Turks had already cut off trade routes to China. Europeans would in time sail west to reach China and India. Following Marco Polo's release from prison in Genoa, he returned to Venice and became a wealthy and respected merchant. He never left Venice again and died at nearly 70.

Marco Polo's experience had a lasting impact on the contact between Europe and the Far East over time. Historians believe that his book influenced later explorers such as Christopher Columbus.

James P. Bonanno

See also Columbus, Christopher

Further Readings

Forman, W., & Burland, C. A. (1970). *The travels of Marco Polo*. New York: McGraw-Hill.

Hart, H. H. (1967). *Marco Polo: Venetian adventurer.* Norman: University of Oklahoma Press.

Larner, J. (1999). *Marco Polo and the discovery of the world*. New Haven, CT: Yale University Press.

Pompeii

Pompeii was an ancient city of the Roman Empire, located near the Bay of Naples in the Campania region of Italy, a few miles southeast of Mt. Vesuvius. Situated at the mouth of the Sarnus (modern Sarno) River, Pompeii was a popular resort town for wealthy Romans and a busy trade center. In the year 79 CE, Mt. Vesuvius erupted, destroying Pompeii, Herculaneum, Stabiae, and many smaller communities. Today Pompeii is one of the most important archaeological sites in the world. Most cities have many layers of occupation and stages of development, but the burial of this entire city under 30 feet of ash and debris has perfectly preserved for all time an ordinary day in the lives of ordinary people of the Roman Empire.

History of the City

The site of Pompeii was likely first settled by Oscan-speaking descendants of Neolithic people in the 8th century BCE. The strategic river location eventually came under the influence of Greeks who had settled across the bay. Pompeii and Herculaneum remained the center of Greek occupation until the 5th century BCE, when Samnites descended from the north and seized control. Rome drove the Samnites from the region in the 4th century BCE and claimed Pompeii. The city was permitted to keep its own language and culture, but its inhabitants were not granted citizenship or given any privileges. This situation was maintained for centuries, until the citizens of Pompeii had a chance to join with other rebels in an attempt to win freedom from Roman oppression. Sulla, a brilliant Roman general, eventually defeated the Campanians and took Pompeii and Herculaneum in 89 BCE. The rebels were granted Roman citizenship despite their defeat, but many liberties were taken away. Rome strategically housed army veterans in the area to maintain order.

The rich natural resources available in the area and easy access to the sea enabled Pompeii to flourish. As Rome became increasingly prosperous, the standard of living in Pompeii increased proportionally. The entire region along the coast of the Bay of Naples became a popular vacation destination for wealthy Roman citizens.

Mt. Vesuvius remained dormant throughout these many centuries of occupation. There was no way for Pompeians to know that they were living at the base of a volcano that had buried a Bronze Age settlement under 20 feet of debris directly beneath them in 1780 BCE. In the year 62 CE, a severe earthquake resulted in catastrophic damage to both Pompeii and Herculaneum. Repairs were still being made 17 years later when the city was destroyed.

The Eruption of Vesuvius

Roman science in the 1st century was based more on mythology than geology. Mild earth tremors were common and were not alarming to the population. Fumaroles—vents of volcanic gas escaping through the crust to relieve pressure—were seen from a distance and reported to be giants roaming the land. The gods would defeat the giants and trap them under the mountain, which would cause the earth to shake. There was no correlation made between seismic activity and volcanic activity.

Major seismic activity began on August 20, 79 CE. A series of quakes increased in frequency over the following 4 days. Animals were restless, and springs near the mountain ran dry. In the middle of the day on August 24, Vesuvius suddenly erupted. A huge column of superheated gas, rock, and ash blasted straight up from the top of the mountain. As the cloud cooled, it spread and drifted with the wind. A vivid eyewitness description of the initial explosion exists in letters written by Pliny the Younger, who witnessed the phenomenon with his uncle from 15 miles away. As the cloud began to collapse, the sky darkened and pieces of pumice rained down on Pompeii. This "Plinean" phase of the eruption lasted about 18 hours. The initial fall of ash, rock, and pumice deposited more than 9 feet of debris on the town. A few unfortunate individuals were struck down by falling stones or collapsing roofs, but there were few deaths on the first day. It has been estimated that perhaps 80% of the population escaped the region by leaving immediately. The 2,000 or so people who decided to take shelter and wait for the event to pass were the unlucky ones.

The true lethality of the eruption occurred in the final few hours of the second day. Surges of pyroclastic material and superheated gas roared down the mountain, reaching the city of Pompeii in minutes. There was no escape. All remaining residents were asphyxiated in seconds. A series of surges deposited an additional nine or more feet of ash and rock, effectively entombing the town. The complete and instantaneous burial of the town protected it from looting and natural weathering. When dawn broke on August 26, all was quiet and still. The entire region of Campania was buried under a thick layer of ash. The eruption changed the course of the river and raised the sea beach, masking the original location of the city. Over ensuing years, the memory of Pompeii and its neighboring cities faded into obscurity.

The Rediscovery of Pompeii

By the 4th century CE, Pompeii no longer appeared on maps. The area was called Civitas. The ash that had buried the region over 200 years earlier had become fertile soil. Farmers moved back into the area and planted their grapevines and olive trees. In 1709, some well diggers unearthed marble. The prince in charge of the region was building a new villa nearby, so the workers continued to strip the marble until the villa was completed. The marble was from the façade of the theater in Herculaneum. In 1738, King Charles III took control of the region and sent workers to the same location in search of additional treasure. Systematic studies and surveys of the area were carried out. Work began in the vicinity of Pompeii in 1748. An inscription identifying the site as Pompeii was uncovered in 1763. The methodical, deliberate work at these sites in the mid-18th century can be considered the origin of the field of archaeology.

Much of the earliest digging at both cities was often haphazard and careless. Workers were unskilled or were treasure hunters. Unauthorized digging was halted in 1860 when Giuseppe Fiorelli, an Italian archaeologist, became director of the excavations at Pompeii and Herculaneum. Pompeii was divided into regions, which were carefully cleared and documented. Fiorelli realized that there were cavities in the ash with bones in them. He took a revolutionary step in analyzing human remains at Pompeii. Rather than removing the skeletons, he had workers carefully fill the cavities with plaster. After the plaster dried, the volcanic debris was chipped away, leaving a cast of the person's dying moments. By studying the individuals, their dress, and the possessions they carried, researchers could reconstruct their last few minutes of life.

A museum was eventually established at Pompeii to house artifacts and dozens of the casts that were created. Pompeii became a mandatory stop on the grand tour of Italy that was so common among the European aristocracy. The richly colored murals that were exposed triggered a revival of neoclassical art. Well-appointed British homes often included an Etruscan salon, with décor copied from Pompeii.

While the public buildings of Pompeii are impressive, it is the private homes that set this site apart. The fine ash that smothered everything proved to be a remarkable preservative. Archaeologists have uncovered jars that still have food inside. Eighty-one loaves of bread were still in the oven of a bakery. Graffiti is intact on the walls of buildings. Shops and restaurants still have everyday tools in context. City planning and actual land use can be evaluated. Pompeii provides a unique and important source of information on many aspects of daily life during the Roman Empire. Much is written about the wealthy senators and citizens of Rome, but the vast majority of the Empire actually consisted of smaller towns and villages. Pompeii provides a snapshot of social, economic, religious, and political life of ordinary citizens of the ancient world frozen at a single moment in time.

Jill M. Church

See also Anthropology; Archaeology; Dating Techniques; Fossils and Artifacts; Museums; Rome, Ancient

Further Readings

Coarelli, F. (Ed.). (2002). *Pompeii.* New York: Riverside.
Deem, J. M. (2005). *Bodies from the ash: Life and death in ancient Pompeii.* New York: Houghton Mifflin.
Grant, M. (1987). *Cities of Vesuvius: Pompeii and Herculaneum.* New York: Macmillan.
Panetta, M. R. (2004). *Pompeii: The history, life, and art of the buried city.* Vercelli, Italy: White Star.

Popper, Karl R. (1902–1994)

Karl R. Popper was a British-Austrian philosopher and theorist of science. He had significant influence upon 20th-century philosophy with his contributions to epistemology, philosophy of science, and social theories. His central works include *The Logic of Science* (1934), *The Open Society and Its Enemies* (1945), and *The Poverty of Historicism* (1957). This last work contains an explication and criticism of historical scholarship as it was being practiced. Popper argued that such scholarship possessed a metaphysical determinism that assumed that time had a definable shape, such as "progress." He rejected sociology's historical determinism that portrayed time itself as a vector of a teleological conception of history.

As the founder of critical rationalism, Popper challenged the methods of empirical science and the inductive approach of logical positivists such as the "Vienna Circle" philosophers devoted to Moritz Schlick. Because observation in itself is insufficient for establishing scientific validity, the critical rationalists proposed the "principle of falsification." In contrast to the classical empiricism that strove for perfect validity, critical rationalists argued that science is doing its best work when it puts forward theses as statements that are capable of being proven wrong. Despite any number of arguments, assertions can never be entirely verified. The conclusion is that scientific knowledge does not improve by positive evidence. Instead, according to the principle of falsification, the point is to prove all the false hypotheses wrong by finding compelling counterexamples. "Verification" is a mistaken notion. Theories that withstand scientific scrutiny are "more valid," according to Popper, and falsifiability is a much better criterion of demarcation between scientific and nonscientific theories. In the area of social philosophy, he likewise demonstrated the invalidity of "truth claims" for ideologies, be they sociohistorical or political theories. Preferring a motif of indeterminism, his political ideas merged into a liberalistic pleading for a pluralistic, liberal, and democratic "open society."

Popper's scholarly work focused mainly upon what scientists are doing when they are doing "science," and his reflections on methodology mark the central starting point of his thinking. Critical rationalists argue that any scientific theory is abstract and conjectural by nature, making it difficult to identify secure knowledge. Therefore, genuine scientific theories require a specific logical structure:

openness to testability and revisability. By being structurally open to a trial-and-error process, that is, by being falsifiable, new conceptual theories are far more effective than dogmatic assertions of truth by an establishment. Falsifiability provides both a new approach to the challenge of ultimate justification and a method of distinguishing metaphysical statements from theories of scientific validity and reliability. In this way, we see how Popper's critique of historicists is a methodological one.

In *The Poverty of Historicism,* Popper's critique goes against approaches that make historical predictions their main objective and thereby attempt to grasp universally valid patterns of history. Because historicism argues that historical events underlie inexorable laws of development and advance toward an ultimate and discernable end, historicists strive to empirically establish an authoritative chronology of events. Given this position, sociology becomes a mere science of theoretical history in which time assumes an orientating function. At the same time, historicists hold that the method of universalization is not transferable to the social sciences. As a result, social laws must be structured differently from common generalizations. Thus, to be valid for all human history, such laws have to transcend the succession of time. These epoch-spanning laws of historical development now provide the basis for large-scale forecasts that can be identified as prophecies and distinguished from technological predictions. While the former refer to unchangeable events and characteristically serve forewarning purposes, technological predictions, which Popper prefers, are of constructive value, entailing useful instructions or guidelines for dealing with situations most likely to come.

According to Popper, a holistic conception of society that follows unique evolutionistic laws of succession is scientifically unsupportable. Holists mistake tendencies and singular theorems for universal laws. But, because each scientific law must be verifiable empirically, and because the laws-of-development hypothesis and evolutionism are both confined to observing unique events, these theorems cannot get universalized in terms of laws and scientific predictions.

In order to specify his objections to historicist methods, Popper criticized the interpretation of time as a criterion for the elevation of "static laws" to "connective laws" akin to Auguste Comte's and John Stuart Mill's distinction between laws of coexistence (time-independent) and laws of succession (time as a constitutive coefficient). Indeed, laws can contain statements about dynamic processes, but they can never point beyond individual cases or subsume singular, basically distinct causal connections under one rule. Assertions about periodicity, such as the circle of the year, are bound to incorporate/consider a number of single laws that cannot be abstracted, such as those of the earth's rotation, thermal inertia, etc. For this reason, the perception of dynamic succession or development can be due only to metaphorical illustrations of certain tendencies, not to scientific laws.

Over and above this, Popper points out that historicist doctrines provide a theoretical breeding ground for authoritarianism and totalitarianism. First, he refers to Plato's ideal state as resulting in socially immanent and decadent tendencies by maintaining a strictly hierarchical form of government, stifling all change for the sake of political stability. Second, Popper refers to Hegel's dialectic progression of history as being directed toward a perfection that, in practice, results in the glorification of the Prussian monarchy. Third, he argues against the Marxist economic oversimplification of social spheres.

Rejecting such forms of collectivism, Popper proposes the autonomy of the social sciences and a method of analyzing historical events by reference to the behaviors of individuals. Unlike holistic approaches, a "technological" social science recognizes the incalculability of human characteristics. It allows both for the logic of particular circumstances and the unintended side effects. Learning from this methodological individualism, political institutions can be designed in a way to prevent incompetent leaders from wreaking havoc. Similarly, Popper advocates what he calls "piecemeal social engineering." Instead of large-scale utopianism, social and political planning has to proceed stepwise in consideration of human fallibility and the irreversibility of time. By emphasizing the value of democracy as the nonviolent generation and deposition of political leadership, Popper was a contributor to democratic theory from a functionalistic angle. Because of these ideas, Popper strongly defends an open society that is capable of monitoring social phenomena and minimizing misery to enable its members to take part in a broad landscape of critical discourse.

Christiane Burmeister

See also Critical Reflection and Time; Epistemology; Law; Marx, Karl; Plato; Russell, Bertrand

Further Readings

Catton, P., & Macdonald, G. (Eds.). (2004). *Karl Popper: A critical appraisal.* London: Routledge.
Magee, B. (1968). *Karl Popper.* Tübingen, Germany: Mohr.
Miller, D. (1994). *Critical rationalism: A restatement and defence.* Chicago: Open Court.
Popper, K. (1956). *The open society and its enemies.* Princeton, NJ: Princeton University Press.
Popper, K. (1960). *The logic of scientific discovery:* London: Hutchinson.
Popper, K. (1999). *The poverty of historicism.* London: Routledge.

POSTHUMANISM

See TRANSHUMANISM

POSTMODERNISM

In few areas is it more problematic to arrive at a clean definition than it is for postmodernism. Not the least of the problems is the resistance of postmodernists to being defined, or, in many cases, to admit the authority or even the possibility of definition as an activity. Before attempting a definition, a series of useful distinctions can be drawn. However, postmodernists are very critical of scientific theories and empirical evidences. Consequently, they do not take seriously conceptions of time in terms of evolution and relativity (among other temporal frameworks).

Postmodernity and Postmodernism

The first important distinction to be made is that between postmodernity and postmodernism. Postmodernity is a name given to a period of history, and postmodernism is the body of theory that has developed to explain that period. Opinions differ about when postmodernity is supposed to have begun, with dates ranging between 1968 and 1973. All agree that conditions in the world have changed since then. In international politics, the sites of authority have fractured from the relatively straightforward conflict of the Cold War to the multipolar, less predictable, and more confusing international situation of today. Other fundamental changes have been made to our styles of work, with entirely new industries, work hours, and arrangements than were the case before. The assumption underlying the notion of postmodernity is that the world has seen not simply changes in style but a fundamental shift in the way the world operates, a shift that has been to the disadvantage of predictability, order, and rationality.

Those who argue for 1968 as a convenient date for the onset of postmodernity point to the student riots of that year, when the post–World War II baby boomer generation, the best-fed, best-educated generation in world history, spurned the cultural conventions they grew up with and demanded change. These revolts did not demand a specific set of political, social, and economic changes; they demanded *change,* as a general rejection of the old. The impact of the baby boomer generation is very significant, but even it was swept along by the broader transformation taking place after the events of 1973. This was the year when the international economy changed forever as a result of the oil shocks brought on by a newly radicalized Organization of Petroleum Exporting Countries (OPEC). The oil shocks were provoked by the oil-producing countries, most of which were from the Muslim world, wanting to express anger at the continued support by the West of Israel, which had been decisive in the recent Yom Kippur war. This marked a fundamental change in the balance of economic and political power and a dramatic shifting in priorities in global politics and economics. The widespread social changes that have occurred in the West are largely a product of these developments. Postmodernity can perhaps best be dated, therefore, from 1973.

It is important to note that "postmodernity" as discussed here is nothing more than a title given to a period by historians, like "Renaissance" or "Dark Ages." Others have called this period Late Capitalism. Still others have rejected the idea that the events of 1973 mean we can no longer speak of "modernity." This debate becomes a question about the periodizing of history and the usefulness of such a procedure.

Postmodernism as Reactions to Postmodernity

We have seen, then, that postmodernity and postmodernism are not related. Postmodernism is, as the suffix implies, an "ism," a series of reactions that have arisen to explain the times known to some as postmodernity. It is quite consistent to see value in postmodernity as a historical term while also rejecting the postmodernism that has arisen as a series of reactions to explain postmodernity. Most introductory essays to postmodernism begin with the insistence that any attempt at a comprehensive delineation and understanding of postmodernism is inherently contradictory and bound to fail. To overcome this problem, most characterizations of postmodernism portray it not as a coherent body of doctrine but as a general mood, or, as described in the previous paragraph, a series of reactions. What is more, the series of reactions are often expressed in negative terms.

Postmodernism is almost entirely confined to universities and literary circles. And within universities, some faculties are more likely to be favorable to postmodernism than others. Most branches of the sciences are hostile, whereas departments of English or French literature, architecture, visual arts, and sometimes anthropology and sociology are more likely to react favorably; opposition to postmodernism in philosophy departments, particularly in English-speaking countries, has grown since the mid-1990s.

In addition to these divisions between faculties, there is also a division based on geography. We have already noted this division among philosophy departments at universities. There are two general strands to the postmodernist reactions to postmodernity. One strand of postmodernism is content to *acknowledge* the changes that have taken place since 1973 and to try to understand them. The other, more radical strand is more willing to *celebrate* those changes. Broadly speaking, this fissure divides postmodernists in the Anglo American academic community from those from the Continental (mainly French) academic community. This is made more complicated when we note that this division is by no means exclusively a geographical one. The two styles of postmodernism, while having a geographical dimension, are principally divided by a series of contrasting emphases with respect to some important questions. The first of these dividing points centers around their attitudes toward philosophical analysis. Anglo American postmodernists may be cautious about analysis as a tool but still acknowledge its value. Postmodernists of the Continental variety, by contrast, are more inclined to view analysis as part of the problem they are looking to overcome than as a useful tool to gather new and better understandings.

A second major area of divergence can be seen in the attitudes toward metanarratives. Most postmodernists, whether Anglo American or Continental, see postmodernity as a time when traditional metanarratives broke down. A metanarrative is a general intellectual framework through which we view history. For example, the communist metanarrative is of a progressive, and inevitable, succession from feudalism, through capitalism to socialism, and, in the future, on to communism. A Christian metanarrative, by contrast, proceeds from a primitive innocence in Eden, followed by the Fall and the condition of sin and death among humans, relieved by the redemption of Jesus Christ, and which will be brought to an end when Christ returns to reward the faithful and judge the damned. The most oft-quoted definition of postmodernism comes from the French thinker Jean-François Lyotard, who defined it in terms of incredulity toward metanarratives. The differences lie in their contrasting attitudes to the end of metanarratives. As noted above, most postmodernists from the Continental tradition are likely to celebrate the end of metanarratives. They claim that not only are metanarratives no longer needed, they are no longer welcome. For with the end of metanarratives comes the end of the tyranny of history, and, more particularly, the end of the presumption of scholars to be chroniclers of historical fact. Instead, postmodernists argue, we have a mass of assertions and claims that can all compete for our attention as best they may, with little difference in the outcome of one being chosen over another.

Underlying this hostility to metanarratives is the postmodernist hostility to what they see as the dominating and bullying nature of science and reason. The central claim of postmodernists of the Anglo American strand is that rationality is a historically conditioned faculty, which means that different historical epochs will produce different notions of rationality. This is not a point many opponents of rationality would dispute. Indeed, many of the people derided by postmodernists, such as the philosopher Bertrand Russell, made these points long before postmodernism was an intellectual force. Others, usually of the Continental strand of postmodernism, are more extreme and seek to condemn what some call "legislative reason" as being inherently domineering and oppressive. In contrast to this, they say, postmodernism is a liberation from rationality, because it is a liberation from all socially constructed bounds and norms. As one prominent postmodernist put it in 1992, postmodernism is about splitting the truth, the standards, and the ideal into what has been deconstructed and what is about to be deconstructed and denying in advance the right of any new doctrine, theory, or revelation to take the place of the discarded rules of the past. David Harvey, in an influential postmodernist work published in 1991, enthused that postmodernism wallows in the fragmentary and chaotic currents of change, as if that is all there is. In a similar vein, Gregory Bruce Smith identified postmodernism as fundamentally a sign of disintegration, transition, and waning faith in what he called the Enlightenment project.

In defining postmodernism, then, we need to take account of these two strands of interpretation. The more moderate version of postmodernism is the assertion that we cannot *know* anything; we can only interpret, and any interpretation we make can only express our partial and narrow perspectives. The more radical version of postmodernism is the assertion that not only can we not know anything, but also our claims to knowledge are bound to be hegemonic and impatient of dissent, which means that our ability only to interpret from our partial and narrow perspectives constitutes a liberation from that tendency toward hegemony, which is particularly evident in science and rationality.

Behind the differences of emphasis and geography, there is a common political heritage for much of postmodernism. This is because postmodernism is a phenomenon of the political left. The reason postmodernists are anxious to write the obituary of metanarratives is that many of them were, earlier in their lives, proponents of variations of socialism and communism, which, as we have seen, have strong metanarrative components. This can be traced back to the disillusionment of German socialists after the failure of the Spartacist revolt in Berlin in 1919. Not only did socialist revolution fail, but also the parties of the left were then seen to fail as well, as they showed themselves incapable of resisting the rise of Nazism. By their slavish following of the dictates of Moscow, the parties of the left had betrayed their purpose. The school of Marxist-inspired criticism, known as the Frankfurt School, traced this progressive failure of each institution that had once been a source of hope.

After the Second World War, the Soviet Union joined the ranks of gods that failed. Between the Soviet invasions of Hungary in 1956 and Czechoslovakia in 1968, the promise of communism as a metanarrative of progressive liberation from alienation became ever more difficult to sustain. The choices of the left after 1968 were stark: acknowledge that capitalism and the metanarratives that sustain it had triumphed, or create a system of criticism that denied the legitimacy of any metanarratives at all. Postmodernism adopted the latter approach. The differences of emphasis between the Continental and Anglo American styles of postmodernism were most pronounced on the question of the degree to which Western culture could be salvaged. Critics like Theodor Adorno (1903–1969) and Max Horkheimer (1895–1973) were among the more pronounced cultural pessimists. In *Dialectics of Enlightenment* (1947), Adorno and Horkheimer saw modernity as inherently self-destructive, carrying the germs of its own dissolution and decay. There was a straight line, they argued, from the Enlightenment to Nazism and Stalinism. Later heirs of this high level of pessimism included the Polish-born sociologist Zygmunt Bauman (b. 1925), who argued that modernity is a long road to prison, and Michel Foucault (1926–1984), who saw all society as engaged in a war against people to impose on them a sterile understanding of what it is to be human.

The more moderate postmodernists in the Anglo American schools, however, were not prepared to go this far. Their general argument was to see value in the humanist tradition of the Enlightenment, merely wanting to excise from it the faults and excesses they perceived it brought with it. Advocates of this approach include the English philosopher Michael Luntley and the New Zealand sociologist Barry Smart.

Postmodernists agree on their suspicion of metanarratives, diverging only on the degree of opposition they are prepared to express. Another area of general agreement is in their attitudes toward science. Anglo American and Continental postmodernists agree that science involves a metanarrative, which they question. The metanarrative of science speaks of cumulative knowledge over time, leading to ever clearer understandings of the universe. And, just as important, postmodernists question the claim of science to being grounded in objective truth. But the attitudes toward science reveal the greatest splits between the Anglo American and the Continental styles of postmodernism. The Anglo American attitudes are best articulated in the works of Richard Rorty (1931–2007), whose critique has been directed against foundationalism, the practice of claiming that one's theories rest on objective foundations of truth. The Continental branch of postmodernism, once again, has wandered much further afield in its attitudes toward science. Indeed, it is this area that has provoked the strongest opposition. Working from an epistemic relativism, many Continental postmodernists have pressed the claims that science is a metanarrative like any other, with no special claims to authority, and indeed, meriting extra levels of criticism precisely because of those claims of authority they perceive scientists making.

The Decline of Postmodernism

Postmodernism began to attract some significant critical attention after about 1994. Much of the criticism was led by scientists and by philosophers who take science seriously. Leading the way was a devastating critique by Norman Levitt and Paul Gross, *Higher Superstition: The Academic Left and Its Quarrels With Science* (1994). Other significant milestones included *Derrida and Wittgenstein* (1994) by Newton Garver and Seung-Chong Lee, *The Poverty of Postmodernism* (1995) by John O'Neill, and *The Flight From Science and Reason* (1996) edited by Paul Gross, Norman Levitt, and Martin W. Lewis. But what publicized the decline of postmodernism was what has become known as the Sokal hoax. In 1996 Alan Sokal, a professor of physics at New York University, submitted a paper to the postmodernist journal *Social Text*. The paper, titled "Transgressing the Boundaries: Toward a Transformative Hermeneutics of Quantum Gravity" supposedly demonstrated that the laws of science are nothing more than social constructs—one of the central points of Continental postmodernism. The *Social Text* editors made the mistake of not submitting the article to the usual process of peer review, and on the day the article appeared, Sokal announced in the journal *Lingua Franca* that the article was a hoax.

The hoax and the controversy that followed was a major embarrassment for the editors of *Social Text* and for the wider claims of postmodernism to academic credibility. Sokal followed up his hoax with a scorching attack, coauthored with the Belgian physicist Jean Bricmont, on French postmodernism. The work was published in the United States under the title *Fashionable Nonsense: Postmodern Intellectuals' Abuse of Science* (1998).

Alongside this counterattack, some of the more moderate Anglo American thinkers who at one time had expressed support for elements of postmodernism have since stepped back. In Britain, Christopher Norris, a prominent defender of the works of Jacques Derrida, has more recently launched important critiques against the relativism inherent in postmodernist thinking. And in the United States, the late Richard Rorty, without having changed his position, expressed his regret over having used the term "postmodernist." Most recently, a newer movement called critical realism has arisen as the successor to postmodernism. The intellectual initiative has clearly now passed to the critics of postmodernism.

Bill Cooke

See also Derrida, Jacques; Enlightenment, Age of; Epistemology; Humanism; Metanarrative

Further Readings

Bauman, Z. (1993). *Intimations of postmodernity.* New York: Routledge.

Docherty, T. (Ed.). (1993). *Postmodernism: A reader.* New York: Harvester Wheatsheaf.

Gross, P., Levitt, N., & Lewis, M. (Eds.). (1997). *The flight from science and reason.* New York: New York Academy of Sciences.
Jencks, C. (1996). *What is postmodernism?* London: Academy Editions.
Lopéz, J., & Potter, G. (Eds.). (2001). *After postmodernism: An introduction to critical realism.* New York: The Athlone Press.
Lyotard, J.-F. (1988). *The postmodern condition: A report on knowledge.* Minneapolis: University of Minnesota Press.
O'Neill, J. (1995). *The poverty of postmodernism.* New York: Routledge.
Smart, B. (1992). *Postmodernity.* New York: Routledge.
Sokal, A., & Bricmont, J. (1998). *Fashionable nonsense: Postmodern intellectuals' abuse of science.* New York: Picador.
Waugh, P. (Ed.). (1994). *Postmodernism: A reader.* London: Edward Arnold.

Predestination

Predestination is the idea, found within Islam, Hinduism, and Christianity, that human actions are predetermined by a divine being or superhuman force. This is not to be confused with foreknowledge, the idea that God knows outcomes before they occur. Foreknowledge leaves the decision to the individual, God merely knows the result beforehand. In predestination, God makes the decision as to the outcome of a situation; the individual has no choice.

Islamic thought contains the doctrine of *qadar.* In this doctrine, God (Allah) is understood to be all-powerful and to have control over all that happens. Allah must allow or even cause events to happen; no action occurs apart from the will of Allah. In this sense, predestination occurs when Allah decides to act, with resultant effects on individuals. Hinduism, with the idea of one's *karma* (actions) resulting in the determination of future lives, places responsibility on the individual; nevertheless, gods can act with resultant effects on humans, which is understood as an effect being predetermined for an individual. Thus predestination occurs when a god acts preemptively upon an individual.

In Christian theology, the most prominent example of predestination is found within Calvinism. This doctrine is named after John Calvin, a Protestant Reformation leader of the city of Geneva in the mid-1500s. Calvin was not the first Christian, however, to promote the idea of predestination. In the 300s the Christian theologian Augustine promoted the doctrine that God must make the initial step toward a relationship with a person. This was attributed to original sin (introduced when Adam and Eve disobeyed God in the Garden of Eden) having removed the option of individuals making a move toward God. After the fall of Adam, God's initiating grace was necessary for an individual to move toward God. In addition, God does not choose to give this grace to all, but only to the "elect," those individuals he has chosen to receive his grace. Pelagius, a contemporary of Augustine, developed the counterdoctrine that each person has free will to accept or decline Christ. These two thinkers wrote against each other's doctrines, and Augustine's view eventually prevailed. Pelagius was subsequently denounced by councils and popes. Yet Augustine's idea did not gain a strong following in Augustine's lifetime nor in the Middle Ages. It did not receive much attention until the Protestant Reformation in the 16th century.

Calvinism became closely associated with predestination in part through Calvin's writing about it in his most famous work, *The Institutes,* and partly through the Academy of Geneva, which drew Christians from throughout Europe who were interested in learning about Calvin's ideas.

Although Calvin originated a variety of Christian doctrines, his name is most closely associated with predestination. In addition, Christian predestination is associated with the acronym TULIP, which reduces the doctrine of predestination and Calvinism to five points: Total depravity of humanity, Unconditional election, Limited atonement, Irresistible grace, and Perseverance of the saints. Total depravity of humanity holds that all people are unable to please God through their own volition. Unconditional election states that God chose who would become a Christian and who would reject Christianity; the individuals had no role in the decision. Limited atonement is the idea that Christ's atonement (sacrifice to bring people to God) only included those chosen to become Christians; Christ's death on the cross did not include those God did not choose to become

Christians. Irresistible grace carries the idea that God's decision is irrefutable; those God choose cannot choose not to become a Christian. Perseverance of the saints is the idea that those God will ensure the perseverance of those chosen to be Christians.

While the idea of TULIP is associated with John Calvin, the acronym was not developed until decades after Calvin's death. The situation that spurred the development of TULIP was a debate in Holland over the predestination ideas of Calvin and the free will (the idea that each person chooses to accept or not accept Christ) idea of Jacobus Arminius. After Arminius's death, his followers reduced his free will ideas to five points. Later, at the Synod of Dort in 1618, the adherents of Calvin's idea of predestination countered by reducing Calvin's predestination ideas to five points: The acronym TULIP was the result.

Among Christian denominations today, the Presbyterians, reformed churches, and some Baptist groups accept the idea of predestination. Those who hold to predestination have differing ideas of when God made the choice of individuals. The idea that God made the choice before the fall of Adam and Eve is known as *supralapsarianism*. The idea that God made the choice after the fall of Adam and Eve is known as *sublapsarianism*. The Synod of Dort upheld the sublapsarianism doctrine. In comparing the doctrines of predestination and free will, they are known more specifically as double predestination and single predestination. Double predestination denotes the idea that God chose each person to either be a Christian or a non-Christian (double); single predestination denotes the idea that God predestined the way of Christ, and each person can either choose or reject Christ.

Mark Nickens

See also Calvin, John; Causality; Christianity; Determinism; Islam; Predeterminism; Teleology

Further Readings

Articles of the Synod of Dort. (2005). Michigan Historical Reprint Series. Ann Arbor: University of Michigan Library. (Original work published 1618)

George, T. (1988). *Theology of the reformers.* Nashville, TN: Broadman Press.

PREDETERMINISM

Predeterminism is, literally, the idea that events are determined in advance. All future actions and events are already decided or known (by God, fate, or some other force). This concept is closely related to determinism, and sometimes the terms are used interchangeably. More often, however, predeterminism is categorized as a specific type of determinism. In this case, determinism is defined more generally, as the idea that every event is caused by a chain of past events, without a specific being or force behind it.

Ancient Views

The idea of future events being already decided can be found in many cultures and religions throughout history. One early representation of this view is demonstrated by the Fates (also called the Moirae)—three goddesses in Greek mythology who controlled everyone's life span. As written by the early Greek poet Hesiod, each goddess's name indicated her purpose. Clotho was the spinner, who spun the thread of a person's life. Lachesis was the apportioner, who decided the length of the thread (thus determining the length of the life). Atropos was the inevitable (literally, the "unturning"), who cut the thread at the point where the person was to die. The Moirae acted independently of the other gods, and in some stories even Zeus was powerless against them.

A predeterministic view of the world was espoused by the Essenes (a separatist sect of Judaism) who settled in the Qumran region (near the shore of the Dead Sea) between 110 BCE and 70 CE. According to their beliefs, God determined everything that would happen in the universe before he created it. In accordance with God's plan, there were two ways: that of light (good) and that of darkness (evil). These two ways, which exist throughout the universe, are in constant conflict, which is held in control by God.

Christian Theology

The idea of God being all-knowing has created some questions in Christian thinking, for God's foreknowledge would seem to deny humans their free will. Although humans have knowledge of the world, their knowledge is limited and fallible. According to most monotheistic religions, God is infallible and knows everything (even the future) with certainty. This would seem to create a paradox if one were to believe in both God's foreknowledge and the idea of human free will.

Fifth-century philosopher and theologian St. Augustine of Hippo wrote that because God is omniscient, he therefore knows every future action that is going to happen. We cannot behave in any way other than the way God knows we will. However, Augustine felt that these ideas were not a threat to free will. In essence, God knows about future events because they are going to occur; they do not occur because God knows about them. Our future actions do not become involuntary because of God's foreknowledge, just as our remembering a past event does not make it involuntary. God is eternal, so he sees all of time in a way similar to the way we view the present. The terms *before* and *after* cannot be applied to him.

Other theologians concurred with St. Augustine's view that God's knowledge of future events does not take away from man's free will. Seventeenth-century American theologian Jonathan Edwards wrote that God's foreknowledge does not cause events, but it does make them inevitable. Saint Thomas Aquinas stated that God's knowledge is not in itself a cause of anything in the same way that a sign points to an object without actually causing the object to appear. Regarding the idea of God causing specific events to happen, he wrote that God does not intervene in the world in the sense that he enters into an occurrence of which he was not originally part. God is not absent from anything in the world to begin with, and therefore everything that happens does so because God made it that way.

Despite his agreement with Saint Augustine, Aquinas also wrote "On Evil IV," which includes 24 arguments against the view that human beings have free will. Yet he says that God working in all things is not incompatible with freedom. The human will can act, but the action is initiated by God. Although the action does originate outside of the person, the action is not forced upon him or her.

Martin Luther, who began the Protestant Reformation, felt that God didn't merely know about future events, he controlled them. He wrote that for humans to have the freedom to performing their own actions would be incompatible with God's omnipotence, and to believe such a thing was blasphemy. As human beings, all of our actions are evil unless we have the help of God's grace. It is not within our power to do good, and we are controlled by either God or Satan, who determine our actions.

One way to reconcile the seemingly opposing viewpoints of God's omniscience and human free will is to view future events simply as possibilities. God knows all the possibilities, and humans, by their choices, determine which possibility will occur.

Another possibility is that God can change his mind with regard to future events. At certain points in the Bible (such as Jonah 3:1–10 and Jeremiah 26:17–19), God first stated that he would destroy a city or a group of people but later relented due to human actions.

Jaclyn McKewan

See also Augustine of Hippo, Saint; Determinism; Hesiod; Luther, Martin; Predestination; Teleology

Further Readings

Boyd, G. A. (2001). *Divine foreknowledge: Four views.* Downers Grove, IL: InterVarsity Press.

Hasker, W. (1989). *God, time, and knowledge.* Ithaca, NY: Cornell University Press.

Presocratic Age

The conventional term *Presocratic* refers to philosophical and natural scientific thought in ancient Greece prior to the philosophical career of Socrates; hence the Presocratic period denotes the earliest stages of Greek philosophy. Years of this period began with the oldest recorded fragment of philosophical speculation in Greece; Thales reached his acme, or prime of life, in 585 BCE. This is the most natural beginning point for this period of early philosophy, which was still inseparable from myth. Nevertheless, one major focus of Presocratic thought was the concept of time. Socrates began his philosophical mission in around 434 BCE, in his 35th year when his friend Chaerephon returned from Delphi, which would be one sensible endpoint of the Presocratic age. While Socrates philosophized, there were still around him followers of Parmenides, Heraclitus, Pythagoras, and Democritus, among others.

Time in Presocratic Greece

In the Presocratic world of the Greeks, as across ancient civilizations, the sky was the universal timepiece. The time length from sunrise to sunrise was the natural basic unit of recording time. Each day was divided into 12 parts, as was the night, which would change in length by the season. Time within the daylight hours would have been told by sun dial; time across day and night would have been measured by a terra cotta water clock (*clepsydra*).

The ancient Greeks used a lunar/solar calendar, using both sun and moon, of 12 months. Each month was a lunar cycle. In addition, there were alternate months with 29 or 30 days and alternate years of 354 or 384 days. Extras days or even months were inserted in the calendar to prevent accumulated error. Nautical Greeks navigated and estimated time during the night by the movement of the constellations, planets, moon, and stars. Each city-state kept its own calendar, maintained by magistrates, which began at the new moon. Athenians began the year in summer, and it ran from July to June. Years were marked off into 4-year cycles, called *olympiads*. The first year of Olympiad 1 was 776 BCE. The cycles of the Milky Way would have been the final, limiting hand on the cosmic clock (by repeating its four-fold pattern in its own time). There were also planetary conjunctions and eclipses recorded. Astronomers used such cycles to correct accumulated error in the calendar.

Early Greeks had a circular notion of time; at the beginning of time was a primordial event that began the subsequent cycles of time. Human beings celebrated the passing and coming-to-be of cycles with festivals that harkened back to the first days (*in illo tempore, ab origine,* as Mircea Eliade put it). And indeed many months on the Greek calendar were named after festivals. Time was thought of as a cycle of festivals rather than as an abstraction. The early Greeks adopted much from Egypt, including calendar making. Greek civilization had gone through the Bronze Age during the Homeric period, but their folk religions bore witness to a distant Neolithic past, as well. Olympian sky gods had displaced mother earth goddesses and agricultural gods along with the Titans.

Greek Myth of Time (Kronos)

First-born in the long genesis of the world was Chaos, according to Hesiod, then "wide-bosomed Earth" as a dwelling for the gods. Tartarus, lower hemisphere of the future cosmos, was born next, and after it, Love, "most beautiful by far." From Chaos was born "dark-robed Night," which gave birth to Upper Air and Day. Born first to Earth was Heaven, "eternal dwelling place" for the blessed gods. Earth and Heaven were of one form initially, but separated later in the act of birthing. Heaven and Earth created children, who were sequestered away by Heaven, who had grown to become a wicked father. Earth conceived a plan and made a scythe of flint for one child, Kronos, to use in ambushing and castrating Heaven. Kronos threw his father's male member into space, but its scattered blood created on Earth the first generation of gods. Thus the child Kronos took his father's place in the cosmos. Acting on a prophecy of his own doom, Kronos ate each of his children born of Rhea, lest they overthrow him. But Zeus was hidden from Kronos by a stratagem, and he grew to overthrow his father. Kronos was forced to disgorge his children, who then battled the Titans, defeating them and ostracizing them to Tartarus. This introduced the age of the Olympians.

Herodotus and History

No survey of the Presocratic period, especially with regard to conceptions of time, would be complete without mention of Herodotus. With the *Histories* by Herodotus, the Greeks attained a historical sense of time. Events in the story of mankind gave a linear shape to time; in his *Histories,* there is a succession of more or less remarkable events, which makes up a more or less cogent narrative, and which undid the circularity of time so prevalent in the mythological mind. Herodotus was born in 484 BCE and died between 430 and 420 BCE.

Presocratic Philosophy

Eminent scholar Kathleen Freeman has listed nearly 100 Presocratic thinkers, of whom mostly mere names survive. The best-known and best-documented philosophers of this period include Thales, Anaximander, Anaximines, Pythagoras and members of the Pythagorean school, Heraclitus, Parmenides, Xenophanes, Zeno, Empedocles, Democritus and Leucippus.

Thales

Thales was an obscure figure about whom almost nothing is known. His acme was around 585 BCE, and that marks the beginnings of the Presocratic period of philosophy. He apparently wrote a text on nautical astronomy, but only the title survives. Attributed to him, as well, were "On the Solstice" and "On the Equinox." If he indeed wrote a work on nautical astronomy, he would have been able to read the night's sky as a navigational and timekeeping device perhaps expertly. And since Thales is said to have predicted an eclipse, he was observing patterns in time that few then understood.

Concerning the famous saying attributed to Thales—all is water—we might speculate that this was an early natural scientific reduction of all phenomena to water, either figurative or literal. This accords with the notion of a Milesian school of natural explanation. But Thales is also supposed to have said all things are filled with gods, which, in either a figurative or literal sense, is not at all natural scientific.

If applied to the topic of time, the alleged sayings of Thales would imply, first, that time is water; second, that time is filled with gods. If Thales believed in Kronos, he could say that time is one of the gods, but we have no evidence for this conjecture, either way. More likely is Aristotle's reading that soul is intermingled with all things, because it is the principle of motion. This would entail that soul is the principle of time as well.

Thales might have suggested that time is water, because time was measured by a terra cotta water clock, at least for some ancient Greeks, or by the tides. But this is a speculative reading, as well. Hesiod reported that Thales held Earth to float upon water. Now if Thales suggested that all things begin in water, that the universe *came from* water, as a first principle, which is the likely meaning according to Aristotle, time would be measured by water in a truly cosmic sense. Whatever foundational ideas Thales might have had about time are lost to us forever, however.

Anaximander

Anaximander came from Miletus 25 years after Thales, but not even mere titles of his works, if he wrote any at all, survive. Only a few fragments of his ideas remain. Fragments 1, 2, and 3 deal explicitly with the nature of time. The indefinite is the "original material" of existing things, according to Fragment 1.

In addition, "the source from which existing things derive their existence is also that to which they return at their destruction, according to necessity." The reason for this is that "they give justice and make reparation to one another for their injustice, according to the arrangement of time." Fragment 2 tells us that the indefinite is ageless and everlasting, while Fragment 3 calls the indefinite immortal and indestructible.

And so the image of the cosmos that we infer here is that at the origin of all things was an indefinite out of which came all the existents of the cosmos. While in existence, these existents right a wrong, the nature of which is hotly contested and is determined by the exact rendition of the passage one uses (some saying that Anaximander means existents repay a debt to each other, some saying he means that existents repay a debt to the indefinite). We are told by the fragment that time and necessity arrange this retribution. Then presumably measured time ceases, all things return to the source, and eternity continues on unabated.

Now if this interpretation is correct, then Anaximander has drawn the distinction between *eternity* and *measured time*. It would further seem to indicate that time is both endless (indestructible) and measured. Time and necessity sort out the eternal from the original. The rest is measured time. Further, measured time seems finite (as an accidental feature) and *for the sake of justice* (as its essence). If this is correct, then the entire drama of existence seems to be a morality play; we, as existents, have chosen to affirm the I and negate the Thou. Measured time begins only with our self-separation from the indefinite, and it exists only for the sake of restoring order and establishing justice, at which point all measured time ceases and eternity reigns supreme again. Perhaps the earth remains for eternity, because it is like a stone column, for Anaximander, but he may have been referring only to its structure or its appearance to the gods. In the absence of authoritative works, one may only speculate about possible interpretations; this is the risk run by saying anything substantial about the Presocratic thinkers.

From Fragment 1 we may legitimately infer that Anaximander subscribed to what we might now call a temporal realism, meaning that he treated time as a real thing and as eternal and indestructible. What is far less clear is how he further conceived of time: Is time merely reified, or did Anaximander also deify and worship it? If so, did he anthropomorphize it? Is Kronos meant here, in the naive mythical sense, along with Dike and Ananke? It seems incorrect, however, to read Anaximander in terms of alien religions; we may only say that he believed in necessity, time, and justice, as well as the indefinite.

Anaximines

Anaximines is known to have been from Miletus, hence he was presumably another Milesian natural observer, yet next to nothing, a single sentence, survives of his one writing. He was in his prime of life around 546 BCE. His observations that the soul is air, and that air surrounds the whole universe, give us no solid insight into his notion of time. If we may attribute the ideas of compression and dilation to Anaximines, however, then time would be measured most objectively by those physical natural processes.

The problems of change and motion were the major forum by which the Presocratics dealt with time. Change and motion were problems to the Greek mind. They sought a mechanism of change whether it be water, air, fire, or other. How do generation and degeneration come about? Coming-to-be and passing-away? Some thinkers (Anaxagoras, Parmenides, Zeno, the Pythagoreans) believed that mind, not a process of nature, accounted for change and motion. But they all seemed to strive to explain the phenomenon of change.

For the Presocratics, the question of time came down to developing a concept of *origins*. They still believed in the first times of mythical consciousness (*in illo tempore, ab origine*), as recorded in Hesiod and Homer, but reworked into an early natural scientific idiom. Later scientific notions, therefore, should not be anachronistically attributed to the Presocratics.

Pythagoreans

The figure of Pythagoras is largely apocryphal, but he was a religious reformer and cult leader. He was born on Samos but moved to Croton, perhaps in Olympiad 62. His place in the sequence of Presocratic thinkers is especially difficult, and the later Pythagoreans may have come considerably after the earliest members of the community. A conservative range for the acme of Pythagoras would be between Olympiads 62 and 69 (between 528 BCE and 500 BCE). Thus his prime of life was very close to being directly after the acme of Parmenides and Heraclitus.

Pythagoras refused the friendship of a local tyrant, Cylon of Croton, and the religious leader and his followers were cast out from Croton. They resettled in Metapontum, but the Cylonians followed and apparently massacred the majority of Pythagoreans. The survivors further resettled in Rhegium and Greece. The last Pythagoreans were active around 366 BCE. The ancients seemed confused about the relation between Zeno and Empedocles, on one hand, and the Pythagoreans, on the other. Some sources claimed that Empedocles was a follower of Pythagoras; others said he followed Parmenides. These sources also maintained that Zeno followed first Parmenides, then Pythagoras.

Pythagoras was apparently the first Greek to deify number, that is, he held number to be sacred and worthy of study as a universal ethical force. Number is self-moving and thus the principle of the psyche. Pythagoras said that happiness comes from knowledge of the "perfection of the numbers of the soul," and his followers took the study of number as their single concern. Their study encompassed arithmetic, geometry, music (harmonics), and astronomy. As Pythagorean scholar David Fideler has analyzed their curriculum, arithmetic was the study of number in itself; geometry was number in space; music was number in time; and astronomy was number in space and time. As a consequence, time was seen as number in harmonic motion, or rhythm. Number was considered immanent, not transcendent, to time.

The Pythagorean account of time would probably have involved a number of separate and perhaps conflicting elements. Time was number in harmony, of course. But Diogenes Laertius reported that Pythagoras divided the human life span into segments of 24 (childhood, youth, middle age, and old age), which corresponded to the proportions of the four seasons. And all accounts of the life of Pythagoras include a notion of reincarnation, that is, a sequence of lifetimes, which may have formed a circle (the *monad*) in its full development.

In the Pythagorean table of opposites, "one" and "plurality" are opposites, as are "at rest" and "moving." The one is time at rest, or eternity; its opposite is time as it moves, or fluid time.

Among Pythagoreans, the Tetraktys, a triangular figure made from arranging dots as the first four integers, was considered to be holy ("heaven") and to be the universal order (Kosmos and Pan). Pythagoras held number to be the source and first principle of all things. The monad (unity) was seen as the basis of all number and not a number itself. The dyad contains movement, growth, birth, and other aspects suggesting time in motion. Indeed, the dyad is also Rhea, wife of Kronos. If the monad is the producer of time (just as it is called the "space-provider"), then the dyad is time in motion. Both types of time, monad and dyad, together produce the triad, which is "the all" and "everything."

"Time, and wind, and the void" define where each thing exists, said Pythagoras. But time was also said by Pythagoras to be the sphere surrounding the world. Perhaps we may think of local and global time as an analogy; there is macrocosmic and microcosmic time. The tetrad, the square circumscribed by a circle, contains the nature of change. The integer 10 was called the *decad*. One of its aspects is "eternity (*aeon*)." The decad returns to the monad and shares its qualities. "All things accord in number," said Pythagoras, and his followers elaborated arithmetic and geometric evidence for his insight.

As time is an elemental part of the universe, and as time is number, it follows that time is divine. "Turn round when you worship," was a Pythagorean maxim meaning that we should "adore the immensity of God, who fills the universe." Hence, God transcends time but is also immanent to it.

Since the Pythagoreans ascribed all discoveries to Pythagoras himself, we cannot, in principle, discern the founder from his followers in terms of teachings. Some later Pythagoreans may have believed in circular time. According to Stobaeus, Philolaus, one of the last Pythagoreans, said that "the single world is continuous, and endowed with a natural respiration, moving eternally in a circle, having the principle of motion and change; one of its parts is immovable, the other is changing. . . . The one is entirely the domain of mind and soul, the other of generation and change." This echoes the fragment of Anaximander, of course. Much later, though, Friedrich Nietzsche ascribed a version of eternal recurrence of the same to the Pythagoreans.

Timaeus

One supposed Pythagorean astronomer was Timaeus of Locri, though the figure may well be legendary. Looking back into time immemorial, Plato's Timaeus said, "The sight of day and night and the months and the revolutions of the years have created number and have given us a conception of time, and the power of inquiring about the nature of the universe. And from this source we have derived philosophy, than which no greater good ever was or will be given by the gods to mortal man." Timaeus further said, "The night and the day were created, being the period of the one most intelligent revolution. And the month is accomplished when the moon has completed her orbit and overtaken the sun, and the year when the sun has completed his own orbit." Timaeus told his audience that God created the sun and moon, as well as five planets, "in order to distinguish and preserve the numbers of time." As for the stars, "Their wanderings, being of vast number and admirable for their variety, make up time." But this cosmology is more likely Platonic than Pythagorean.

Religious and Ethical Implications

We should never forget the religious and ethical consciousness of the Pythagoreans; they were united as a community by a set of rules of behavior, however esoteric. Every idea from Pythagoras had an ethical implication. There is an ethical meaning to time. Because mind becomes more aware of number, there is a gradual enlightenment of the individual soul and the society. The universe is the setting for a spiritual transformation, which must be seen as immanent to time, not a mere set of accidents. There is a Logos immanent to time, and a sort of wisdom.

Time is also a beautiful harmony; it is the tempo of the universe. Twenty-three hundred years later, Karl Ernst Ritter von Baer (see entry) suggested that if the rate of human perception were greatly increased, we would hear the orbits of the planets as music. There is a beautiful, higher, nobler understanding of time for the Pythagoreans, because time itself is number, and hence divine. To study number is the same as to study time and divinity.

Heraclitus

Life

With the figure of Heraclitus, we have the earliest Greek thinker with a rather developed philosophy of time. He reached his acme around 500 BCE. Heraclitus almost certainly wrote a book, but his fragments come down to us only through testimonies and traditions. Those fragments are themselves curious puzzles of a hermit's outlook on the ancient world. Though only 126 fragmented passages remain, most of them confront the problems of time, change, motion, and coming-to-be. Fragments from Heraclitus evidence his astronomical knowledge, which entailed an ability to tell time from the stars.

Heraclitus believed in necessity, justice, and time, as did Anaximander. The process of nature contained within itself a deeper Logos, for Heraclitus, and there was a distinctive flavor of morality in his view of the world. Character is destiny, for man. To the extent that we systematize and rationalize Heraclitus, we lose him. His worldview was deeply personal and emotional. His darkest sayings are probably impenetrable by the modern mind. But his metaphysical and religious beliefs do make some sense within the larger Greek cultural milieu.

Heraclitus taught a metaphysic of absolute nonpersistence in change, which he took, figuratively and/or literally, as Fire. Heraclitus may have meant that all things are fire (a "first principle," like Thales's water), or that a ring of fire encircles the remainder of the universe (a most inclusive thing, like Anaximines's air). Or Heraclitus may have seen fire not as the genesis but as the final goal of the universe. Everything must dry up and burn to ash due to the cosmic fire.

As a theory of time, then, Heraclitus's thought denied the ultimate reality of being. The universe burns away like a great bonfire over the long night. What exists solely is becoming; the energetic spark of the instant in time when the power of the universe actualizes itself, and just as soon is gone. There is no smallest uncutable particle in space and likewise no ultimate atom of time. So far down, or up, as one may go in looking, there is only change, not being. There is no ultimate individual or collective. This is as true of cosmic time as it is true of the moment. Heraclitus grasped, for himself, the great truth that all things must pass, and thus discovered the conflagration that is time.

Perhaps the deepest, darkest truth that we get from Heraclitus is that "passing away" comes to all, great and small, and the universe, ultimately, becomes a pile of dust. "This ordered universe, which is the same for all, was not created by any one of the gods or of mankind, but it was ever and is and shall be ever-living Fire, kindled in measure and quenched in measure." And "the fairest universe is but a dust heap piled up at random." Hence Fire is the beginning and final fate of the universe, a great Fire that slowly burns itself out. There is, for Heraclitus, a light that guides the universe and makes meaningful the events of the past, his Logos. It is lightning-like in its enlightening power. It illuminates truth and makes knowledge possible. The deeper question must be, what is the meaning of this cosmic Fire, if its end is only to burn out?

There is a bolt of meaning blazing in the universe, a deeper Logos evident for all to see, but incredibly, no one is willing to see it, according to Heraclitus. Souls are best preserved in a dried body, but man finds pleasure in fluids. Some souls even become soggy and moldy. They cannot see the truth, because they do not look for it. To find meaning, one must look for it. Yet, paradoxically, when we look for meaning, we find something else. "If one does not hope, one will not find the unhoped-for, because there will be no trail leading to it and no path."

Fools cannot see the reason that guides the cosmos, but some reason (Logos) gives meaning to the random pile of dust, according to Heraclitus. Hence his darkest moments give way to a dawn of insight and meaning. These dark sayings are balanced with Heraclitus's conviction that a Logos permeates the universe, and it is open to our access, if only we look for it. Logos (meaning) is everywhere in abundance.

Heraclitus was a hermit, but he was also a warrior in spirit, who saw *ares* (war) as the first principle of existence. War is the father of all things, perhaps in that the cosmos began in strife. Fire, war, Logos, misanthropy; these came together in Heraclitus.

Absolute Nonpersistence

Absolute nonpersistence in change, perhaps the core notion of Heraclitus, is evidenced by the famous saying, variously interpreted and translated as "Those who step into the same river have different waters flowing ever upon them," "It is not possible to step twice into the same river," or "In the same river, we both step and do not step, we are and we are not." This image of a river suggests time as a flow, and in a single direction; hence, the notion of an arrow of time. But the river may well be thought of as the flow of motion through space; there are no eternally existent elemental parts; the entire process of the universe in change absolutely does not persist; each smallest particle, as well, is itself consumed by change and ceases to be.

"The sun is new each day" suggests that each day is a whole relative unto itself, and that there is no highest order of time period. And so a human epoch would be an instant to a god; the size of the sun is the breadth of a man's foot. No two moments are alike, nor does time seem to repeat itself, if this saying be taken literally. Day and night are one; there is no essential difference between days. Hence the quality of time is uniformity, perhaps an indefinite nature, too.

Time Is Fire

Time is a transformation in things from one element to another, continually (re)mixed. Yet fire somehow rests from change in man. What marks off day from night is the sun. Equinoxes and solstices of the sun mark off the seasons, "the hours that bring all things." And the sun stays within the solar ecliptic, "otherwise the Furies, ministers of justice, will find him out," according to Heraclitus. The sun is no wider than a man's foot, perhaps, it might be added, from a man's earthbound vantage point. But surely the sun, seen much closer, would be enormous. Hence (apparent) size is relative to vantage point. Or perhaps he meant to suggest a macrocosm-microcosm relationship—that there may be universes containing our own at indefinite orders of magnitude, in which our own sun would be as wide as a man's foot. . . . But what is the sun, if not fire?

Time is not merely *like* a universe-sized conflagration slowly burning out, it *is* exactly that. Time is the fiery consumption of the universe even until man and earth perish, as measured by the rate of conflagration. All manner of corruption, degeneration, passing away, are manifestations of fire, however minute. Time is itself an elemental force like water, air, and earth or metal, but destructive, corrosive, annihilating of the others. Hence fire ultimately turns all to ash. It dries up the water of Thales. It uses up all the air of Anaximines, which purportedly surrounded the universe. It burns up all the earth and wood and melts all metal until only ash remains. All the elements are exchanged for fire, and then fire yields to the various other elements. Perhaps at this time the entire selfsame affair begins again. Or perhaps he meant that there is a cycle of fire similar to a nitrogen cycle. These fragments may have required initiation into a mystery or esoteric teaching to become comprehensible.

Reciprocal Time

Sleep and waking, life and death, youth and old age, are measures or periods of time that Heraclitus used to show the reciprocal nature of time. Opposites gradually develop into each other. Sleep gives way to waking, which eventually gives way to the former. There are different temporal phenomena in reciprocal states; distortion of time in dreaming, the quickened pace of time in old age, and so on. Each might be said to run according to its own unique clock. Hence, we may reasonably read Heraclitus to mean that time is epicyclical change.

The basis of Heraclitus's ontology is the notion that existents "scatter and again combine" and "approach and separate." These processes mark time or even constitute it. But they are coals in the wind, slowly burning out, like the universe at large. There is a relativity in sequence between the points of a circle in space. Surely it occurred to Heraclitus that points in circular time would be equally relative. Every moment would be the beginning and end of time, consequently. And hence, every day is the same, and astrology, consequently, is fundamentally faulty.

Fragment 52

"Time is a child playing a game of draughts; the kingship is in the hands of a child." This simile is Heraclitus's most explicit word on time, as distinct from "change" or "universe." Time is a child playing because it plays at random, not by strategy and tactics. Hence a child playing at draughts would be moving the pieces without rules and only at whim. Time is the kingship at stake. Why is time a kingship? It is the very being of life, its fire.

Heraclitus is said to have spurned the company of adults and played games with children. But he did not romanticize youth; rather he only believed adulthood to be worse. In another fragment, he shed some small light onto how he envisioned children in charge of a kingship. "The Ephesians would do well to hang themselves, every adult man, and bequeath their city-state to adolescents. . . ." So time has been handed to the least capable out of default by miserable, failed beings, or so it would seem, if the parallel is sound. How is it consistent, though, to say that time is random or worse, and yet the cosmos (which, after all, is only the spatial-material complement to that same time) is guided by Logos? This is evidently another of Heraclitus's antinomies, which will end by saying that they are both random and not random, both according with Logos and not according with it.

Parmenides

Parmenides was born around Olympiad 53. Parmenides was at his acme in his early 60s, at the same time that his antipode, Heraclitus, was also in his prime (as was Pythagoras). Parmenides was one of the most influential of the Presocratic thinkers. At roughly 20 years of age, he was instructed by Anaximander, who at that time was at his acme, or prime of life. The metaphysics of Parmenides took from Anaximander the distinction between being and nonbeing, the distinction between eternity and measured time, and the distinction between the unlimited and the limited. Anaximander apparently considered all six terms as real. Parmenides, however, identified being and truth with eternity and the unlimited, and identified nonbeing and illusion with measured time and the limited. Few known thinkers in the Presocratic world had doubted the testimony of the senses until the figure of Parmenides. And Anaximander's cosmology of three distinct spheres nested in each other was amenable to Parmenides' vision of a spherical "one."

When he was 30, Parmenides met the itinerant Xenophanes of Colophon in Elea. They shared a religious mysticism and a love of poetry. Xenophanes criticized polytheism and anthropomorphism, and Parmenides was a metaphysical monist and a mystic. Close in time to these events, Melissus of Samos became a student of Parmenides. Though the particular dialectic employed by Melissus differed from that of Parmenides, the conclusions were the same: Being is one, eternal and unmovable. Melissus denied time, using a dialectic of negation, like the master, but evidently without achieving a novel contribution, as did Zeno, the better known student of Parmenides. And thus the school of Parmenides at Elea was founded.

Parmenides and his school at Elea evidenced three influences: Anaximander, Xenophanes, and the Pythagoreans. The students of Parmenides may have been influenced by a Pythagorean named Ameinias. However tempting it may be to see in Pythagoras's monad an equivalent of Parmenides' "one," this seems unlikely. Rather than distinct cosmological or ontological doctrines, the similarity between the schools of Elea and Croton is one of lifestyle. The Parmenidean way of life probably resembled the Pythagorean way in that both were lives of religious mysticism and contemplation.

The "Prologue" by Parmenides, which has survived apparently complete, is an exquisite example of inspired philosophy, putting the audience at a spiritual crossroad as spellbound spectator. And the subsequent metaphysical teaching is crystal clear: Being can only be a timeless unchanging thing, perfect and eternal. "For there is not, nor will there be, anything other than what is, because indeed destiny has fettered it to remain whole and immovable."

Because "thought and being are the same," and because "it is necessary to speak and to think what is; for being is, but nothing is not," Parmenides concluded that only reason can bring us to the truth. This reason is the immortal higher path on which Parmenides found himself at the beginning of his "Prologue," and to which he was brought by the "daughters of the sun."

Nonbeing cannot be thought, and therefore is unreal. Nor can we know change; coming-to-be and passing-away are delusions of the senses. What is changeable is temporary and unknowable. Change is unreal, and hence also any notion of measured time. The apparent omnipresence of change is an illusion created by the senses, according to the teachings of Parmenides. Many humans believe the testimony of the senses, but that path is one of darkness and mere opinion. And so Parmenides adopted the Pythagorean opposites of unlimited/limited; one/many; rest/motion; and light/dark. But he identified the unlimited, one, rest, and light with being, while he identified the limited, many, motion, and dark with nonbeing and opinion. In this manner Parmenides collapsed the Anaximandrian and Pythagorean tables of opposites; they are mere names, for him, rather than categories of being.

Anaxagoras

Anaxagoras of Clazomenae wrote one book, and his acme was around 460 BCE. He was born in 500 BCE and came to Athens at 20 years of age. He philosophized in Athens after fleeing the Persians and was active at the same time as Empedocles, with whom he shared many ideas. Anaxagoras set about his mission early in life and pursued it in Athens, perhaps for 50 years, at which time he was forced into exile on charges of "impiety." His life mission was to create a natural history of the heavens. He adopted Anaximines' notion of stars as burning objects fixed on a wheel, but advanced it by suggesting that they are masses of burning stone or metal, which can detach and fall to Earth (as an explanation of the comet at Hellespont). He suggested that there is an ether surrounding the universe and that by the force of the rotation of this ether, vast stones are pulled into orbit, set afire, and recognized as heavenly bodies. Without a clear concept of momentum, Anaxagoras conceived of this force as speed. He hypothesized that Earth is closer to the moon than the sun. He compiled facts on eclipses and suggested that the light of the moon came from the sun and not the moon itself. He hypothesized that the sun is larger than the Peloponnesus, and that the moon has ravines and plains and is made of earth. He even suggested that the Milky Way comprised the light of many stars, which are shaded from the sun by the earth.

Anaxagoras had a clear notion of elemental entities, called *homeomeries,* which are originally mixed, but then separate off in a winnowing motion, like unto like. This primal mixture is a chaos of countless elements, because the elements are actual qualities rather than abstract categories of qualities (an infinite number of seeds in no way resembling one another). In contrast, Empedocles waxed poetic about this primal union. They shared the proposition that elements always have been and always will be. This implied an infinity of the past during which all elements still existed, and in precisely the same number. And it is logically consistent to say that these elements existed in a primal confusion only if there is a directionality of time, and a sense of a *point of origin.* Infinite time is consistent with directionality, but infinite time seems paradoxical with a sense of primal origin. Time, for them both, was an awkward mixture of cyclical and linear notions.

Anaxagoras was evidently very concerned about drawing the metaphysical implications of his vision; a set of propositions of great/small, mixing/separating, and infinite/finite compose several of the fragments, but so far as we may judge, there is no driving dialectical discipline behind it. Indeed, the account of separation told by Anaxagoras is a tissue of contradictions that would drive a careful logician to distraction. Anaxagoras, we might say, saved Zeno the work of reducing his position to contradiction. This must suggest that he was only partially concerned with systematic consistency and far more concerned with communicating a vision of the world and how it operates at its farthest and highest reaches, presumably, the enlightened natural scientist's view.

By emphasizing mind, Anaxagoras was still something of an echo of Anaximander. Empedocles used mind as an explanation but sought to account for the motions of the heavens more than the motives of love and strife. He studied the heavens as Socrates studied Logos, or as Empedocles studied earthly nature: methodically, minutely, patiently, and with an open mind. Yet, by including mind, Anaxagoras surely implied that there is a purpose or design to the universe. Otherwise, why would mind be necessary, if we are explaining the orbits of masses of molten metal? The essence of mind, in contrast to the elements, is purpose. The universal mind had a purpose, presumably, behind the mixture and separation, the formation of orbits, and the rise of life on heavenly bodies, though the fragments spare few details.

As for Earth itself, it is flat and hovers on air it has compressed underneath itself. Thus Anaxagoras required the notion that air was constrained (as in a clepsydra) and tremendously pressurized under the weight of Earth. Unfortunately we lack a fragment explaining *what* constrains the air under Earth, and so on. Here Anaxagoras may have relied on the analogy, drawn by Parmenides, between Earth and a pillar (but once again, what holds up the pillar?). Such analogies did little in the face of Zeno. Most notably, Anaxagoras could not seem to decide whether the whole is one or many.

Zeno

Life

Melissus of Samos was an important follower to Parmenides, but beyond question, the most famous pupil was Zeno of Elea. Conflicting stories have been told of Zeno having been a resistor against tyranny and a victim of torture, but facts are scarce. If Plato's account in his dialogue *Parmenides* is not fictionalized, then a young Socrates heard a middle-aged Zeno and an elderly Parmenides hold forth. (But since so much scholarship has rested on that passage, if Plato's account in *Parmenides* is just good fiction, as one alternative careful chronological calculation suggests, then a much different sequence to the Presocratics must be conceived.) One source suggested that Zeno wrote his book in his youth, but even this is uncertain. The traditional date of his acme is 450 BCE. Almost nothing trustworthy is known of Zeno's life, but his enormous contribution to Western thought, especially logic, could hardly have been greater, for Zeno should be recognized as the discoverer of dialectical thinking.

Unfortunately, only fragments from Zeno's literary production survive. It is part of an ongoing debate about Zeno as to whether he wrote one or more books. And there exists no reliable way to reconstruct his arguments into a single logical system, though it seems likely that there was such a scheme. Testimony about Zeno of Elea comes from Plato's *Parmenides* and Aristotle's *Physics,* yet a complete image of Zeno the logician must always escape us. Reportedly, Zeno had some 40 dialectical syllogisms (*epicheirêma*) to indirectly support various Parmenidean teachings. He began each dialectical syllogism with a hypothesis such as "things are many," and then he reduced the assumption to absurdities. Because the initial hypothesis resulted in a contradiction, we are justified in concluding its opposite proposition. In short, he assumed the proposition of his opponent and showed that it yielded a contradiction, and then he concluded his own proposition, a technique called "indirect proof" or *reductio ad absurdum* by later logicians.

A Sample Epicheirêma

In Fragment 3, Zeno argued that if things are many, they must be both (a) finite and (b) infinite in number:

> (a) If there are many things, it is necessary that they are just as many as they are, and neither more nor less than that. But if they are as many as they are, they will be limited.
> (b) If there are many things, the things that are, are unlimited; for there are always others between the things that are, and again others between those. And thus, the things that are, are unlimited.

The conclusion to Zeno's dialectical syllogism is that if we assume that there are many things, the same thing will be both limited and unlimited. We may feel justified in assuming that Zeno would then have drawn the consequence that such a contradiction is absurd. And so the supposition which inspired the dilemma—that things are many—must be rejected.

Zeno's Paradoxes of Motion

Aristotle seemed to suggest that Zeno posited four principle paradoxes in the conclusion that motion does not exist. But how these paradoxes fit together with other parts of his logic is unknown.

1. *The Stadium.* Zeno argued that before a runner can traverse the stadium, he must reach the halfway point, and so on (presumably, that the runner must reach half way to the half way mark, and so on). But this would mean that the runner would have to cover an infinite number of points to traverse the stadium. Yet it is absurd to think he would cover an infinite number of points in a finite amount of time. Therefore the runner can never really traverse the stadium. Zeno's paradox of the stadium means to reach the conclusion that *motion does not exist.* It seems entirely likely that this notion would have led, by a dialectic of being and nonbeing, to the Parmenidean proposition that all things are one. Aristotle, the sole source, commented that Zeno ignored the difference between points *infinite in their extremes* and points *infinite in their divisibility.* Though a runner cannot traverse the first sort of infinity, he can traverse the second such infinity (and hence indeed traverses the stadium), Aristotle concluded, at least preliminarily. The runner presumably touches each point he passes over (i.e., the track), Aristotle worried, so if the track is infinitely divisible, it still poses a problem that he would cover an infinite number of points in a finite amount of time. Aristotle would finish his remarks in the *Physics* by saying, "In a way it is but in a way it is not" possible to touch an infinite number of points in a finite time.

2. *Achilles and the Tortoise.* Apparently Zeno proposed the paradox that Achilles would never be able to overtake a tortoise, even though he were moving at a much greater speed. Zeno arrived at the paradox by the same line of reasoning that he used with the stadium argument. That is, Achilles would have to reach the midway point between himself and the tortoise before he could overtake the tortoise. But by the same logic, Achilles would also have to reach the midpoint between himself and the midway mark, and so on. Achilles would never be able to touch an infinite number of points to get to the tortoise. And so, paradoxically, Achilles will never be able to overtake a tortoise.

3. *The Arrow.* Relying on Aristotle's account of the paradox of the arrow, Zeno started with the premise that anything occupying a place exactly equal to its own size is at rest. Zeno then added only one additional premise, that at any present moment, what is moving occupies a space precisely equal to its own size. Zeno concluded from these two premises that at any present moment, what is moving is at rest. To this conclusion Zeno added a new premise, that what is moving always moves at the present moment. Zeno drew his conclusion that what is moving is always at rest. Another source, Diogenes Laertius, told his readers, "Zeno abolishes motion, saying, 'What is in motion moves neither in the place it is in nor in one in which it is not.'" Thus, the arrow shot from a bow and seeming to travel at high speed is at rest!

Aristotle's evaluation of Zeno's arrow paradox proved highly valuable to subsequent philosophy of time. For Zeno's paradox of the arrow relied on the assumption that time is a succession of discrete *now*s. But Zeno was wrong, according to Aristotle, precisely because "time is not composed of indivisible *now*s, no more than any other magnitude." His idea was that a continuum, a line, for example, is not composed of indivisible points that somehow touch and make the line continuous. In short, there are no indivisibles in time, or no time atoms, because *time is not composed of points in a line.* The implications of this rejection of atoms of any sort would require centuries, and even millennia, to play out, though. For, if time does not consist of a succession of discrete *now*s, of what *does* it consist?

4. *The Moving Rows.* Zeno's fourth and final paradox requires the following diagram and legend:

AAAA

Δ BBBBE→

←ΓΓΓΓ

A	stationary bodies
B	bodies moving from E toward Δ
Γ	bodies moving from Δ toward E
Δ	starting place
E	goal

By Aristotle's rendition, Zeno presumed two equally spaced columns of men (Β and Γ) marching in opposite directions in a stadium. One group marches from Δ to Ε, while the other group marches from Ε to Δ. They march at equal speeds past a set of stationary columns of men (Α). Apparently Zeno then argued that the marching columns would pass each other twice as fast as they would pass an equal number of men in a stationary position. From this Zeno inferred that "the half is equal to the whole," meaning that the marching men were, paradoxically, moving both half as fast and fully as fast, at the same time. But this is absurd. Therefore, the marching men were not really in motion.

It seems likely that Zeno presumed that each marching row would be across each stationary column for an equal period of time, as Aristotle suggested. But Aristotle then went on to claim that Zeno's fallacy lies in ignoring that the amount of time required to pass half of the A's was equal to half of the time required to pass all the Γ's. But things are not so clear-cut, as Kirk, Raven, and Schofield brilliantly demonstrated: "Zeno needs only to get us to accept the plausible idea that if a body moves past *n* bodies of size *m*, it moves a distance of *mn* units; simple arithmetic will then show that moving *mn* units will take half the time of moving 2*mn* at the same speed." And so Zeno would have been able to show, after all, that the men are marching at full speed and half speed, at the same time.

Or Zeno might have answered Aristotle's criticism by assuming, instead of columns of marching men, indivisible bodies moving at a speed such that each would be across from a stationary body (another indivisible body) for but an instant. This would escape Aristotle's comments (for what would it mean that each B must pass each Γ in half of an indivisible time?) while raising interesting questions about space, time, and atomic bodies.

Evaluation of Zeno

Even as fragmented isolated arguments of a larger system of logic, what did remain of Zeno's work(s) has caused thinkers headaches for centuries, however, and Zeno's paradoxes of motion remain awe inspiring in a timeless way.

From the Parmenidean point of view, Zeno's project was highly successful. It showed the absurdities implicit in the hypothesis of motion, as our five senses testify to it. To combat Zeno's challenge, Aristotle attacked the rather commonsense notion of time as a continuum composed of discrete present moments. But this already gives the victory to Zeno, because he has proved his point of logic: Motion, as it is given to us by the senses, is not what it seems. Now the modern mind hastens to translate Zeno's paradox of marching rows into relativity theory. But once again Zeno has already won, for Einsteinian relativity defies common sense and the testimony of the senses, and so motion is not what it seems. And an additional devastating Zenonian point of logic came from Kirk, Raven, and Schofield: "If the distance a body moves is simply a function of its position relative to other bodies, is there any absolute basis for ascribing movement to *it* at all?"

Or to use the Parmenidean idiom, mortals fooled by the illusion of motion "wander knowing nothing, two-headed . . . carried along, deaf and blind at once, dazed, undiscriminating hordes, who believe that to be and not to be are the same and not the same."

Empedocles

Life and Influences

Empedocles of Agrigentum (Sicily) lived from 484 to 424 BCE, according to the traditional chronology, and was born into nobility. He was evidently an orator, scientific thinker, poet, and democratic figure in the face of tyranny. Regal in dress and imposing in manner, Empedocles built a legend around himself, claiming to have a golden thigh and to be divine. He wrote two poems, "On Nature" and "Purifications," both of which survive in fragments. Empedocles was in his acme around 450 BCE. His exact relations to the other Presocratics are unknown.

In the surviving fragments, he claimed to have been inspired by "much-wooed white-armed maiden muse." And he suggested that he had an elixir of life against old age; it could also bring the dead back to life.

As a general observation, Empedocles wrote, we come to be familiar only with what we immediately experience, and each of us takes our own sum of experience to be the totality of knowledge. But we learn little to nothing of the whole, and when we die, our knowledge dies with us. Only by the muse's inspiration, presumably, was Empedocles able to shake humankind out of this ignorance. And so Empedocles created his own version of the ageless philosophical distinction between ignorance and true knowledge and indeed gave voice to an ancient skepticism about human knowledge by painting humankind in a fallen state of knowledge.

What we can infer from the fragments of Empedocles, it seems, is a rather naive (uncritical) realism toward change and motion, which, like his natural science, is most reminiscent of Anaximander. A chronological question then raises its ugly head: Which, if either, was the teacher of the other? There is no philological way to settle this issue.

Yet there is no evidence of a clear distinction of eternity and measured time, as would be found in Anaximander's ideas, unless Empedocles' obscure "realm of piety" counts as eternity. Indeed, in Empedocles there is a world of change at the expense of a world of eternity. If so, this would have been an irreconcilable difference from Anaximander.

Some ancient authors reported that Empedocles was a Pythagorean, and there is significant evidence for the claim. While the surviving fragments from "On Nature" seem inspired by the natural science of Anaximander, those from "Purifications" suggest a strong Pythagorean influence on the ethics and religion of Empedocles. Allegedly, Empedocles publicized the secret doctrines of Pythagoras and was expelled, as was Plato. Or perhaps Empedocles was an itinerant member of both Pythagorean and Parmenidean communities for however long a period.

Many scholars see a parody of Parmenides' poem in the verses of Empedocles. (If Empedocles was reacting to Parmenides' challenge against motion, he should be placed contemporary with, or after, perhaps immediately after, Parmenides.) But other ancient authors claimed that Empedocles was lampooning Xenophanes. One story held that he jumped to his death into Mt. Etna.

Account of Nature and Change

Empedocles lived in his own world of the elements (earth, air, fire, water) but also the Olympians (Zeus, Hera, Hephaestus, Aphrodite, "sharp-shooting Sun and gracious Moon"), "Titan Aether," and the realm of piety, as well as the cosmic forces, love and hate. His world was further populated by an array of nymphs ("Sunshine, Speed, Delay, Beautiful, Ugly"), goddesses (Iris, Chthoniê), and the like ("lovely Infallibility" and "dark-eyed Uncertainty"), all anthropomorphized and personified in a rather naive way. Evidently, Empedocles identified Zeus with fire, Hera with air, Aïdoneus with earth, and Nestis with water.

These primal elements and forces work through the world by a "double process"; scattering (moving from one to many) and gathering (moving from many to one). This beginningless and endless scattering and gathering is the objective natural course of the universe. Thus Empedocles' fragments give evidence of a rather detailed observational natural science. His remarkable speculations about the origins of the species have resulted in him being considered as something of an ancient Darwin. But his natural science was always interwoven with the fantastic. So far as his geography went, Earth is most comparable to a "roofed cave," this term having, doubtless, an ethical meaning, as well. As to physiology, the blood around the heart, according to him, is "thought in mankind," put there by fortune. The body decomposes at death into the elements, he said, but Empedocles evidently also believed in metempsychosis, as did Pythagoras, and claimed to already have been a girl, a bird, and a "dumb sea-fish." The destiny of a soul can thus be said to be divided into a long sequence of lives.

Empedocles held that the elements never came into being and can never pass away, suggesting that *time is infinite both in the past and in the future*. More explicitly, in fragment 16 he referred to "infinite time," which will never be emptied of love and hate. In this sense he has broken with the ancient mythical notion of cyclical time in favor of a rather linear conception of time.

Time is an objective force of nature, not a figment of the human mind. If there were no "infinite time," all of nature would be at a standstill, forever. But the elements are real and pervasive, for Empedocles. These elements appear most closely related to what modern metaphysics calls "concrete universals." Thus Empedocles adopted a sort of naive realism about *time and motion as they appear to the five senses*. He did not doubt the testimony of his own eyes, gifts from Aphrodite, who, having built "tireless eyes" from the elements, "fastened them together with clamps of affection." His own unique prototype of qualitative pluralism implied that *time can be measured by the double processes of scattering and gathering.* Perhaps the transformations of individual elements would provide us, in theory, with elemental clocks, too, but that is speculative.

Unfortunately, Empedocles gives a rather contradictory account of *how time operates.* Some fragments suggest that time operates by strict necessity; there is an "oracle of necessity." Yet his account of the origin of species implied that time operates by chance, "for things can be mingled at random." Motion occurs without a mechanism (i.e., from the cosmic-force love) yet leads to mechanical results (events and things of nature). This paradox is typical of the worldview of Empedocles.

Significance

Now if Empedocles really was responding to the Eleatic school, he did not enter into a dialectical battle with Zeno, his contemporary; he did not, at least in the surviving fragments, directly confront Parmenides' theory that motion does not exist. He offered no defense of the senses vis-à-vis the arguments of Parmenides. Rather, he developed his own account of time and change—qualitative pluralism—in isolation; if he had serious rivals, he did not name them or hint at their theories.

Indeed, it may be correctly noted that Empedocles took the way of opinion, as described in the poem by Parmenides, but in an uncritical way, leaving him without having refuted or moved beyond the problem of motion.

The only way to interpret any remotely Parmenidean influence in the writings of Empedocles would be to take his elements as όντα (self-existing, eternal, incorruptible "thing")—a stretch, because Parmenides took there to exist only one όντα. Rather, it seems that Empedocles was most engaged in the thoughts of Anaxagoras. Anaxagoras took countless qualities to be elemental homeomeries; Empedocles allowed only four. But both believed that macroscopic objects comprise masses of microscopic particles.

In his atomic speculations, Empedocles went well beyond Anaxagoras. Now the absolute number of particles of each element in the universe, and hence the total amount of particles, remained finite and constant; now time operated by a conservation of matter and a constant motion. Similar notions of mixing and blending linked Anaxagoras and Empedocles, of course. With the introduction of infinite time in the past, there is no sense of mind as the author of an original motion in the sense of Anaxagoras, however (unless love and strife are theoretical remnants of mind; but why, then, are love and strife necessary, if mind suffices?). Empedocles' theory of effluences (microscopic openings in matter) allowed him at least the possibility of a remarkable insight into time and change at an atomic level. If time is matter in motion, then microscopic motion would require a microscopic scale of time. And his acceptance of a void in the effluences certainly second-guessed Anaxagoras and tested the waters for Democritus and Leucippus.

Indeed, Empedocles certainly set the stage for the subsequent atomists. Yet his insistence that love and strife are authors of motion is a hard doctrine to resolve with an atomistic understanding of motion, unless the atoms themselves are energized by these cosmic forces (an equally speculative claim).

Leucippus and Democritus

Many thinkers laid groundwork for the atomist school of thought in Athens. Leucippus and Democritus, both of Abdêra, were preceded by the so-called Milesian school of natural philosophy (Thales, Anaximines, Anaximander); the Pythagorean cosmology of number; the elemental ontology of Empedocles and Anaxagoras; and the dialectic of Zeno and Parmenides, along with their notion of όντα. Each source provided an idea or principle for constructing an elegant theory of atoms.

Leucippus reached his acme around 430 BCE, and Democritus did so around 10 years later. Leucippus may have coined the first terms or concepts of atomism: *atoms* (literally, indivisible), *great void, contact* (arrangement), *aspect* (position), and *rhythm* (form), among others. Leucippus wrote one book, *The Great World Order,* and possibly a brief work called *On Mind,* from which this important principle comes to us as fragment 2: "Nothing happens at random; everything happens out of reason and by necessity." The fact that an atomist would write anything "on mind" suggests he believed in a mind behind the cosmos of atoms and void, but we know no details.

Democritus may have plagiarized from Leucippus; either way, we should consider Leucippus as the earliest known atomist. Democritus produced an evidently enormous literary estate. His works were arranged into the categories of ethics, natural science, mathematics, music, technical works, and a long series of monographs on causes, all of which are known only by title in various fragments. According to fragment 5, in *Small World Order,* Democritus apparently attacked Anaxagoras as an original thinker and as a student of nature. Another work carried as its title *Pythagoras,* but nothing is known of it. It is certain that Democritus invented an astronomical calendar, and evident that he saw in nature a periodic cycle of seasons, migratory birds, weather patterns, (mis)fortune, and more. The fragments of his calendar that remain show a highly scientific mind working with a folk wisdom of unknown antiquity. We are told in fragment 12 that the "great year" of Democritus (and Philolaus the Pythagorean) was considered to be 82 years with 28 intercalary months. Democritus was, then, familiar with the problems of calendar making and timekeeping in general.

Fragments on Atoms

Perhaps the most famous declaration of Democritus is, "Atoms and void [alone] exist in reality." This first historical formulation of atomism remains readily understandable into the 21st century, even if the current idioms are quarks and space. Democritus had discovered, for the Greeks, the notions of elemental particles of matter and of empty space. He envisaged atoms as indivisible chunks of matter existing in space. These smallest particles, in great numbers, constitute the object of sensory experience, that is, macroscopic objects. Though they were microscopic, Democritus imagined his atoms to have many of the same characteristics as the macro objects; extension in three spatial directions; arrangement; position; and duration in time, motion, speed, and form. Thus the microscopic or microcosmic particles are the indivisible, smallest parts of a whole physical body. It was not until Sir Isaac Newton and his contemporary Roger Joseph Boscovich later came to question this extended particle ("corpuscular") assumption in the theory of atomism (though Newton retained his commitment to the existence of some extended matter in the universe) that such reasoning would become suspected of a fallacy of division.

Democritus's affirmation of a void goes far more against common sense than does his affirmation of atoms. Indeed, some sort of atomism makes common sense, but the notion of a void was roughly that of vacuum; common sense believes nature abhors one, and thus a void cannot exist. Earlier thinkers from Anaximines onward gave a metaphysical stature to air or vapor. And where space between bodies was considered by the Presocratics, it was considered to be filled by the ether. Even the effluences of Empedocles sealed up and left no void. And so the genius of Democritus becomes evident even in the paltry number of his fragments.

Atomism poses its own epistemological problem: If atoms truly are beyond our senses, how do we know their nature, characteristics, or even their actual existence? Democritus faced the epistemological challenge head on by allowing his theory to remain just that, a theory, rather than involve himself in contradictions. And so he wrote, "We know nothing accurately in reality, but [only] as it changes according to the bodily condition, and the constitution of those things that flow upon [the body] and impinge upon it." Applied to his own atoms and void, this meant that we cannot know atoms directly but only through their physical effects at a macroscopic level. Until the instrumental period of science, thinkers would be able to do little more than theorize about atoms.

Yet this, for Democritus, is ultimately true knowledge. For there are two types of knowledge; sensory knowledge, which he called the "bastard," and "one genuine" sort of knowledge, which is mind comprehending ideas. The encyclopedic knowledge Democritus evidenced in his literary corpus suffices to show his regard for learning and abstraction. But he denigrated the testimony of the senses, a tradition among such diverse men as Heraclitus, Parmenides, and Pythagoras. Our senses alone will only mislead us. And so it must have been something of a puzzle to him as to how to reconcile his blanket rejection of the senses with his own attribution of properties in macroscopic (sensory) bodies to microscopic bodies. An equally vexing problem could be posed; if Democritus is certain of the existence of his own mind in the process of discerning physical affects of atoms, then something more than just atoms and the void exist.

What seems certain is that Democritus envisaged *time as the motion of matter through space*. This is far more elegant than the vision of any predecessor. He discovered the dependence of knowledge on a specific level of being; "humanity is a microcosm." Certainly, the universe as a whole is the final macrocosm; but humanity finds itself to be a miniature universe unto itself. So much more so is the atomic world; it is a microcosm at a second remove, and the final one, for Democritus. Applied to time, then, we would expect an entirely different frame of reference for time at micro- and macrocosmic levels.

Thus there must have been an uncertainty principle built into his theorizing about atoms, as about everything else: "We know nothing in reality; for truth lies in an abyss." Nor can we know causality, even in a world of physical bodies; "I would rather discover one cause than gain the kingdom of Persia," said Democritus. These epistemological concerns about natural science made Democritus a timeless philosophic and scientific figure.

Atomic Time and Zeno's Paradox

Democritus discovered the notion of the smallest, indivisible particle. He envisaged the atom as extended, and thus likely also considered a line to be composed of points with no space between them. If this is so, then he likely also believed time to be composed of a succession of discrete present moments. This would all mean that Democritus would have been susceptible to Zeno's paradoxes in both space and time. In short, Democritus was dependent on Euclid's conception of space and time, but therein lay the paradox. Almost certainly Democritus referred to Parmenides and Zeno when he wrote, "It has often been demonstrated that we do not grasp how each thing is or is not." But no fragment offers a hint of reply.

Again, the problem Democritus faced was due to his notion of corpuscular matter, and likely a notion of discrete present moments. The solution here, as with Zeno's paradox of the moving rows, would have been to envision the atoms as dimensionless points, not extended in space but emitting forces or powers. Unless Democritus took that route, though, he would have been saddled with Zeno's paradox, for his atoms would not be able to move, and the void could never be crossed. In fact, he would have been unable to show how time ever began in the first instant. To leave corpuscular atomic theory, though, would have meant crossing over to point-particle theory, a move we have no evidence he made.

Zeno's paradox is ultimately mathematical in nature, and the discovery of the calculus of infinitesimals finally silenced him, but only many centuries later. And so calculus was of no help to Democritus. What Democritus did achieve was to create the scientific type—entirely liberated from mythology and metaphor—within his theory and his own person. After his appearance, science would continue a relentless, if halting, progress. In the meantime, Socrates and his followers, including the young Plato, were already taking their places on the stage of philosophy, and thus the so-called Presocratic period of Greek thought came to an end.

Greg Whitlock

See also Anaximander; Anaximines; Cosmogony; Cronus (Kronos); Eliade, Mircea; Empedocles; Heraclitus; Herodotus; Mythology; Parmenides of Elea; Pythagoras of Samos; Thales; Xenophanes; Zeno of Elea

Further Readings

Fideler, D. (Ed.). (1987). *The Pythagorean sourcebook and library* (K. S. Guthrie, Trans.). Grand Rapids, MI: Phanes Press.

Freeman, K. (1948). *Ancilla to the Presocratic philosophers*. Cambridge, MA: Harvard University Press.

Kirk, G. S., Raven, J. E., & Schofield, M. (1983). *The Presocratic philosophers* (2nd ed.). Cambridge, UK: Cambridge University Press.

Nietzsche, F. (2001). *The Pre-Platonic philosophers*. Urbana: University of Illinois Press.

Robinson, J. M. (1968). (1968). *An introduction to early Greek philosophy.* Boston: Houghton Mifflin.

Wheelwright, P. (Ed.). (1966). *The Presocratics*. Indianapolis, IN: Odyssey Press.

Zeller, E. (1980). *Outlines of the history of Greek philosophy* (13th ed.). New York: Dover Publications.

PRIGOGINE, ILYA (1917–2003)

It is unusual that a winner of the Nobel Prize in chemistry succeeds in arousing a continuing interest of nonscientists in his research. Ilya Prigogine, who won that most prestigious award in 1977, is the exception that proves the rule. His study of the thermodynamics of irreversible processes not only is important in the history of science but also may have far-reaching implications for the philosophical understanding of time, which Prigogine discussed in a series of popular books read by a wide audience.

Ilya Romanovich Prigogine was born on January 25, 1917, in Moscow. Because his family had trouble with the Soviet regime that had been established after the October Revolution, the Prigogines emigrated in 1921 to Germany and in 1929 to Belgium. Prigogine studied chemistry at the Free University in Brussels, where he also became professor after the Second World War. In 1959, he was appointed director of the International Solvay Institutes in Brussels and professor at the University of Austin in Texas. There he also founded, in 1967, the Center for Statistical Mechanics and Thermodynamics. For his scientific work, Prigogine was honored not only by the Nobel Prize but also by more than 50 honorary degrees as well as by a Belgian title of nobility, viscount. On May 28, 2003, Prigogine died in Brussels.

Prigogine's principal field of research was thermodynamics, the science of energy and its transformations. Classical thermodynamics studies closed systems—systems that are thermically isolated from their environment and whose entropy can, according to the second law of thermodynamics, only be constant or increase. On a macroscopic level this means that closed systems become more and more disordered. Yet everyone can observe physical systems that, at least temporally, show an increase in order, for example, organisms. These are open systems; that is, systems that, by constantly exchanging energy with their surroundings, increase their internal order. To develop and maintain the complexity of their bodies, organisms must eat, breathe, and excrete. It is, however, not the case that every open system is able to increase its own complexity; only open systems that are far from thermodynamic equilibrium self-organize (*equilibrium* means a state in which the forces acting on the system are in balance). Prigogine called nonequilibrium systems *dissipative structures,* and he tried to apply their thermodynamic analysis not only to organisms but also to social systems.

A characteristic feature of dissipative structures is that they are historical systems: The processes by which they originate, develop, preserve themselves, and dissolve are irreversible. Prigogine's theory of nonequilibrium systems can thus be regarded as a physics of history. He considered his model of dissipative structures to be more realistic than the classical models of closed systems and near-equilibrium open systems. Consequently, regarding the basic ontological categories of natural science, Prigogine argued passionately for a revolution whose maxim is succinctly expressed by the title of one of his books on philosophy of nature, *From Being to Becoming* (1980). In this work, two concepts of time are distinguished. The concept of external and universal time refers to time as a parameter of motion; it is used when we want to communicate about processes and use clocks as instruments to quantify the succession of events by counting conventionally fixed units. The concept of internal and individual time refers to time as a property of the development of physical systems; it is used when we want to determine the intrinsic age of a system by counting the number of irreversible transformations of a certain type that have been generating the present state of the system.

In the tradition of philosophers like Peirce and Whitehead, Prigogine criticized the standard worldview of physics for being founded on the conceptual separation of the arbitrary initial conditions of a system from the dynamical laws its behavior follows: This way of objectifying nature cannot capture the essentially historical nature of all that is existing. Because dissipative structures are continuously exchanging energy with their environment, Prigogine thought that we humans, after having understood that we are such structures, will be able to develop a new understanding of ourselves as insolubly being a part of nature. The anthropological implications of his new ontology of nature Prigogine explained in his most famous philosophical book, which he wrote with the philosopher Isabelle Stengers, *Order out of Chaos: Man's New Dialogue With Nature* (1979). Whereas his philosophical convictions are, to say the least, quite controversial, Prigogine's far-from-equilibrium thermodynamics has become one of the cornerstones of research into complex systems and their natural historicity.

Stefan Artmann

See also Becoming and Being; Chemistry; Entropy; Time, Units of; Whitehead, Alfred North

Further Readings

Balescu, R. (2003). Obituary: Ilya Prigogine (1917–2003). *Nature, 424,* 30.

Nicolis, G., & Prigogine, I. (1977). *Self-organization in non-equilibrium systems.* New York: Wiley.

Prigogine, I. (1997). *The end of certainty.* New York: The Free Press.

Prime Meridian

The prime meridian is an imaginary half-circle reference line extending north and south from one pole to the other and passing through Greenwich, England. It marks 0° longitude and divides the western and eastern hemispheres of the earth. The line that meets it at both poles and is exactly 180 degrees away from the prime meridian is the international date line. The prime meridian is the standard basis for determining time throughout the world. It is the starting point for all the world's time zones. This meridian is the location of UTC (universal time coordinated) as well as Greenwich mean time (GMT). Noon GMT is defined as the time at which the sun crosses the Greenwich (prime) meridian.

An international agreement in 1884 established the prime meridian in its current location. This line runs through the transit circle telescope, built in 1850 by Sir George Biddell Airy, the seventh astronomer royal, at the Royal Observatory Meridian Building in Greenwich, England. The crosshairs in the eyepiece of the transit circle telescope precisely define 0° longitude for the world. It is located at 51° 28' 38" north latitude. As the earth's crust is moving very slightly all the time, this exact position moves very slightly.

Longitude is a measure of both time and location on the earth. As the earth spins on its axis, a specific location and time can be determined relative to the prime meridian. This north-south line marks noon of the day that begins at the international date line and is the origin from which east or west longitude is measured. One degree of longitude equals 4 minutes of time the world over, but the distance of 1° longitude varies depending on the latitude of the location. Every 15° east measured from the prime meridian marks another hour later; every 15° to the west marks another hour earlier.

History

Lines of latitude and longitude appeared on maps at least 3 centuries before the Christian era. Hipparchus was the first astronomer to determine the difference in longitude and chose Rhodes as the location for his prime meridian, that is, his 0° east or west. By 150 CE, Ptolemy plotted grid lines on 27 maps of his first world atlas. The equator was set from previous astronomical observations, and he chose a line running through the Canary Islands as the prime meridian for his maps.

Later mapmakers moved the prime meridian to the Azores, Cape Verde Islands, Rome, Copenhagen, Jerusalem, St. Petersburg, Pisa, Lisbon, Rio, Tokyo, Paris, and Philadelphia. This placement of the line that marks 0° east or west is purely political, as it is not based on any natural phenomenon.

Beginning in 1667, and continuing for over 200 years, French cartographers used the longitude line running through the Paris Observatory to be the prime meridian. Other meridian lines were given names such as the Rose Line but were never used universally. The English king Charles II founded the Royal Observatory at Greenwich in 1675 for the purpose of improving navigation, and its longitude became another prime meridian.

The development of the accurate chronometer by Englishman John Harrison made it possible for English ships to determine their location based on comparison of their time and the time at a known longitude. Harrison was a clockmaker and not an astronomer, but he was able to solve the problem of determining longitude at sea. This was recognized in 1773.

Ocean charts drove the need for one internationally agreed-upon prime meridian. In 1871, the first International Geographic Congress (IGC) met in Antwerp, Belgium. The general view was that the navigation passage charts for all nations should use the Greenwich meridian as zero, so when ships exchanged longitude at sea, locations and times would match. This did not apply to land maps and coastal charts. In 1875, the second IGC met in Rome. France was willing to accept the Greenwich prime meridian if the rest of the world would accept the metric measurement system. In October 1884, at the invitation of U.S. President Chester Arthur, the International Meridian Conference was held in Washington, D.C., and 41 delegates from 25 nations voted 22 to 1 for Greenwich as the location of the prime meridian. Santo Domingo was against it, and France and Brazil abstained. The United States had already chosen Greenwich as the basis for its national time zones. Seventy-two percent of the world's commerce already used sea charts that used Greenwich as the prime meridian.

International commerce and communication required one standard. Since 1884, the world has had only one prime meridian.

Ann L. Chenhall

See also Harrison, John; Latitude; Longitude; Time, Measurements of; Time, Teaching; Time Zones

Further Readings

Barnett, J. E. (1998). *Time's pendulum: The quest.* New York and London: Plenum Trade.

Raymo, C. (2006). *Walking zero: Discovering cosmic space and time along the prime meridian.* New York: Walker.

Sobel, D. (1995). *Longitude: The true story of a lone genius who solved the greatest scientific problem of his time.* New York: Penguin Books.

PROGRESS

Progress is most easily defined as forward movement toward a destination. The theory of progress, however, is commonly defined as the forward, irreversible pattern of change throughout human history, the destination being the future. In its simplest form, progress is known to be change for the better. Although it may seem like an easy concept, it is widely debated and easily refuted based on its reliance on subjective matter—a lack of empirical proof about what is indeed better.

A critical aspect of progress is time. History is critical in evaluating progress, and history would not have been written without change. Without looking back in time on the condition of human life, science, and morality, it is impossible to know if advances have been made; thus, all progress must be measured relative to the past. Progress throughout history is not continual but rather takes place over time through setbacks and dissonance. In addition, goals, hopes, and dreams change over time, making what could have been measured as progress a century prior, now obsolete.

Progress is a relatively recent idea as applied to society as a whole. In ancient times, the idea was foreign, and in fact, most civilizations viewed the state of being as declining rather than improving. The idea was that life had been perfect in a former golden age and slipped into the silver, then bronze ages, identifying a downgrading of humanity. French historian Charles Perrault said in 1687 that there appeared to be little left to learn and that there was no reason to envy future generations.

The idea of progress took hold in the 18th century in the work of philosophers, scholars, and theorists such as Immanuel Kant, Marquis de Condorcet, and Georg Wilhelm Friedrich Hegel, among others. Prior to this, there was little hope that the world was in fact on its way to becoming a better place. This was the shift from the idea that man had been created perfect, and there was a push to live up to that standard to the idea that intelligence equaled progress, and the more knowledge each generation could obtain, the more forward movement, or progress, would be seen. Most of these thinkers agreed that progress had been made throughout history and was continuing in their respective times. They did not, however, share opinions on the ultimate goals of society and what was to be the ultimate goal.

Hegel saw history as progress toward freedom and the chaos of history as having great purpose toward the future. Kant wrote about a human race looking into the future and advancing to a "universal civil society," with maximum individual freedom afforded to all. Condorcet used mathematical methods in his approach to the social and moral sciences and believed in progress and perfectibility. His Enlightenment theory specifically addresses the likelihood and reality of perfectibility being attained within human history.

The theory suggests that the movement of change is irreversible in direction and that although it is not considered to be a continuous stream of forward change, due to occasional regression or stalled movement, the ultimate result is positive change. The pace of progress is not easily defined, as it varies widely with such fluctuations in direction and cannot be adequately measured in terms of time.

The opposition to this idea of eventual forward movement is quickly dismissed by the cliché "history repeats itself." There are those who subscribe to the thought that history is in fact cyclical, and events, or basic forms of events, reoccur over time. For this reason there is a school of thought that does not accept the idea that history is an upward climb toward that which is better; rather, this school holds that history will return in a similar form in the future. And then there are those still who agree that there is a definitive pattern of history that also moves in an irreversible direction but who argue that change is for the worse.

Among its supporters, many wonder whether progress is eternal, or if at some point it will level off to a point from which no further advancement can be made. Progress is also proven to be poorly defined in that there is no solid agreement as to the breadth of progress. Some argue that it is limited to human inventions, productions, and intellect. Others would say that it also should be inclusive of the improvement of the very nature of man himself.

Many who disagree with the theory on the whole have varied reasons for its dismissal.

The idea of progress is sometimes debated as immeasurable, and therefore its legitimacy is questioned. The argument does not center on the facts of history, which are knowable, but that the determination that an improvement has been made over earlier times is subjective. Many factors can complicate the ability to identify progress, including but not limited to the subjective nature of any determination of what is better. Some may see the automobile as evidence of human progress, while environmentalists may argue that its role in pollution and its drain on the natural resources of the earth actually make things worse.

In science, at least, it is commonly understood that there is progress. Seldom is it disputed that advances have been made, and it would be difficult to argue that curing disease and prolonging life through scientific research and newer medicines are not to be viewed as positive. Although their value is largely undisputed, even scientific advances cannot be seen to represent unequivocal progress; they are simply the closest thing to measurable progress that exists.

Amy L. Strauss

See also Enlightenment, Age of; Hegel, Georg Wilhelm Friedrich; Kant, Immanuel; Marx, Karl; Medicine, History of; Spencer, Herbert; Teleology; Teilhard de Chardin, Pierre

Further Readings

Easterbrook, G. (2003). *The progress paradox: How life gets better while people feel worse.* New York: Random House.

Lasch, C. (1991). *The true and only heaven: Progress and its critics.* New York: Norton.

Pirie, M. (1978). *Trial & error and the idea of progress.* La Salle, IL: Open Court.

Van Doren, C. (1967). *The idea of progress.* New York: Praeger.

Prophecy

Prophecy has played a significant role in world religions, laying the groundwork for fulfillment of both religious and secular expectations of the future. The term *prophecy* derives from the Greek *pro-,* meaning "before" and *phanai,* "to speak," implying a foretelling. The term has become closely associated with supernatural abilities, and the word *prophet,* derived from the Greek *prophete,* has come to mean "one who speaks for another," usually understood to be a divine entity. Prophets channel revelations that include predictions of the future as well as admonitions to return to the laws of a belief system in order to avoid disastrous consequences. Often referred to as "seers," prophets receive their messages through various means, including trancelike states, dreams, visions, or agitated conditions induced by music or dance. Others receive special knowledge through the interpretation of physical signs, including astrological signs. Prophets have also been viewed as teachers and religious leaders. Three of the world's major religions describe their most venerated leaders as prophets. Judaism and Christianity revere the prophets of the Hebrew Bible, and Islam regards Abraham, Noah, Moses, and Jesus as respected prophets but Muhammad (571–624 CE) as the last and greatest prophet.

In the ancient world, the Persians, Assyrians, Chinese, Celts, Indians, Egyptians, and others sought out prophets who were often associated with temples and royal courts. During the later Hellenistic period, prophets, called oracles, were attached to shrines, one of the most important being the Oracle of Apollo at Delphi. The word *oracle,* derived from the Latin *orare* meaning "to speak," particularly in a public forum, refers both to the seer and to the shrine, and the term can be used interchangeably. The temple at Delphi was dedicated to Apollo, the Greek god of medicine, healing, poetry, music, and prophecy. Unlike most other Greek gods, Apollo had no direct Roman counterpart; however, later Roman poets often referred to him as Phoebus. The archaeological remains of this site are located near Mount Parnassus in the valley of Phocis, which the Greeks considered the center of the earth and the universe. The name Delphi is believed to be derived from the Greek *delphus,* meaning "womb," reinforcing its sacred origins.

The priestess of the oracle at Delphi was known as the Pythia and was consulted before all major undertakings, particularly battles. However, the oracle did not directly predict the future but rather gave advice and counsel, usually couched in ambiguous language that might be interpreted in various ways. Historic records dating to the 9th century BCE recount visits to the oracle by important Greek leaders, such as Lycurgus, Solon, Croesus, Lysander, and Philip II of Macedon. By 191 BCE the shrine at Delphi had come under Roman power, and the oracle continued to be consulted by Roman leaders, including Nero and Hadrian. It has been estimated that the pronouncements of the oracles at Delphi and other shrines had an important effect on the shaping of the Greco-Roman hegemonies.

Prophetic teachings play a particularly essential role in Judaism, Christianity, and Islam, which emphasize a personal relationship with God and a sense of individual moral responsibility resulting in future judgment. Judaism is based on the Hebrew Bible (*Tanach*), which is traditionally divided into three parts: the Law (the first five books, called the *Torah*); the Prophets; and the Writings or Wisdom Books. Particularly important are the later prophets, men of position such as Isaiah and Jeremiah, who spoke against religious hypocrisy as well as secular practices of their times, setting them in opposition to established religious tradition. Writing between the 8th and 3rd centuries BCE, they pointed to threats by Assyria, Egypt, and later Babylonia as God's sign that Israel needed a return to more ethical conduct to avoid disaster. The so-called minor prophets, men of humble origins, such as Amos, Hosea, and Micah, also spoke out against social inequality and served as the moral conscience of the community. Other important prophets of the Hebrew Bible (in Christianity, the Old Testament) include Daniel, Samuel, and Elijah.

The Old Testament book of Isaiah is particularly significant in Christian theology and contains the foretelling of a young woman who shall conceive a son and call him Immanuel, Hebrew for "God is with us" (Isa 7:14). Christians consider this a reference to Jesus Christ, the Messiah; however Judaism contends the prophecy has not yet been fulfilled and that believers await the first coming of a savior. The Hebrew prophets solidified the concepts of a messiah and a millennial period that is incorporated into Christianity and, to some extent, Islam. The only purely prophetical book of the Christian New Testament is The Book of Revelation, also referred to as the Apocalypse of St. John, in which John describes the events culminating in the Second Coming of Christ, the final judgment, and the establishment of a new world of peace and justice. Islamic tradition holds that prophets were sent by God to each nation, and all received revelations from God. The prophets who received *Sharia* (a divine code for life) that was ultimately written down and collected into holy books are also referred to as messengers. More than 25 prophets are mentioned in the Qur'an.

Prophecy is an important component in spiritual traditions throughout the world. Prophets pronounce visionary accounts of the future, which may or may not be predictions, but are rather interpretations of consequences based on present action. This particularly applies to beliefs regarding the ultimate future of humanity, and most of the world's major religions contain Messianic prophecies. Judaism, Christianity, Islam, Hinduism, Buddhism, and Native American religions all contain spiritual traditions that foretell the coming of a savior who will return, or send another in his place, to restore justice to the world.

In some beliefs, such as Taoism and ancient Mayan belief, time is cyclical rather than linear, and prophecy is based on predictable recurring events. In the contemporary secular world, researchers continue to investigate claims of some persons' apparent ability to access secret information and predict future events through means not scientifically explainable. Parapsychology is an academic field of study that seeks to determine the nature of those abilities by which some individuals are evidently able too see, hear, or predict events that are not apparent to others; these phenomena include clairvoyance, telepathy, extrasensory perception, precognition, and regression in time. Whether such powers are divinely inspired, supernatural, or scientifically explainable, or whether they turn out to be merely hoaxes, the desire to ascertain the future remains a powerful human motive.

Some modern scholars and theologians look for prophets in the contemporary context. In the tradition of Old Testament prophets and teachers, modern-day visionaries are often social activists, such as Martin Luther King, Jr. and others worldwide who call upon society to reform and promote peace, justice, and tolerance. In this view, then, the future is not to be foretold to passive listeners, but rather created by concerted action.

Linda Mohr Iwamoto

See also Apocalypse; Bible and Time; Christianity; Ecclesiastes, Book of; Futurology; Islam; Judaism; Nostradamus; Omens; Paracelsus; Qur'an; Revelation, Book of; Toffler, Alvin; Verne, Jules; Wells, H. G.

Further Readings

Fontenrose, J. (1981). *The Delphic oracle, its responses and operations, with a catalogue of responses.* Berkeley: University of California Press.

Ramsey, W. M. (1986). *Four modern prophets.* Louisville, KY: Westminster John Knox Press.

Proust, Marcel (1871–1922)

The French novelist and essayist Valentin Louis Georges Eugène Marcel Proust wrote essays and reviews as well as two novels before he became famous for his novel *À la recherche du temps perdu* (translated variously as *Remembrance of Things Past* or *In Search of Lost Time;* in this entry, *Recherche*).

Proust was the son of Adrien Proust, a prominent physician of that time, and his wife Jeanne née Weil, daughter of a wealthy Jewish family. In 1881 Marcel suffered his first attack of asthma, a disease that was to accompany him from that time onward and that finally led to his death at the age of 51. After baccalauréat and military service, he began to study law and political sciences in Paris. He finished these studies in 1892 and 1893, respectively, but against his father's will decided not to start a career in the foreign ministry and instead to begin a new study of "lettres," which could be described as a general study of humanities. Proust chose philosophy as his main subject and received his licentiate in 1895. In 1896 *Les plaisirs et les jours,* a collection of prose writings, was published but not widely recognized. In the same year, he began to write his first novel, *Jean Santeuil.* He stopped working on it in 1904; the fragments were not published until 1952. Many themes of the *Recherche* can already be found in these fragments.

Between 1896 and 1908 Proust published some translations of the British art historian John Ruskin. In 1907 he began the essay "Contre Sainte Beuve" (published posthumously in 1954), which today is considered to be his preliminary stage of the *Recherche.* "Contre Sainte Beuve" gradually changed its nature to finally become *À la recherche du temps perdu* from 1909 onward. The novel consists of 15 volumes, which are divided into 7 parts. The first, *Du côté de chez Swann* (*Swann's Way*) was published 1913, to be followed by *A l'ombre des jeunes filles en fleurs* (*In the Shadow of Young Girls in Flower*) in 1918, *Le côté de Guermantes* (*The Guermantes' Way*) in 1920, and *Sodome et Gomorrhe* (*Sodom and Gomorrah*) in May 1922. Proust died in November 1922, leaving enough material behind to publish three more novels posthumously. The fifth part of the novel, *La* *prisonnière* (*The Prisoner*) was published in 1923; the sixth, *Albertine disparue* (*The Fugitive*) in 1925, and the last, *Le temps retrouvé* (*Finding Time Again*) in 1927.

The main subject of the *Recherche* is time. The novel describes the life of the protagonist Marcel from his own perspective. The protagonist is not identical with Proust, but there are many similarities to Proust's own life.

The novel wants to give an answer to the question, "What happened to the time lost?" Proust is influenced by the model of time described by the French philosopher Henri-Louis Bergson (1859–1941). Bergson divides memory into two parts, which are named *memoire* (memory) and *souvenir.* Memoire is the cold intellectual side of the memory, while souvenir is an involuntary evolving memory. This *memoire involontaire* (involuntary memory) is often caused by sensations such as a smell or a stone touched by the foot. The perhaps most famous example for souvenir in the *Recherche* is the moment in which Marcel eats a madeleine (small French cake) dipped into tea. This trivial experience triggers a revival of the protagonist's whole life in Combray. Time therefore is not simply a linear experience; it is possible that "lost time" may be brought back to life again by an involuntary remembrance. The lost time comes back as it really was for the one who experienced it.

The *Recherche* itself is an *édifice immense de souvenir,* in which the reader follows Marcel on his way through time described from his perspective. Time is preserved in the memory of the people, and the time they are preserving is lost for the world once they have died. In the last part of the novel, *Le temps retrouvé,* Marcel decides to write down his memories, and with them the world as he knew it, in a book. The novel thus contains a kind of circle, in which the reader finds out that he was following Marcel's search for a way to preserve time, which is found in the end. The solution found is to write a novel, which Marcel decides to do. The work to be written after the story of the novel ends is the same novel that was read by the reader.

For Proust, then, the only way to preserve lost time and all of its souvenirs is through the making of art. The *Recherche* is such a piece of art and the answer to the protagonist's question. It lets the reader relive Marcel's memories, or at least grants access to a version of them, thereby retrieving the time as experienced by the protagonist.

Markus Peuckert

See also Bergson, Henri; Consciousness; Dostoevsky, Fyodor M.; Goethe, Johann Wolfgang von; Joyce, James; Mann, Thomas; Memory; Novels, Time in; Time, Phenomenology of; Tolstoy, Leo Nikolaevich; Woolf, Virginia

Further Readings

Albert, C. (2003). *Monsieur Proust* (B. Bray, Trans.). New York: NYRB Classics.

Bernard, A.-M. (2004). *The world of Proust, as seen by Paul Nadar.* Boston: MIT Press.

Carter, W. C. (2000). *Marcel Proust: A life.* New Haven, CT: Yale University Press.

Psychology and Time

The dimension of time is essential for human cognitive functioning. Because events are perceived over time and actions evolve over time, the ability to process temporal information is essential to monitor the environment and control our behavior. Although we speak of a "sense of time," there exists no sensory organ for the perception of the passage of time or duration comparable to our sensory perception of colors or shapes, sounds or melodies. Time is not a concrete entity in the world we experience. Our brain must actively construct temporal relationships from the sensory information we perceive.

The Experience of Time

In his *Confessions,* Saint Augustine thus concludes his analysis of the experience of time: "It is in thee, my mind, that I measure times." He saw the perception of time as constructed by our self; that is, the experience of time represents the mental status of the beholder, reflecting one's cognitive state and emotional well-being. The accuracy and precision of subjective time estimation is linked to overall cognitive functioning, that is, to attention and memory processes. Our sense of duration depends on the degree of attention we pay to the passage of time and memories of comparable time intervals. Our subjective well-being also strongly influences how time is experienced. Time seems to fly during pleasant activities, but to drag during periods of mental distress. Our sense of time depends on an intricate interplay between specific cognitive functions and influences of our momentary mood states.

The perception of time can be classified in numerous ways, but two concepts form the building blocks of our temporal experiences—*succession* and *duration*. The perception of succession refers to the sequential characteristics of events; in other words, their temporal order. The perception of duration refers to the time interval subjectively experienced between two events or to the persistence of an event over time. The taxonomy of elementary temporal experiences derives from these two basic concepts and comprises the perceptual phenomena of simultaneity, successiveness, temporal order, the subjective present, and duration.

The first three of these experiences relate to the temporal properties of two events that are perceived as happening simultaneously or nonsimultaneously. For instance, our sensory systems have different temporal resolutions for the detection of nonsimultaneity. The highest temporal resolution (the lowest threshold of detection) is observed in the auditory system, where acoustic events 2 to 3 milliseconds apart are detected as nonsimultaneous. The somatosensory system has a slightly higher threshold, whereas the visual system has the lowest temporal resolution, with a threshold approximating 20 milliseconds. Interestingly, the detection of nonsimultaneity of stimuli is not perceptually sufficient to indicate their temporal order. Although we may be aware that two events did not occur simultaneously, we are still unable to tell which one of the two events occurred first.

The temporal-order threshold is more comparable across senses. The onset of two events, independent of sensory modalities, must be at least 20 to 40 milliseconds apart before an observer can reliably indicate their temporal order. The temporal-order threshold thus represents a fundamental perceptual limit. The temporal succession of events over time (the order in which they occur) can only be perceived if they occur approximately 20 to 30 milliseconds apart.

Regarding the perception of duration, a perceptual mechanism that integrates separate successive events into a unit or perceptual gestalt has repeatedly been suggested. We do not just perceive individual events in isolation, but automatically integrate them into perceptual units (or *gestalts*). While listening to a metronome at a moderate speed, we do not hear a train of individual beats but automatically form perceptual units, such as 1–2–3, 1–2–3, etc. These are mental constructs—physically speaking, they do not exist. The duration of this temporal integration mechanism, referred to as the subjective or specious present, seems to be limited to 2 to 3 seconds. Experimental investigations have demonstrated that temporal intervals can be accurately reproduced when their duration does not exceed 3 seconds. Intervals longer than 3 seconds are usually reproduced shorter than the presented interval.

In sensorimotor synchronization (a task in which a sensory signal has to be precisely synchronized with a motor act), if the interstimulus interval is longer than approximately 2 seconds, performance breaks down. Anticipation of the signal is no longer possible. Other examples come from bistable perception (e.g., the Necker cube), where a single stimulus leads to two mutually exclusive perceptual interpretations that alternate in time. The spontaneous rate of perceptual alternation approximates 3 seconds. Based on these findings, researchers have established the categorical distinction between *perception of duration* (for intervals up to 3 seconds) and *estimation of duration* (for longer intervals). Events lasting only a few seconds are processed on the present perception as a whole, whereas longer intervals must be estimated from memory.

A different classification of time phenomena, which still encompasses the above-mentioned elementary time experiences, includes three interrelated dimensions: (1) time estimation, (2) time awareness, and (3) time perspective.

1. Abilities to estimate time are measured by the precision in estimating clock time, that is, in experimental settings in which subjects are requested to tell which one of two presented stimuli was longer or, in real life, when we have to judge whether water has boiled for 3 minutes.
2. Time awareness is the subjective impression of time as moving quickly or slowly, that is, the

feeling that time passes too fast when we are having fun or too slowly when we are desperately waiting for something specific to happen.

3. Time perspective refers to the conception of a past, a present, and a future.

Because we experience time in these three-dimensional aspects, time perspective is a fundamental dimension in the construction of subjective time, which emerges from the cognitive partitioning of human experience into past, present, and future. Human endeavor bridges the past, present, and future, as the memory of past events can be used to plan and act in the present to reach future goals. In this respect, present time is experienced through attention, past time is defined by memory, and future time exists as expectation and prediction.

Psychological and Neural Models of Time Perception

From a systemic perspective, organisms must interact with the environment on different timescales. Experience and behavior are interactions that span time ranges in microseconds (localization of sound in space), tens of milliseconds (detection of succession, phoneme recognition), hundreds of milliseconds (motor control, speech segmentation), seconds-to-minutes (conscious perception of duration), and circadian rhythms (the daily sleep-wake cycle). Additionally, annual cycles influence psychological states and determine an individual's physiological functions. The anticipation of future decades of human life is relevant for long-term decisions, for example, when a young person saves money in a retirement plan, thereby opting for a momentary loss of money to gain future benefits. This classification of relevant timescales between the range of milliseconds and decades encompasses two aspects of time that have been described since ancient times. Time appears to be either cyclic (it repeats itself periodically) or linear and irreversible (time flows in one direction only and one moment does not repeat itself). The cyclic aspect of time is apparent in the recurrence of days and the repetition of the seasons. Nature has adapted to these cyclic properties by establishing endogenous biological clocks in organisms. The circadian (about one day) clock as well as circannual clock regulate fundamental aspects of physiology and behavior and are entrained (synchronized) by the periodicity of light.

Over the past few years, a body of evidence has shown that different time perception mechanisms are associated with different timescales. For example, on a variety of sensorimotor tasks, temporal integration windows of around 250 milliseconds and of around 1 second have been postulated to mark the transitions between different timing systems. It has been suggested that an automatic timing system is responsible for shorter intervals (milliseconds). Such a system can measure time without attentional modulation, whereas a cognitively controlled timing system for intervals longer than a second requires more strongly cognitive circuits in the brain. Furthermore, in relation to the concept of the specious present, intervals up to 2 to 3 seconds have been shown to be processed differently than intervals exceeding this time range. Even for longer intervals, it is conceivable to assume distinct processes for different durations. For example, the estimation of a one-hour interval, but not the estimation of a minute, is related to an individual's circadian rhythm.

Cognitive models of time perception in the seconds-to-minutes range distinguish two fundamental perspectives in time estimation. In prospective time estimation, an observer judges the duration of an interval she or he is presently experiencing. The observer's attention is directed to time while a particular duration is being estimated. In retrospective time estimation, the observer a posteriori estimates a time span that has already elapsed, and, therefore, duration has to be reconstructed from memory. The most prominent cognitive models of prospective time estimation assume an "internal clock" with a pacemaker producing subjective time units (analogous to the ticks of a clock). The time units produced are registered only when attention is actually concentrated on time. As a result, an attentional gate opens, and time units are fed into a counter. When attention is distracted from time—for example, when one gets absorbed in another task—the attentional gate closes, and time units are not recorded. The number of units that have been recorded during a physical time period is then compared with a memory store. The unit counts are compared with the stored representations of time periods, which can be verbalized as seconds or minutes. If more attention is directed to time during the time interval to be estimated, duration is experienced as being longer.

In retrospective time estimation, the duration of a time interval that has already passed has to be judged. In contrast to prospective duration estimation, the observer estimates duration from the amount of processed *and* stored memory contents. In general, the more different events that occur during a time span, the longer the experienced duration. According to this model, the subjective impression of a long time interval depends on the activity of a person with diverse experiences. These two components of time estimation help explain the time paradox familiar to everyone.

The same physical time period can be judged differently, depending on a person's prospective or retrospective perspective. For example, the 10 minutes spent in a dentist's waiting room may seem eternal. We may overestimate the duration of that period simply because, under those circumstances, we pay a lot of attention to the passage of time (prospective estimation). However, when looking back at that waiting period, nothing really remarkable occurred and, therefore, this time span shrinks to a negligible period of time (retrospective estimation). In a different example, when we spend 10 minutes talking to an attractive person, we are not paying attention to time, as we are absorbed in the conversation. Time even seems to pass too quickly. However, in retrospect, we have memorized so many stimulating and emotional moments that we experience this time period as having lasted considerably longer.

The neural mechanisms underlying the perception of time have yet to be identified. Nevertheless, investigations of the neural basis of time perception in the seconds-to-minutes range support the hypothesis of the involvement of brain circuits embedded in the frontal lobes of the cortex and the basal ganglia. These circuits are modulated by the dopamine transmitter system and are thought to be critical for temporal processing.

Evidence for this anatomical hypothesis comes from studies of patients with brain lesions and from investigations using brain imaging techniques. Patients who suffered an infarction in their frontal lobes or traumatic brain injury predominantly affecting frontal brain areas display impaired estimation of time intervals. In healthy volunteers, brain activation studies using a functional magnetic resonance imaging (fMRI) technique show that the processing of duration is associated with activation in the right prefrontal cortex and the striatum (as part of the basal ganglia).

Regarding the neurotransmitter systems, animal and human studies indicate that both dopaminergic agonists (drugs that stimulate the system, like methamphetamine) and antagonists (drugs that inhibit the system, like haloperidol) influence the temporal processing by increasing and decreasing clock speed, respectively. Additional evidence for the involvement of the dopamine system in time perception comes from patients with Parkinson's disease. These patients have decreased dopaminergic function in the basal ganglia and show deficits in the discrimination of temporal intervals. Hence, overall, studies show that the integrity of the dopamine neurotransmission within the fronto-striatal circuitry of the brain is an essential component for the processing of time in the seconds-to-minutes range.

The experience of time is also influenced by hallucinogenic drugs such as LSD and psilocybin, which have similar pharmacological properties acting on the serotonergic transmitter system. People report the feeling of a slowing down of the passage of time and often overestimate time intervals, as minutes can appear to be hours, or time seems to stand still. Marijuana also affects the subjective sense of time, as the user's time estimates can become inaccurate. Individual reports are complemented by experimentally controlled investigations, which explain their findings within the framework of the dopamine hypothesis of time perception. The serotonergic hallucinogens psilocybin and LSD probably act indirectly on dopaminergic transmission. Moreover, marijuana can also influence dopamine activity via cannabinoid receptors on nerve cells of the dopamine system in the basal ganglia.

Other brain regions play a decisive role in the range of milliseconds. For example, the important role of the cerebellum in temporal processing has repeatedly been emphasized. Patients with damage to cerebellar structures exhibit severe deficits in time perception and motor timing of short intervals lasting only hundreds of milliseconds.

Psychophysical and neuroimaging studies in humans, as well as neurophysiological recordings in animals, indicate that a network of cortical areas contributes to the processing of time intervals in this short time range. In a widely distributed network spanning distinct regions of the brain, neural populations within each region may encode duration as a result of specific biological time-dependent changes. Time-dependent changes result from intrinsic neural properties, such as short-term synaptic plasticity. This view postulates that a centralized pacemaker-accumulator system (the "internal clock") is not involved in the processing of time when intervals reach up to hundreds of milliseconds.

In contrast, a stronger localization of functions (i.e., the involvement of a focal area in the brain) has been postulated for the perception of temporal order. Many studies have shown that patients with lesions in the left hemisphere and aphasia (as opposed to patients with lesions in the right hemisphere) have difficulties perceiving the temporal order of two events. These patients require longer intervals between two stimuli before they can distinguish their temporal order.

Children with specific language deficits have difficulties detecting the sequence of events in the milliseconds range. These observations suggest a causal relationship between the detection of temporal order and language processing on the phonological level. According to the phonological processing hypothesis, rapidly occurring elements in the speech signal have to be adequately processed for the identification of stop consonants (e.g., *d* in *dry* or *t* in *try*). In language-impaired individuals, a basic auditory deficit in temporal-order detection leads to impairments in phoneme identification, which is anatomically traceable to temporo-parietal areas in the left hemisphere. Such results demonstrate how intimately related temporal processing mechanisms are with other cognitive functions. In this specific case, a deficit in perception of temporal order has a detrimental effect on language processing. As will be discussed below, disturbances in cognitive functioning and emotional processing can also have profound effects on the experience of time. Any change in a person's mental status has an effect on the processing of time, as minute as the change may be.

Cognitive and Emotional Views of Time

The perception of the passage of time with changing pace is part of our daily experience. We do not perceive time as a steady-paced flow; the subjective passage of time varies considerably. The prospective model of time estimation can help explain several everyday time phenomena in relation to attention. An individual who is concentrating on the passage of time in an uneventful or unpleasant situation, such as nervously waiting for something specific to happen, experiences a slower passage of time and overestimates duration. When, however, the same person is suddenly distracted from concentrating on time, as when he or she is having fun, time seems to pass more quickly, and duration is more likely to be underestimated. According to the cognitive models, the way attention is concentrated on time during a given time span leads to the collection of more or fewer subjective time units. When we devote more attention to time, more time units are collected in a hypothetical counter. When we concentrate more on distracting events during a given time interval, fewer time units are collected, leading to the impression of a shorter duration. According to this theory, the allocation of attention determines the perception of time.

However, this reasoning does not clarify why individuals in certain circumstances actually focus their attention more strongly on the present time. It can be assumed that concentrating less on the passage of time (and perceiving it as passing more quickly) is associated with general psychological well-being. This state is associated with the ability to have meaningful thoughts and engage in self-rewarding activities.

Boredom-prone persons, for example, more often perceive time as passing slowly, even when they are busy performing a task. Institutionalized individuals, like those who live in residential homes for the elderly and whose days are highly regulated and monotonous, experience time as passing very slowly. There is ample evidence that depressed patients perceive a slowing of the pace of time and tend to overestimate durations in time-judgment tasks. Cancer patients who experience high levels of anxiety overestimate duration and report that time passes too slowly. In more general terms, these studies suggest that the overestimation of time intervals is a sign of emotional distress that draws attention away from meaningful thoughts and actions and directs it to the passage of time. Individuals who are institutionalized and/or suffering from emotional distress are not able to engage in their usual role function and have to spend much of their time in situations where they are not emotionally or cognitively engaged, like a series of waiting periods. Both the feeling of meaninglessness and the absence of a stimulating environment can manifest themselves in a state of distress or an existential vacuum that leads to the complaint of the slow passing of time.

Related to the time perspective (past–present–future), a similar entanglement of cognitive and emotional processes manifests itself in decision making. Everyday we have to make choices that have immediate, as well as delayed, consequences. A student may have to decide whether to go to a party tonight or to stay home and study for an exam scheduled tomorrow (with the possible later higher reward of passing the exam). We frequently have to make decisions based on predictions of rewards on different timescales. The process of deciding whether to opt for an immediate reward or for a delayed, but higher, reward is strongly related to scholarly and professional success. To function effectively, we must voluntarily postpone impulsive urges for immediate gratification and persist in goal-directed behavior to achieve positive outcomes in the future. Time perspective is considered a personality trait affecting cognition, emotion, and goal-related actions of an individual.

Ideally, we are able to flexibly switch temporal perspectives according to the situational demands; for example, we resist the temptation of the social gathering tonight because we can anticipate the future consequences. Some individuals, however, have too strong a focus on the present (related to stronger impulsivity and the inability to curb momentary urges) and are inadequately able to cope with everyday demands. For example, a stronger focus on the present and less on the future is highly related to risky behavior, such as gambling, careless driving, unprotected sex, or drug abuse. However, too much emphasis on the past and on the future are also dysfunctional, as they deprive one of important hedonistic features in life that can only be experienced at the present moment. A balance of temporal perspectives is healthy, both psychologically and physically.

A time phenomenon that haunts nearly every adult can be explained by the retrospective models of time estimation. A common complaint is, "Time passes too quickly!" During childhood and adolescence time seems to have a much slower tempo. People even complain that, as they age, time continuously speeds up. At least two factors, but probably more, influence this subjective perception. One lies in the time perspective of an adult, which, due to the individual's social orientation, can be characterized as continuously changing with advancing age. For the elderly, the length of the future time perspective generally decreases when measured by the number of years for which plans are made or personal events anticipated. A shorter future temporal perspective, however, can also influence the awareness of time. Studies show that elderly subjects who report fear of death feel more pressured by the passage of time. Men experiencing a midlife crisis are confronted with the shortening of their time perspective and also experience more time pressure.

A second factor that causes time to fly as we grow older lies in factors influencing retrospective time estimation. Prospective time estimation models cover the experience of the momentary passage of time. An association between age and the speed of time or the subjective duration of a time span, however, typically refers to longer intervals, like weeks, years, or even decades. A common disquieting discovery of an adult is "Have I already been working here for 10 years?" Looking at the past necessarily invokes memories and leads to a personal account of one's life. As predicted by the model of retrospective time estimation, we construct time in reference to the amount of changing information processed and stored. The more the contextual changes stored in memory during a given time span, the longer the experienced durations. Thus, time periods in one's life filled with a lot of changes are perceived as being subjectively longer than periods of time when few changes have occurred.

This provides the second explanation for why a lot of adults complain that time speeds up as they get older. During the course of a lifetime, many people get into the rut of everyday habits. The number of new experiences and openness to lifelong learning often decreases with age. If experiences do not differ significantly from day to day, they are not specially stored in memory. The routine of getting up in the morning, going to work, having lunch in the canteen, going home, watching television, and going to bed will not be stored as memorable events. Thus, in retrospect we have lost all these days, which results in a contraction of subjective lifespan.

Childhood, adolescence, and early adulthood, in contrast, can be characterized as periods of life during which new experiences occur on a daily basis, and skills and knowledge are acquired at a high rate. In retrospect these time periods are filled with many events, so the time period seems comparatively long. This explanation also offers a remedy available in a person's propensity to counteract the tendencies of repetition and custom. Although the general tendency toward routine cannot be fully avoided with increasing age, willingness to change habits and redefine one's goals throughout life will not only stimulate an individual in the here and now but will also lead to a subjective slowing down of the passage of time when we look back on a period of our life.

Applied Research in the Psychology of Time

After initial research in the late 19th century and the early 20th century, the topic of time perception was neglected in the field of psychology for many decades. However, over the last 20 to 30 years, a considerable body of knowledge has been collected regarding the processes underlying the experience of time. Diagnostic tools have been developed to assess disturbed temporal processing mechanisms in various neurological patient populations. Patients with acquired focal brain lesions following a stroke or severe traumatic brain injury, patients with Parkinson's disease or with temporal-lobe epilepsy, and patients with schizophrenia have all demonstrated specific impairments in time estimation and motor timing. These findings are discussed in relation to alterations in several cognitive domains related to time processing—specifically, a pacemaker-accumulator type internal clock, memory, and attention.

A considerable body of applied research concerning possible training procedures exists, albeit in one domain only and controversially discussed—neuropsychological training procedures for improving temporal processing abilities in subjects with language disorders. Based on the diagnostic findings that patients with aphasia and children with language-learning impairments have difficulties detecting the temporal order of stimuli, training methods in temporal-order detection have been developed to improve not only the ability to perceive temporal order but also to improve basic language competence. In these computer-based feedback training procedures, the temporal order of two successively presented acoustic stimuli has to be identified at decreasing interstimulus intervals (time between two stimuli). The interstimulus interval is lowered when the sequence of stimuli can be reliably identified. In this way, thresholds for the detection of temporal order can be sufficiently decreased. It has been shown that successful training can also improve phoneme discrimination ability, which may well depend on a high acuity in temporal resolution. It is likely that similar training procedures will be developed in the future to improve temporal processing functions in patients with other kinds of neurological syndromes. Due to the interdependence of time perception and cognition, novel time perception deficits—related to the taxonomy of temporal experience—in various neurological and psychiatric patient populations are likely to be detected.

The experience of time could become a topic in psychological assessments by providing an additional approach to diagnose the mood states of various patient groups, such as individuals with depression or cancer patients with anxiety or depressive symptoms. As outlined above, the feeling that time passes too slowly is an indicator of psychological distress resulting from an inability to focus on meaningful thoughts and to engage in purposeful actions. In contrast, individuals who are able to distract themselves during a stressful period not only experience a faster passage of time but also experience less mental distress. The reported findings in the psychology of time emphasize the need to address the search for meaning as a coping factor in psychotherapy. Time perception could, for instance, be addressed in psychotherapeutic approaches as a means to positively influence psychological well-being and related subjective experiences.

As the experience of time provides insight into a person's state of mind, the investigation of time perception could also provide crucial insight in the understanding of the mechanisms of self-control and impulsiveness, as in children with attention deficit hyperactivity disorder or in individuals abusing drugs. For example, drug abusing persons exhibit a stronger present time perspective and are more impulsive than abstainers. Existing studies show that alcoholics have a weaker future perspective than social drinkers, and heroin addicts have shortened time horizons, as they are less likely to set goals for the future. Even substance use (alcohol, tobacco, marijuana) in college students is related to a shorter future perspective and a stronger present orientation. At the same time, addicted individuals, such as smokers craving a cigarette or patients addicted to stimulants like methamphetamine or cocaine who are being treated in a drug-treatment program, perceive an indicated time interval to pass more slowly and overestimate it.

The model of cognitive time perception links these separate characteristics of interest. As individuals addicted to a drug show a stronger emphasis on the present time (as opposed to the future), they consequently pay more attention to the momentary passing of time. Allocating attentional resources to time leads to a subjective slowing of time and to an overestimation of duration. An altered sense of time could be one reason why impulsive individuals do not delay gratification and act on impulse. For such a person, the benefit of resisting temptation might lie subjectively too far in the future. Based on drug users' general difficulties with decisions that involve delayed rewards (these difficulties extend into many aspects of life), it has been suggested that treatment programs should develop intervention strategies that cognitively restructure the perception of these choices to shape more adaptive and health-promoting behavior. Moreover, in the therapeutic process, the setting of positive rewards and goals should not be extended too far into the future and should adapt to the individual's shortened time horizon.

The study of psychological time is only slowly entering mainstream contemporary psychology. The experience of time is dependent on numerous factors. Some of these are the individual characteristics of the person, the physical properties of events that mark the time intervals, mental contents that are processed during the time interval, and, last but not least, whether subjects were instructed to estimate duration before or after a target interval is presented (prospective vs. retrospective time perception, respectively). As it is hard to control for all these factors, results from simple time perception tasks are often difficult to explain. Nevertheless, the measurement of time perception will become part of the standard methodological inventory in psychology. First, and on a very personal level, the experience of time has an existential dimension for all of us, because we have only a limited time to live. Second, knowledge of the psychology of time can also pay off on a very pragmatic level.

The following is a story reported not long ago in the media. The management of a hotel had to decide whether to replace an old elevator, an action that would have been very costly. Hotel guests had repeatedly complained that the elevator moved too slowly. A little trick based on knowledge of the experience of time stopped these complaints. Mirrors were hung up in the elevator. Although the elevator still moved at the same pace, nobody complained any more. The hotel guests, now distracted by their own images, no longer focused on the passage of time and did not consider the time spent in the elevator too long at all.

Marc Wittmann

See also Amnesia; Augustine of Hippo, Saint; Cognition; Consciousness; Memory; Perception; Time, Phenomenology of

Further Readings

Draaisma, D. (2004). *Why life speeds up as you get older: How memory shapes our past.* Cambridge, UK: Cambridge University Press.

Levine, R. (1997). *A geography of time: The temporal misadventures of a social psychologist, or how every culture keeps time just a little bit differently.* New York: Basic Books.

Pöppel, E. (1997). A hierarchical model of temporal perception. *Trends in Cognitive Science, 1,* 56–61.

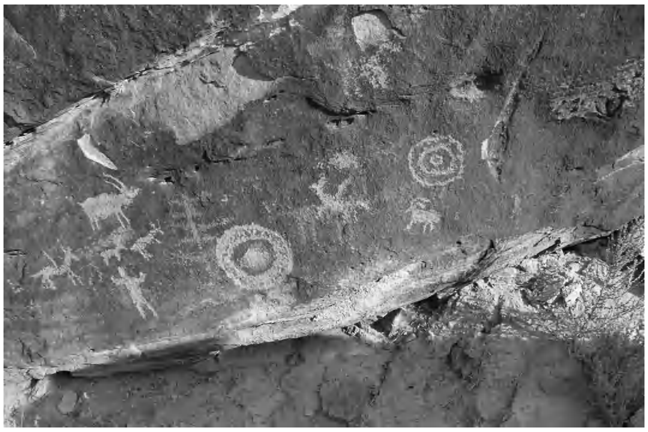
Strathman, A., & Joireman, J. (Eds.). (2005). *Understanding behavior in the context of time: Theory, research, and application.* Mahwah, NJ: Lawrence Erlbaum.

Wittmann, M., & Lehnhoff, S. (2005). Age effects in the perception of time. *Psychological Reports, 97,* 921–935.

Zakay, D., & Block, R. (1996). The role of attention in time estimation processes. In M. Pastor & J. Artieda (Eds.), *Time, internal clocks and movement* (pp. 143–164). Amsterdam: Elsevier.

Pueblo

The early Spanish explorers of North America, presumably impressed with the affinity of the southwest indigenous peoples to their great houses of multilevel apartment-like villages and cliff dwellings, gave the name Pueblo to these tribes, meaning both village and a people or nation. The Pueblo people compose 25 tribes, including the Hopi, Zuñí, Acoma, and Tao, with languages stemming from three branches: the Uto-Aztecan, the Tanoan, and the Keresan. They live in one of the oldest continuously settled regions of North America, in the asperities of the arid plateaus of Chaco Canyon and other parts of the Four Corners area (so named because it comprises the corners of four states: New Mexico, Arizona, Utah, and Colorado) and the surrounding vicinity, also known as the House Made of Dawn. They are presumed to be descended from the first group of migrants to enter the Americas. The ancient Pueblo have many nomenclatures: Desert Archaics, Hisatsinom (Hopi: "people of long ago"), and Anasazi (Navajo: "ancient enemy"). These ancestors, like many ancient astronomers, considered the celestial movements sacred and attempted to harmonize with the cosmos and the six sacred cardinal directions (North, South, East, West, Zenith, and Nadir). The result manifested into building plans and architectural locations that contained apparent stellar alignments in addition to colors and symbols with assigned directional and cosmic representations.



Desert archaic calendar. Rock etchings can be found along the Gunnison River, mainly of the Ute tribe. Also represented are pictographs of the Pre-Anasazi: the Desert Archaics.
Source: Barbara Jetley.

The Desert Archaics to Pre-Hisatsinom

From 9000 to 8000 BCE, a nomadic tribe referred to as the Desert Archaics occupied the mesas throughout the hunter-gatherer period. Their knowledge of celestial cycles appears to have been well established: Petroglyphs representing constellations line many rock walls throughout and surrounding the House Made of Dawn. Scholars posit these storyboard images to be recordings of astrological events, histories, and calendars. Upon those high plateaus is a unique view of celestial movements. It can be presumed that the various stellar patterns were observed and calculated from ancient days, for around approximately 700 CE the Hisatsinom culture, whose people resided in pit houses, begin construction on the near five-story complex archaeoastronomy dwellings, or great houses, with major structures designed with internal solar and/or lunar alignments.

Hisatsinom Culture

The great houses in the House Made of Dawn were once thought to have been haphazardly constructed, but based upon closer examination by scholars such as Anna Sofaer, it is thought that the structures in the Chaco Canyon area were planned and executed with the purpose of recording solar, lunar, and other important stellar movements. Scholars posit that these structures were low in population save for ceremonial times, when pilgrimages were made from the surrounding 150 communities (and perhaps further), which were connected via a precisely constructed set of roads. The structures of the great house are oriented north–south and east–west to form a three-community house that shares in a lunar minor alignment, representing the moon's rise, its meridian, and other occasional observances. In addition, there is a solar and lunar observatory at Fajada Butte that was used to mark solstices, equinoxes, and the 18.6-year cycle of the lunar northern and southern extremes. The Chaco Canyon phenomenon thus embodies the ancient Puebloans' worldview.

The *kiva,* a round, partly underground structure that forms the nucleus of each great house, remained part of the Pueblo religion and culture. The kiva represents the world below or sacred womb, while the kiva's *sipapû,* a hole or indentation in the floor, symbolizes the "earth navel" believed to be the entrance for the people and kachinas or spirits. Their legends of creation begin with a speculation of endless space, elucidating how Spider Woman created a web-matrix for the foundations of the earth and sky. Hopi legends tell of four cycles the humans evolved through as Spider Woman led the journey, the last journey guiding them from the world below through the sipapû.

Pre-Puebloan Culture

A mass exodus from the great houses occurred around 900 to 1300 CE. It brought about new or altered religions; for the Hopi it was the advent of the kachina celebrations, with the New-Fire Celebration in November to start the New Year. The kachina season officially commences in the halcyon days of winter solstice, with rituals for each month of the nearly 7-month season, which concludes in July. The year's remainder operated through the snake or flute season.

In the Hopi tradition, all things animate and inanimate have a kachina. The masked Puebloan dancers symbolically represent these spirits wearing celestial regalia representing the morning star, the sun, and the earth. The symbols within paraphernalia, pictographs, and sand paintings have many cosmic representations: eagle—sun or sky god; fire—life's creation; spider—earth; bear—west; mountain lion—north; wildcat—south; wolf—east, and so forth. Colors can moreover represent the cardinal directions: yellow—north, white—east, green/blue/black—west, and red—south. Like the sand designs of the Tibetans, the Puebloan sand paintings are formed exclusively for ceremonial purposes and swept away at the observance's conclusion.

There were annual, biannual, and quadrennial celebrations. The biannual festivals alternated between the snake and flute societies; the snake during odd years, the flute during even years. Quadrennial celebrations accompanied priestly initiations, and for the duration of that year each of the festivals was extended; for example, a 1-day ceremony lasted 5 days, or a 5-day ceremony lasted 9 days. The extended ceremonies possibly served as training periods for the new priests, who were educated in astrological movements and accompanying traditions.

Pueblo Culture

The Spaniards attempted to eradicate the Puebloan belief system, and so struck at the core by destroying numerous kivas, including filling one with sand and positioning their church atop it, in effect preserving the "kiva beneath the altar." Many atrocities were suffered by the Puebloans at the hands of the Spaniards during early colonization, although the Pueblo tribes held fast on several occasions, including the revolt of 1680. Despite such efforts to supplant indigenous belief, the Pueblo have continued their ceremonial observances. In the late 19th century, at Eldon Mesa, anthropologist Alexander M. Stephen witnessed a winter solstice observance of the sun's arrival at the great house called House of the West.

Contemporary Puebloans

The destruction of the sacred Spider Woman hill in 1984 during a highway construction project enraged the Puebloan communities; in response, after the Puebloans received the assistance of LaVan Martineau, assurances were given that the remaining rock images within the Clear Creek Canyon would be recorded and preserved. Similar to other indigenous peoples, the Puebloans are participating in mainstream society while holding fast to their traditional customs and actively researching their ancient culture.

Pamela Rae Huteson

See also Anthropology; Chaco Canyon; Navajo; Sandpainting; Solstice; Totem Poles

Further Readings

Eggan, F. (1990). *Social organization of the western pueblos*. Chicago: University of Chicago Press. (Original work published 1973)

Fewkes, J. W. (1985). *Hopi katcinas*. Mineola, NY: Dover. (Original work published 1903)

Patterson-Rudolph, C. (1997). *On the trail of Spiderwoman*. Santa Fe, NM: Ancient City Press.

Smith, W. (1990). *When is a kiva? And other questions about southwestern archaeology* (R. H. Thompson, Ed.). Tucson: University of Arizona Press.

Sofaer, A., Zinser, V., & Sinclair, R. M. (1979). A unique solar marking construct. *Science, 206*(4416), 283–291.

Stephen, A. M., & Parsons, E. W. C. (1936). *Hopi journal of Alexander M. Stephen*. New York: Columbia University Press.

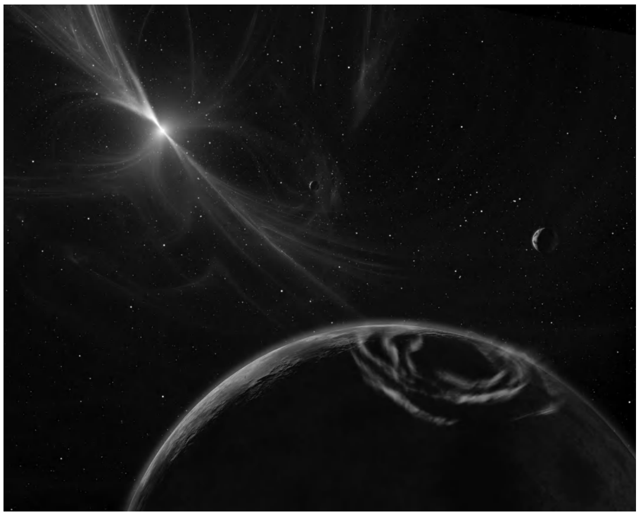
Watson, D. (1955). *Indians of the Mesa Verde*. Mesa Verde National Park, CO: Mesa Verde Museum Association.

Pulsars and Quasars

Pulsars and quasars are celestial objects that often emit radio waves but can also emit energy in the visible light, X-ray, and gamma-ray ranges of wavelengths. Unlike quasars, pulsars are rapidly spinning neutron stars that often have a rotational period so regular that, as timepieces, they are more accurate than atomic clocks. Although quasars are neither stars nor timepieces, they are among the most distant observable objects in space, so distant that observing them is akin to looking at the past.

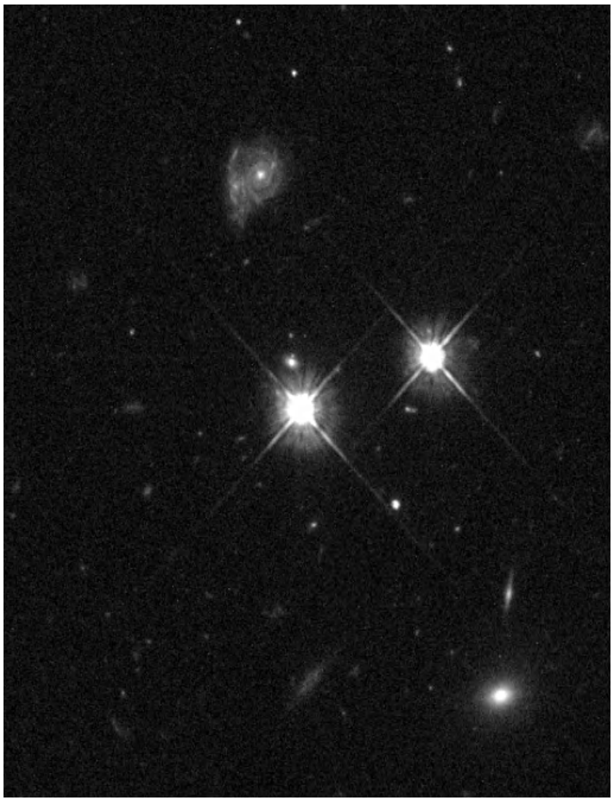
First discovered in 1967 by English radio astronomer Antony Hewish and his Irish graduate student Jocelyn Bell, pulsars are the result of a supernova explosion of a midsized star. The ensuing gravitational collapse of such a star forms a neutron star. Pulsars get their name from the regular pulses of radio waves that emit from their magnetic poles. They behave like lighthouses, but with radio waves in place of flashes of light. Each pulsar has a period, the time it takes for it to rotate once; this period can range from a millisecond to 8.5 seconds. As time passes, and the pulsar ages, the period will grow longer, meaning that the pulsar's spinning slows as its magnetic force increases. One type of pulsar is the millisecond pulsar, which has the shortest period. Its weak magnetic field allows for greater rotation speed. The periods of millisecond pulsars are stable and predictable enough to trump the timekeeping of atomic clocks. Another type of pulsar is the binary pulsar, which is one star in a binary star system in which two stars revolve around each other. Because of their atomic makeup—neutron-saturated nuclei—pulsars may have the mass of the sun but are extremely dense, sometimes less than 20 miles in diameter. For this reason, identification of their periodic pulses is often the only way these objects are discovered and observed.

Another source of radio emissions, quasars are pragmatically named, the term originating from the acronym QSRS (quasi-stellar radio source). Some can be radio-quiet, instead emitting X-rays or



This artist's concept depicts the pulsar planet system discovered by Aleksander Wolszczan in 1992. Pulsars are rapidly rotating neutron stars that are the collapsed cores of exploded massive stars. They spin and pulse with radiation, much like a lighthouse beacon.

Source: NASA Jet Propulsion Laboratory.



The Hubble Space Telescope achieved its 100,000th exposure June 22, 2002, with a snapshot of a quasar that is about 9 billion light-years from Earth. The quasar looks as bright as the star, because it produces a tremendous amount of light from a compact source.

Source: NASA Goddard Space Flight Center.

gamma rays. Quasars appear starlike in that they can be observed optically as a point, or star, of light. However, their emissions are redshifted, which refers to their spectra's longer wavelengths. Redshift is a quality often attributed to objects that are accelerating away from the observer, and cosmological redshift refers to the infinite expansion of space-time and matter since the big bang. Because quasars are the most distant objects observed, their optical light appears faint. However, calculations including distance and speed led to figures of great magnitude, and quasars are sometimes posited to emit a trillion times the radiation of the sun. The most popular theory of the source behind this energy is that quasars are spinning disks of dust that surround a massive black hole. Given the great distance and theorized relationship to the big bang, quasar emissions are arriving from the cosmological past. Unlike the timepiece pulsar, the quasar is a preserver of time, displaying a picture of long ago.

Karlen Chase

See also Big Bang Theory; Black Holes; Clocks, Atomic; Light, Speed of; Observatories; Telescopes; Time, Galactic; Time, Measurements of; Time, Sidereal; Universe, Contracting or Expanding; Universe, Evolving; White Holes; Wormholes

Further Readings

Audouze, J., & Israel, G. (Eds.). (1988). *The Cambridge atlas of astronomy.* New York: Cambridge University Press.

Dickinson, T. (2004). *The university and beyond* (4th ed.). Buffalo, NY: Firefly Books.

Punctuality

Punctuality is defined as the act of arriving at or completing a task, event, or engagement at or before a previously designated time. Perhaps most easily thought of as being "on time" or "on task," punctuality, or the lack of, is in most cases an individual trait or tied to an individual event or task. It is, however, a more widespread problem across some cultures.

By far, punctuality is a much higher priority in countries that are largely industrialized, such as the United States, China, Germany, and the United Kingdom. For countries such as Spain, India, and those in Latin America and the Middle East, however, punctuality is a much lesser priority. When a culture relies heavily on clocks, time dictates the start of events, meetings, and the like. It is in these cultures that watches, clocks, and timepieces are generally kept in unison. In event time, the focus is less on time and more on the event itself, meaning that people living by event time will see an event through before carrying on to the next.

In fact, Latin American governments have recognized the general issues with being on time as a widespread problem that affects their ability to compete globally. Ecuador, in particular, estimates that as much as 10 percent of its GDP is lost to lateness. Ecuadorians live largely based on event time, better known locally as Ecuadorian time. In 2003, Ecuadorians were encouraged to synchronize their watches in an effort to eliminate tardiness. Similarly in Peru, a national campaign called *la hora sin demora,* or "time without delay," was launched to encourage its citizens to be more timely.

International business and travel offer further insight into the punctuality differences across the world. Detailed statistics are kept for all types of commercial travel, including airplanes and trains. Schedules and connections are dependent on their punctuality, and reputations can be damaged by excessive lateness. To that end, Japan, a country that is hypersensitive to the clock and the need to be punctual, has developed such a reliance on the adherence to schedules that its transportation workers fear reprimand for delays. Commuter trains connect with only minutes to spare before their riders must make their next connection. Such a focus on punctuality has been blamed for accidents, such as the one that occurred in 2005 when nearly 100 people were killed because the commuter train's engineer was trying desperately to make up 90 seconds.

Punctuality is to an extent a relatively modern concept. Clocks and standardized time have only been in use for little more than a century. Prior to that, there were wide variations in the keeping of time, thereby making punctuality nearly impossible. Clocks were set relative to the sun's position, making them inaccurate. It was not until a global standardized time plan went into effect that there was a gauge of timeliness.

Time is of the essence in many modernized countries, where sales of time-saving devices and gadgets have skyrocketed over the past 20 years. The pace of the industrial world has quickened, although its preoccupation with speed and attention to the clock do not necessarily mean increased punctuality.

Amy L. Strauss

See also Comets; Eclipses; Globalization; Old Faithful; Solstice; Sunspots, Cycle of; Time, Measurements of; Timepieces; Watches

Further Readings

Brislin, R. W., & Kim, E. S. (2003). Cultural diversity in people's understanding and uses of time. *Applied Psychology: An International Review, 52*(3) 363–382.

Morrison, T., & Conaway, W. A. (2006). *Kiss, bow or shake hands: The bestselling guide to doing business in more than 60 countries.* Avon, MA: Adams Media.

Pythagoras of Samos (c. 569–c. 496 BCE)

Pythagoras was a classical Greek philosopher, mathematician, scientist, and mystic from the Aegean island of Samos. Known as the "father of numbers," he is best known for the Pythagorean theorem, which carries his name. Over the centuries, mathematicians, architects, artists, and musicians have built upon Pythagoras's theories, making those theories the very foundation of the modern understanding of music, astronomy, and mathematics.

Pythagoras was the son of Mnesarchus, a merchant from Tyre. As a child, he traveled widely with his father and gained a broad education from his experiences. He studied with three philosophers in particular—Pherecydes of Syros, Thales, and Anaximander. These men introduced Pythagoras to mathematics, cosmology, astronomy, and geometry. In 535 BCE, Pythagoras moved to Egypt and studied with Egyptian priests at a temple in Diospolis. The rites, rituals, and secrecy he learned in Egypt became part of the religious school he set up later in Italy. The Persians captured Pythagoras when they invaded Egypt in 525 BCE and took him to Babylon. He studied with the magi in Babylon where he learned about Babylonian mysticism, arithmetic, and music.

After his release, Pythagoras returned to Samos, where he set up and ran a school for a few years. Then he moved to southern Italy in 518 BCE, to a village named Croton where he established a secret religious society, emphasizing virtue and strict rules of conduct. The members of this society, known as Pythagoreans, were vegetarians, took vows of silence, and participated in purification rites. They believed in transmigration of the soul, meaning souls are continuously reincarnated as persons, animals, or plants. The Pythagoreans' way of life sought to release the soul from this cycle. Pythagoras lived in Croton until a village noble plotted against him and forced Pythagoras to flee. He went to Metapontum, where he died.

Pythagoras was deeply interested in mathematic principles, especially the abstract philosophy of numbers. He believed that everything, even the order of the universe, could be defined numerically, that is, in terms of harmonic ratios. He applied this theory to mathematics, music, and astronomy. He discovered that music has proportional intervals based on the numbers one through four. Therefore, he held that the universe is based upon the sum of these numbers—10. Pythagoras, or one of his followers, discovered that when the side of a square is squared, the resulting figure equals the area of the square. From here came the concept of the square root.

Although its true origin is uncertain, Pythagoras generally gets credit for developing the so-called Pythagorean theorem, that is, the hypotenuse squared of a right-angled triangle is equal to the sum of the squares of the sides ($a^2 + b^2 = c^2$). Unfortunately, none of his writings has survived to corroborate this association. Egyptian and Babylonian documents show that both of these societies knew about the theorem well before Pythagoras was born; however, some ancient sources believe Pythagoras was the first person to prove the theorem. Pythagoras believed that numbers connected music and math through ratios. Legend tells that Pythagoras discovered a relationship between tonal sound and simple ratios when he passed a blacksmith shop one day and heard the sound of the hammers beating on various size anvils. This principle of tonal harmony and size ratio is called Pythagorean tuning.

Another discovery usually accredited to Pythagoras, or his followers, is the golden ratio. This ratio is a line divided into two parts such that the longer section (a) has the same ratio to the shorter section (b) as the entire length (a + b) has to the longer section (a). In the 20th century, this ratio began to be called *phi,* named after the Greek letter in the name of a Greek sculptor Pheidias who employed the ratio. Numerically, the ratio equals about 1.618034. Since the Renaissance, many artists and architects have used the golden ratio, or its corollary the golden rectangle, in their work, believing that this measure is aesthetically pleasing.

In astronomy, Pythagoras influenced the modern understanding of the movement of heavenly bodies. He held that the planets rotated on an axis and revolved around a central point. He also held that mathematics could explain these movements. Furthermore, he was one of the first people to understand that the moon orbited the earth, that the earth was round, and that Venus was both the evening and morning star.

Pythagoras's work in mathematics, music, and astronomy was revolutionary in his day and forms the basis of much of our understanding of the universe. His discovery of timeless principles truly makes him the "father of numbers."

Terry W. Eddinger

See also Anaximander; Anaximines; Empedocles; Heraclitus; Parmenides of Elea; Presocratic Age; Pythagoras of Samos; Thales; Xenophanes; Zeno of Elea

Further Readings

Kahn, C. H. (2001). *Pythagoras and the Pythagoreans: A brief history.* Indianapolis, IN: Hackett.

O'Connor, J. J., & Robertson, E. F. (1999.) Pythagoras of Samos. Retrieved November 3, 2007, from http://www-groups.dcs.st-and.ac.uk/~history/Printonly/Pythagoras.html

Riedweg, C. (2005). *Pythagoras: His life, teaching, and influence* (S. Rendall, Trans.). Ithaca, NY: Cornell University Press.

Q

Quantum Mechanics

Quantum mechanics is a theory in physics that was introduced by Max Planck in 1900 to solve the problem of describing the intensity of radiation emitted by a black body at a given wavelength and constant temperature. Essentially it is a modification of certain views or beliefs of the classical world, especially in relation to the motion of bodies or structureless particles. It changes in a radical way the classical view of how energy is shared in a system of particles, and it also gives properties to systems not found in classical mechanics. Classical notions of time, for example, do not hold for quantum phenomena.

Properties of Quantum Systems

One important property that has been recently discovered in quantum systems is that of entanglement, in which pairs of separate particles behave in a cooperative manner. Another very important property found only in quantum systems is particles with spin. The electron was found to have a spin value of one-half. Other particles were subsequently discovered in nature to have other spin values, and this led eventually to the grouping of the different particles of nature according to their spin value. Particles with half-integer spin values are called *fermions,* with the electron as the prime example. Others with integer spin values are called *bosons,* with the photon (particle of light) as the most well-known example. In classical systems where the laws of Sir Isaac Newton are valid, energy is distributed according to Boltzmann statistics. However, in quantum mechanical systems, energy is distributed using Bose-Einstein or Fermi-Dirac statistics. Integer-spin particles distribute their energy in terms of Bose-Einstein statistics and half-integer-spin particles employ Fermi-Dirac statistics.

In classical mechanics, the position of a particle is measured as time changes. In mathematical terms we say position is a function of time. On the other hand, in quantum mechanics, position and time are treated as independent variables on an equal footing. Position no longer becomes a function of time. In other words, there is a given probability that a particle can be at any position at any time. It is this probability that varies with position in space and time. In classical mechanics we can predict with certainty the position of a particle at any given time. This makes quantum mechanics a statistical theory, unlike Newtonian mechanics.

Black Body Radiation

A black body is defined as one that absorbs all electromagnetic energy (radiant energy) incident on it at all wavelengths. A good approximation to a black body is a closed cavity kept at constant temperature with blackened interior walls and with a small hole that allows electromagnetic radiation to enter and exit the cavity. Measurements of the intensity (total power radiated per unit area per unit wavelength at a given temperature) of radiation emitted by a black body were independent of the physical and chemical properties of the black body but varied with the temperature T. In 1879, J. Stefan found an empirical relation between the total power emitted per unit area of a black body R (total emittance) and temperature T. Subsequently, in 1884, Ludwig Boltzmann derived the same relation from thermodynamics. This relation is known as the Stefan-Boltzmann law and is given as $R = \sigma T^4$ where $\sigma = 5.7 \times 0^{-8}$. $Wm^{-2}K^{-4}$ is a constant known as Stefan's constant. It was also found that the intensity distribution at a given temperature had a well-defined maximum at wavelength denoted λ_{max}. In 1893, Wilhelm Wien showed that λ_{max} varies inversely with temperature as $\lambda_{max}T = 2.898 \times 0^{-3}$ mK, which is called Wien's law.

The first accurate measurements of the emittance (power radiated per unit area per unit wavelength) were made in 1899 by Otto Lummer and Ernst Pringsheim. The emittance is obtained from a calculation of the energy density (energy per unit volume), ρ, of electromagnetic waves in the cavity that is used to model the black body. The energy density is calculated by first assuming that standing electromagnetic waves exist in the cavity. The number of such waves or modes per unit volume per unit wavelength is shown to be $(8\pi/\lambda^4)$, where λ is wavelength. The energy density is then obtained by multiplying this number by the average energy per mode with wavelength λ. Lord Rayleigh and James Jeans treated the energy of a mode as having a value between zero and infinity and with average energy obtained from Boltzmann statistics. They calculated the average as kT, where k is Boltzmann's constant. The energy density is obtained as $(8\pi/\lambda^4)\ kT$. This is the Rayleigh-Jeans result. The emittance can be obtained by multiplying the energy density by $c/4$, where c is the speed of light. In the limit of long wavelengths, the calculated emittance follows the experimental curve for the emittance. It can be concluded that the Rayleigh-Jeans result describes only the radiation characteristics in the long-wavelength limit. It fails to exhibit the observed maximum and diverges as wavelength approaches zero, which corresponds to the short wavelength limit.

A solution to the black body radiation problem required the application of radically new ideas. The classical physics that had been applied by Rayleigh and Jeans and others failed to describe the radiation characteristics of black bodies completely. In December 1900, Max Planck postulated that the energy of a mode cannot take on continuous values between zero and infinity. He proposed that the energy of a mode in the cavity can only take on discrete values equal to $nh\nu$, where n is a positive integer or zero, h is a constant to be determined, and ν is the frequency of the mode. The average energy of a mode at temperature T was then calculated using the discrete form of the Boltzmann distribution. This new average energy was then used to calculate a new energy density. In order to satisfy Wien's law, it was found that the constant $h = 6.55 \times 10^{-34}$ Js, where J denotes joule (the unit of energy) and s stands for second (the unit of time). The constant h is a fundamental constant called Planck's constant. Using these new ideas, in which energy was treated as having discrete values, Planck was able to obtain good agreement with experimental results over all wavelengths.

Planck assumed that the sources of black body radiation were oscillators in the walls of the cavity that could only vibrate with energies $nh\nu$. Albert Einstein extended Planck's ideas and assumed that radiation consists of particles called photons, each traveling with the speed of light c and having energy equal to $h\nu$. Einstein treated black body radiation as a gas of photons in thermal equilibrium with the walls of the cavity at temperature T. A question naturally arises concerning the distribution in time of the photons emitted by a black body. Clearly, since the emission of photons from a black body is a random process, we may want to find out the average number of photons emitted by the black body within a fixed time interval. There must therefore be a well-defined probability that a certain number of photons will be emitted from the black body within some time interval. In order to detect individual photons within short time periods, photodetectors had to be developed, and a full description of such detectors needed quantum mechanics, because they were based on the photoelectric effect that we now present in the next section.

Photoelectric Effect

Many other effects required the application of Planck's ideas. Some of these include the photoelectric effect, the Compton effect, atomic line spectra, and the Stern-Gerlach experiment. Evidence for the quantization of radiation energy came as a result of an explanation of the photoelectric effect. This effect was discovered by

Heinrich Hertz in 1887 as he was in the process of confirming Maxwell's theory of electromagnetic waves. Hertz found that ultraviolet light incident on metallic electrodes caused sparks. It was confirmed that the sparks were due to the ejection of electrons from the metallic surface, and this phenomenon was termed the photoelectric effect.

Philipp Lenard performed experiments to determine the mechanism of the photoelectric effect. Lenard found that there is a minimum frequency of radiation, depending on the type of metallic electrode, below which there is no emission of electrons. Also, the maximum kinetic energy of the emitted electrons varies linearly with the frequency of the ultraviolet radiation. Such observations could not be explained using Maxwell's classical electromagnetic theory. However, in 1905, Albert Einstein proposed an explanation based on Planck's quantum theory. Einstein postulated that radiation is made up of discrete particles, called photons, which carry energy equal to Planck's constant times the frequency of the radiation. It was assumed that localized photons carrying energy are absorbed by atoms in the metallic electrodes. Electrons in the atoms gain sufficient kinetic energy to escape and are ejected as photoelectrons. Einstein's theory was confirmed later by R. A. Millikan in a series of experiments.

The theory of the photoelectric effect was developed in 1963 by Roy Glauber. Essentially, Glauber supposed that a device that measures the arrival of photons at given times was located at some point in space. He then proceeded to calculate the probability of this event over a short time interval denoted Δt. He obtained an expression that was proportional to the intensity of the radiation impinging on the photodetector and the short time interval Δt. Using this result, other researchers like Leonard Mandel were able to derive the probability for an arbitrary number of photodetections to occur within a longer time interval. They found that this number obeyed a Poisson probability distribution. Their result applied to stationary or nonfluctuating light beams.

Compton Effect

The interaction of light with matter was also an intensely studied area of research. Many researchers such as Charles Barkla in 1909 studied the scattering of X-rays, which are high-frequency electromagnetic waves. It was found that X-rays were scattered without a change in wavelength as they passed through matter. Barkla used J. J. Thomson's classical theory to explain his results. His results agreed well with Thomson's theory, but he also obtained results that were anomalous and could not be explained with the model of Thomson. The results showed that the scattered radiation had the same wavelength as the incident radiation (λ_0) as well as a component with wavelength (λ_1) greater than the incident radiation. The Compton shift, $\Delta\lambda$, defined as $\Delta\lambda = \lambda_1 - \lambda_0$, was found to be proportional to $\sin^2\theta$, where θ is the angle between the scattered and incident beams. It was also confirmed that the Compton shift was independent of both the material scatterer and the wavelength of the incident radiation.

Compton's explanation of the shift in wavelength was based on considerations of energy and momentum conservation between interacting particles. The scattering was modeled as an incident photon with momentum $\vec{p}_0$ (the arrow indicates that momentum is a vector quantity) colliding with an electron at rest and then giving rise to a scattered photon with momentum $\vec{p}_1$ and an electron with recoil momentum $\vec{p}_2$. By applying the laws of conservation of energy and momentum, Compton was able to demonstrate that $\Delta\lambda = (2h/m)\sin^2(\theta/2)$, where h is Planck's constant, m is the mass of the electron when at rest (rest mass of the electron) and c is the speed of light or the speed of a photon. This theory explained the origin of the modified component of the scattered radiation. In explaining the unchanged component of the scattered radiation, it was assumed that it originated from interactions with tightly bound electrons such that the recoil momentum of the electron was negligibly small. This would give rise to radiation with approximately the same wavelength as the incident radiation.

Spectral Lines

It was realized very early that atoms emit light when heated as well as when an electrical discharge is passed through a volume of gas. It was also observed that the visible light was not emitted at a continuum of frequencies but exhibited a certain regularity. The spectrum of the emitted light was found to be made up of discrete lines or colors. These observations among others led to the belief that the constituent atoms of matter had some internal structure that gave rise to the regularity in the emission spectrum. A seminal discovery was made in 1885 by Johann Balmer concerning the emission spectrum of the hydrogen atom. Balmer obtained a simple empirical formula that described the lines in the hydrogen spectrum. He found that the wavelength (λ) for each line was given by $\lambda = 364.56[n^2/(n^2-4)]$ nanometers, where $n = 3,4,5, \ldots$ More work by Johannes Rydberg and Walther Ritz resulted in a more general result for calculating all wavelengths of the hydrogen spectrum. This new empirical formula for the inverse of the wavelength is $1/\lambda = R_H (1/n^2 - 1/k^2)$, where R_H is called the Rydberg constant (for hydrogen), $n = 2$ corresponds to the Balmer line spectrum, and k is always greater than n. By 1925, five sets of spectral lines had been discovered. They were the Lyman ($n = 1$, $k > 1$), Balmer ($n = 2$, $k > 2$), Paschen ($n = 3$, $k > 3$), Brackett ($n = 4$, $k > 4$), and Pfund ($n = 5$, $k > 5$) series of spectral lines.

In 1913 Niels Bohr made an astonishing breakthrough in explaining the spectrum of the hydrogen atom. Following Ernest Rutherford, he assumed that electrons in atoms move in simple circular orbits around the heavy stationary nucleus of each atom. He also assumed that only so-called stable orbits are allowed. This was a deviation from classical mechanics, in which an infinity of orbits would have been allowed. Bohr further assumed that an electron in a stable orbit does not radiate electromagnetic energy. Electromagnetic energy can only be given off by the atom if an electron makes a transition between two allowed stationary states. The frequency of the emitted radiation is obtained from the relation $E_1 - E_2 = hv$, where E_1 is the energy of the initial stationary state with higher energy, E_2 is the energy of the final stationary state with lower energy, h is Planck's constant, and v is the frequency of the emitted radiation. Bohr also pointed out that the orbital angular momentum, L, of the electron moving around the nucleus in a circular orbit can only take on the values $L = nh/2\pi$, where $n = 1,2,3, \ldots$. These assumptions were then used by Bohr to derive the energies of the stationary states of atoms. By equating the Coulomb force on the electron to the centripetal force and invoking the quantization of orbital angular momentum, Bohr obtained his famous formula for the allowed energies of an electron as

$$E_n = -\frac{m}{2\hbar^2}\left(\frac{Ze^2}{4\pi\varepsilon_0}\right)^2 \frac{1}{n^2}$$

where m is the mass of the electron, $\hbar = h/2\pi$, ε_0 is a constant called the permittivity of free space, Ze is the charge of the nucleus, and $-e = -1.6\times10^{-19}$ coulombs is the electronic charge. The above formula showed that the energies of a single electron in an atom were discrete and therefore quantized. The quantum number n, which can take values from 1 to infinity, is called the principal quantum number, and the subscript n in E_n shows that there are a set of discrete energy levels E_1, E_2, $E_3 \ldots$ that depend on the value of the principal quantum number. The ground state is the state with lowest energy, that is, $n = 1$, and all other states are called excited states of the atom. Using the Bohr formula, the empirical result of Rydberg and Ritz was confirmed, as was a value for the Rydberg constant. The Bohr model of one-electron atoms gives good predictions for their energy levels. The energy quantization of atoms was confirmed in 1914 by James Franck and Gustav Hertz. It fails, however, in describing atoms with two or more electrons. Also, Bohr's assumption that electrons orbit the nucleus in circular orbits is unfounded. Using his quantum mechanics, Bohr later on tried to relate new results to well-known classical physics results. He proposed what is now called the correspondence principle, which states that the results of quantum mechanics must tend asymptotically to those obtained from classical physics in the limit of large quantum numbers.

Stern-Gerlach Experiment

A very important experiment that required quantum mechanics for its description is the Stern-Gerlach experiment performed in 1922 by Otto Stern and Walther Gerlach. This experiment was designed to measure the magnetism effect of atoms, or atomic magnetic moments. Due to the fact that electrons orbit the nucleus of atoms, they set up current loops within the atoms. This has the effect of giving atoms a physical property called a magnetic moment. The magnetic moment is essentially the product of the current and the area of the loop enclosed by the current loop. When atoms with magnetic moments are placed in magnetic fields, the atoms will experience forces if the magnetic field is nonuniform. This is the basis of the Stern-Gerlach experiment, in which they sought to measure the magnetic moment of atoms by detecting the deflection of atoms as they passed through a nonuniform magnetic field. They found that the force on the atoms was such that the orbital angular momentum of the electron must be quantized in units of Planck's constant. Thus their result again required quantum theory for its explanation.

Dual Nature of Electromagnetic Radiation

Because of the work of Planck, Einstein, and Bohr, it became apparent that electromagnetic radiation possessed both wave and particle properties. Wave properties were used to explain classical interference and diffraction of electromagnetic waves, whereas particle properties were required to explain the photoelectric and Compton effects. In 1923–1924, Louis de Broglie proposed that material particles may possess both wave and particle properties. De Broglie was attempting to extend wave-particle properties applicable to electromagnetic radiation to all particles. Einstein proposed that the energy of a photon is given as $E = h\nu$, where E is energy, h is Planck's constant, and ν is frequency. The photon momentum is given as $p = h/\lambda$, where λ is the photon wavelength. De Broglie proposed that free material (massive) particles would also obey the Einstein energy relation as well as have their wavelength related to momentum by the relation $\lambda = h/p$. This wavelength is known as the de Broglie wavelength. These ideas provided an explanation of the quantization of angular momentum used in the Bohr model of one-electron atoms and were later used to further develop the theory of quantum mechanics.

In 1927, Clinton Davisson and Lester Germer investigated the reflection of electrons from crystals. They confirmed that electrons possessed wavelike properties in agreement with the de Broglie hypothesis. Independently, G. P. Thomson examined the transmission of electrons through a thin foil of polycrystalline material. Thomson obtained a series of concentric rings when transmitted electrons struck a photographic plate. This result was also obtained in a similar experiment using X-rays in the Debye-Scherrer method used to study X-ray diffraction. Thus, electrons can be diffracted like X-rays and thus exhibit wave properties. These experiments and others confirmed the wave nature of particles and validated the de Broglie hypothesis.

Theories of Quantum Mechanics

A new theory was required to explain many of the experimental results that defied classical physics. The new theory was called quantum mechanics and was developed during the years 1925 to 1930. Two versions of this theory were created at about the same time. The first is known as *matrix mechanics* and was developed by Werner Heisenberg, Max Born, and Pascual Jordan in 1925 and 1926. This theory associates a matrix to all physical quantities, and such matrices obey a noncommutative algebra. A second version was developed by Erwin Schrödinger in 1925 in which a wave function played the central role in describing physical quantities. Later on Schrödinger and Paul Dirac were able to show that both versions of quantum mechanics gave the same results and differed only in their mathematical structure.

The Schrödinger formulation of quantum mechanics required a wave function to describe microscopic systems that could not be explained using classical physics or classical wave equations. This version of quantum mechanics had closer ties to classical physics, because the wave function satisfied a wave equation. This wave equation is now known as the Schrödinger wave equation, and it was while Schrödinger was presenting a seminar in Berlin that it was suggested to him that particles must obey such an equation. Schrödinger followed the ideas of de Broglie—that particles exhibited wave properties—and developed a wave equation to describe the wave nature of particles. The solution to this wave equation gave the wave function of the system, and it contained information about the particle's location in space and time. The wave function is usually denoted by the Greek symbol $\Psi(\vec{r},t)$, where $\vec{r}$ is the position of the particle and t is time. The wave function has a probability interpretation in the sense that the product of Ψ with its complex conjugate Ψ^*, that is, $|\Psi|^2 = \Psi\,\Psi^*$, is the probability per unit volume or probability density of finding a particle in some infinitesimally small volume of space at a given instant in time. This probability interpretation of the wave function is credited to the German theoretical physicist Max Born, and it won him the Nobel Prize in 1954.

In this new theory, we no longer calculate the exact position, energy, momentum, and so forth of a particle, but instead we compute average values for these physical quantities. The Schrödinger wave equation in its time-dependent form and for a particle with motion in one dimension along the x-axis is given as

$$i\hbar\frac{\partial\Psi}{\partial t} = -\frac{\hbar^2}{2m}\frac{\partial^2\Psi}{\partial x^2} + V\Psi$$

where $\hbar$ is Planck's constant h divided by 2π ($\hbar = h/2\pi$), $i = \sqrt{-1}$, m is the mass of the particle, and V is the potential energy of the particle. On the left side of the equation, $\partial\psi/\partial t$ is the partial derivative of ψ with respect to time, and $i\,\hbar\partial\psi/\partial t$ gives information about the total energy of the particle. On the right side, $\partial^2\psi/\partial x^2$ is the second-order partial derivative of ψ with respect to the spatial variable x. The term $-(\hbar^2/2m)\ \partial^2\psi/\partial x^2$ gives information about the kinetic energy of the particle. The final term $V\psi$ tells us about the forces acting on the particle. The special case of V= 0 represents a free particle or a particle under the influence of no forces.

It should be noted that the wave function depends on x and t. Also, the potential energy can depend on x as well as t. In the one-dimensional case, $|\Psi|^2$ gives the probability per unit length of finding the particle at a given location on the x-axis, and therefore, the probability that the particle will be found in the small interval that we call dx about the point x on the x-axis is $|\Psi|^2 dx$. This means that it is not possible to specify with certainty the location of the particle along the x-axis, but we can assign a probability for observing it at a given position in accord with Born's statistical interpretation of the wave function. Given the existence of a probability distribution for the position of the particle, the average position of the particle can also be computed. Such an average or expectation value of the position is denoted $\langle x\rangle$ and is defined by the integral

$$\langle x\rangle = \int_{-\infty}^{\infty} x|\Psi(x,t)|^2 dx.$$

Note that $\langle x\rangle$, in general, depends on time, but for certain wave functions describing particles with definite energy (stationary states), it is independent of time. Averages of functions of x, that is, $\langle f(x)\rangle$ can be found in a similar manner as

$$\langle f(x)\rangle = \int_{-\infty}^{\infty} f(x)|\Psi(x,t)|^2 dx.$$

The uncertainty in the position of the particle is denoted Δx and is defined as

$$\Delta x = \sqrt{\langle x^2\rangle - \langle x\rangle^2}.$$

Now consider the average momentum of the particle $\langle p\rangle$. Because there is no well-defined path for the particle, there is no function connecting momentum p with position x. Therefore we cannot treat momentum as a function of position, that is, $p(x)$, and use the formula for finding the average of a function of x to find the average momentum. To obtain the average momentum we use the relation

$$\langle p\rangle = m\frac{d\langle x\rangle}{dt}$$

where m is the particle mass to find $\langle p\rangle$ from $\langle x\rangle$. It can be shown that

$$\langle p\rangle = \int_{-\infty}^{\infty} \Psi^*\left(\frac{\hbar}{i}\right)\frac{\partial\Psi}{\partial x}dx$$

where Ψ^* is the complex conjugate of the wave function. The above expression can be rewritten as

$$\langle p\rangle = \int_{-\infty}^{\infty} \Psi^*\left(\frac{\hbar}{i}\frac{\partial}{\partial x}\right)\Psi dx.$$

The expression for finding the average position can also be rewritten as

$$\langle x\rangle = \int_{-\infty}^{\infty} \Psi^*(x)\Psi dx.$$

It is found that that the average value for other physical quantities (observables) as well takes the general form

$$\langle O\rangle = \int_{-\infty}^{\infty} \Psi^*\left(\hat{O}\right)\Psi dx$$

where $\langle O \rangle$ is the expectation value of the observable and $\hat{O}$ is an operator representation for the observable. In the case of position, the operator is x, and for momentum the operator is $(\hbar/i)\partial/\partial x$. Another important operator is the kinetic energy operator, which is $-(\hbar^2/2m)\ \partial^2/\partial x$. To find the average energy of the particle, $\langle x \rangle$, we sum the average kinetic and potential energies as

$$\langle E \rangle = \int_{-\infty}^{\infty} \Psi^* \left\{ -\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V \right\} \Psi dx$$

where the potential is treated as a function of x. The operator representation for energy is therefore

$$-\frac{\hbar^2}{2m}\frac{\partial^2}{\partial x^2} + V.$$

This operator has a special name; it is called the Hamiltonian and denoted H. It should be noted that when H acts on the wave function, it produces the same result as the operator $i\hbar\partial/\partial t$ acting on the wave function. It was Heisenberg who first pointed out that the uncertainty in position Δx is related to the uncertainty in the particle's momentum Δp . The relationship is termed the Heisenberg uncertainty principle and is written as an inequality $\Delta p \Delta x \geq \hbar$. The uncertainty principle imposes limits on the simultaneous values of the momentum and position. Essentially, large uncertainties in position lead to small uncertainties in momentum and vice versa. We should note that the uncertainty principle does not place any restriction on the precision with which position measurements can be made. Once we make position measurements with uncertainty Δx, possible values of the momentum will have a spread of $\Delta p = \hbar/\ \Delta x$ about an average value.

The other formulation of quantum mechanics involves the use of matrices to describe the wave function as well as all observables of a given system. For a given quantum mechanical system, we usually obtain a set of wave functions that describe the system. A particle in the system can be described by one of these functions or by a linear combination of two or more wave functions. The wave functions that describe the system can be labeled by the set $\{\psi_n\}$ where, for simplicity, n is a discrete index. The system can be in one or a combination of these basis wave functions. These basis wave functions are orthonormal and form a complete set. The orthonormality of the wave functions can be expressed mathematically by the following equations:

$$\int_{-\infty}^{\infty} |\psi_n|^2 dx = 1$$

$$\int_{-\infty}^{\infty} \psi_n^* \psi_m dx = 0, n \neq m.$$

Completeness of the wave functions means that the system can always be described by a linear combination of the set of wave functions $\{\psi_n\}$. Therefore, the wave function Ψ is given as

$$\Psi = \sum\nolimits_n c_n \psi_n$$

where the coefficients in the expansion, c_n, uniquely specify the wave function of the system. In terms of matrices, we can specify the wave function as a column matrix with entries $c_1, c_2, \ldots, c_d$, where d is the number of wave functions in the set $\{\psi_n\}$. Operators are represented by square matrices with elements, O_{mn} , given as

$$O_{mn} = \int_{-\infty}^{\infty} \psi_m^* \hat{O} \psi_n dx$$

where $\hat{O}$ is the operator in the Schrödinger formalism.

Another version of quantum mechanics, called *second quantization,* involves the use of new operators called creation and annihilation operators, which are combinations of the momentum and position operators. The Hamiltonian of any system can be rewritten in terms of these new operators as well as the wave function of the system. This version of quantum mechanics is widely used in current research.

The time evolution of a quantum system determines the wave function at later times t, given an initial wave function at an earlier time t_0. This time evolution is determined by the time-dependent Schrödinger equation. Given the initial wave function $\psi(t_0)$, the wave function at time t is $\psi(t)$ and is given by the solution to the Schrödinger equation as

$$\Psi(t) = \exp\left(-\frac{i}{\hbar}H(t-t_0)\right)\Psi(t_0)$$

where H is the Hamiltonian of the system. We remind the reader that there are two ways we can represent wave functions and operators. Operators can be in either differential or matrix form. The wave function can be represented as a normal function of space and time or as a column matrix. These two representations were termed the Schrödinger and Heisenberg representations respectively. If the wave function is time-dependent and the operators time-independent for either representation, we call this the Schrödinger picture of quantum mechanics. If the wave function is time-independent and the operators time-dependent, it is called the Heisenberg picture. These two pictures are related to each other by a time-dependent unitary operator $U(t,t_0)$. The property of unitarity is such that $U(t,t_0)$ $U^{+}(t,t_0) = I$, where $U^{+}(t,t_0)$ is the Hermitian conjugate (adjoint) of the operator $U(t,t_0)$, and I is the unit operator. The Heisenberg wave function at the later time t is equal to the Schrödinger wave function at the earlier time t_0. If $\Psi_S(t)$ is the Schrödinger wave function, then the Heisenberg wave function, Ψ_H, is given as

$$\Psi_H = U^{+}(t,t_0)\Psi_S(t) = \Psi_S(t_0).$$

Hence, the Heisenberg wave function is equal to the Schrödinger wave function at some fixed earlier time t_0. Now if A_S is an operator in the Schrödinger picture, then the corresponding operator in the Heisenberg picture is given as

$$A_H(t) = U^{+}(t,t_0)A_S U(t,t_0).$$

It is important to note that at time t_0, $A_H = A_S$. At this time the Schrödinger and Heisenberg operators coincide. Therefore, both pictures coincide at t_0, and the average value of any operator in both pictures is the same at any given time. The equation that determines the time evolution of the Heisenberg operators is called the Heisenberg equation of motion and is given as

$$\frac{dA_H}{dt} = \frac{1}{i\hbar}[A_H, H],$$

where the square bracket term is the commutator between the operator A_H and the Hamiltonian H. It is defined as $[A_H,]=A_H H-HA_H$.

In summary, quantum mechanics is a theory that has had tremendous success in describing the behavior of microscopic particles. It became a requirement because of the failure of classical physics in describing the microscopic world. It has become a useful tool that allows us to better understand the laws of nature and to create new devices to improve the quality of life.

Roger Andrews

See also Causality; Einstein, Albert; Light, Speed of; Planck Time; Time, Measurements of; Time, Relativity of; Time, Reversal of; Time Travel

Further Readings

Bransden, B. H., & Joachain, C. J. (1989). *Introduction to quantum mechanics.* London: Longman.

Glauber, R. J. (1963). The quantum theory of optical coherence. *Physical Review, 130,* 2529.

Griffiths, D. J. (1994). *Introduction to quantum mechanics.* New York: Prentice Hall.

Mandel, L. (1963). *Progress in optics* (Vol. 2) (E. Wolf, Ed.). Amsterdam: North-Holland.

Sakurai, J. J. (1994). *Modern quantum mechanics.* Boston: Addison-Wesley.

Qur'an

The Qur'an (also Koran and Quran; from the Arabic, meaning "to read" or "to recite") is the foremost sacred writing in Islam. According to Muslim belief, the Qur'an contains the words of Allah (God) as transmitted to the prophet Muhammad over a short span of time, from 610 to 632 CE (or BH 12 to AH 10, referring to the year of the Hegira, in which Muhammad went to Medina); it is Allah's final revelation to humanity. As such, the Qur'an cannot be changed or altered over time. The Qur'an consists of 114 chapters, called *sura*s (singular, *sura* or *surah*), which are composed of 6,239 verses called *ayat* (singular, *aya*).

The development of the Qur'an is intertwined with the life of Muhammad. He was born and raised in the city of Mecca (in present-day Saudi Arabia). In the early 600s, he began to leave the city periodically and go into the mountainous area surrounding Mecca to pray. In the year 610, while in a cave in Mt Hira, Muhammad heard the voice of an angel say "recite." Muhammad protested. The command happened again, and again Muhammad protested. At the third time the angel said, "Recite in the name of the Lord who created, created man from clots of blood! Recite: Your lord is the most generous, who teaches by the pen; teaches man what he knew not" (96:1–3).

Muslims consider this interaction the beginning of the Qur'an and refer to this incident as the Night of Power (Laylat al-Qadr), which is the holiest night of the year for Muslims. Over the next 22 years, Muhammad reported hearing the voice of the angel Gabriel (or another angel) relaying the word of Allah to him. He remembered these words and taught them to others. Most scholars believe Muhammad was illiterate, so some of the revelations were written down by other followers, and some revelations were memorized. Altogether, these revelations form the Qur'an.

Muslims celebrate the initial revelation each year during the month of Ramadan; this practice is mandated in the Qur'an (2:183–185). During this month, Muslims refrain from eating, drinking, smoking, and sexual relations between sunrise and sunset.

The compilation of the Qur'an began after the death of Muhammad. The first Muslim leader after Muhammad, Caliph Abu Bakr, ordered that the Qur'an be compiled and recorded. The task involved collecting the various portions of the Qur'an that people had written down along with interviewing many who had memorized portions of Qur'an. Under the third Caliph, Uthman, the Qur'an was collected into one book.

The earthly Qur'an itself is believed to be a copy of the heavenly Qur'an. This is spoken of in 43:2–3: "We have revealed the Qur'an in the Arabic tongue that you may grasp its meaning. It is a transcript of our eternal book, sublime, and full of wisdom." Muhammad is understood to have received the Qur'an piece by piece over a 22 year period.

To Muslims, therefore, the Qur'an is the word of Allah. (Some exceptions do occur. Sura 1 consists of a prayer of man, plus Muhammad or angels speak in several places throughout the Qur'an.) As such, the Qur'an should not be translated into another language without guidance; translation yields errors, because not all words in one language have a direct one-to-one correlated word in another language. If the Qur'an is to be translated, a commentary at the bottom of the page should be included along with the original Arabic in a parallel reading on the same page or the facing page. Numerous translations into other languages do exist, although these should not be considered "official" versions.

The shortest sura is three ayat long, whereas the longest sura is 286 ayat long. Each sura has a title, which is derived from a word or idea from within the sura. The suras are not listed chronologically (as given to Muhammad) but roughly from longest to shortest. Nevertheless, the Qur'an begins with a special sura (eight ayat) which is a prayer to Allah. It begins: "Praise be to Allah, lord of the Creation, the compassionate, the merciful, king of judgment-day! You alone we worship, and to you alone we pray for help." The sura following this prayer sura is the longest sura in the Qur'an. The shortest sura (three ayat) is the 104th sura, whereas the last sura has five ayat.

The revelations (suras) were given to Muhammad while in Mecca and Medina. The suras given in Mecca tend to be shorter than the suras given in Medina; over time the messages to Muhammad lengthened. Because the suras are arranged roughly according to length with the longest first, the suras given in Medina tend to come before the suras given in Mecca. Coming as they do at different times in Muhammad's life, the suras cover a wide range of issues. Some suras are praises to Allah, some contain instructions, some relate history, some warnings, and some blessings.

Muslims believe that, over time, Allah sent numerous prophets prior to Muhammad to convey his message. In this the Qur'an is similar to the Jewish Bible, or Christian Old Testament. All three contain the figures Adam, Noah, Moses, and Abraham (along with other prophets). The Qur'an and the Christian Bible, or New Testament, both contain stories of Jesus. Yet the similarity is in name only, because each tradition's scriptures relate different stories of these characters. In addition, in the Qur'an the prophet Muhammad is supreme to all other prophets.

Practically speaking, the Qur'an is used during sermons and read by Muslims. In addition, many Muslims attempt to memorize much, and some all, of the Qur'an. All Muslims memorize at least a small portion of the Qur'an, because it is used during prayers in the mosque.

The U.S. government allows limited use of the Qur'an for official functions where a "holy scripture" is required. In 2007, a Muslim U.S. Congressman was sworn into office using Thomas Jefferson's Qur'an. Also in 2007, a North Carolina Muslim woman successfully sued the court to allow her to use a Qur'an during the swearing-in ceremony for a trial.

Mark Nickens

See also Adam, Creation of; Bible and Time; Islam; Moses; Noah; Religions and Time; Time, Sacred

Further Readings

Esack, F. (2005). *The Qur'an: A user's guide*. Oxford, UK: Oneworld.

Sells, M. A. (2007). *Approaching the Qur'an: The early revelations*. Ashland, OR: White Cloud Press.

R

Rahner, Karl (1904–1984)

Karl Joseph Erich Rahner was one of the most influential Roman Catholic theologians and philosophers of the 20th century; his life's work was to reconcile Thomistic philosophy and theology with modern thought (Immanuel Kant, German Idealism, Martin Heidegger). Influenced by Heidegger, he stressed the importance of time: Death is always present during life, and the essence of death is completion of the human being as being in the world.

Rahner was born in Freiburg in southwest Germany on March 5, 1904. He was the fourth of seven children of Luise and Karl Rahner. In 1922 Rahner entered the Society of Jesus, and he was ordained a priest in 1932. From 1934 to 1936 he was back at Freiburg, where he frequented the lectures and seminars of Heidegger and Honecker and wrote his dissertation, *Spirit in the World.* But neither Honecker nor Heidegger accepted Rahner's interpretation of Thomas Aquinas. For Honecker it was not the true Thomas, and for Heidegger it was too transcendental. Subsequently, Rahner changed departments and successfully wrote a dissertation and postdoctoral thesis in theology. Afterwards he became a member of the faculty of theology at the University of Innsbruck, Austria, a position he held from 1937 to 1938 and again between 1948 and 1964. In 1964 Rahner transferred to the University of Muenster and in 1967 to the University of Munich, spending his last years in Innsbruck. In 1976 Rahner published *Foundations of Christian Faith,* which summed up his theology. He died in Innsbruck in 1984.

Between 1948 and 1964, Rahner developed the main principles of his influential Christian transcendental philosophy and theology. First and foremost, Rahner analyzed the conditions that make it possible for a human being to gain knowledge and to act. His main argument is as follows: Human beings transcend themselves and their world in every act of questioning and thinking. With questioning and thinking, humans encounter the mystery of existence, which Christians believe is grounded in God. Rahner developed the idea that humans are essentially oriented toward this mystery and that authentic searching into the depth of God's mystery is a transformative journey that enables humans to acquire true knowledge and to act as free persons—ultimately accepting death as the completion of their being in time and in the world. Technically speaking, God is the condition that makes every human act possible. That means that God's very existence, which surpasses everything (transcendent), is the condition that makes all human knowledge and acts of freedom possible. Rahner calls God's grace (the Holy Spirit) the "supernatural existential" of every human being; it transforms all human efforts and attracts human beings to God. In contrast to Heidegger, the human being is not *dasein* (being in the world understanding time and being), but *daGott* (being in relation to God, whereby God is the basis of their true essence). Therefore, the ultimate goal is communion with God.

How can the reality of the supernatural existential be discovered? Influenced by Saint Ignatius's Christian spirituality as well as by Heidegger, Rahner developed a philosophy and theology of time. Humans understand their death to be the end of their time on earth. In a way, death is the end of their "world." Thus humans must grasp the importance of time by reflecting on the end, even as they hope that death is not the final end. Christians believe that the resurrection of Jesus Christ reveals that death is not in vain. Transformed by this belief, they see their time on earth as God-given. Internalizing this faith-reality, Christians live "in God's time" by ordering their actions according to God's will—by doing good and avoiding sin.

Nikolaus J. Knoepffler

See also Aquinas, Saint Thomas; Christianity; God and Time; Heidegger, Martin; Kant, Immanuel; Religions and Time

Further Readings

Marmion, D., & Hines, M. E. (2005). *The Cambridge companion to Karl Rahner.* Cambridge, UK: Cambridge University Press.

Rahner, K. (1961 et seq.). *Theological investigations* (20 vols., various trans.). London: Darton Longman Todd.

Rahner, K. (1978). *Foundations of Christian faith* (W. V. Dych, Trans.). New York: Seabury.

Rameses II (1304–1213 BCE)

Rameses II (the Great) ruled Egypt at a time when the nation was at the height of its glory. Son of Seti I, Rameses II was the third Egyptian pharaoh of the 19th dynasty of the New Kingdom. He is one of the most famous pharaohs in history, noted for his building achievements, his major battle with the Hittites, and his connection with the biblical exodus. In addition, he was unusual in that, standing 5 feet 8 inches, he was about 5 inches taller than the average Egyptian, and he had red hair.

Rameses II has a unique connection with time in several ways. First, Rameses enjoyed an extraordinarily long life. He had the longest reign of any pharaoh, ruling more than 66 years, from 1279 to 1213 BCE and dying at 92 years old. He was born in 1304 BCE, and Seti I appointed him as coregent when Ramses was 14 years old. He came to the throne as sole ruler in his early 20s. Rameses had at least eight wives, all of whom held the title Great Royal Wife, including the famous Nefetari, two daughters of Hittite kings, and two of his own daughters, and he fathered more than 100 children.

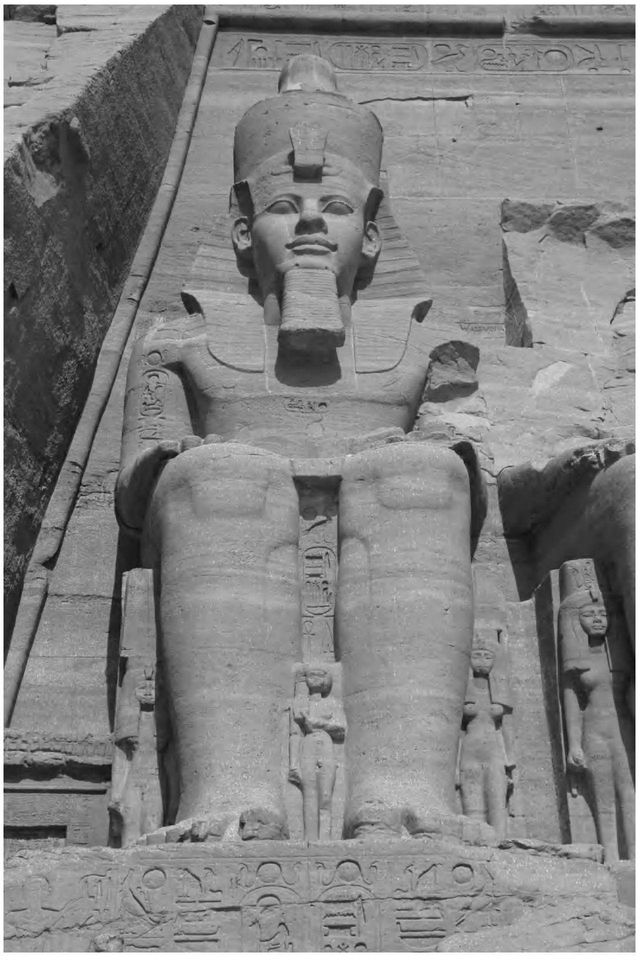
Second, Rameses II is connected with time through the sheer quantity of buildings that remain of his reign some 3100 years later. Rameses tried to make a lasting name for himself through his unparalleled building program. No other pharaoh constructed as many temples, erected as many statues, or built as many royal cities as Rameses II. He built a large mortuary complex near Thebes known as the Ramesseum. This complex, measuring 300 by 195 meters, contained a great temple, several large courts, and a colossal statue of him that stands 17 meters high and weighs over 1,000 tons. In addition to completing his father's temples at Thebes and Abydos, he built or expanded temples in Karnak, Abu Simbel, Abydos, Luxor, and Thebes in Egypt and in at least five cities in Nubia. In these complexes are pictures and written descriptions glorifying Rameses and his deeds. They show a particular interest in his battles, especially accounts of the battle of Kadesh. He also expanded Pi-Rameses, a city in the Nile delta area, and made it his new capital. This extraordinary amount of building reflects a healthy economy and a wealthy nation.

Third, Rameses II tried to make his mark on Egyptian history by being a great warrior. Even before Rameses became pharaoh, Seti I made him the commander of the army and sent him to Nubia, where he put down a revolt and gained valuable experience. His famous battle, the Battle of Kadesh, occurred near the city of Kadesh in Syria. Here, he fought the Hittite empire, a group that posed the greatest threat of the time to Egyptian expansion. Seti I had taken Kadesh temporarily from the Hittites a few years earlier, but the city quickly returned to Hittite control.

In the spring of 1274 BCE, Rameses II marched the largest professional army in ancient history, four divisions of chariots and infantry, into Syria toward Kadesh in hopes of dealing a final, crushing defeat to the Hittites. The Hittites sent out spies that gave Rameses false information, leading him to think that the Hittite army was hundreds of miles away when they really were hidden behind the city. Rameses, personally in command of the Amun division, separated his divisions. Then, he pushed his division forward and ahead of the other divisions. The Hittites sprang their ambush, routed two of Rameses's divisions, and nearly captured Rameses himself. The Egyptians were able to regroup and forced the Hittites to retreat temporarily. Both sides suffered heavy losses. The following day the two kingdoms fought another battle to a stalemate. Rameses had to return home without the decisive victory he wanted and with only a written truce. To cover over the lackluster events of the battle, Rameses had accounts of his great heroics in battle and his dubious victory written on temple walls throughout his kingdom.

After a few more attempts to push the Hittites out of Syria, Rameses II and Hattusili III, a new Hittite king, made a detailed peace treaty in 1258 BCE. Both sides agreed to the treaty due to a new threat—the Assyrians. In the treaty, not only did both sides agree to cease hostilities against each other, but they also agreed to come to the other's aid in the event of external or internal aggression. This is one of the earliest known peace treaties in world history. Archaeologists have found copies of the treaty in Hattusa, the Hittite capital, and in Egypt on the temple walls at Karnak and at the Ramesseum.

Rameses II is perhaps most renowned for being associated with the unnamed pharaoh of the biblical exodus. This tradition has strong support. The book of Exodus points out that the pharaoh had slaves working on massive building projects. Rameses conducted many building projects using slave labor, as did Seti I, his father. Also, early Christian writers, such as Eusebius of Caesarea (275–339 CE), connected Rameses II with the pharaoh of whom Moses demanded the release of the Israelites. Critics, however, point out that internal biblical chronology does not support this connection. They also point out that no Egyptian



The façade of the temple of Abu Simbel, with one of the four figures of Ramses II. Ramses II reigned for 66 years during the 13th century BCE.

Source: Matej Michelizza/iStockphoto.

writings mention an Israelite exodus associated with the time of Rameses II. This argument is dubious, because no Egyptian writings from the time of any pharaoh mention an Israelite mass departure. Although the identity is uncertain, Rameses II is as likely the pharaoh of the exodus as any (if indeed there actually was an exodus).

Rameses II continues to be prominent in Egypt. In 1955, Egyptians placed the 83-ton, red granite, colossal statue of Rameses II in Rameses Square in Cairo. However, they moved the statue in 2006 to the future site of the Grand Egyptian Museum on the Giza Plateau. Here, the image of Rameses will greet visitors near the museum's entrance. Furthermore, Rameses II has been the subject of many popular modern novels and movies, including

Anne Rice's 1989 book *The Mummy or Rameses the Damned* and the 1998 animated movie *The Prince of Egypt.*

Terry W. Eddinger

See also Archaeology; Calendar, Egyptian; Egypt, Ancient; Mummies; Rosetta Stone

Further Readings

James, T. G. H. (2003). *Rameses II.* Vercelli, Italy: White Star.

Tyldesley, J. (2001). *Rameses: Egypt's greatest pharaoh.* New York: Penguin.

Rapa Nui (Easter Island)

Rapa Nui is a small volcanic island in the eastern Pacific that marks the southeasternmost extent of the Polynesian Triangle, the northernmost point being Hawai'i, and the southwesternmost being New Zealand. Within the area described by these three points, Polynesians coming from West Polynesia settled virtually every island: Samoa, Tonga, and Fiji. Rapa Nui is currently part of Chile and is the only Polynesian island with this status. As one of the world's most isolated land masses, Rapa Nui has exerted fascination over the Western world for over a hundred years. This is primarily because of the *moai*—the huge monumental stone heads that are unique to that island. What is remarkable about Rapa Nui, and indeed about all Polynesian islands, is the amount of differentiation (material, cultural, and linguistic) that occurred among islands and archipelagos following colonization around 1,000 years ago—a relatively short time span for such extraordinary developments to take place.

Rapa Nui was first discovered by Europeans in 1722 and named "Easter Island" because it was spotted on Easter Sunday. Archaeology has revealed that Rapa Nui was settled roughly at the same time as virtually every other island in East Polynesia, around the 11th or 12th century CE. The Polynesians who settled the remote little island may have reached it by accident, but scholars are generally agreed that, once it was colonized, no return voyages were made to the "home" island. As they always did, the Polynesian colonists brought with them as many useful plants and animals as they could. However, few of these transplants survived both the long journey and the inhospitable terrain of the island. The only animals that endured were the chicken and rat (pigs and dogs not having been successfully transferred), and the sweet potato was the only crop that grew; the land was unsuitable for coconuts, breadfruit, and taro. The sweet potato is of South American origin (all other Polynesian plants and animals originally derive from Asia), so it is certain that Polynesian seafarers reached the American continent and transported the plant all over the Triangle.

Several centuries following colonization, the islanders began to quarry the soft volcanic tuff and to carve out the *moai,* the largest of which is 10 meters tall. Almost 900 of these statues have been inventoried on the island in various states of completion. The moai were highly standardized through the centuries and originally wore red tuff-carved topknots on the top of their heads and had inlaid coral and stone eyes. They are thought to be the representations of deified ancestors, and, while the moai are unique to Rapa Nui, stone and wood "tiki" statues are found throughout eastern Polynesia, pointing to an ancestral concept. However, nowhere else in Polynesia does anything exist to parallel the size of the moai. They are interesting because the Polynesians, using only stone tools and no machinery, were able to quarry, carve, transport, and erect these massive statues. Theories about how it was done abound, and experimentation has produced interesting results. Nevertheless the controversy continues and forms part of the island's allure. Probably before and certainly after Rapa Nui was discovered in 1722, the islanders began toppling the moai, sometimes in such a way as to break off the head from the shoulders. It is thought that this was done during the intense warfare that characterized life on the island; by the late 1800s no statues were left standing. Those that stand today have been restored in modern times.

The reasons for such intense warfare are no doubt varied, but it is generally agreed that limited land and food resources were major factors. While the island was originally forested, the Polynesians practiced slash-and-burn agriculture, resulting in accelerated erosion, which made the soil less fertile and productive. It is also thought that the islanders overharvested the lumber to transport and erect the moai. For these reasons Rapa Nui is often used as a case study for what happens when humans fail to plan ahead with respect to their environment.

Additional unique developments on Rapa Nui included the unique Birdman cult, in which the winner of an annual contest became the islandwide chief. Young men, specially chosen and trained to represent their districts, would swim out to a small offshore island to collect the season's first eggs of the sooty tern and return with the eggs unharmed. They would have had to brave rough seas, cliffs, and shark-infested waters to do so. Finally, in the 19th century Rapa Nui produced a number of wooden tablets incised with a strange hieroglyphic-type "alphabetical" writing, called *rongorongo*. All attempts at decipherment have been in vain, and most scholars agree that rongorongo was invented after its creators were exposed to European writing and that it may perhaps not be an alphabet, or indeed true writing, at all.

Rapa Nui will endure for centuries as the most mysterious of Polynesian islands, a favorite haunt of archaeologists, amateur scholars, writers, and tourists.

Robert Bollt

See also Anthropology; Archaeology; Ecology; Erosion

Further Readings

Bahn, P. G., & Flenly, J. (1992). *Easter Island, earth island*. New York: Thames & Hudson.

Fischer, S. R. (2006). *Island at the end of the world: The turbulent history of Easter Island*. London: Reaktion Books.

Flenly, J., & Bahn, P. G. (2003). *The enigmas of Easter Island*. Oxford, UK: Oxford University Press.

Rawls, John (1921–2002)

The American philosopher John Rawls's major works include *A Theory of Justice* (1971), *Political Liberalism* (1993), and *The Law of Peoples* (1999). Rawls's theory revived normative political philosophy, drew up an alternative conception to the prevalent utilitarian paradigm in ethics, and is the essential starting point for the communitarianism-liberalism debate. By developing an influential theory of just distribution between generations, Rawls points out the importance of the relation between justice and time.

Rawls sets out a theory of justice in order to determine an institutional order that should guarantee an equitable distribution of social primary goods (basic rights, freedom, opportunities, income). Following the classical political philosophers Immanuel Kant and John Locke, he develops a social contract theory that has as its starting point the thought experiment of an *original position*. This is intended to create fair starting conditions for agreeing on basic principles of social justice. The design of the original position is to stand in a *reflective equilibrium* with considered judgments of justice.

A predetermined condition for the process of negotiation in the original position is the information deficit of those involved. They have knowledge of general facts about society, politics, economics, and psychology, but the *veil of ignorance* prevents their knowing what social position or natural talents they have. Their temporal circumstances are also unknown to them, such as the stage of development of their civilization. The otherwise self-interested, that is, rational-acting, agents thus arrive at a reasonable solution to the question of distribution, because they have to abstract from their personal interests. Because no probabilities regarding one's own position within society are available, the decision is based on the risk-avoiding *maximin principle*. According to this, we choose as principles of justice those whose worst possible results are still better than the results of any other set of principles.

The first principle of justice is then that each person is to have an equal right to the most extensive system of equal basic liberties compatible with a similar system of liberty for all. An unequal distribution is allowed only in respect of the subordinated principles of social and economic justice. Inequalities are to be arranged so that they are to the greatest benefit of the least advantaged (*difference principle*), consistent with the just savings principle, and attached to offices and positions open to all under conditions of fair equality of opportunity.

The limitation of the difference principle by the just savings principle points to the connection between justice and time. Those in the original position don't know which generation they belong to. But because they know that they are contemporaries, they would have no reason to save for future generations. Rawls presupposes that the participants represent family lines. They have ties of sentiments to their descendants (original edition), or should conclude principles in the way that they would have wished earlier generations to have done (revised edition). The parties in the original position will then decide on a just savings principle for the preservation of basic freedoms, equitable institutions, and an appropriate accumulation of capital, in order to guarantee provision for the worst-off members of future generations. They ask what they could have expected from their forebears under the respective historical circumstances, and what they are prepared to pass on to their descendants. Because no knowledge of their own temporal position is available from behind the veil of ignorance, the parties must take the standpoint of every time period. They have no pure time preferences, because they have no reason to favor or discriminate against any particular position in time.

Rawls finds it necessary to put a discount on future benefit in order to avoid the consequences of a utilitarian just savings principle, which would sacrifice the present generation for the sake of future generations. It appears impossible, however, to determine the exact savings rate.

Robert Ranisch

See also Ethics; Kant, Immanuel; Morality

Further Readings

Freeman, S. (2007). *John Rawls*. London and New York: Routledge.

Rawls, J. (1999). *A theory of justice* (Rev. ed.). Oxford, UK: Oxford University Press.

Redemption

The word *redemption* is derived from the Latin *redemptio,* which means "buy back." The noun *redemption* and the verb *redeem* are used in English Bibles to translate Hebrew and Greek terms that refer to liberation from bondage by means of a ransom. The term is used metaphorically in the Christian Bible to refer to God's deliverance of people from their slavery to sin and death by means of Christ's death on the cross. It is similar to the biblical concept of salvation in that both bear the connotation of deliverance from an unfortunate state of being. Redemption, however, implies the payment of a ransom to deliver someone or something from bondage, whereas salvation implies rescue from a danger or threat. Although the term originates in the Judeo-Christian tradition, it can be applied more broadly to any religious conception of the transformation from an undesirable state of existence to a better one. In religions with a concept of a personal God, people require the help of a savior to deliver them from their situation. In religions that lack the idea of a personal God, people can undertake certain self-disciplines to redeem themselves. Many religions include the idea that a blessed afterlife awaits those who have been redeemed.

Redemption is related to the past, present, and future. It assumes that people experienced some kind of primordial bliss that was lost at some point in the past through disobedience or error. Later, God acted on behalf of his people to provide release from the consequences of their sin. Deliverance is available in the present and results in experiencing certain blessings in the present. Redemption also opens up the hope of a greater future, either a return to the previous state of perfection or a totally new creation.

Ancient religions promoted concepts that could be characterized as redemption. The Egyptian myth of Osiris, who was slain by his brother Seth but was brought back to life by Isis, offered salvation to those who identified with Osiris. The Romans sacrificed to vegetation gods in order to appease their wrath and ensure a bountiful harvest. Zoroastrianism taught that the redemption of the world would take place when Ohrmazd finally defeated Ahriman. Mithraism offered the hope of eternal life by participation in a bull-slaying ritual. Gnosticism promised initiates who learned the secret knowledge that their souls would return to their pure state after death.

In the Hebrew Bible, the deliverance of Israel from slavery in Egypt became the archetypal image of redemption (Exod 6:6; 15:13). When Israel was exiled in Babylon, the prophets reminded them that God was their redeemer (Isa 41:14; 43:14; 44:24; 49:26; 60:16; 63:16). The past event of the Exodus sustained their hope in the midst of their present circumstances. The verbs *pada* and *ga'al* are used frequently in the Hebrew Bible with the meaning of "release by means of a payment." For example, a person condemned to death for allowing his ox to kill someone could be redeemed by payment of a ransom (Exod 21:30). The term *redeemer* (*go'el*) was used to refer to a close male relative who paid the ransom (*kipper*) to buy back the mortgaged property of distressed relatives (Lev 25:25–34) or to buy them out of slavery (Lev 25:47–52). The term *redeemer* is applied to God elsewhere (Ps 19:14; 78:35; perhaps Job 19:25). People cannot redeem themselves (Ps 49:7); only God can redeem them (Ps 130:7–8).

In the New Testament, *redemption* and *redeem* are used to describe deliverance from sin and death, made possible by Christ's death and resurrection. Two groups of Greek words bear this meaning. One group consists of the verb *lytroō* ("redeem") and the nouns *lytrosis* and *apolytrosis* ("redemption"). The nouns *lytron* and *antilytron* are translated as "ransom." The other group consists of the verbs *agorazō* and *exagorazō*, which suggest the imagery of purchasing slaves in the marketplace. In Mark 10:45, Jesus states that his life would end in self-sacrifice that would serve as a ransom for others. Paul states that Christ has redeemed people from the curse of the law (Gal 3:13; 4:5). Sometimes the ransom is mentioned but not specified (1 Cor 6:20; 7:23), but elsewhere the self-sacrifice of Christ (Titus 2:14; Heb 9:15) and the blood of Christ are specified as the ransom price (Eph 1:7; Heb 9:12; 1 Pet 1:18–19; Rev 5:9). The New Testament writers never clarify whether the ransom was paid to Satan or to God. Redemption is also used to describe the future deliverance of the world, God's people, or the body (Lk 21:28; Rom 8:23; Eph 1:14; 4:30).

Later Christian theologians attempted to explain more precisely how Christ's death provided redemption from sin and death. These are referred to as theories of the atonement, a term coined in English to refer to reconciliation with God ("at-one-ment"). The dominant view for the first thousand years was the *Christus Victor* view, which held that Christ defeated Satan and evil spiritual powers by means of his death. Anselm of Canterbury argued that Christ satisfied God's just punishment for sin. Abelard's "moral influence" theory argued that Christ's love shown in his self-sacrifice motivates others to love God and follow his ways. Calvin and other Protestants went beyond Anselm's "satisfaction" theory to develop a "penal substitution" theory: Christ bore God's wrath as the penalty for sin in place of others. More recently, theologians such as Karl Barth, Rudolf Bultmann, and E. P. Sanders have emphasized redemption through participation in Christ's death and resurrection. Most theologians do not view these theories as mutually exclusive, but they tend to argue that one represents the central or dominant idea of the New Testament authors. These theories of the atonement have in common the belief that Christ's death and resurrection was an epoch-changing event that enables people to experience the blessings of the age to come already in the present.

Although other religions may not use the specific terminology of redemption, some teach the concept of deliverance from an unfavorable state of being to a blessed state. They offer the hope of a better future that will replace the burdens and shortcomings of the past. This change of state can be achieved by one's own efforts or by relying on divine help. In Islam, people can receive the mercy of God on the Day of Judgment by following the guidance of the Qur'an. In Buddhism, one can achieve a state of *nirvana* by following the Eightfold Path. In Mahayana Buddhism, the *bodhisattva* lives in a compassionate and sacrificial way so that his limitless store of merit can be transferred to other unworthy persons in order to liberate them. In Hinduism, one can obtain release (*moksa*) from *samsara*, the cycle of death and rebirth.

Gregory L. Linton

See also Abelard, Peter; Anselm of Canterbury; Bible and Time; Christianity; Egypt, Ancient; Eschatology; Judaism; Last Judgment; Salvation; Sin, Original

Further Readings

Hill, C. E., & James, F. A., III (Eds.). (2004). *The glory of the atonement: Biblical, theological, & practical perspectives*. Downers Grove, IL: InterVarsity Press.

Lyonnet, S., & Sabourin, L. (1970). *Sin, redemption, and sacrifice: A biblical and patristic study.* Rome: Biblical Institute.

Sharpe, E. J., & Hinnells, J. R. (1973). *Man and his salvation: Studies in memory of S. G. F. Brandon.* Manchester, UK: Manchester University Press.

Regress, Infinite

Infinite regress arguments are used by philosophers as methods of refutation. A hypothesis is defective if it generates an infinite series when either such a series does not exist or its supposed existence would not serve the explanatory purpose for which it was postulated.

The English philosopher John Locke (1632–1704) criticized the view that an act is free only if we freely choose whether to perform that act. Because freely choosing is itself an act, he argued, this commonly held theory is absurd because that act of choice must then, according to the theory, be preceded by still another act of choice that is free. It generates an infinite series of acts of free choice, one act of choosing determining the acts of another, and so on *ad infinitum*. Because such a series does not in fact occur, he argues, this account of what it is to act freely must be wrong.

Infinite regress arguments are frequently used to demonstrate that an explanatory hypothesis cannot in principle explain what it is supposed to explain. It would be absurd to suppose that the only way we can justify any of our beliefs is by appealing to other beliefs. Such an explanation is fatally flawed, because it generates either an endless chain of beliefs or a circular chain. And because we certainly don't entertain an infinite number of beliefs, the chain must circle back on itself. But a circular explanation doesn't explain anything; hence an alternative account of belief-justification is needed. The foundationalist answer is to say that the foundation of some beliefs is experience itself, not just beliefs about experience.

Some infinite regresses are linear, not circular. Suppose someone thinks the explanation as to why anything at all exists is that God made things exist. Then the God-hypothesis, when thus invoked, simply adds to the burden of explanation. On pain of infinite regress, we cannot explain why anything at all exists by invoking the existence of still another entity (God). For then that entity's existence calls for explanation.

Merely generating an infinite series is not in itself objectionable. The claim "Every natural number has a successor" entails an infinite series of natural numbers. Likewise, the claim "For every event there is a temporally precedent event that is its cause" entails both an infinite series of events and an infinite series of moments of time at which they occur. Yet the existence of an infinite series of natural numbers is mandated by logic and mathematics, and the concept of a beginningless series of events and temporal moments is not self-contradictory. There is no warrant in logic therefore for Thomas Aquinas's claim that these infinite series "cannot" go on forever. This is a misuse of an infinite regress argument.

Throughout the history of philosophy, infinite regress arguments have sometimes been used to demonstrate that ultimately some features of the universe cannot, on pain of infinite regress, be explained at all. The brute fact that some things exist is just one example.

Raymond Dynevor Bradley

See also Aquinas, Saint Thomas; Cosmological Arguments; Eternity; God and Time

Further Reading

Passmore, J. (1961). *Philosophical reasoning.* London: Duckworth.

Reincarnation

Reincarnation (also called *transmigration* or *metempsychosis*) is the religious or philosophical view that humans, and possibly also animals and plants, have multiple existences. This view is most prevalent in Asian religions of Indian origin, such as Hinduism, Jainism, Buddhism, and Sikhism. However, it also appears in the religious and philosophical thought of "primitive" religions and in some ancient Middle Eastern and Greek religions like Manichaeism, Gnosticism, Orphism; and the work of some early Christian thinkers, such as Origen, may also be interpreted as referring to reincarnation. The modern current of thought called theosophy also teaches reincarnation. Among recent philosophers, J. M. E. McTaggart (1866–1925), Sarvepalli Radhakrishnan (1888–1975), and John Hick (1922–) are prominent exponents.

In ancient Greece, Orphism held that the soul goes through multiple incarnations (in humans or through other mammals) until it attains release from the cycle of birth and death. At this stage, the soul recovers its original pure state. Pythagoras (c. 569–c. 496 BCE) and Plato (c. 427–c. 347 BCE) accepted similar views.

Reincarnation is generally linked with the moral cosmic law of Karma ("act"). Hindus, Jains, and Buddhists, for instance, hold that actions in one life can affect conditions—particularly the initial conditions—in a future life of the same individual. In Hinduism this process of birth and rebirth goes on indefinitely until one achieves *moksha,* the realization that the individual soul (*atman*) and the absolute soul (*Brahman*) are one.

Jainism puts particular emphasis on the method of nonviolence, *ahimsa,* to achieve this.

Buddhism adds the wrinkle that reincarnation occurs without the existence of an unchanging, substantial soul. Buddhists view the individual as a complex of psychophysical elements and states (*skandhas*) changing from moment to moment. Upon death, the individual who has not extinguished desires or cravings (and not achieved *nirvana*) will continue as a composite of psychic dispositions and energy. This psychic composite will then seek/require a new incarnation.

Among Tibetan Buddhists, spiritual leaders, or *lamas,* are commonly viewed as reincarnations of preceding lamas. Selection of the new lama, from a pool of child candidates, is often based on the right child recognizing unique possessions of the previous lama.

The leading scientific researcher on reincarnation, or at least on the past-lives possibility, is Ian Stevenson, head of the Department of Neurology and Psychiatry at the University of Virginia. His studies involve investigating the truth of detailed claims regarding alleged past lives, usually claims made spontaneously by children. Some of these detailed claims regarding past people, he concludes upon investigation, point decidedly at past lives as the best explanation. A recent dispassionate assessment of Stevenson's studies by the philosopher Robert Almeder affirms that the evidence these studies provide for reincarnation is strong.

One of the most fascinating versions of reincarnation is proposed by the Jane Roberts/Seth books. Seth is a "personality" that dictated the books through the American medium-poet Roberts (1929–1984). In this version, all of time is ultimately simultaneous. Hence, our historical events (past, present, and future) are like many parallel programs taking place along different electromagnetic frequencies (like simultaneous television programs). One can generally focus only on the present program/life, but in principle one's consciousness could switch programs and experience "past" or "future" ones—because these are in fact taking place simultaneously. Occasional glimpses of other "past" or "future" lives would constitute examples of such switches.

The central *moral* rationale for this theory is that it alone provides for cosmic justice. Only in some multiple-lives view could all individuals receive fair treatment over the course of their existence. Only in such a view, for instance, could humans have equal chances at mastering whatever moral or spiritual wisdom is necessary for advancement to higher "heavenly" realms. One-life theories would make this learning too chancy, given that many children die in infancy and that others face impossible circumstances.

Critics have responded that reincarnation does not really help here because of the lack of conscious memory of one's past lives' deeds, mistakes, and lessons. Not remembering one's past makes learning across lives impossible. Defenders of reincarnation reply that improved wisdom and increased moral sensitivity can occur across lives even in the absence of memory of past lives. For instance, one could find oneself in one's current life more attuned to the needs and suffering of others—human and nonhuman—without knowing *how* one has become so compassionate. The *how* could be due to one's past inner and outer accomplishments—even if they are currently forgotten.

A second standard philosophical objection to reincarnation questions the metaphysics of the vehicle carrying multiple personalities across lives, given the fact of bodily discontinuity. What makes the current "I" the same underlying being as the "I" of a person who lived in, say, the 1700s? Is it the same "soul-substance"? But what is that? What would make our two souls two, as opposed to one, other than a memory connection between them? And even if there were a seeming memory connection, how could this be separated from one's having knowledge of another person's inner life acquired in some odd, but non-memory, way? Do *genuine* memory links (across persons in different bodies) not require first establishing numerical sameness of souls? Does this, in turn, not first require genuine memory links? This looks like a vicious circle.

Defenders of reincarnation generally hold that the memory links between lives may indeed be retained but at a subconscious level during those lives, so as to prevent memory overload and to allow for a fresh perspective in each new life. Moreover, such memory links might become conscious (to the underlying soul) during the span "in between" lives, or at the end of the multiple lives series. As for what makes two apparent souls the same single soul, the answer could be some indefinable unique inner feel, much like two sets of fingerprints or of two DNA samples that turn out to point to one person. The individuality of a person, defenders claim, remains rather inexplicable even over a single life.

Carlo Filice

See also Afterlife; Buddhism, Mahayana; Buddhism, Theravada; Buddhism, Zen; Hinduism, Mimamsa-Vedanta; Hinduism, Nyaya-Vaisesika; Hinduism, Samkhya-Yoga; Nirvana; Religions and Time

Further Readings

Almeder, R. F. (1992). *Death and personal survival: The evidence for life after death.* Lanham, MD: Rowman & Littlefield.

Filice, C. (2006). The moral case for reincarnation. *Religious Studies, 42,* 45–61.

Hick, J. (1976). *Death and eternal life.* New York: Harper & Row.

Roberts, J., & Butts, R. F. (1994). *Seth speaks: The eternal validity of the soul.* San Rafael, CA: Amber-Allen.

Stevenson, I. (1974). *Twenty cases suggestive of reincarnation.* Charlottesville: University Press of Virginia.

Stevenson, I. (1987). *Children who remember previous lives.* Charlottesville: University Press of Virginia.

Relativity, General Theory of

The theory of general relativity (GR) is one of the main milestones of modern cosmology. Derived by Albert Einstein at the beginning of the 20th century, it encompasses the description of the motion of bodies within a gravitational field. Furthermore, its postulated predictions have been tested and supported by many observations and make GR therefore a widely accepted theory. General Relativity describes many phenomena, such as the relativity of time and cosmic evolution, within a gravitational field.

Meaning of Relativity

As in special relativity (SR), the term *relativity* corresponds to two or more observers who make measurements with respect (relative) to each other. This means that there exists no absolute point or frame to which measurements can be referred. To picture this, consider a passenger inside a train that passes by a station. This passenger observes a trolley travel inside the train with a velocity of about 0.3 meters per second. To an observer standing at the station, that trolley appears to have the velocity of the train plus the 0.3 meters per second. The two measurements of the velocity of the same object differ, depending on the position of the observer. This example demonstrates that there is no independent point from which the observations appear to be the same; they can only be regarded relative to each other. In terms of physics, there is no absolute preferred frame (position) in which physical processes are measured and described. Every observer located at an arbitrary position, like the train or the platform, describes the movement correctly. The most important aspect is that, for all freely moving observers, without the presence of any other forces the physical laws are the same independent of their respective relative velocity. Another fundamental fact of SR and GR is the constancy of the speed of light. In each frame, it has the same value.

The Equivalence Principle

In GR, the argument of relativity is extended further in order to include gravity. Einstein's realization was in understanding that the gravitational force is equivalent to an inertial force and in thereby concluding his *principle of equivalence*. (An inert force appears if movements are described in accelerated frames, like standing in an accelerated subway.) Imagine a free-falling elevator in a building. To a person standing within it, it seems that there is no gravity, because the inert force counterbalances the gravitational force. However, to an observer standing outside, it is clear that the elevator is accelerated toward the ground by the gravity field of the earth. Inside the elevator, the person does not feel the gravitational field, and all physical laws within this frame are written without considering gravity.

A further example to demonstrate this equivalence is given by the picture of an astronaut inside a spaceship. Let us consider two special cases, one with the spaceship standing on the surface of the earth and one with the spaceship being constantly accelerated. In the latter case, the astronaut will feel the inert force due to the acceleration, and with that a certain weight, as if a gravitational force is acting. On the surface of the earth, however, gravitational force is exerted on the astronaut inside. But the astronaut is not able to distinguish whether he or she is at rest within a gravitational field, or experiencing an inertial force due to the acceleration. Hence, gravitation can be seen either as the attracting force or the inertial force. This means that gravity can be "switched off" locally by going into a frame in which the inert force cancels the gravitational force. Such a system could be a free-falling elevator or a satellite in orbit.

Note that both examples above imply that the inertial masses must be equal to the gravity masses. This equality is stated by the so-called *weak equivalence principle,* whereas the *strong equivalence principle* comprises the indistinguishability between a free-falling or accelerated system and a system that is at rest within a gravitational field.

Naturally, most physical processes will be described in a local system without gravity. The resulting equations of motion, for the objects under consideration, can be transformed into a system that includes gravitation. In the latter system, the equations will be different from those in the local frame. This is due to the fact that gravity alters the underlying geometry of spacetime. Unlike classic physics, where time is considered as absolute, in SR and GR it is connected to the space coordinates. The gravitational field distorts this geometry and leads to a curving of spacetime. The basic idea is to connect the spacetime curvature with the gravitational attraction of massive bodies. Many consequences arise from this statement.

Gravity and Time

A massive body curves spacetime due to its induced gravitational field, as a ball will curve the surface of a stretched cloth. This distortion has many consequences—for example, the bending of light near massive objects. This feature, observed during the solar eclipse in 1919, was a further experimental proof for GR. The first experimental verification of GR was the explanation of the perihelion precession of Mercury, as predicted and described by GR. An interesting case we would like to address is the influence of gravity on time, which arises naturally in GR.

Let us take the example of the spaceship again, with two astronauts inside. One stands at the bottom, the other at the top. Both carry clocks with them in order to measure the time spans between two light impulses emitted by a laser located at the bottom. If the spaceship is floating freely in space (without being accelerated and not under the influence of a gravitational field) then the measured time span between the two light impulses will be the same, that is, the astronaut at the bottom will measure the same time among two light emissions as will the other at the top, who measures the duration between their arrivals. The same is true if the spaceship moves with a constant velocity. It will take longer for the light to reach the top, but because the spaceship does not change its velocity, the additional distance the light has to cover will be the same for both impulses. Therefore, the measured time span of both observers will be equal.

However, if we transfer this situation to a spaceship that is undergoing acceleration, the time intervals between the two clocks will differ. The astronaut at the top will observe a longer time span between the light arrivals as compared with his partner at the bottom of the spaceship (see Figure 1). To understand this, consider the time that the light needs to reach the top. In the case of the accelerated spaceship, the distance the light has to cover is longer due to the additional distance the accelerating spaceship travels compared to the spaceship with constant velocity. Therefore, the time for the first light impulse to arrive is larger. But due to the acceleration the second impulse will need even more time to arrive at the top, because the distance it has to cover is larger, as it was with respect to the first impulse. Therefore, the time span between the light arrivals will be longer.

This result is not very surprising. However, when we recall that a constant accelerated system cannot be distinguished from one that is at rest within a gravitational field, it leads to the conclusion that the same behavior will be observed in a system under the influence of gravity. Thus the time is running faster at the top of the spaceship (the measured time intervals are longer) with respect to the bottom (the measured time spans are shorter). Hence, gravity affects the passing of time!

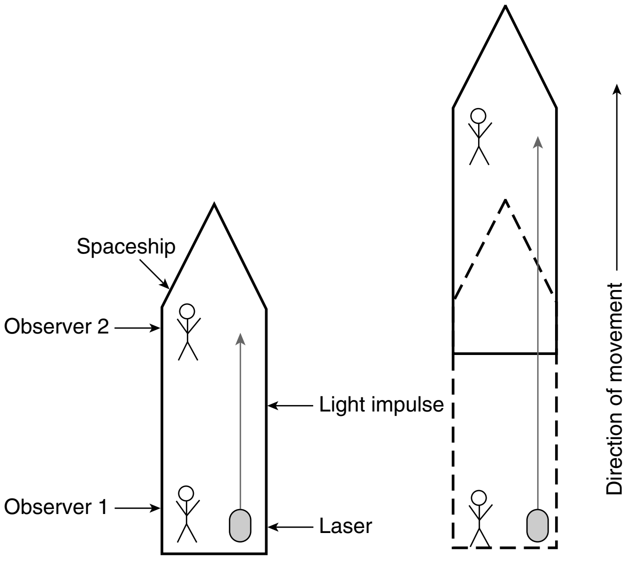


Figure 1 The case of the accelerated spaceship

Notes: Both observers measure the time interval between two light impulses. One is located at the top, the other at the bottom. Due to the acceleration, the velocity of the spaceship changes, and therefore there is a difference between the distances the two impulses cover. For the second light impulse, it will take more time to arrive at the person standing at the top. Therefore, the time intervals the two observers measure will be different. The upper astronaut will obtain a longer time span between the impulses, while the lower one will observe a shorter time span. Thus, time runs more slowly at the bottom compared to the top.

Another very famous experiment to measure the time difference caused by the gravitational field of the earth was been done by R. V. Pound and G. A. Rebka in 1960. They used the so-called Mösbauer effect to verify the time difference between two clocks, one at the top and the other one in the basement of a tower at Harvard University.

There are many more interesting features described by GR. However, one major problem that arises is the inconsistency between GR and quantum mechanics. There have been attempts to unify both theories in order to obtain a theory called quantum gravity. At the moment the most promising one is presented by string theory, but experimental proof of this theory has not yet been accomplished.

Veronika Junk

See also Cosmogony; Einstein, Albert; Galilei, Galileo; Light, Speed of; Newton, Isaac; Quantum Mechanics; Relativity, Special Theory of; Space; Space and Time; Spacetime, Curvature of; Spacetime Continuum; Time, Relativity of; Twins Paradox

Further Readings

Deutsch, D. (1997). *The fabric of reality: The science of parallel universes and its implications.* New York: Penguin.

Einstein, A. (1961). *Relativity: The special and the general theory.* New York: Three Rivers.

Guth, A. H. (1997). *The inflationary universe: The quest for a new theory of cosmic origins.* Cambridge, MA: Perseus Books/Helix Books.

Magueijo, J. (2003). *Faster than the speed of light.* New York: Penguin.

Weinberg, S. (1972). *Gravitation and cosmology: Principles and applications of the general theory of relativity.* Hoboken, NJ: Wiley.

Relativity, Special Theory of

The special theory of relativity (STR) is a fundamental theory of space and time that was formulated and published in 1905 by Albert Einstein (1879–1955). The theory gives up the notion of the absolute and independent character of space and time. Length and time measures change according to an observer's state of motion. Special relativity is based on the assumption that the laws of nature have the same form in any uniformly moving frame of reference (the *principle of relativity*). As a most popular result of the STR, Einstein derived the famous relation $E = mc^2$, which states the equivalence of matter and energy. Over the years the STR has been confirmed in many tests and experiments. Along with the quantum theory, it is considered a foundation pillar of modern physics.

The Principle of Relativity and Inertial Systems

Any quantitative law of mechanics, or rather physics, is expressed with respect to some fixed spatial and temporal frame of reference represented by three spatial coordinates plus a time coordinate. This can be realized in a terrestrial laboratory providing the frame for a measurement. An experiment may be performed equally well in a racing car, cutting a corner at high speed. Quite obviously these two systems are not equivalent: Due to the permanent change of direction (i.e., the velocity vector), pseudo forces appear within the racing car. These prevent, for example, a body, thrown straight upwards by the driver, from following a simple straight trajectory as it would in the stationary laboratory of an institute. The trajectory within the racing car reference does not follow the simple Newtonian law of motion. Among all possible frames of reference, physical laws take the simplest forms in so called *inertial systems*. These are systems in which bodies that are exposed to no pseudo forces whatsoever, like centrifugal or Coriolis forces, rest or move uniformly; that is, with constant speed and direction. To a good approximation, the earth's surface can be regarded as an inertial system. Although any point on it is moving in a complex way, the appearing pseudo forces are negligible.

Four centuries ago, the Italian naturalist Galileo Galilei (1564–1642) stated that uniform motion is not an inner property of a body but rather a quantity that is to be defined relative to a framework or an observer. Galileo illustrated this by the example of a body resting on a uniformly drifting boat on a silent lake. The question as to whether the concerning body is moving has to be answered in different ways, depending on whether an observer is sitting in the boat or resting on the bank. Both systems, boat and bank, can be considered as inertial systems in an idealized case. Isaac Newton (1642–1727), though sharing Galileo's view in considering relative motion as relevant exclusively, nevertheless assumed the existence of absolute space. He argued, however, on the basis of spiritual rather than physical criteria and admitted the impossibility of proving the existence of absolute space.

The Principle of Relativity Beyond Mechanics

After centuries of empirical research, classical electrodynamics—the theory of electromagnetic fields' and charged particles' dynamics—was brought to its early perfection in the 1860s by the Scottish physicist James Clerk Maxwell (1831–1879). In an accomplishment similar to Newton's reduction of classical mechanics to just three fundamental laws, Maxwell succeeded in expressing the nature and dynamics of electromagnetic fields with a system of just four equations. Following these Maxwell equations, the propagation of light should always occur with the same universally constant velocity. This was, however, in disagreement with Galileo's principle of relativity: The migration velocity of a light beam should certainly have different values depending on whether a resting or a moving observer is watching it. Furthermore, a constant universal speed of light should have the consequence of an absolute space, defined as the frame within which the light velocity adopts the well-known value of 300,000 kilometers per second.

Michelson-Morley Experiment and the Abandonment of "Ether"

It had long been presumed that, like sound waves, which cannot propagate without substantial material, electromagnetic waves should run within some medium of unknown nature, the so-called ether. This picture is clearly accompanied by the concept of an absolute space, namely the ether rest frame. In 1881, for the first time, the physicist Albert A. Michelson (and repeatedly later together with Edward W. Morley) performed a historical experiment to verify or exclude the existence of ether. For this purpose Michelson constructed a set of mirrors placed on two perpendicular tracks, along which he sent two light beams that would finally superpose on a screen. As is well known in the context of waves, one expected to observe some characteristic pattern of interference. The experimental geometry was set up so that one of the beams ran along the earth's orbit around the sun, and the other ran perpendicular to it. This meant the first beam would have to propagate against the ether drift, like a swimmer against the stream, while the other was not affected this way. According to the ether concept, this should have caused the two light beams to have slightly different velocities. If the whole gadget is turned by 90°, the roles of the beams—as well as their velocities—must exchange. This must inevitably lead to visible modification of the interference pattern on the screen. The experiment, conducted with highest accuracy and precision, did not show any such modification, however; the run time of the beams was evidently not influenced by some ether drift. This important result caused scientists to doubt the existence of ether.

The Lorentz Transformations and Einstein's Principle of Relativity

Nevertheless most scientists at that time were not willing to give up the idea of absolute space and time. The Dutch mathematician and physicist Hendrik A. Lorentz (1853–1928) conceived a mathematical gimmick to reconcile the Michelson-Morley result with the ether concept. He suggested any object moving with respect to the ether would contract by a tiny amount along the direction of motion. For this he postulated some mechanism of electromagnetic nature, acting on an atomic scale, but not yet determined in greater detail. Furthermore he invented a purely mathematically motivated new time coordinate, the *proper time,* as well depending on the reference system's velocity against the ether. With his *Lorentz transformation* rules it was perfectly possible to describe any physical scenario from any inertial system's perspective and still preserve the principle of relativity for electrodynamics. The Maxwell equations are, purportedly, invariant against the Lorentz transformation.

In the first years of the 20th century, Albert Einstein, then a "3rd class expert" in the Swiss patent office, started to address the physical and philosophical problem of space and time. Presumably without knowing about the Michelson-Morley result, he was convinced that absolute concepts of space and time would not be maintainable. He further postulated a universal version of Galileo's (mechanical) principle of relativity. According to Einstein, not only the rules of mechanics but rather any law of nature should keep the same form in any inertial system. This theory again assumes the universal constancy of the speed of light independent of the observer. He published his epoch-making work "*Zur Elektrodynamik bewegter Körper*" ("On Electrodynamics in Moving Bodies") on September 25, 1905. Therein he interpreted in a revolutionary manner Lorentz's mathematical preparatory works in terms of really varying spatial and temporal measures, depending on the observer's state of motion. Distances should reduce with increasing velocity, just as do time intervals. The speed of light acts as a universal limit: Neither matter nor information can propagate faster than light.

A Train, Tracks, and the Relativity of Simultaneity

It is possible to demonstrate the relativistic concept of time in a vivid manner using the term *simultaneity.* As a thought experiment, we consider a train passing over a track with considerably high velocity. Let the train be open along its complete extension, so that the light of a bulb at the middle of the train can reach both the front (F) and the back (B) inside. There in each case a photocell is located, activating a signal when a light beam is detected. Let the train have the length L. We denote the signal event at the front/back end by S_F and S_B respectively. At some time t_0, a passenger switches on the light, located exactly at the halfway point M *(middle)* between the detectors at F and B. The observer inside the train and in motion along with the train is called the train observer. He will observe that the light beams approach both of the train endings F and B with identical speed and that the signals S_F and S_B are activated at the identical time $t_1 = t_0 + ½\ L/c$ (where c is the speed of light). Thus the events S_F and S_B appear *simultaneous* to the train observer. We call the time interval $\Delta t = t_1 - t_0 = ½\ L/c$ the runtime of the light beams in the train inertial system.

Let us now take the perspective of a person resting on the track (the track observer) and repeat the simple experiment. Both observers synchronize their clocks at the time t_0, when the light bulb in the train is switched on. Further we choose the time t_0 so that the bulb at M is just passing the track observer exactly at time $t_1 = t_0 + \Delta t$ (that is, the time when the signals are activated in the train inertial system). After the light bulb is turned on, the light beams in each direction are propagating with identical (light) speed c. During the time interval Δt, the beam approaching the front end covers the distance $c\Delta t$ towards F. During the time change Δt, the train (and so F) is moving on by a distance $v\Delta t$, where v is the speed of the train. Thus the front signal S_F will not yet be activated at $t_1 = t_0 + \Delta t$, because F, moving forward at the speed of the train, tried to "escape" from the light beam moving forward behind it. On the other hand, the back end signal S_B will move a little toward the light beam traveling backward during the same time and will thus be activated a little earlier than t_1. From the track observer's view, this obviously means that the signal event S_B occurs earlier than S_F—while it was simultaneous for the train observer. Nevertheless both inertial systems—train and track—are equitable in the physical sense. The concept of simultaneity is in fact dependent on the observer.

The Light Clock in the Express Train

In a similar way it is possible to demonstrate a consequence of the Lorentz transformations, according to which the clock of a moving observer is running more slowly than a resting clock. For this purpose we construct a light clock in the following way. On both the ceiling and the floor of a train car we fix mirrors that face each other, their reflecting surfaces adjusted horizontally face to face. At time t_0 we send out a very short light signal (say one photon) from the floor mirror to the ceiling mirror; this signal will then be reflected up and down between the mirrors for an arbitrary time. We denote the train velocity by v and the distance between the mirrors by d. The situation is trivial in the train inertial system. The photon starting at t_0 reaches the upper mirror at $t_0 + d/c$, is reflected, arrives at the lower mirror at $t_0 + 2d/c$, gets to the ceiling mirror again at $t_0 + 3d/c$, and so on. We call the time interval between the two reflections Δt.

Next we analyze the light clock from the view of an external observer, resting on the track again, whose clock is synchronized with the clock of the train observer at t_0. Because the mirrors move along with velocity v, the movement of the photon also has a forward velocity component, as it remains between the mirrors. If it continued to move up and down with light speed c, the photon would obtain a total velocity $c' = \sqrt{(c^2+v^2)}$ that is, the vector sum of the horizontal and the upright components of its movement), in clear contradiction to the universal constancy of the speed of light. The upright velocity component must be lower than c by a small amount in order to not exceed a total velocity of c. Necessarily, due to the slowed perpendicular velocity, the time intervals $\Delta t'$ between two reflections increase. As $\Delta t' > \Delta t$, the light clock is "ticking" more slowly in the track observer's frame.

The existence of time as a relative quantity is confirmed today by a multitude of experiments. Well known are the measurements with the help of atomic clocks, covering long distances in airplanes. When they return to the place from which they departed, these clocks show a delay by a tiny fraction of a second compared with the clocks resting at the airport. Another proof for this so-called *time dilation* is the fact that certain elementary particles, *muons*, created in high layers of the atmosphere by cosmic rays, reach the earth's surface at a much higher rate than one might expect according to their tiny average lives. In the relativistic framework, this result is interpreted in terms of a considerably slowed run of the muons' "clocks." Thus the muons obtain significantly longer average lifetimes and can easily reach the ground instead of decaying halfway to the earth's surface.

Analogous to the effect on time intervals, spatial measures are also subject to relativistic effects at high velocities. As recognized by Lorentz prior to Einstein, length scales in a moving frame of reference are contracting from a resting observer's perspective, an effect called the *Lorentz contraction.* Whereas Lorentz considered this as a real electromagnetic effect on an atomic scale and a result of motion against the ether, in Einstein's interpretation it was generated purely by the change of reference frame. The above-mentioned argument, whereby muons reach the earth's ground due to their enlarged lifetimes, is quite obviously useless from the muons' own perspective: In their view, rather, a clock resting on the earth's surface is running more slowly than their own! Nevertheless the muons *do* reach the earth. The reason is that from their perspective, the thickness of the atmosphere—the distance they have to pass down to the earth—is greatly shortened due to the Lorentz contraction. This explains again conclusively the high rate at which muons are detected on the ground.

Effects of relativistic nature lack any relevance for our daily lives. This is simply due to the enormously high speed of light compared with any human experience. Relativistic effects of noticeable degrees only occur in frames of reference moving against each other at at least 10% of the speed of light. Muons from high up in the atmosphere arrive at more than 99% of this speed. Our lives would be considerably different if the speed of light were much lower, perhaps 200 kilometers per hour or so. Then a motorcyclist would confront relativistic effects, and a fast car driver could travel the entire length of US Route 66 and back while aging only a few minutes.

Space, Time, and Spacetime

In the framework of special relativity, space and time lose the absolute character that has been considered self-evident over millennia. The German physicist Hermann Minkowski (1864–1909), who was devoted to a stringent mathematical formulation during his last years, suggested that we should understand space and time henceforward as components of a four-dimensional spacetime. In the common three-dimensional position, space—the distance *d* between two points—is calculated employing the appropriate *x*-, *y*- and *z*-coordinates as

$$d^2 = (x_1-x_2)^2 + (y_1-y_2)^2 + (z_1-z_2)^2 = (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2.$$

In the four-dimensional *Minkowski space,* the spatiotemporal "distance" between two events (i.e., between points in spacetime) is determined in an analogical manner using the formula

$$\Delta s^2 = (c\Delta t)^2-[(\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2].$$

The light speed c in the first summand of the right-hand side guarantees the time coordinate to obtain the dimension of a length and can thus be directly compared with the spatial components. Δs is of special interest, because it is invariant against Lorentz transformations. This means that the spatiotemporal distance $(\Delta s)_A$ between two events measured by some observer A is the same as $(\Delta s)_B$ observed from a moving system B.

The Equivalence of Matter and Energy

The day following the submission of his work "On Electrodynamics of Moving Bodies," Einstein sent a follow-up paper to the journal *Annalen der Physik* titled "*Ist die Masse eines Körpers ein Maß für dessen Energieinhalt?*" ("Is the Mass of a Body a Measure for its Energy Content?") Therein he discusses the consequences of momentum (i.e., the product of mass and speed of a body) in a theory of relativity. In this context Einstein shows in a simple mathematical derivation that the mechanical energy E of a body and its mass m are always connected via the relation $E = mc^2$. Mass and energy are thus nothing but distinct realizations of the same physical quantity. This plays an important role in physics, for example, in the study of nuclear bonds. A helium nucleus, for example, has a mass lower than the sum of its constituents' masses (two protons plus two neutrons). The mass difference corresponds to the amount of energy needed to dismantle the nucleus to its parts. Equally, the Einstein formula explains the destructive power of nuclear weapons, which are based on the release of the very same binding energy.

Helmut Hetznecker

See also Cosmogony; Einstein, Albert; Galilei, Galileo; Light, Speed of; Newton, Isaac; Quantum Mechanics; Relativity, General Theory of; Space; Space and Time; Spacetime, Curvature of; Spacetime Continuum; Time, Relativity of

Further Readings

Brown, H. R. (2005). *Physical relativity: Space-time structure from a dynamical perspective.* Oxford, UK: Oxford University Press.

Einstein, A. (1988). *Relativity: The special and the general theory, a clear explanation that anyone can understand.* New York: Gramercy. (Original work published 1920)

Jammer, M. (2006). *Concepts of simultaneity: From antiquity to Einstein and beyond.* Baltimore: Johns Hopkins University Press.

Petkov, V. (2005). *Relativity and the nature of spacetime.* Berlin: Springer.

Woodhouse, N. M. J. (2003). *Special relativity* (Springer Undergraduate Mathematics Series). Berlin: Springer.

Religions and Time

Religious beliefs and cultural traditions set the tenor for the way humans conceive the individual self, the world, and the relationship between the two. Integral to these beliefs are the various conceptualizations of time, a necessary element in any attempt to explain human existence. Although each religious culture's understanding tends to have unique aspects, nevertheless most follow one of two basic ways in which time has been and continues to be conceived. These are time as a line and time as a circle. Linear time is apparent in daily life. Birth is followed by growth, aging, decay, and death. Time always seems to move ever forward in a straight line. Yet the cycles of life, as seen in stars, seasons, animal migrations, and so forth, are also readily apparent. Nature exists in cycles. Both images thereby play important roles in the way humans conceive time, and in the vast majority of traditions, there is a blending of the two, with one tending to be dominant. While linear time commands the greatest attention in the Abrahamic religious traditions, in the Westernized urban world, and in science, cyclical time has been integral to most indigenous and most Asian religious and cultural traditions. This entry examines the roots and basis for these conceptualizations of time in various religious traditions and how they effect the beliefs and practices of the people who adhere to them.

Indigenous Traditions

Indigenous peoples have typically lived in a world in which the physical and spiritual realms are closely connected. Their cosmogonic myths, or origin stories, explain their beliefs regarding Creation and validate their own origins as well as their connection to each other, to their homeland, to the creator spirit or spirits, and to the spirits of their ancestors. These and other myths validate traditional practices, social mores, and even political order, and provide members a sense of belonging to a community and a place, a sense of order and consistency, and a set of religious beliefs and behavioral guidelines. This is why land, ethnicity, culture, and religious beliefs all intertwine with indigenous peoples. Time and space are a part of most Creation stories as well, and each has its sacred characteristics. Often associated with origin stories are eschatological beliefs regarding end times, and together they form an integral part of most religious traditions and indigenous cultures. Such stories and beliefs in nearly all traditions derive from the basic longing in humans to have some sense of their origins, identities, and destinies. In speculating on both beginnings and finalities, there also tends to be an understanding of time that mixes linear and cyclical elements. These are not confined to indigenous traditions and can be found in nearly every religious belief system, in one form or another.

The homelands of indigenous peoples are typically marked by sacred space and infused with the presence of spirits. The intimate relationship between individual and land is vital to self-identity. To the extent that this relationship is physical and material, it exists within time, has a beginning and an end, and is temporal. To the extent that it exists as connection with the world of spirits and ancestors, it exists outside physical time, and is secure, more permanent, and sacred. It enhances both stability and a sense of timeless belonging. Traditions help maintain this relationship, for through them each subsequent generation forms an unbroken connection back to the original ancestors and their primordial beginnings.

Rituals also play an important role in this connection. During ritual, the linear motion of time is suspended, and a communion with the eternal is made. Some rites, known as rituals of return, may take participants back to the time when scared events occurred or may bring the past into the present with Creation happening again and sacred events being replayed. They afford the opportunity for individual and community to experience the original state of purity and a reaffirmation of oneness with the eternal and ever-present world of the unseen spirit. Such rituals display a belief either in the ability to reverse time or that sacred time is eternal and can be experienced at any moment. Scholars have speculated that the Mesopotamian peoples chanted their Creation myth, the *Enuma Elish,* every new year for this purpose, for even the recitation of sacred stories is believed to return individuals to sacred moments and sacred time. This cyclical understanding of time is reflected in several ancient calendars in cultures as diverse as those of the Aztecs, the Babylonians, the Chinese, and the Norse.

This close-knit relationship between the spiritual, natural, and human realms and between past and present helps confirm individuals as members of their communities and provides them a sense of belonging to the world in which they live. Rituals and myths work together to reaffirm this connection, and also to take one beyond the limits of linear time and give one access to the realm of eternity where the sacred becomes manifest. Adherence to tradition maintains the relationship and keeps members of the community inoculated from the dangers and evils that exist outside. However, it may also close adherents to those who exist outside their communities and belief systems.

Abrahamic Traditions

In the ancient Middle East, there were a variety of religious cults and cultures that followed the indigenous modeling of time, seeing it cyclically, and that also believed in a close connection between the world of humans and that of the spirits and ancestors. In early Greece, several time concepts were prevalent. Both Pythagorus and Plato saw time as cyclical and repetitive. Hesiod viewed it as cyclical, repetitive, and also episodic, believing that the present universe will come to an end after humans pass through five different stages, only to begin again. Pherecydes of Syros, a 6th century BCE Greek philosopher and cosmologist, developed his own views of the beginning of the universe and was the first in the Western world to elaborate a concept of transmigration of an eternal soul. He presented Chronos (time) as one of the three eternal divinities in his writings, which clearly suggest a cyclical view of time.

With the development of Judaism, the first of the major Abrahamic religious traditions, the concept of time as predominantly linear began to gain acceptance in the Middle East. This view originates for Jews in the biblical Book of Genesis. Yahweh, most likely a clan deity who eventually came to be seen as the one almighty, created the universe and everything in it in 6 days. Although humans are created during this time, they are shown to stand apart from the rest of Creation, not a part of it. Once Creation is complete, it is the duty of humans to oversee it and keep it functioning within the framework of Yahweh's commandments, while he oversees Creation's linear progression. He is very much a part of the historical process, is affected by human actions and events that occur in his Creation, and occasionally becomes involved in influencing outcomes. On one hand, he is shown to be loving and compassionate, but on the other, he also gets angry and revengeful. He has favorites, whom he blesses, and others whom he condemns.

As a consequence of the belief in the Divine's intimate involvement in the world and in time, all three Abrahamic religions conceive of a sacred history, especially when revelations and/or special events have happened in the development of their respective traditions. Their growth and their contemporary manifestations are tied to their understanding of sacred time and history, and its chronological unfolding factors heavily into their belief systems as well as their respective understanding of self, community, and relationship to their conception of the Divine. It is no coincidence that the counting and measuring of time became an important point of focus for the scientific thinkers and theologians within these religions. In the 6th century CE, the Christian calendar was formulated to begin with what 6th century Christian scholar Dionysius Exiguus thought to be the year of the birth of Jesus (1 AD). The Muslim calendar begins with the year of the departure of Muhammad from Mecca to Medina and the official beginning of Islam (1 AH). The implication is that whatever happened before is, at best, of little relevance in comparison to what has happened since. Significant and sacred time begins with religions' respective beginnings.

Judaism

The Abrahamic approach to time and the Divine begins with Judaism, which was the first of the major religious traditions to formally adopt the linear concept of time. One of the purported reasons the ancient Hebrews rejected the prevalent concept of cyclical time was to separate themselves and their tradition from the polytheistic beliefs of the day. Unlike the pagan gods of other religions, Yahweh was believed to manifest himself to his people in historical time, giving it a sacred dimension. As Judaism crystallized into an established religious tradition in the region, its beliefs came to have a great influence over subsequent generations of both Jews and non-Jews.

Early biblical interpreters believed that time has always existed, while medieval Jewish philosophers held that time began along with universe at the moment of Creation. Not only did Judaism present its own approach to time, it also asserted a special relationship between its followers and Yahweh. This relationship is expressed in the concept of Jews as chosen people, a belief that has long been fundamental to Jewish self-identity as an ethnic and religious community. Yahweh has singled them out for a special purpose, and thus all subsequent events in the history of the Jews are key to the history of the world and of humanity. The concept of linear time is fundamental to explaining the evolution of this relationship and of the pivotal events that occur in history. Jewish prophecies have suggested that all the sufferings their community has experienced in the last two millennia have had a greater purpose, for the Jews are God's chosen, and God will use them to eventually establish his wisdom and righteousness on earth.

The Hebrew peoples of the first millennium BCE lived in independent theocracies in the lands of Israel and Judah and were free to practice their beliefs. However, once those lands were taken over by surrounding empires, they began to hold forth hope for a messiah, a Jewish king and spiritual leader, to return control of their homeland and reestablish the supremacy of their beliefs there. The messiah was to be God's vehicle for ending their oppression, hunger, illness, and death, and to bring about happiness for Jews and the rebuilding of their temple in Jerusalem. Their sacred stories assured them that when the messiah makes his presence manifest, barren land will be made fruitful, all weapons will be destroyed, and peace will prevail for the entire world. His appearance will validate biblical prophecies, prophecies that are embedded in linear time. This expectation continued for more than 2,000 years for most Jews, and for many it continues up to the present day. It has been a unifying concept and a hope that has been instrumental in the Jewish community's survival.

Christianity

Amidst the social and political turmoil of the Middle East 2 millennia ago, Jesus was born in the Jewish community that was under Roman rule in the land of Judah. The influence of his Jewish upbringing on his thinking is obvious. The New Testament's presentation of his views shows a similarity in many ways to those of the Hillelite Pharisaic school of Judaism, and the understanding of time is clearly linear. Like the Jews, he saw God as functioning within historical time, although his description of God's personality traits suggests more compassion and less strictness in judgment. Nevertheless, the view of a historical, revengeful, and preferential God who condemns is there as well. Many of the early followers of Jesus believed him to be the Jewish messiah, and thus expected his imminent return after his crucifixion, as per his own apparent prophecies and teachings. This belief came to be a bedrock of Christianity, and like the Jews, Christians await their messiah's return as a fulfillment of historical prophecy. Because Jews did not recognize Jesus as the messiah predicted in their scriptures, Christianity taught that Jews lost their status as chosen people, relinquishing it instead to Christians as the true inheritors of the biblical label and of the special relationship with God in history and in prophecy.

Although they separated from Judaism, Christians nevertheless continued to adhere to many elements of Jewish thinking, including the view of time as linear, the belief that humans are uniquely separate from and above the rest of Creation, and the view that God functions within time and with human characteristics, including such traits as revenge, hatred, and condemnation. They also adopted the concept of a divine plan for the world, one in which good will ultimately overcome evil. Such a view is predicated upon the belief in a linear time and the fundamental role that God has given the chosen people in fulfilling that plan. Among the theological and doctrinal additions of Christianity was the eschatological belief in an eternal heaven and an eternal hell, the former reserved for faithful Christians, the latter for everyone else. Integral to this belief and process is the expectation of the return of Jesus as messiah, although Christians differ among themselves as to when and how. During the last 2 millennia, heightened anticipation of the return of Jesus has happened at a rate of more than once every generation, and these have been especially prevalent at the end of each millennium. Toward the end of the 1990s, for example, there were dozens of such expectations. Most were quite benign and resulted only in disappointment for their followers. A few, such as the Heaven's Gate cult, led to deadly consequences. Begun in the 1970s in Oregon, the followers of this cult believed that Jesus would return along with a comet just before the end of the millennium. In order for their souls to unite with him, 38 members committed suicide in conjunction with the appearance of the Hale-Bopp Comet in 1997.

Currently, there are two primary Christian eschatological interpretations of time. The first is known as *premillennialism,* and it has been the more prevalent view in the vast majority of the more recent messianic expectations in the last century or so. Its adherents tend to draw heavily on an interpretation of the Hebrew Bible (Daniel 9:24–27) and the New Testament (Revelations 20:1–7) in believing that Christ, as the messiah, will return to the earth to defeat the Antichrist, reign here for 1,000 years before the final judgment of humanity, and then return to heaven with the saved. As they have countless times in the past, many premillennialists see the signs that foretell the imminent reappearance of Jesus occurring today, and various publications interpret these signs and events as proof of his impending return. Among these is the Left Behind series, a set of novels by Tim LaHaye and Jerry Jenkins, that supports a premillennialist view and has attracted countless Christian followers who hope to witness the glory of Jesus and the kingdom of God on earth in their lifetimes.

There are several *postmillennialist* beliefs as well, and each finds justification for its eschatological views in alternate interpretations of the same section of the Book of Revelation mentioned above. Generally speaking, postmillennialists believe that the return of Jesus will happen after 1,000 years (some understand this number symbolically) of gradual increase in the power of Christ and Christianity to bring about the kingdom of God in the world. The powers of Satan will be overcome, and he will be defeated for eternity. Jesus will then participate in final judgment, and there will be an end to history.

Islam

Muhammad was born in the late 6th century CE in the city of Mecca, and in 622 he began the religion of Islam, which is based primarily on his teachings as written in the Qur'an and the Hadith. The latter is a collection of stories about and teachings of Muhammad that were not included in the Qur'an. Both texts reveal the influence of Christianity and Judaism in his thinking as well as his reactions to them and their teachings. Like the Jews, he considered Abraham as his ancestor and Jerusalem as a holy city. Initially, he had his followers face in the direction of Jerusalem when they prayed, but later, due to a subsequent conflict with Jews, he had Muslims face toward Mecca for their prayers instead. Muhammad accepted essential aspects of the Genesis Creation story, strict monotheism, the ability of humans to receive divine revelation, the existence of angels and demons, many Jewish dietary rules, and the linear understanding of time. Like Jews, he rejected image worship and polytheism. With regard to Christianity, there are many stories about Jesus in the Qur'an, including his birth to a virgin, his teachings, and his miracles. Muhammad considered him a special prophet of God, and Mary, the mother of Jesus, is given great praise in the Qur'an, where she is mentioned more than in the New Testament. Islam accepts the concepts of a paradise and a place of damnation. Both are seen to exist in time, for eternity.

Prior to Islam, the tribes who lived in and around the Arabian peninsula followed time through observations of the solar and lunar cycles. However, they did not have a formalized concept of the year, nor did they count years as such. The past was marked by significant events. Like the Jews, Arabs considered sunset as the beginning of a day. Muhammad initiated a strict adherence to the 12-month lunar year, and ever since the time of his second successor, Umar, it has been followed by the religious orthodox in Islam. Some scholars believe Muhammad did this because the periodic interdiction of a 13th month to bring lunar and solar calendars together was important to the various "pagan" cults and festivals in and around Mecca at the time, and he wanted to end all practices associated with them. Over the centuries, there have been various attempts to adjust the Islamic calendar to align with the solar year or with the agricultural seasons, but none have been able to find a great following among Muslims.

In Islam, all reality, including time, is based on and under the complete control of Allah. Because Allah exists beyond time, he is timeless, while humans are caught in the cycle of time. History and human existence unfold relative to Allah's will, thus both are important in Islam. The Qur'an emphasizes the omnipotence of Allah and suggests a form of predestiny, or at least precognition. In the Hadith, there is reference to a heavenly book, in which everything that happens is written. This notion of predestiny became a fundamental doctrine in several Muslim schools. Allah is said to preordain what will occur in the world, while humans simply act it out. He decides what will take place in every moment with every being, from the time they are in the womb until they breathe their last breath. At the same time, however, Islam holds humans personally responsible for their actions.

Understanding and tracking time became an important function in Islam, because Allah is believed to be very much involved in time and history and is in the continual process of creation. Medieval mosques often had on their staffs an individual (*muwaqqtt*) whose job it was to measure time. Early Muslim philosophers believed the world to be temporal, while later thinkers describe an eternal physical Creation. Both views remain dependent on linear time as the vehicle through which Allah oversees and controls existence.

Like Christians, many Muslims believe that in order for the Divine Will to prevail in the world, everyone must convert to their way of believing. Time will then take on a new and spiritual dimension. This has been the justification for both traditions to proselytize throughout the world and to seek to subdue alternative religious belief systems, all of which are said to be obstacles to the fulfillment of the divine plan. Similar to Jewish and Christian messianic expectations, Twelver Shiites, members of the dominant sect of Islam in Iran, also believe in a messiahlike figure who will usher in this new reality. His name is al-Mahdi. He was the 12th *imam,* or spiritual leader, in the lineage begun by Ali, the son-in-law and younger cousin of Muhammad. Al-Mahdi is said to have disappeared at the age of 5, after leading the funeral prayers of his father, the 11th *imam.* Twelver Muslims believe that the reappearance of al-Mahdi will bring about peace and justice in the entire world. Adopting the evangelizing approach of the Christian church, Islam began its own method of spreading its version of time, reality, and the Divine, and converting the people in all the lands its armies conquered.

All three Abrahamic religious traditions believe in the importance of ordering the world toward the fulfillment of their respective eschatological expectations. This is especially so in Christianity and Islam. In the case of fundamentalists from both traditions, this desire can lead to dire consequences for those who are judged as nonbelievers. The medieval Inquisition is a good Christian example, while the more radical Muslim fanatics of the last several decades represent a contemporary example of a similar ideological mindset. Tied in with the eschatological beliefs of the Abrahamic traditions is the view that the faithful individual has a responsibility to work toward making the world a better place. "Better," however, typically means converting others to one's own belief system, be it religious, political, social, or something else. Moreover, the molding of others' beliefs and practices is, for many, necessary to help bring about or create the environment in which eschatological expectations can be fulfilled. Time, therefore, is a fundamental element in the cosmological and eschatological beliefs of both Christianity and Islam, and each generally believes that true followers will spend eternity with God or Allah in heaven, while all others will spend an eternity in a hell. Because both eternal salvation and eternal damnation would no longer have the same relevance if time were to cease, eternity is understood within the framework of a linear reality.

Dharma Traditions

Although they have much in common with indigenous traditions around the world, the dharma traditions, those that have their origins in the Indian subcontinent, tend to have a richer and more diverse conceptualization of time than is found in other belief systems. This is due in part to the long history of philosophical development in India. The typical understanding of time posits a broad and overarching cyclical movement, within which there exists a linear aspect. Whereas time is seen to move in an apparently linear fashion, in reality it moves in a circular one. It is similar to traveling down a straight road. While one appears to be heading in a linear direction, if one were to move along the road in the same direction long enough, one would return to the spot from which the journey began. In the same way, life moves in an apparently linear direction, but ultimately returns to its origin. As previously mentioned, a similar way of thinking can be found in ancient Greece.

One of the bigger differences between the dharma traditions and the Abrahamic traditions deals with eschatological beliefs. While Christianity and Islam seek acceptance of and compliance with a particular belief system and set of doctrines, such an approach is, for the most part, nonexistent in Asian religions, especially in the dharma traditions. In the latter, there is no concept of a deity who demands such compliance and who condemns to eternal hell all those who do not adhere. Instead, it is generally believed that everyone, eventually, will gain a release from the bondage of the birth/death cycle. This freedom is referred to by many names, such as *kaivalya, nirvana, moksha,* enlightenment, and liberation. Because it is a personal accomplishment, it is independent of what anyone else does. Therefore, there is no incentive to try to convince or coerce others into following one's own beliefs, practices, or way of life as a requirement to gain that freedom. There is no need for missionaries to convert others. There is no eschatological view that is dependent upon world adherence to a particular path.

Origin stories are common in most Asian traditions as well, although events from the mythological past tend to have more symbolic than historic significance, because a linear chronology of world occurrences is far less significant than in the Abrahamic traditions. The dharma traditions—Hinduism, Jainism, Buddhism, and Sikhism—all believe in karma and in rebirth, in one form or another. Good actions lead to positive results, and bad actions lead to negative results. Although the concept presupposes cause and effect, goal orientation, and existence within a linear time frame, it conforms to the overall cycle concept of the traditions. Unlike the Christian and Muslim beliefs that certain actions, or lack thereof, result in damnation that will last an eternity, most Asian traditions reject any eternal state for the individual soul, other than liberation. In this regard, one of the unique aspects of the dharma traditions is the view that any reality confined within cyclical time is a form of imprisonment, from which one must ultimately free oneself. Thus, much of the philosophy and teachings within these traditions is geared to methods of escape from this endless cycle.

Hinduism

There are a variety of Hindu concepts of time, including various cosmogonies and eschatologies, but all fit into the overall concept of a cyclical reality. The earliest views date back to at least the Vedic period, more than 3 millennia ago. One of the oldest of the philosophical schools to propose a concept of time is Samkhya, in which there is an eternal and timeless duality, Purusha (male) and Prakriti (female). The former is seen as unchanging consciousness that underlies all existence, while the latter is the material reality that is ever-changing. Other views describe an episodic characteristic, with existence moving through four *yuga*s, or cosmic ages, after which the universe and all Creation come to an end, including time. The resulting state is known as *pralaya,* of which there are several types and degrees of dissolution. Generally speaking, during this state, all form, all qualified existence, all differentiation, and all things that have a beginning will end; all that remains is Brahman, the unqualified eternal absolute. Although time ends as well, nevertheless, the state is said to last for several billion years. Here, everything that ever was and will be is in a state of potentiality. Then, Brahman again begins the Creation process, by first dividing itself into Brahma (the Creator), Vishnu (the Preserver), and Shiva (the Destroyer). The *yuga*s begin anew, the cycle is in motion, and everything starts over again. According to some schools of Hindu philosophy, this will go on for eternity. The Puranas, a series of ancient texts, each have their own cosmology, but all tend to draw from the pattern above. Because of this, the goal of individual life is to get beyond attachment to the temporal, to all that comes to an end and to identify oneself instead with the deathless and endless absolute Divine.

Jainism

The Jain tradition acknowledges neither beginning nor end to the cosmos. Physical and nonphysical reality has always been and will always be. It continues in long cycles, during which there is a gradual fall of moral and physical existence followed by their reassertion. This process is believed to continue for eternity. All beings are bound within these cycles except those who are able to escape and become liberated. This can result only from the extinction of the interaction of the eternal soul with all that is nonsoul. The latter consists of time, matter, space, and inertia and is also eternal but constantly in flux. Karma is produced with every interaction and weighs down the soul and imprisons it. Once all karmic residue is annihilated, the soul becomes eternally liberated in the state of *kaivalya.* This freedom is the ultimate goal of life in Jainism, so methods for accomplishing this are essential aspects of Jain teachings. Those who are believed to have attained this state are the most revered beings within the tradition and are considered divine.

Buddhism

Gautama Buddha lived in the middle of the 1st millennium BCE in India, and the tradition that follows him represents an important source of non-Brahmanical thinking in India in those early days. However, the Buddha wrote nothing, and in the 1,000 or so years that followed his death, a great number of texts were written that all claim to contain his teachings. As a consequence, there is a diversity of views regarding origins, destinies, and time within the tradition. Some texts have elaborate cosmologies; others either do not address the issue or present a fairly simplified version. Some schools within the tradition see these stories as metaphorical; others as real. However, all Buddhist schools traditionally see time as cyclical and liberation from the birth/death cycle as the ultimate goal.

As an example, the *Agganna Sutta,* a Theravada Buddhist text, tells of existence going through cycles of expansion and contraction, creation and dissolution. Desire, ego, and other such traits are what lead to creation and what bind an individual to countless rebirths. When one follows the teachings of the Buddha, such as the Eightfold Path, then one is able to step outside the cycle of birth and death and attain *nirvana,* or liberation. Pure Land Buddhism, one of the largest of the Mahayana schools, believes in a heavenly realm known as the Pure Land, where those who remember Amitabha Buddha with faith will be reborn, rather than returning to the birth/death cycle on earth. Once there, they will remain to work out all their karma and will eventually gain the wisdom that will lead them to liberation. The Tibetan Buddhists have elaborated their view of cyclical time, which is expressed in the concept of *bhavachakra,* the "wheel of time." In paintings, the wheel is held by Yama, the lord of death. It depicts the eternal cycle of life through which all beings pass until they reach liberation.

Sikhism

The Sikh tradition draws its cosmogonic views from the Guru Granth Sahib, the primary scripture of Sikhism, and one can see the influence of various Hindu concepts therein. There is the belief in a singular transcendent Divinity who is infinite and exists beyond time and place. At the same time, the Divine pervades all Creation and is omnipresent. Existence goes through countless cycles of creation and dissolution. When there is no creation, the Divine exists as the One. Because of Divine Will and through Divine Sound, creation occurs, and all existence becomes manifest. Eventually, all that is created will end, and only the one truth, the one Divine will remain. The goal of human life is to end lust, greed, anger, pride, and attachment to the material world, and to find spiritual union with the One.

Other Asian Traditions

Buddhism, and to some extent Hinduism, has had such a predominant effect on thinking throughout Asia that it is sometimes difficult to separate its influence from those of the indigenous traditions in many Asian religious cultures. However, the pre-Buddhist traditions of Confucianism and Taoism in China have definite non-Buddhist approaches to time.

Confucian time follows both a 12-month lunar cycle and a 12-year cycle, with each year associated with an archetypal animal. The number 12 is also important in the I Ching, one of the Five Classics in the Confucian religious tradition, and is connected with the zodiac and 12-year cycle. It is believed by many Chinese that learning to live in accordance with the changing energy and influences that occur throughout the 12 years will bring harmony and success to one's life.

Lao Tzu, the founder of Taoism, had a very different approach. He wrote that the Tao preceded all existence. First there was the Tao, and from it came the One, then the two and the three, then the myriad of things—all Creation. As to what the Tao is, Lao Tzu says that no one can say; nevertheless, the goal is to be in harmony with it and to find balance of yin and yang, the dualistic aspects of material existence and nature. Taoists believe that aligning one's life and being in accordance with the Tao will raise one's consciousness of reality and experience of the Tao. There are no eschatological views in either Confucianism or Taoism as such.

The Shinto tradition in Japan reveals a blend of linear and cyclical thinking. There is a clear cosmogonic belief, as expressed in the Kojiki, the most important text in the tradition. However, there is no eschatological belief. Creation happened, it will continue, and it does so in cycles. A ritual that occurs at the most sacred shrine at Ise reveals the Shinto view of time, tradition, and change. The temple there is rebuilt every 20 years using the exact design that was used to build the original shrine in the 3rd century CE. The sacred items within the old shrine are then moved to the new one. Thus, every generation has a new shrine, but each one is an exact duplicate of the original. The newness of each generation is thereby acknowledged, but it is encouraged to be a continuation of the traditions of its elders. In this way linear and cyclical time are blended together.

Conclusion

The concept of time is understood in vastly different ways in the various religious traditions and cultures of the world. Most of these views originate in cosmogonic myths that are meant to provide their followers a sense of self and place in their social communities, in their homelands, and in their world. Along with inspiring feelings of pride of self, origin stories occasionally lead to xenophobic attitudes and may also be used to justify aggression against outsiders, but this has not been historically common. Eschatological beliefs, on the other hand, have the greatest potential for causing conflict between groups, especially when such beliefs include within them the need for followers to evangelize outside their own community of believers. Yet, with the exception of Buddhism and some elements of other traditions, non-Abrahamic religions that follow cyclical time have not traditionally manifested a need to convert others to their way of thinking and being. Moreover, many such traditions have considered outsiders as inherently unqualified to be a part of their religious and cultural communities, due to ethnic or geographic restrictions that are embedded in their belief systems.

For those who follow the linear view of time, such as the adherents of the Abrahamic traditions, science, and the Westernized urban view of the world, the situation has been quite different. These belief systems place humans outside, above, and in control of the cyclical realm of nature. They also tend to promote a similar attitude toward adherents of a cyclical worldview, such as indigenous peoples and the followers of most

Asian religious traditions. Followers of linear time have typically characterized cyclical cosmogonies as contrived and unrealistic, as the products of childish fantasy, and even as pagan heresy. They have also depicted the followers of cyclical time in a similarly negative way. Such views have usually been carried by Christian and Muslim missionaries in their in proselytizing activities around the world. Working tirelessly in their evangelizing efforts, they have often sought to diminish and even obliterate other cultures and belief systems and replace them with their own worldviews, sectarian beliefs, lifestyles, and conceptualizations of God and time. Thus, adherents of a linear view of time are gradually but inevitably replacing the cyclical view of time with their own, and many of the more extreme individuals and groups that are active in this process do so with the belief and even the hope that their efforts will lead to a fulfillment of their own eschatologies, and to an imminent end of the world as we know it.

Ramdas Lamb

See also Bible and Time; Buddhism, Mahayana; Buddhism, Theravada; Buddhism, Zen; Christianity; Eschatology; Genesis, Book of; God and Time; Hinduism, Mimamsa-Vedanta; Hinduism, Nyaya-Vaisesika; Hinduism, Samkhya-Yoga; Islam; Judaism; Shinto; Taoism; Time, Sacred

Further Readings

Balslev, A. N. (1983). *A study of time in Indian philosophy.* Wiesbaden, Germany: Otto Harrassowitz.

Eliade, M. (1987). *The sacred and the profane.* New York: Harcourt.

Kort, W. A. (1985). *Modern fiction and human time: A study in narrative and belief.* Gainesville: South Florida Press.

Padgett, A. G. (1992). *God, eternity and the nature of time.* New York: St. Martin's.

Raju, C. K. (2003). *The eleven pictures of time.* New Delhi, India: Sage.

Ridderbos, K. (Ed.). (2002). *Time.* New York: Cambridge University Press.

Yamada, Y., & Kato, Y. (2006). Images of circular time and spiral repetition: The generative life cycle model. *Culture & Psychology, 12*(2), 143–160.

Renan, Joseph Ernest (1823–1892)

In the 19th century, the French philosopher Joseph Ernest Renan studied and considered the theory of evolution, recognizing its obvious challenge to biblical beliefs and theistic theologies. He accepted this new framework of time and valued the advances in science (especially chemistry) over the dogmas of religion. His dynamic worldview became future-oriented, expressing a deep concern for the survival and fulfillment of our species in the distant ages to come.

Renan had been educated in ecclesiastical colleges and seminaries, but he began to doubt Roman Catholic scholasticism. Instead, his interests shifted from theology to philosophy (particularly the thoughts of G. W. F. Hegel), mathematics, and philology. Becoming very skeptical of religious beliefs and being most liberal in his own thoughts, Renan left the faith in order to embrace a scientific understanding of and rational appreciation for the splendor of this universe. He is best remembered for his controversial book *Life of Jesus* (1863), which enraged the religionists of his time because of its strictly human portrayal of the Nazarene. His voluminous writings also included such daunting topics as the history of Israel and the origins of Christianity. However, Renan's amazing speculations on the future of humankind within cosmic immensity are found in his volume, *Philosophical Dialogues and Fragments* (1871).

Even though Renan foresaw the persecution of scientists by a religious society, he nevertheless anticipated the triumphs of science and reason in the future. He maintained that the remote past demonstrates the ever-increasing consciousness of our species. And, for him, the ongoing progress of the human mind held the key to comprehending the directional evolution of this universe. Therefore, with critical optimism, Renan envisioned a gradual ascent of humankind within the evolutionary development of the natural world. Consequently, he held that an immense advancement of consciousness would result in the emergence of a group of superior individuals who far exceed the human beings of today. His imagination saw these forthcoming divine beings to be as far above our present species as the human beings of today represent an advancement over those lower animals that are found in the deep fossil record.

Within his organismic interpretation of the evolving universe, Renan suggested that sidereal reality would eventually become a cosmic zygote. Furthermore, over immeasurable time, from this cosmic zygote would emerge a single being that will delight in its sensations and perceptions (just as a finite human being on earth enjoys its feelings and emotions). As the totality of reality, this ultimate being of trillions of finite beings will have evolved into an organic unity out of the awesome multiplicity of a living universe (just as an organism on our planet emerges as a complex unity out of those trillions of atoms that make up its genetic information). As such, all existence will be participating in this cosmic unity of infinite diversity.

Thus, the visionary and free-thinker Renan saw the meaning and purpose of humankind fulfilled in the far distant future, when all of the matter of space, which is now the composition of endless distinct galaxies, becomes this single universal being. This thinking and enjoying final entity is the emergent God as that cosmic consciousness within which everything will be preserved and experienced throughout all eternity.

H. James Birx

See also Hegel, Georg Wilhelm Friedrich; Teilhard de Chardin, Pierre; Unamuno y Jugo, Miguel de

Further Readings

Renan, J. E. (1966). The higher organisms of the centuries to come. In F. E. Manuel & F. P. Manuel (Eds.), *French utopias: An anthology of ideal societies* (pp. 381–391). New York: The Free Press.

Renan, J. E. (2000). *The future of science.* Boston: Adamant Media.

Robertson, J. M. (2005). *Ernest Renan.* Whitefish, MT: Kessinger.

REVELATION, BOOK OF

The title of the last book in the canonical Christian scriptures, the Book of Revelation or Apocalypse of St. John, lends its name to an entire scriptural as well as popular literary genre of end-time scenarios called "apocalyptic." One of its opening words, *revelation,* translates from the Greek, ἀποκάλυψις. Here, the sense of the word *revelation* includes an uncovering of things previously unknown or possibly unknowable and has nothing to do with the end of time as such. Yet it is through the Christian Book of Revelation that apocalyptic literature became defined as those narratives that include catastrophic end-time scenarios.

Although it is by no means the first end-time religious narrative, Revelation became the standard for defining apocalyptic literature. This genre includes the many canonical and noncanonical apocalypses of Judaism and Christianity, apocalypses of other religious traditions, and even secular narratives that continue to be produced.

The Book of Revelation brandishes a dense if not impenetrable poetic imagery. It addresses the specific historical needs of a particular group of people in a particular place and time and at the same time provides sufficient allegory, and opacity, to invite wide interpretation from believers in whatever place and time it has been read.

As obscure as the imagery may be, the structure and content are fairly straightforward. The book begins with salutary, epistolary, and testimonial opening remarks typical of early Christian writing, including establishing the authority of the writer who self-identifies as "John," a "servant" of Jesus Christ and "brother" to his readers. Sometimes referred to as "John the Revelator," the writer follows his opening remarks with angelic messages to seven Christian churches. In Jewish and Christian numerology, the number seven represents completion. That the writer addresses seven Christian churches would have been sufficiently understood by early Christians to have meant that the complete Christian church was being addressed.

After the messages to the churches, the narrative launches into a vision of how the end-time will progress. The vision begins with God and "the lamb" on two heavenly thrones. Seven seals of seven scrolls are opened, and seven trumpets are blown, heralding the penultimate struggle between good and evil. Imagery includes evil epitomized in the dragon, the whore, the evil city, the monster from the sea, and the beast from the land. All these are set against the good represented by God, heavenly angels, the lamb, and God's people who number the numerologically significant 144,000 (12 × 12 × 1,000).

After more angelic messages, the "son of man" arrives in the clouds and is told by angels to reap the sheaves and to press the grapes with God's wrath. When he follows their command, blood flows from the presses. Then come praises from the conquering holy ones in heaven while those unbelievers left behind are visited by seven plagues from seven bowls. After the plagues follows the judgment of the great whore (the antivirgin), the beast (the Antichrist), and Babylon (the anti-Jerusalem). Babylon falls as heaven rejoices and God's enemies are defeated. A dragon is chained for 1,000 years during the worldly reign of righteous, believing monarchs. After this millennial reign, there is the final war and its defeat of evil. At the conclusion of this final battle, Satan and the beast are bound and tormented forever. All the dead are resurrected and judged, with the righteous being given the new heaven and new earth, while the unrighteous are either made new (21:5), die a final death in the lake of fire (21:8), or are simply left outside of the new Jerusalem (22:15). The book closes with blessings and curses and Jesus's assurance that he and all this is "coming soon."

The book is heavily indebted to its prototype, the Hebrew scripture's Book of Daniel, for its inspiration, structure, and content. From the very first verse, Revelation invokes a mystical world of divine mandate, messianic revelation, angelic message, and ecstatic vision, all capped with blessings and curses.

Mystical numbers figure prominently and add to the book's allegorical nature. In addition to the familiar numerology of 7s and 12s, the infamous number 666 (or 616 or 665, depending on the scribe) in Chapter 13 identifies the "monster from the land" in the dramatic struggle between divine and evil forces. Scholarly consensus holds that the number reflects a Greco-Roman name-code device from the early Christian era, with most agreeing that in this case the code refers to Caesar Nero. Last, if perhaps somewhat less famously, the millennial number of 1,000 years (or possibly 2,000 years, depending on how liberal the interpretation) also figures prominently in the narrative. This fact resulted in high apocalyptic expectations among some Christian groups around the turn of the 1st and then the 2nd millennia CE.

In addition to mystical visions and numerology, other elements in Revelation that are common to apocalyptic narratives of the time include the cosmic struggle between divine good and supernatural evil reflected in cataclysmic earthly wars and plagues; tropes of court drama with thrones, sealed communiqués, witnesses, prosecution, judgment, and punishment; general resurrection with special status for resurrected martyrs; and the appearance of a transformed earth and a heavenly city.

Whether the author was intentionally obscure or time has obscured the book's meaning, the cultural context of Revelation and even its authorship offer their own levels of obfuscation. The text provides often conflicting clues as to its historical origin, indicating possible assembly, revision, or redaction over time. From the elusive identity of its author (or authors), to doubts about its Christian provenance, to struggles for its reception as part of the Western Christian canon that continued well into the 5th century CE, to early and ongoing internal Christian debates as to whether it is properly understood as literal, allegorical, historical, or prophetic, the Book of Revelation holds a rich and varied, if somewhat checkered, history and an unquestioned influence on the theological, political, and artistic imagination when anticipating the end of time.

David V. McFarland

See also Bible and Time; Christianity; Ecclesiastes, Book of; Eschatology; Gospels; Judaism; Religions and Time; Time, Sacred

Further Readings

Bauckham, R. (2001). Revelation. In J. Barton & J. Muddiman (Eds.), *The Oxford Bible commentary.* Oxford, UK: Oxford University Press.

Gabel, J. B., Wheeler, C. B., & York, A. D. (2000). The apocalyptic literature. In *The Bible as literature: An introduction.* Oxford, UK: Oxford University Press.

Ricoeur, Paul (1913–2005)

The French philosopher Paul Ricoeur, who taught at the Sorbonne and the universities of Nanterre and Strasbourg as well as at the University of Chicago, attained an international reputation for his work, particularly in the fields of phenomenology and hermeneutics. He is widely regarded as among the foremost philosophers of the 20th century.

The main part of Paul Ricoeur's reflections on time is presented in his three-volume work *Temps et récit,* published in French between 1983 and 1985 (in English translation, *Time and Narrative,* 1984–1988). Everyone is familiar with Saint Augustine's famous remark: "What, then, is time? I know well enough what it is, provided that nobody asks me; but if I am asked what it is and try to explain, I am baffled" (*Confessions,* XI, 14). Ricoeur took Augustine's statement very seriously, maintaining the irremediably aporetic character of philosophical reflection on time: There is an aporeticity of temporality, which means that when philosophers think about time, they run up against aporias—that is, insurmountable difficulties that cannot be resolved through standard philosophical frameworks. In fact, *Time and Narrative* presents three theses at once. The first is expressed negatively: There is no philosophical answer to the nature of time. Even contemporary phenomenology, begun by Husserl, failed in its attempts to resolve the aporias raised by the problem of time. Moreover, Ricoeur himself gives no general definition of time in his work.

Ricoeur's second thesis—this time expressed positively—claims that it is narrative, the act of retelling, that provides an answer to the aporias of the problem of time, an answer that is poetic and not speculative. This explains the title *Time and Narrative*. Narrative is the guardian of time. It is defined with the help of two concepts borrowed from Aristotle's *Poetics*. These are *mimesis,* that is, the representation of action, and *muthos,* the "emplotment," the synthesis of aims, causes, and chance brought together under temporal unity in a complete action. To tell a story is to unify through a single narrative thread successive events that are, at the outset, distinct or even disparate. Narrative is therefore the "guardian of time" in the sense that it transforms anonymous time into human time. Narrative gives a consistency, a cohesiveness to our experience of time.

The third thesis is that this role of narrative is as valuable for historical narrative as for fictional narrative (literature). There is a crisscrossing between history and fiction that is not reducible to a mere fusion of genres. Far from being two completely separate genres, history and literature share a common center, which is the activity of telling stories with reference to temporality. History is a true narrative of the past. Fiction is an imaginative narrative that can take time as its object. (Here, Ricoeur analyzes three examples: Thomas Mann's *The Magic Mountain,* Virginia Woolf's *Mrs. Dalloway,* and Proust's *Remembrance of Things Past*). The time of narration is "narrated time." In one respect, it is about time having become the object of the narrative, being actively involved in a story (fiction), practically becoming a character in the novel. In another respect, narrated time is the time of events reinscribed in a chronology (history).

Time, Natural and Phenomenological

The main aporia of time concerns the opposition between subjective time and objective time, between the time of consciousness and the time of nature, between psychological time and cosmological time. This is the most obscure aporia of time. On the one hand, time seems to be an element of nature independent of our existence. On the other hand, time seems to be a process that is inseparable from consciousness. There is no succession without memory, and no memory without consciousness. Ricoeur illustrates this aporia using Saint Augustine's theory, which he opposes to that of Aristotle. Augustine analyzes psychological time in Book XI of the *Confessions.* The past is no longer, the future is not yet, and the present unceasingly slips away. Time as a whole tends toward nonbeing. What gives existence to time, in fact, are the operations of the mind. Therefore, one must say that there are, in fact, three times: the "present of the past," the "present of the present," and the "present of the future." These three times are present in our mind, corresponding respectively to memory, intuition (*contuitus*), and expectation. Time here is reduced to the consciousness of time. It is an "extension of the mind" (*distentio animi*).

As a counterpoint to Augustine's position, which is taken up by Husserl, there exists another approach to the problem of time: Rather than seeking it in the mysteries of our consciousness, we observe time in nature, at the very heart of the world. On this point, Ricoeur refers to Aristotle's *Physics* (IV, 10–14), which studies the time of nature. For Aristotle, time is not only in the soul; it is in all things: in the earth, the sea, and the heavens. Time is connected to movement, for all movement occurs in time, but it is not the same as movement, of which it is the number and the measure. Being in time means being measured or measurable by time. In this perspective, time is defined as "the number of movement according to the before and after." Time is a measure of movement. But, in order to measure movement, time itself must be measured by a movement, which provides it with an objective unit of measurement. That is why, Aristotle explains, we measure not only movement by time but also time by movement. In order to obtain the most universal measure of time possible, we must not use just any movement, but choose the circular movement of the heavenly bodies (the sun and moon), the movement with which we are the most familiar and that is the most regular. In this way, we determine, with the help of movement of the planets, units of measurement that are more and more precise (year, month, day, hour, etc.) by which we can measure all other movements, calculate their speeds, and compare them to one another.

For Ricoeur, the two approaches to the problem of time, through nature and through consciousness, are incompatible. One cannot reconcile the theories of Aristotle and Augustine. The cosmological approach of Aristotle can only lead to cosmological time and never fully grasp psychological time, which is not reducible to measured time. But the approach to the problem of time by consciousness is incapable of taking into account the fact that time cannot be reduced to a structure of human subjectivity, as has been suggested by philosophers such as Augustine, Kant, and Husserl. If such were the case, the history of the universe and of the earth before the appearance of human beings—which lasted several billion years—would simply be inconceivable. For Ricoeur, it is as impossible to generate natural time from phenomenological time as it is to proceed in the other direction, and it is impossible to include phenomenological time in natural time.

After having shown the aporetic character of philosophical reflection on time, Ricoeur concludes that philosophy cannot escape the maze of the aporetic nature of temporality. His position consists, then, in recognizing the powerlessness of philosophy to resolve the problem of time, whose solution must be found outside of its specific field. In Ricoeur's estimation, it is narrative (historical or fictional) that acts as Ariadne's thread, allowing us to leave the maze of the aporetic nature of temporality. In its historiographic and literary forms, narrative is the "guardian of time"; it unifies our temporal experience and allows us to work out a "third time," which connects lived time with cosmic time. It is through narrativity that cosmic time becomes human time. To narrate an event is to reinscribe a fragment of lived time into the universal calendar of the world's time. Ricoeur's idea is that narrative weaves a link between our lived times, which are all different, and the world's universal and common time. Narrative presupposes a particular form of time; it unfolds in the context of "calendar time," which is dated time, a universal framework that allows us to make the events of the world coincide with human events. This dated time involves a zero point, chosen by convention (e.g., the birth of Christ), a line that can be traveled in both directions, and regular intervals (hours, days, years, centuries), calculated as a function of the movement of the planets. In fact, narrative involves three elements: dated time, duration (measured time), and place.

Narrative

Narrative, then, is a third time, a bridge connecting lived time and world time. This thesis of Ricoeur seems to work better with historical narrative than fictional narrative. Literary narrative is, in fact, fictitious; it is free from the problem of including lived time in cosmic time. Fiction, then, seems to be a work closed in on itself, cut off from the world, and not a bridge between us and the world. Ricoeur's answer to this objection is the following: Literary narrative is never a pure fiction cut off from the world, a totally self-contained text. Fictional narrative is a description of the world or of certain experiences in the world. In this sense, there exists a "world of the text." The world of the text is, on the one hand, a fictitious world, but on the other hand, a virtual world, a possible world that offers a totally new experience of the world.

Certain narratives describe in this way a specific experience of time, which Ricoeur calls "fables about time." In this type of narrative, time is narrated in the sense that it is the object itself of the narration. Authors of fiction, unlike historians who are bound to tell the truth, have tremendous freedom. They can make imaginative variations on time; move from one flow of consciousness to another as in *Mrs. Dalloway;* escape the measured time of the calendar like Hans Castorp, hero of *The Magic Mountain;* or travel in the past, like the narrator of *Remembrance of Things Past.* Regarding this last work, analyzed in detail by Ricoeur, the experience of time and of lost time, which means wasted time and past time, has forever sunk into the past. This novel describes, at the same time, the experience of time rediscovered thanks to involuntary memory, through which a present sensation awakens an identical past sensation, which emerges with everything around it; and thanks also to art, which aims at rediscovering lost time, restoring these extratemporal experiences through style and metaphor. The time rediscovered is the time saved by the work of art. For Ricoeur, the world of the text contained in the narrative is therefore a new experience of temporality, that is, an invitation to reconfigure one's own temporality. The reading of a text is that through which the work returns to the world.

Ricoeur notes that historical narrative is not fundamentally different from fictional narrative. They are made of the same fabric, because both are about narratives, emplotments, and syntheses of temporal experience. They all have the same objective: In both cases, narrative refers to a temporal experience. History and fiction are intertwined. History contains fiction. On this point, Ricoeur gives the example of the analysis of the trace. There is a paradox of the trace, of the vestige. It is an object that is both present and past. It is there, present before us, and yet it belongs to the past; it is no longer there. Ricoeur mentions Heidegger's solution, which consists in saying that the object is not what is past but the world where the object was created and to which it belongs. In order to interpret a trace, to understand it, the historian has to imagine its context in the past, its former world, and, in this operation, the imagination plays an essential role. Inversely, the narrative contains the historical. Fiction is virtually history to the extent that it often makes reference to history; for example, in *Remembrance of Things Past,* Proust refers to the Paris of 1914–1918, even if this reference is not bound by the truth.

There are, of course, differences between historical narrative and fictional narrative. Historical narrative aims at the truth. It seeks to represent the past as it really happened. That is why it strives to inscribe lived time into cosmic time by means of calendar time. Ricoeur calls this relationship between historical narrative and the past *représentance. Représentance* is not imitation, but the fact of representing, of referring to the past.

In *Time and Narrative,* there are not two but three forms of narrative. Narrative is the guardian of time. This is true for fictional narrative, historical narrative, and the narrative one might call everyday or ordinary. There is a narrative of ordinary life. Individuals talk about their lives, they reconfigure their stories, and they constantly synthesize their temporal experiences. In talking about his life experience, the individual works out his "narrative identity." Narrative identity is retrospective; it is woven from accomplished actions to which it is, by nature, posterior. Narrative supposes action. At the beginning of his work, Ricoeur emphasizes that the operation of emplotment by which he defines the narrative always refers to actions. He distinguishes "*mimèsis* II"—strictly speaking, the act of recounting—from "*mimèsis* I," the prenarrative experience of action. Before talking about one's life, one must live it. But to live one's life, one must recount it. Narrative identity is the history of a life; it is formed by narratives that individuals make regarding their own lives through a dynamic process of unending rectification. It is both fictional and historical, for even the fictions that individuals recount about themselves are part of their identities. This concept of narrative identity, which functions as well for the individual as for the community, is the solution to the paradox of individual identity, which is defined neither by identity-substance given once and for all (Leibniz) nor by always fluctuating identity-fiction (Hume). Narrative identity is an evolving identity; it never ceases to construct and deconstruct itself. To complete the notion of narrative identity, all that remains is to introduce the decisive role of memory, neglected in *Time and Narrative*. This gap will be filled in the last major work of Ricoeur, *Memory, History, Forgetting*.

Ricoeur begins this book by developing a phenomenology of individual and collective memory that inquires into the notion of the "duty of memory." He then offers an epistemology of the historical sciences that brings out three distinct stages in the work of the historian: the documentary phase (testimonies, archives), the explanation and understanding phase (research into causes, be they social, cultural, political, or other) and the representative phase (establishing the literary form of the narrative, periodization). Far from being closed in on itself, the historical narrative is a representation of the past; it refers to a past that no longer is but was. In the third part, Ricoeur develops a hermeneutic of the historical condition that analyzes in particular the complementary notions of historicity and forgetting. The work concludes with a reflection on "difficult forgiveness," which is situated halfway between memory and forgetting.

Christophe Bouton

See also Aristotle; Augustine of Hippo, Saint; Heidegger, Martin; Husserl, Edmund; Kant, Immanuel; Mann, Thomas; Proust, Marcel; Woolf, Virginia

Further Readings

Ricoeur, P. (1984, 1985, 1988). *Time and Narrative* (3 vols.) (K. McLaughlin & D. Pellauer, Trans.). Chicago: University of Chicago Press.

Ricoeur, P. (2004). *Memory, history, forgetting* (K. Blamey & D. Pellauer, Trans.). Chicago: University of Chicago Press.

Rip Van Winkle, Tale of

The tale of Rip Van Winkle, written by Washington Irving (1783–1859), is a time-honored classic in both its theme and historical context. Through this piece of American folklore, Irving reminds his audience that indolence and unawareness of sociocultural and political change can lead to disaster. Time is the major theme in this tale.

The tale was published as part of a collection of stories in 1819. The collective work, known as *The Sketch Book of Geoffrey Crayon,* also includes Irving's other famous tale, *The Legend of Sleepy Hollow.* "Rip Van Winkle" is set in a small Dutch village in the Hudson River Valley in New York State. The village is situated at the foot of the Catskill Mountains, which play an integral role in the story. The Hudson River Valley would not only be immortalized through Irving's two most famous stories but also would become his later home. The time period is set both before the American Revolution (in the beginning) and afterwards, when Rip awakens.

In the beginning, the audience is introduced to the titular character as a well-liked member of the community. However, in Rip's own house, misery seems to stem from his henpecking wife, Dame Van Winkle. Dame Van Winkle is simply upset with Rip's natural aversion to labor within his own house. One day after a characteristic barrage of nagging from Dame Van Winkle, Rip sets off into the Catskill Mountains to escape. Accompanied by his equally henpecked dog, Wolf, Rip originally seeks to shoot some game, but instead runs into the spirit of famous explorer Henry Hudson.

After helping his new acquaintance to carry a keg of liquor he was struggling with further up the mountain, Rip encounters the rest of Hudson's

This illustration of a scene from Washington Irving's 1819 Rip van Winkle shows a group of people outside the George Washington tavern as they crowd around, point at, and otherwise inspect an old man with a long white beard and a walking stick.

Source: Getty Images. Engraved by T. Doney from a drawing by T. H. Matteson for the *Columbian Magazine,* 1850s.

crew entertaining themselves in a game of ninepins. Initially uneasy with the unsmiling crew, Rip settles down to sample some of the liquor in the keg. After many samples, Rip finds a nearby grove and falls into his renowned 20-year slumber.

Not knowing that he has slept 20 years, Rip awakens on what he supposes to be the next morning and heads back down to the village, unable to locate Wolf. That is, he cannot locate Wolf until he enters the village. There he finds an aged Wolf, who does not recognize his master. As if that weren't enough for the bewildered Rip, he soon discovers that he has arrived on an election day. Confused at the inquiry of his political allegiance from a passerby, Rip mistakenly cries "God bless the king!" After shouts of outrage from the newly liberated populace, Rip Van Winkle explains his identity, which is confirmed by a kindly old neighbor. Rip is welcomed back to the community and sees the effect of time upon everything he remembers before his famous slumber. His children are now grown up; his wife has died, as have many of his former friends.

Washington Irving's tale is a response to the rapidly advancing times of political and social change that characterized the American Revolution. Perhaps even more, it is a reminder that idling away one's own time in such a turbulent historical period can be disastrous. The so-called sleepers or more appropriately named "Rip Van Winkles" need to honor their proverbial "wake-up calls."

There is no doubt that Irving was inspired to pen "Rip Van Winkle" by taking direction from an earlier German folktale known as "Peter Klaus the Goatherd". The tale also bears a strong resemblance to another German folktale collected by the Brothers Grimm known as "Karl Katz". In fact, the postscript written by Diedrich Knickerbocker, Irving's infamous narrator throughout the *Sketch Book* and some of his earlier works, mentions a German superstition.

The tale of Rip Van Winkle inspired others in turn to produce further works based on the story. There have been successful stage adaptations of the tale, as well as operettas and animated films featuring Rip Van Winkle. The earliest screen adaptation is the short film entitled *Rip's Twenty Years' Sleep* (1896), starring Joseph Jefferson as Rip Van Winkle and now housed in the National Archives.

Dustin B. Hummel

See also Novels, Time in; Sandman; Sleep

Further Readings

Burstein, A. (2007). *The original Knickerbocker: The life of Washington Irving.* New York: Basic Books.

Irving, W. (2003). *Rip Van Winkle.* New York: Sea Star. (Original work published 1819)

Rites of Passage

Rites of passage are rituals or ceremonies that individuals in many societies must endure in order to pass from one stratum of life to another. Some examples of rites of passage include naming ceremonies, initiation into adulthood, marriage, childbirth, and funerals.

Arnold Van Gennep described rites of passage, or *rites des passages,* in his 1906 book of the same name. Van Gennep discussed the significance to individuals and society of certain ceremonies or life events that act as a doorway from one stage of existence into another. While passing through this doorway, the initiate found him or herself in a dangerous stage or interface (in some cases literally) of liminality, after the Greek for "threshold." Van Gennep further subdivides rites of passage into rites of separation (preliminal rites), for example, funerals, transition rites (liminal rites) such as initiation, engagement, and pregnancy, and rites of incorporation (postliminal rites) like marriages. These three stages of rites not only transform the individual but reinforce the validity of the social group as a corporate whole by its participation in the events, as well as by the *transformé*'s desire to become part of it.

Victor Turner argues that if the basic model of society is a "structure of positions," the liminal phase is an interstructural situation. During this stage the initiate is separated from the society as a whole by physical means, clothing, or behavior, as he or she is neither what was nor what will be. By analogy we might compare this to a pupa stage between larva and adult in entomology—neither what was nor what will be, but an inchoate form in between. It is during this phase that the individual is intentionally remolded into something different from before by rituals that can cause the initiate to be made to look foolish (as in the Bemba *chisunga*) or ultrapious (as in Holy Orders), or in some manner is stripped of the previous identity and becomes structurally invisible. As an example, when one joins the military, one's old identity is stripped away—literally—as such personal statements as clothing and hair are removed, the name is replaced by "recruit" or "private," and one is subjected to humiliating public medical examinations and torturous training exercises. Eventually the recruit is accepted into the society in the new identity as "soldier" (or "marine," etc.). By passing through these rituals together, the group members feel a sense of cohesion that may outweigh those of kinship bonds, as when age mates (those who have been initiated into an age set at approximately the same time) are compelled to protect each other even against their own kin, as described by Laura Bohannan.

Among the most often described rites of passage are initiation rites from childhood into adulthood, which Turner finds to be core periods in social instruction. In the modern Western world, this often takes the form of a driving license examination or the bar mitzvah and bat mitzvah found in Judaism. In other cultures these can be painful and dangerous genital surgeries such as the subincision found among the Arunta of central Australia, in which a boy's penis is split lengthwise along the urethra, spread flat, and bound to an object to keep it that way until it heals. One of the boy's incisors also is knocked out. Among the Nuer of the Sudan, boys between the ages of 14 and 16 who wish to become men must have a series of parallel incisions called *gar* carved into their foreheads so deeply that it is said that they can be detected on the skulls of dead men. Following the ceremony, the new man takes a new name from his favorite ox, and thereafter is known by his "ox name." These men then belong to a named age-set of men of similar age who form a fraternity for life. Bruno Bettelheim argues in *Symbolic Wounds* that, at least in the male case, bloody rites of passage give men the right to take credit for giving birth just as women can. Women give birth to children, but men give birth to men.

In the early 21st century, more is made of female genital mutilation in the literature than is made of male genital mutilation, as was done in the mid-20th century. An example of female genital mutilation as part of a rite of passage can be found in clitoridectomy as practiced by the Ibibio of southeastern Nigeria, described by John C. Messenger, Jr. An older woman sponsors a girl who has had her first menses and oversees the excision of her clitoris. She then recovers and is instructed in womanliness in a fattening house. After sufficient healing and weight gain, the girl is released from the fattening house and, following a ceremonial leap from a large boulder, is considered to be a woman when her feet touch the ground. She then is known as *mbopa*–fattening girl, or debutante. According to Messenger, the Ibibio claim that clitoridectomy makes women far more libidinous than men.

Somewhat less bloody rites of passage include the vision quest found among Native Americans of the Plains culture area. Although there are variations, the core idea is that for a boy to become a young man, he must have a sacred vision that will guide his path in life. In the vision the boy will meet his spirit companion and receive several symbols that will resonate like wave harmonics with small objects put in a spirit bag that will serve as his soul. Some of the ordeals that boys go through in order to have their visions include fasting to induce hypoglycemia, praying in a sweat lodge to induce dehydration and loss of electrolytes, going naked into the wilderness alone for up to several weeks and risking exposure to the elements, and staring at the sun all day to induce sensory deprivation. One would be surprised if, after enduring all the ordeals, the boy did not have a vision.

Somewhat similar is the walkabout found among some Australian Aboriginal groups. The Zambian Bemba sing and dance the *chisunga* ceremony following a girl's first menses. As described by Audrey Richards, it is designed to give a girl access to supernatural power through her knowledge of symbols that will bring her from "unproductive girlhood to a potentially dangerous but fertile womanhood" and prepare her for marriage.

Some rites of passage are required for initiation into religious groups as well, such as the tonsure ceremonies found in monastic communities. Zora Neale Hurston described her initiation into New Orleans Hoodoo, a syncretistic religion combining Christianity with West African spirit religion primarily found among the Yoruba and Dahomeans and closely related to Haitian Vodoun. Hurston was required to lie naked under a cloth overnight on an altar in preparation for her initiation ceremony as a member of Hoodoo. This is reminiscent of the "mourning" ceremony found among the Spiritual Baptists of Saint Vincent described by Jeannette Henney, and it allows one to come naked into the world again from a dark place, that is, to be reborn.

Michael J. Simonton

See also Anthropology; Life Cycle

Further Readings

Bettelheim, B. (1954). *Symbolic wounds: Puberty rites and the envious male.* New York: The Free Press.

Evans-Pritchard, E. E. (1969). *The Nuer: A description of the modes of livelihood and political institutions of a Nilotic people.* New York: Oxford University Press.

Henney, J. (1980). Sex and status: Women in St. Vincent. In E. E. Bourguignon (Ed.), *A world of women* (pp. 161–183). New York: Praeger.

Hoebbel, E. A. (1960). *The Cheyenne: Indians of the Great Plains.* New York: Harcourt, Brace, Jovanovich.

Hurston, Z. N. (1990). *Mules and men.* New York: Harper & Row.

Hurston, Z. N. (1990). *Tell my horse: Voodoo and life in Haiti and Jamaica.* New York: Harper & Row.

Richards, A. (1995). *Chisunga: A girl's initiation ceremony among the Bemba of Zambia.* London: Routledge.

Service, E. (1978). *Profiles in ethnology.* New York: Harper Collins.

Turner, V. (1967). Betwixt and between: The liminal period in *Rites de Passage.* In V. Turner, *The forest of symbols: Aspects of Ndembu ritual* (pp. 93–111). Ithaca, NY: Cornell University Press.

Van Gennep, A. (1960). *The rites of passage.* Chicago: University of Chicago Press.

Rome, Ancient

Rome was a highly developed society that remained a distinct nation-state for more than 12 centuries. Throughout all that time, there was continual social and political evolution. In the beginning, Rome was ruled by kings. It developed into a republic with elected leaders and a senate and then became an autocratic empire ruled by a series of emperors. In the earliest years, there was little interest in anything more than "local time." Every city had its own calendar and its own way to reckon time. As Rome evolved into a more complex society and absorbed more neighboring cultures, elaborate calendars, astronomical knowledge, and historical recordkeeping developed. At the same time, however, for centuries there was a lack of timekeeping to regulate the workday. Everything was measured relative to sunrise and sunset, and there was no division of time shorter than an hour.

Concept of Time

The era of kings and the early republic are the most poorly documented periods of Roman history. Historical writing by Romans did not occur until Rome had conquered all of Italy and Greece recognized Rome as a world power.

Greeks began to synchronize time in the 3rd century BCE. By charting Olympic Games and their victors in relation to the reigns of kings, a chronology was established. Two Alexandrian scholars, Eratosthenes and Apollodorus, continued and expanded this work through the middle of the 1st century BCE.

As Rome grew and expanded into the Republic, Hellenic synchronization of time changed to accommodate the Romans. The first Roman writer of chronography was Cornelius Nepos. He systematically attempted to place Roman events into the framework of Greek chronology. His *Chronica* was written in the mid-50s BCE. Nepos synchronized events and people from Greek and Roman history. The foundation of the city of Rome, which had had a mythological beginning to this point, was calculated to have happened in the 2nd year of the seventh Olympiad (751 BCE). From this fixed point of reference, he assigned dates to past events. Later historians continued his work. Varro finished a work titled *De Gente Populi Romani* in 43 BCE; it quickly became the canon of chronology. Varro calculated the date for the founding of Rome as 754 BCE.

Establishing a Calendar

Romans numbered their years by labeling the founding of Rome by Romulus, the first king, as year 1. By today's reckoning, the date 753 BCE is used. Years were not numbered. Events were remembered by the names of the two consuls in charge of the state when the event occurred. This method was exceedingly cumbersome, because two consuls were elected each year, and some served more than once. The list of consuls was called the *fasti consulares*. The word *fasti* refers to the Roman calendar and almanac. The word evolved to refer to lists or registers that had to do with keeping time. The *fasti diurni* was a yearbook of religious ceremonies, market days, and court dates. *Fasti dies* were the days in which legal business could be transacted. The *fasti* would be posted in the Forum and other public areas. The word eventually came to be used generally to refer to annals or historical records. The poet Ovid wrote an epic work titled *Fasti,* using the months of the calendar as a frame to weave together Greek and Roman stories and events. There was a book for each month, but only the first six have survived. In Ovid's *Fasti,* festivals are described chronologically and traced to their legendary origins, in verse. While brilliantly written, the poem is also full of patriotism and flattery toward the imperial family.

The earliest Roman calendar began on March 1, and lasted for 10 months; Martius, Aprilis, Maius, Junius, Quintilis, Sextilis, September, October, November, and December, followed by two unnamed winter months. The months were calculated on the lunar cycle. Numa Pompilius, a later ruler, is credited with naming the winter months Januarius and Februarius and adding them to the calendar. Having 12 months based on the lunar cycle resulted in a year of 355 days. Astronomers were aware of the solar year, and periodic adjustments were made to the calendar to stay in line with the seasons by adding a 13th month every other year. This month was called Mercedonius (Latin for wages). For 600 years, politicians used Mercedonius to their advantage. The month would be shortened or lengthened, added or removed arbitrarily to further their personal political goals.

When Julius Caesar came to power, he decided to stabilize the calendar. By 46 BCE, the calendar was so out of sync with the seasons that he added Mercedonius and two additional months. This 455-day year became known as the Year of Confusion, but it did synchronize the calendar with the seasons once again. New calculations based on the earth circling the sun were used to determine the months. The new moon, an object of reverence to the Romans, occurred on January 1 in 46 BCE. Caesar declared it to be New Year's Day. His new 12-month calendar was so improved over the previous one that it remained in use, essentially unchanged, until 1752, when it was determined to be 11 days off.

The names of the months are still in use today except for Quintilis, the fifth month, which was renamed Julius in honor of Caesar after his calendar reform. Similarly, Sextilis, the sixth month, was changed to honor Augustus in 8 BCE. Other emperors tried to make similar changes, but they did not last.

Romans did not number each day in their months consecutively. Each month was divided into three parts, and days were counted in relation to these three fixed points (except for February, which had its own system). The Kalends fell on the 1st day of each month. The Nones fell on the 5th or 7th day of each month, and the Ides on the 13th or 15th day.

The Julian reform of 46 BCE gave our calendar the 12 months as well as their order, length, and names. Astrology introduced the division of the months into units of 7 days. Each day of the week was considered subordinate to one of the seven planets whose movements were believed to regulate the universe. One minor modification in the 3rd century CE renamed the day of the sun, *dies solis,* the day of the Lord—*dies Dominica.*

Finally, each day of the week was divided into 24 hours, which were reckoned from midnight, as we do today.

Measuring the Time of Day

Romans had no way to measure the passage of hours in a day. Time was calculated generally from sunrise and sunset—two fixed moments that were the same for everyone. Romans divided the daylight hours into 12 equal units, with midday occurring when the 6th hour became the 7th. Midnight was the moment at the beginning of the 7th hour after sunset. Romans calculated daylight hours from sunrise and nighttime hours from sunset. Days are longer in the summer than in winter, so the actual length of the hour fluctuated through the year. Hours were not subdivided into any smaller unit of time, so the variation in length was of no concern.

The Sundial

At the end of the 4th century BCE, Romans were still content to divide the day into two parts: before midday and after. By the time of the wars against Pyrrhus, the day was further divided into early morning, forenoon, afternoon, and evening. The concept of "hours" was finally introduced to the city in 264 BCE during the First Punic War. The Greeks had been measuring the sun moving across the sky with sundials since the 5th century BCE. Valerius Messalla, one of the Roman consuls that year, brought the *horologium* (sundial) of Catana back from Sicily as war booty and set it up on the *comitium* (a public meeting place), where, for almost 100 years after, it provided artificial time. The Romans did not understand that the vertical stylus in the center of the sundial that casts the shadow had to be calibrated for the latitude where it was located. However, most individuals probably looked on the sundial as a novelty and continued to go about their business as they always had.

In the year 163 BCE, Romans were finally given their first sundial accurately calculated for their latitude. As reliance on more precise time measurement grew, sundials were set up in public places. They were expensive, so only the wealthy could place such a status symbol in their homes. While sundials were useful tools, they were useless on cloudy or foggy days. This difficulty was remedied a few years later when water clocks were also imported from Greece.

The Water Clock

The water clock, or *clepsydra,* was fairly simple in concept. Water would be released from a container steadily to mark the passing of time. The container would have lines measuring the passage of each hour. A sundial was used initially to grade and calibrate the water clock. After the hour marks were made, one simply refilled the reservoir at sunrise and sunset. From the time of Augustus, after 10 BCE, water clocks grew more elaborate and precise. The presence of a water clock in a private home was a status symbol.

Punctuality was still impossible, even in Imperial Rome. Both sundials and water clocks depended on the hours of the day being divided into 12 equal parts, but there is fluctuation in the length of the day throughout the year. Timekeeping for the Roman was a hit-or-miss activity.

Ancient Romans were profoundly interested in the concept of timekeeping. Methods to track, organize, record, and measure time are seen repeatedly in their history. However, Roman life was never scheduled with precision to the extent it is today. The inaccurate methods for measuring hours remained empirical, and daily schedules remained fluid and elastic throughout the course of the empire. The study of ancient Rome provides a fascinating look at a complex urban society filled with cosmopolitan people who maintained the rural, agrarian pace of their roots in their daily lives.

Jill M. Church

See also Caesar, Gaius Julius; Calendar, Julian; Calendar, Roman; Clocks, Mechanical; Lucretius; Nero, Emperor of Rome; Ovid; Plotinus; Sundials; Timepieces

Further Readings

Aveni, A. (2000). *Empires of time: Calendars, clocks, and cultures.* New York: I. B. Tauris.

Barnett, J. E. (1999). *Time's pendulum: From sundials to atomic clocks, the fascinating history of timekeeping and how our discoveries changed the world.* Orlando, FL: Harcourt Brace.

Blackburn, B., & Holford-Strevens, L. (1999). *The Oxford companion to the year: An exploration of calendar customs and time-reckoning.* New York: Oxford University Press.

Carcopino, J. (1940). *Daily life in ancient Rome: The people and the city at the height of the empire.* New Haven, CT: Yale University Press.

Cowell, F. R. (1980). *Life in ancient Rome.* New York: Penguin Putnam.

Feeney, D. (2007). *Caesar's calendar: Ancient time and the beginnings of history.* Berkeley: University of California Press.

Richards, E. G. (2000). *Mapping time: The calendar and its history.* New York: Oxford University Press.

Rosetta Stone

The Rosetta Stone is an artifact from the 2nd century BCE that was found in Egypt in 1799. It is a fragment of a carved stone decree. The message on the tablet is written in two Egyptian language scripts—Demotic and Hieroglyphic—as well as in Greek. By studying the known Greek, 19th century scholars were eventually able to translate the mysterious hieroglyphs that had baffled their predecessors for centuries. With the translation of hieroglyphic script, the secrets of an ancient and powerful society could be read from firsthand historical accounts for the very first time.

The word *stone* is somewhat misleading; it evokes thoughts of a geological and not a cultural artifact. The object we see today is only a fragment of the original tablet that dates back to 196 BCE. Inscribed on the black granite stone is a decree of the Greek government, which ruled over Egypt at this time. Hieroglyphics were rare after the 4th century BCE but were still used for some religious and governmental purposes. This is why the decree on the stone is written in three different languages: hieroglyphs, because it was a government document; Demotic, which was the common language of the Egyptian people at the time; and Greek, the language of the foreign government. It is believed that such stones would have been placed outside of temples for public viewing.

After the death of Cleopatra VII in 30 BCE, Egypt became part of the Roman Empire. As the Romans converted to Christianity, so did the Egyptians. As time went by, religious importance shifted away from the temples of the old cults, and they began to close. In 392 CE, the Byzantine emperor Theodosius issued an edict to close them all. The Rosetta Stone was most likely damaged during Justinian's reign in approximately 535 CE. During this time temples were being destroyed and their stones recycled for construction projects throughout Egypt. The piece of the stone we see today was eventually moved to Rashid and was used to build a fortress around 1480 CE. Time reduced this stone from a highly regarded object to just another building block.

The stone was discovered in Rashid (Rosetta), in July of 1799. There is some dispute among scholars as to who actually uncovered it. Pierre Francois Xavier Bouchard, a French soldier, is most often credited with the find. The French soldiers immediately realized the importance of the piece and brought it to the Egyptian Institute in Cairo. This establishment had been founded to house the ancient artifacts gathered by the French scholars who accompanied Napoleon on his expedition to conquer northern Egypt. These scholars were recording the relics of Pharaonic Egypt and sending this information back to Europe.

The discovery of the Rosetta Stone was announced to the world on Sept. 15th, 1799. Copies were made and sent to Paris in 1800. The stone was then moved to Alexandria for further study. After Napoleon's defeat in 1801, the Rosetta Stone was surrendered to the British as part of the Treaty of Alexandria signed that same year. The French were allowed to make a cast of it before they were forced to leave Egypt. When the stone first arrived in England, it was housed at the Society of Antiquaries in London. Casts were sent throughout the UK for study. In 1802, it was officially donated to the British Museum by King George III. It has been on display there for more than 2 centuries.

It would be nearly 20 years before someone would solve the mystery of the hieroglyphs written on this artifact. At the time of its discovery, the written language of the Egyptian people was Coptic, which uses Greek letters, along with a few additions, to spell out the Egyptian language. By this time, Demotic was a long-forgotten dialect, and so this part of the text on the stone was also a mystery to modern scholars. It was not known if it was an alphabetic language like Coptic or a more symbolic language like hieroglyphics.

Two scholars are associated with the translation of hieroglyphs. Thomas Young was an English scientist and researcher. He mastered many subjects during his long and successful career. By 1814 he had completely translated the Demotic text of the Rosetta Stone. In the next few years he had achieved a basic understanding of hieroglyphics, although it was later determined that many of his findings were incorrect. Some of Young's conclusions appeared in the famous article "Egypt" he wrote for the 1818 edition of the *Encyclopedia Britannica*. However, he did not publish his complete findings until 1823.

Jean-Francois Champollion is the name usually associated with the Rosetta Stone. Today, he is also credited with being the father of egyptology. Champollion was born on December 23, 1790, at Figeac in France. At the age of 10 he began formal study at the lyceum in Grenoble. By 1806, he spoke a dozen different oriental languages, including Coptic. At just 16 he published a paper that theorized that the Coptic language of the modern Egyptians was the same verbal language as that of the ancient Egyptians. This theory would be the basis of his later work translating the Rosetta Stone. It is thought that Champollion's immense interest in this topic came from the Napoleonic campaigns in Egypt during his childhood. He dedicated his career to studying the Pharaonic times of Egypt linguistically and archaeologically. He traveled around Europe studying Egyptian collections and taking extensive notes of all of his observations. He was appointed curator of the Louvre's Egyptian exhibit when it opened in 1827. In 1828, Champollion traveled to Egypt for the first and only time. It was an extensive 2-year journey mapping and studying ancient artifacts throughout the Nile region.

By 1818, Champollion had succeeded in figuring out that some signs were strictly symbolic and that many others had phonetic value. Therefore, the ancient Egyptian script was at least partially alphabetic. This breakthrough allowed Champollion and other scholars to crack the code of the ancient Egyptians. A language thought to be lost in time was now legible. The ability to read hieroglyphic carvings has allowed scholars to study and understand the documents of an ancient civilization that are nearly 5,000 years old.

Jessica M. Masciello

See also Anthropology; Egypt, Ancient; Language; Museums; Rameses II

Further Readings

Honour, A. E. (1968). *The man who could read stones: Champollion and the Rosetta Stone.* London: World's Work.

Parkinson, R. (2005). *The Rosetta Stone.* London: British Museum.

Rousseau, Jean-Jacques (1712–1778)

The cultural critic, political philosopher, novelist, pedagogue, and composer Jean-Jacques Rousseau was born June 28, 1712, in Geneva, Switzerland, and died July 2, 1778, in Ermenonville, France. Rousseau is regarded as one of the most important critics of modernity. In analyzing modern society, he discusses various aspects of time, such as the origins of humankind and its basic traits and the acceleration of civil life and time as a political factor. According to Rousseau, processes in modern society are too rapid and ought to be slowed down.

Rousseau attained fame with his *Discourse on the Arts and Sciences* (1750), which was a response to a prize question by the Academy of Dijon, asking whether the sciences and arts contribute to the corruption or to improvement of morals. Rousseau's essay presents a radical critique of the idea of social progress that appears in the Age of Enlightenment. Sciences and arts, he argues, will not bring about a better society. They have their origin in human vices and are symptomatic of a lack of virtues. In all eras, the attempt to escape from ignorance leads to slavery and intemperance. Rousseau appreciates the virtues of the plain man who condemns sciences. In his criticism of contemporary society, he contrasts it with the ideal of an earlier, golden age of mankind when life and virtues were supposedly pure.

Rousseau's second discourse, *On the Origin and Basis of Inequality Among Men* (1754), seems to intend a reversal of modernity, too. He describes the development of human species, which at the same time is a process of degeneration. In doing so he is interested not only in giving a history of humankind but also in analyzing the timeframe when the basis of human traits emerges. Reason and language are not essential for human beings. They are not consistent in time; they are rather the results of a random process.

The thesis of Rousseau's essay is that the origins of social inequality and human corruption are to be found in the structures of civil society and not in human nature. As a proof, he develops a unique concept of the state of nature. At the same time he makes clear that philosophers such as Thomas Hobbes who have analyzed the state of humankind have not taken their analyses far enough back in time to show humankind's real nature.

Rousseau describes the transition from the natural man (*homme naturel*) to civilized man (*homme civilisé*). What distinguishes the first humans from animals is the mere fact that humans are free agents. The idea of freedom remains central to Rousseau's work as a criterion for a legitimate political order. However, freedom is in danger when human beings leave the state of nature. Social inequality and dependency arise together with the emergence of private property and the division of labor. This situation has been transferred into civil society by introducing a contract, initiated by the rich to perpetuate their profitable position.

The transition can be understood as antiteleological and anti-Aristotelian. There is no immanent end in time. Human nature does not find its perfection in culture. It ends up in a cultural state due to random circumstances.

In Rousseau's second discourse, he seems to have in mind a time when human existence had found an ideal form of life. He describes a bygone age when development of human species should have stopped: the *golden age.* It is not the time of the first isolated living human beings, but that of pastoralists (*homme barbar*) living in a free and loose society. However, Rousseau's golden age is a moment outside of time. He is quite clear about the hypothetical character of the described history of the human species. The state of nature probably never existed. Furthermore Rousseau's contemporaries could not return to this early stage of development, because human nature cannot go backwards. Hence Rousseau has another approach, which is supposed to be valid for his contemporaries, and which can be found in his political writings.

Rousseau's political main work, *The Social Contract* (1762), deals with the possibilities for maintaining human freedom in civil society. For that purpose Rousseau introduces the idea of a social contract that, unlike the contract in the second discourse, keeps humankind free. Natural freedom has to be transformed into civil freedom by submitting oneself to the general will (*volonté générale*). Rousseau's perfect form of government is a republic. To establish such a government, some exact conditions must be fulfilled. For Rousseau, Corsica was the only place in Europe where his republican state could have been established.

A republic can only be founded at a certain point in time. The people have to have the need for socialization, but they should be in a quasi-uncultivated state. Similar to Émile, the boy in Rousseau's pedagogical writing, the folk are in their youth. At this time they can be taught. Rousseau strives for the forming of a civil ethos through a kind of national education and religion to protect civil freedom. According to Fetscher, Rousseau's philosophy is especially concerned with the possibility of slowing down progress. Although, over time, humans give in to vices, a well-ordered government can hold back this kind of depravity.

Rousseau is ranked as one of the first and most radical critics of modernity. His work can be understood as a reaction to the ideology of social progress, the acceleration of civil life, and a new experience of space and time in the modern world. He sees the life of modern humans as a whirlwind (*tourbillon social*) in which it is vital for them to maintain their freedom and naturalness. *Saint-Preux,* one of the main figures in Rousseau's famous novel *Julie, or the New Heloise* (1761), experiences the accelerated life in the city. He suffers from modern relativisms, the need for various truths, values, and identities for different places and different times. Rousseau, on the other hand, praises the calm life, a contemplative life in nature as it is described in his unfinished book *Reveries of a Solitary Walker.*

Rousseau has been read in various ways. He is regarded as the main figure of the French revolution, as a socialist, and as a liberal; some see him as the mastermind of totalitarianism. Moreover, Rousseau was a romantic conservative. He attempts to protect humankind against the dangers of modern society. His ideal was a native life in close communion with nature. He was clear, however, that this form of life is an anachronism. Hence he hopes for education to protect people against corruption and the transformation of human beings to virtuous citizens in a well-ordered republic.

Robert Ranisch

See also Aristotle; Enlightenment, Age of; Teleology

Further Readings

Berman, M. (1988). *All that is solid melts into air: The experience of modernity.* New York: Penguin Books.

Damrosch, L. (2005). *Jean-Jacques Rousseau: Restless genius.* New York: Houghton Mifflin.

Rousseau, J.-J. (1987). *Basic political writings* (D. A. Cress, Trans.). Indianapolis, IN: Hackett. (Original works published 1750–1762)

Russell, Bertrand (1872–1970)

Bertrand Russell was born into the English aristocracy and went on to become an outstanding philosopher, public intellectual, and social activist. His parents died when Russell was very young, and he was brought up by his widowed grandmother. He studied at Cambridge University and, along with his colleague G. E. Moore (1873–1958), was instrumental in overturning the prevailing orthodoxy of Hegelianism in English philosophy at the time. His early works of philosophy, in particular *The Principles of Mathematics* (1903), had a profound effect on trends in logic and in understanding the importance of language.

The most productive years of Russell's life as a philosopher were devoted to producing, with Alfred North Whitehead (1861–1947), the monumental three-volume *Principia Mathematica* (1910–1913), which was designed to show that pure mathematics follows from logical premises and uses only concepts that are definable in logical terms. This project was never completed, as the proposed fourth volume never appeared. This was due partly to the authors' exhaustion and partly to growing doubts as to the validity of what was being attempted. As Kurt Gödel went on to show, at a certain point the inexorable logic of some mathematical propositions was less clear than originally supposed. And Ludwig Wittgenstein had persuaded Russell that some of the demonstrably logical mathematical demonstrations were little more than tautologies. As Russell said late in his life: "I think that the timelessness of mathematics has none of the sublimity that it once seemed to me to have, but consists merely in the fact that the pure mathematician is not talking about time." Nevertheless, the *Principia* remains one of the most daunting monuments to raw intellectual power ever produced.

It was during the First World War that Russell felt the need to write a new sort of book, one that could extend beyond academic philosophy to reach the general citizen. The first of these works was *Principles of Social Reconstruction* (1916), a series of lectures on issues surrounding postwar reconstruction. This book was enormously successful and established a wider audience for Russell than philosophers had hitherto thought possible, or desirable. During this time Russell lost his position at Cambridge, due largely to a campaign led by J. M. E. McTaggart (1866–1925), who opposed his pacifist views. Russell went to prison for several months in 1918 for his opposition to the war.

The most important of the later technical works were *Analysis of Mind* (1921) and *Analysis of Matter* (1927), *An Inquiry Into Meaning and Truth* (1940) and *Human Knowledge: Its Scope and Limits* (1948). The themes that were constant in Russell's work were analytical method, empiricism, realism, and the relations between things. The best of his popular writings are *The Scientific Outlook* (1931), *Religion and Science* (1936) *History of Western Philosophy* (1946), and *Why I am Not a Christian and Other Essays* (1957). Russell's mathematical ability meant he had a clearer understanding of relativity than most philosophers, then or now. He put this to good effect in popular accounts like the *ABC of Relativity* (1925).

An important element of Russell's writing, particularly in his general works, was his focus on placing humanity squarely back in nature. He outlined this development in a late essay, revealingly titled "The Retreat From Pythagoras." His departure from pure mathematics was an important component of that "retreat." Part of his strong opposition to Kant, Hegel, and pragmatism lay in his suspicion that, in their various ways, they were attempting to place humanity back at the center of the universe, thus reversing the trajectory begun by Copernicus. Russell did not say anything fundamentally new about time, but he did take seriously his responsibility to incorporate time, as understood since Einstein, into a naturalistic outlook on life. The Idealism of Kant and Hegel, as well as pragmatism, struck Russell as variations of hubris. So too did notions of personal immortality, which struck him as "aristocratic." Instead, he pleaded, mainly rhetorically, for a life of moderation in matters intellectual alongside a capacity for extremes of feeling and compassion.

Much of Russell's later career was spent as a public intellectual, with occasional forays back into technical philosophy. Reversing the usual trend, Russell became increasingly radical as he got older. In 1955 he wrote what became known as the Russell-Einstein Manifesto. Albert Einstein cosigned it as one of the last things he did before his death. The Russell-Einstein Manifesto laid the foundations for the peace movement. In 1958 Russell was instrumental in setting up the Campaign for Nuclear Disarmament, serving as its first president. Two years later he founded the even more radical Committee of 100 to participate in civil disobedience against Britain's nuclear policies. Russell led from the front, going to prison in 1961 for the second time in his life. In 1963 he established the Bertrand Russell Peace Foundation as a vehicle to further world peace. During these years of social and political activism, Russell frequently resorted to apocalyptic metaphors of time running out, or the race between disarmament and catastrophe.

Russell was married four times. The first, to the American Quaker Alys Pearsall Smith (1865–1951) ended in 1911, although they were not divorced until 1921. The second, to Dora Black (1894–1986) ended in 1932. The third, to Patricia Spence, ended in 1952. Russell's fourth marriage, in 1952 to Edith Finch, was the happiest of the four and continued until his death in 1970.

Bill Cooke

See also Einstein, Albert; Frege, Gottlob; Gödel, Kurt; Hegel, Georg Wilhelm Friedrich; Humanism; Kant, Immanuel; McTaggart, John M. E.; Whitehead, Alfred North

Further Readings

Clark, R. W. (1976). *The life of Bertrand Russell.* New York: Knopf.

Jager, R. (1972). *The development of Bertrand Russell's philosophy.* New York: Humanities Press.

Russell, B. (1948). *Human knowledge: Its scope and limits.* New York: Simon and Schuster.

Russell, B. (1959). *My philosophical development.* New York: Simon and Schuster.

Russell, B. (1967–1969). *The autobiography of Bertrand Russell.* Boston: Little, Brown.

S

Sagan, Carl (1934–1996)

Carl Sagan, born in Brooklyn, New York, was an American astronomer, astrophysicist, and exobiologist who wrote the introduction for the first edition of Stephen Hawking's *A Brief History of Time,* published in 1988. Around age 5 Sagan became interested in astronomy, and his curiosity was further kindled by reading a library book about stars. He became an avid reader of science fiction, especially the Edgar Rice Burroughs books about John Carter of Mars. Sagan graduated from Rahway High School in New Jersey in 1951, named in the yearbook as the male "most likely to succeed" and "class brain." He went on to complete his B.A. with general and special honors in 1954, his B.S. in physics in 1955, and his M.S. in physics in 1956, all from the University of Chicago. Sagan completed his Ph.D. in astronomy and astrophysics in 1960, with a dissertation titled "Physical Studies of Planets."

From 1960 to 1962, during his postdoctoral fellowship at the University of California, Berkeley, Sagan helped to develop an infrared radiometer, which was sent to Venus aboard *Mariner 2*. He then spent a year as visiting assistant professor of genetics at Stanford University School of Medicine. In 1963 he began a joint appointment as lecturer (and later assistant professor) of astronomy at Harvard University and as an astrophysicist at the Smithsonian Astrophysical Observatory. Upon being denied tenure at Harvard, Sagan went to Cornell University where he became director of the Laboratory for Planetary Studies at the Center for Radio Physics and Space Research and David Duncan Professor of Astronomy and Space Sciences.

Sagan's research interests included the greenhouse effect on Venus, the seasonal changes on Mars due to dust storms, the origin of life, and the search for extraterrestrial intelligence. His mentors included Gerard Kuiper and Nobel laureates H. J. Muller and Joshua Lederberg. Sagan maintained a close association with NASA beginning in the 1950s, working with the Apollo, Mariner, Pioneer, Viking, Voyager, and Galileo programs. He was author, coauthor, or editor of more than 20 books and published more than 600 scholarly and popular articles. Sagan was a successful popularizer of science, most notably with the 1-part series "Cosmos: A Personal Voyage," which was first broadcast in 1980. He also wrote the science fiction novel *Contact,* published in 1985 and adapted as a major motion picture released in 1997.

Honors awarded to Sagan include the NASA award for distinguished public service (twice), the NASA Exceptional Achievement Medal, the NASA Apollo Achievement Award, the Leo Szilard Award for Physics in the Public Interest, the Sidney Hillman Foundation Prize, the Public Welfare Medal (the highest award of the National Academy of Sciences), and the Pulitzer Prize for nonfiction, as well as many others. He was a fellow of the American Institute of Aeronautics and Astronautics, received 22 honorary degrees, and Asteroid 2079 Sagan was named in his honor.

Sagan was married three times and fathered five children. He was married to his first wife, Lynn Alexander (later Lynn Margulis), from 1957 to 1963. They had two sons, Jeremy and Dorion. His second marriage was to Linda Salzman, from 1968 to 1981. They had one son, Nicholas. His third marriage, which lasted from 1981 until his death, was to long-time collaborator Ann Druyan. They had one daughter, Alexandra (or Sasha), and one son, Samuel.

Sagan suffered from the blood disease myelodysplasia and underwent extensive treatment, including three bone-marrow transplants. He died of pneumonia in a Seattle hospital in 1996.

Linda Cara Katherine Shippert

See also Evolution, Cosmic; Nuclear Winter; Space Travel; Time, Galactic; Time, Sidereal; Universe, Contracting or Expanding; Universe, Evolving

Further Readings

Cooper, H. S. F., Jr. (1976, June 21). Resonance with something alive—I. *The New Yorker,* p. 39.

Cooper, H. S. F., Jr. (1976, June 28). Resonance with something alive—II. *The New Yorker,* p. 30.

Davidson, K. (1999). *Carl Sagan: A life*. New York: Wiley.

Sagan, C. (1996). *The demon-haunted world: Science as a candle in the dark*. New York: Ballantine Books.

Saltationism and Gradualism

In the explanation for the origin of new life forms throughout organic evolution, the temporal framework is very important. Two major positions have been offered to account for the process of speciation. Darwinism maintained that the emergence of a new species occurs slowly over a vast period of time in terms of slight variations and natural selection; as such, biological gradualism supplements geological gradualism in natural history. This interpretation upheld the continuity of organic evolution. In the 20th century, neo-Darwinism also supported biological gradualism, claiming that the process of speciation results from the slow accumulation of favorable minor changes in the genetic makeup of an organism. Over time, these positive slight alterations enhanced the adaptation, survival, and reproduction of a species in a changing environment. In sharp contrast, most sudden major mutations in genetic makeup are usually harmful to an organism and result in its sterility or death. If no members of a population can adapt to changes in the environment, then the population becomes extinct. Because biological evolution has been occurring for about 4 billion years, it is generally held that there has been sufficient time for organic history to account for the staggering creativity of life forms in terms of biological gradualism. Nevertheless, the fossil record attests to the fact that most of the species that have ever existed on the earth slowly or suddenly became extinct.

There is no consensus among naturalists concerning the conceptual issue of time and speciation. Although Charles Darwin supported evolutionary gradualism, his contemporary Thomas Henry Huxley argued for a form of saltationism. Huxley maintained that the appearance of a new species represents a major leap, or saltation, in organic evolution. Therefore, in sharp contrast to Darwin himself, Huxley did not claim that biological history represents an organic continuum. To some naturalists, the incomplete fossil record suggested that species both appear and vanish suddenly throughout evolutionary time. In the middle of the 20th century, the saltationism position was revived by Richard B. Goldschmidt in his controversial book *The Basis of Evolution* (1940). In this work, the geneticist claimed that the change from species to species cannot be explained in terms of the accumulation of atomistic changes in an organism (microevolution). Instead, Goldschmidt favored macroevolution with its quantum speciation. Consequently, he put forward his “hopeful monster” hypothesis, which argued that macroevolution (not microevolution) resulted in the instantaneous appearance of a new species and even higher taxonomic groups.

More recently, Niles Eldredge and Stephen Jay Gould presented their “punctuated equilibrium” hypothesis, which claims that a new species appears in a small isolated population during a relatively short period of geological time (only several tens of thousands of years). Unfortunately, this interpretation of “rapid” evolution, along with the incomplete fossil record and alleged lack of transitional fossils in the geological column, provided biblical fundamentalists and religious creationists with a basis they can use for discrediting the immense age of the earth in general and the process of organic evolution in particular.

For scientists, however, geological time and biological time are linked in organic evolution and the process of speciation. This remains the case regardless of whether or not rates of evolutionary change have varied greatly throughout those vast eras of time represented by earth history.

David Alexander Lukaszek

See also Darwin, Charles; Evolution, Organic; Geological Column; Huxley, Thomas Henry; Paleontology

Further Readings

Goldschmidt, R. B. (1982). *The material basis of evolution.* New Haven, CT: Yale University Press.

Gould, S. J. (1989). *Wonderful life: The Burgess Shale and the nature of history.* New York: Norton.

Gould, S. J. (2002). *The structure of evolutionary theory.* Cambridge, MA: Harvard University Press/Belknap Press.

Stanley, S. M. (1984). *The new evolutionary timetable: Fossils, genes, and the origin of species.* New York: Basic Books.

Salvation

Salvation comes from the Latin *salus,* which means "sound, safe." The study of salvation is called *soteriology*. Salvation in a religious sense indicates an ultimate safety. Initially a person is in a state of spiritual danger, which indicates a future (or also present) punishment in some form; therefore the significance of salvation changes over time. Through the intervention of a deity or spiritual awareness, the individual is removed from spiritual danger and receives a spiritual reward. This turn from danger and punishment to safety and reward is salvation.

Note that the word *salvation* has European roots (Latin) and therefore is foremost a Christian concept. Most religions teach that nonpractitioners face danger and punishment, whereas adherents receive safety and reward. That similarity is expressed in a variety of methods depending on the religion. The word *salvation* is found almost solely within Christianity, yet the idea of turning from spiritual punishment to spiritual safety runs constant in all religions. For this reason, the concept of salvation has been used to describe other religious belief systems. Christianity makes the strongest use of the idea of salvation. Christianity focuses on Jesus Christ, whom Christians believe to be both a physical man and God incarnate. Christian salvation teaches that an individual needs to accept Jesus Christ as coming from God and follow Jesus's teachings in order to receive salvation. The reward for the adherent is eternity in heaven with God. The punishment for nonbelief is an eternity in hell apart from God. This is a broad characterization of Christianity, which itself has three main groups—Catholic, Orthodox, and Protestant—each with a different understanding of salvation. All three believe that Jesus is the cornerstone of salvation. Catholic Christians believe salvation is most properly practiced within the confines of church membership. Therefore Catholics receive salvation from within the Catholic Church. Orthodox Christians believe salvation is most properly practiced within the desire for a holy life. Orthodox Christians receive salvation from Jesus as they grow in holiness. Protestant Christians believe that salvation is most properly practiced as the individual accepts Jesus in a one-to-one experience with God. Protestants receive salvation from Jesus when they accept Jesus as God of their life and follow this through in action. These three Christian aspects of salvation developed over time, with Catholic and Orthodox developing concurrently and the Protestant aspect developing later.

The idea that salvation can be represented in an experience (or experiences) is found only in Protestant Christianity. This experience is known as "being saved." Christian Catholicism and Orthodoxy do not have the experience of "being saved"; instead, both teach that the experience of God should be manifested within the Church. Because Christians believe that nonbelief results in an eternity in hell, they proselytize.

Judaism does not focus on salvation as an act of believing or accepting. Instead, Jews escape spiritual danger and receive spiritual safety in trying to live a life focused on God (in Hebrew, *Yahweh,* often transliterated as Jehovah) coupled with a desire to combat sin, which is described in the Tanakh, or Jewish scriptures (which Christians refer to as the Old Testament). Yahweh will reward those who follow him through spiritual and physical blessings. Conversely, Yahweh will punish nonadherents, although the manner of punishment differs among the different Jewish religious groups. Traditionally Judaism has not proselytized because the religion teaches that Yahweh has chosen the Jews as an example to humanity of how to live.

Islam teaches the doctrine of salvation. Within Islam, Muslims will go to heaven (paradise) whereas non-Muslims will go to hell. In this sense, Islam and Christianity are similar. Yet the two religions differ in that the doctrines of God are different. In Islam, salvation occurs when one accepts Allah as the only God and Muhammad as his greatest prophet, strives to follow Muslim precepts, and strives to defeat sin. Islam focuses dually on both the acceptance of Allah and the life lived in service to Allah. Islam promotes proselytizing.

Hinduism and Buddhism, being Eastern religions, share the ideas of karma (actions) and transmigration (reincarnation). In these religions salvation is not achieved by believing in a god (Christianity and Islam) or living out a life in obedience to a god (Judaism), but by being personally responsible for one's actions.

In Hinduism, one is aided in reaching spiritual knowledge, or even purity, by a plethora of gods. Negative actions can be erased through positive actions with the result that karma is negated, and the Hindu reaches *moksha,* or release from the stream of rebirths. This can be considered salvation in the sense that a person has escaped from the continued punishment of rebirths: The *atman* (soul) has joined with Brahman, an impersonal Spirit that is beyond the illusion of life. Time, therefore, plays an important aspect because the adherent moves closer to release through the passage of accumulated lives. Hinduism teaches that all humans are part of the Hindu religious system, and Hindus therefore do not proselytize. One who is not aware of Hinduism and therefore does not adhere to the Hindu faith is living an ignorant life as a result of negative actions in past lives; once the nonadherent develops good karma (actions), the person will be rewarded by being born in an environment that teaches Hindu practices.

In Buddhism, one is guided by the teachings of the Buddha (Siddhartha Gautama). The Buddha is not worshipped as is the Christian God, Islamic Allah, Jewish Yahweh, and Hindu gods. Instead the Buddha participates in the act of salvation through instruction of how to reach total spiritual awareness, which leads to entering Nirvana (a place beyond suffering and the importance of individually lived lives). Buddhists can be said to have salvation in that one can move from spiritual punishment (reincarnations upon the earth) to spiritual reward (move into Nirvana). Thus, just as in Hinduism, the salvation aspect is dependent on time as one progresses through numerous lives. This instruction is found in the Four Noble Truths taught by the Buddha. Buddhism is further divided into two major groups, which view the Buddha's teachings in slightly different ways. Theravada Buddhists hold that each Buddhist is responsible to him- or herself alone and can draw on only him- or herself for a realization of the Four Noble Truths. Mahayana Buddhists believe that individual Buddhists are aided by bodhisattvas, individuals who have been enlightened and have chosen to remain in earthly lives for the purpose of helping others to reach spiritual awareness.

Mark Nickens

See also Bible and Time; Calvin, John; Christianity; God and Time; Islam; Judaism; Religions and Time; Time, Sacred

Further Readings

McGrath, A. E. (2006). *Christian theology: An introduction.* Oxford, UK: Blackwell.

Oxtoby, W. G., & Segal, A. F. (Eds.). (2007). *A concise introduction to world religions.* New York: Oxford University Press.

Sandman

The Sandman is a mythological character, which, at least from the 17th century on, has associated with time, especially the time for children to go to bed. A parallel can be drawn from the Sandman to Hypnos, the god of sleep. Hypnos's mother is Nyx, the goddess of night; his twin brother is

Thanatos, the god of death. As the donor of sleep, Hypnos has power over gods and humans. In Homer's *Iliad* Hypnos usually appears in human shape, but to hide from Zeus, Hypnos disguises himself as the bird of the night. Hypnos can make people fall asleep with his pure appearance, but he sometimes uses the noise of his wings or juices out of a horn to put people to sleep.

The oldest known source of the Sandman is from Sweden. In 1691, a Sandman-like figure, called Jon Blund, was mentioned there. The *Oxford English Dictionary* contains an entry on the Sandman from 1772: "sandman noun (the sandman) [sing.] an imaginary man who is said to make children fall asleep." A German dictionary entry from 1777 describes the Sandman in two versions: First, it is a man transporting and selling sand. Second, in fun, parents say to their children that the Sandman is coming when they become tired and rub their eyes, as if one had put sand into them. This explanation refers to another root of the Sandman history, the Sandmen and Sandwomen, who lived in the German Vogtland. The sand they prospected was used as scouring powder for cleaning.

In the 19th century, the Sandman character found its way into various areas of literature and music. In 1815, E. T. A. Hoffmann wrote the narration *The Sandman*. One of its main characters is Coppelius, a cruel man who scatters sand into children's eyes until they are bleeding and even tears them out of their sockets. Like the earlier version of the Sandman, Coppelius appears in the evening time. Hans Christian Andersen's *The Sandman* was published in 1841. In the original text, the Sandman is called Ole Lukøje, meaning "Ole, shutter of eyes." He sprinkles sweet milk into the eyes of children. While they are sleeping, he comes and opens his umbrella with pictures on it for the children who have behaved, so that they will have pleasant dreams. The others don't dream anything. In music, the character was used by the composer Robert Schumann, who set music to the poem "The Sandman," by Hermann Kletke. In Engelbert Humperdinck's opera *Hänsel und Gretel* (Act Two, Scene Two) from 1893, the Sandman appears to the two frightened children who stay in the forest during the night and he sings: "The little Sandman am I. . . ." He wants to bring some grains of sand for their tired eyes.

Between 1988 and 1996, the American author Neil Gaiman wrote a famous comic book series called *The Sandman*. The protagonist of the series, who was also called Morpheus, is the ruler of the world of dreams. Also, in the 20th century, the Sandman appeared on radio and television series and shows. Every Tuesday since 1923, the radio station KHJ (Kindness, Happiness, Joy), situated in Los Angeles, has broadcasted bedtime stories with the title "Sandman." On May 22, 1956, Radio DDR (Radio German Democratic Republic) began with the program "The Sandman Is Coming." On television, the Sandman had his first appearance on November 22, 1959, at the DFF (German Television Broadcasting). Since then, *Unser Sandmaennchen* (Our Little Sandman) is watched by millions of children and adults every evening at 6:50 p.m. in various countries. It is probably the most famous children's program on German television.

The figure of the Sandman manifests an interesting time structure concerning his age of appearance and his moment of emergence. One cannot say how old the Sandman is, because he is often described and represented as a little man, sometimes with a beard but also with a young face. However, the age of his Ancient Greek ancestor differs between an old and a young person. The Sandman combines old age and youth, often has a wise personality, and stays in contact with children. From today's pedagogical point of view, the Sandman stands for continuity and steady recurrence, and he ends the day with a nice, calming evening greeting.

Sophie Naumann

See also Mythology; Novels, Time in; Rip Van Winkle, Tale of; Sleep

Further Readings

Hoffmann, E. T. A. (2004). *The sand man*. Whitefish, MT: Kessinger Publishing.

Tatar, M. (2003). *The hard facts of the Grimms' fairy tales* (Rev. ed.). Princeton, NJ: Princeton University Press.

Sandpainting

Sandpainting (also referred to as "drypainting") remains a significant and well-known feature of religious ceremonies in a number of cultures, especially among Native Americans in the U.S. Southwest, Tibetan Buddhists, and Australian Aborigines. These colorful, symbolic images serve different functions in different parts of the world but also share some common features. As the name *sandpainting* implies, the artists and religious functionaries generally work with simple materials, but their work involves intricate patterns that follow age-old designs. Because sandpaintings depict meaning on a supernatural or cosmic level, they provide insight into ways by which various peoples view time and eternity, key intellectual and spiritual frames of reference in all cultures. Although sandpaintings are more important for their original roles in ritualistic contexts, connoisseurs and collectors also recognize the aesthetic qualities of sandpaintings, which have acquired commercial value in some regions. As a result, the religious origins of these ancient artistic traditions have become better known, at least on a rudimentary level.

Although practiced among the Pueblos and other indigenous peoples of the American Southwest and Great Plains, sandpainting has assumed its highest profile in the Navajo traditional religious system. The Navajos use sandpaintings while performing ceremonies to invoke blessings from the supernatural world (e.g., rain, crops, health) and also in their famous curing ceremonies. In the traditional manner, the Navajo discover the causes of problems or illnesses through divination and then determine the appropriate ritual procedures—or "ways"—to remedy the situation. These elaborate ceremonies, called "chants" or "sings," include many ritual components, and drypainting procedures play a critical role. Whereas the chants survive in limited numbers, scholars have documented many hundreds of sandpaintings to accompany curing ceremonies. The singers who lead these rituals are highly respected professionals, and they determine—in consultation with other people who are involved in the ceremony (including the patient)—the precise combination and order of features. Such ceremonies can last up to 9 nights, and each day has a traditional set of procedures, all of which purify the place and patient/client for this special occasion and invoke the presence and aid of the gods, the "Holy People." Singers and their assistants often require many hours to prepare a painting, which can be small or so large that it requires the construction of a special hogan. They prepare a background of sand or buckskin and dispense the colorful materials (e.g., crushed minerals, charcoal, dried and crushed flowers, cornmeal, and pollen) with their hands to create the detailed pattern, which includes geometric images, lines, and figures—a diagram of reality, the visible and normally invisible realms. Even colors have symbolic meaning, and each scene includes figures that relate to mythology; the singer's attention to every detail makes the painting powerful. As the patient sits in the painting and comes into physical contact with its symbols, the image provides an actual place for human beings to encounter cosmic forces. Navajo refer to the sandpainting, in effect a cosmic map, as *iikaah*—a place where the gods come and go. In fact, the paintings portray Holy People, sacred animals and plants, and astronomical bodies. Because these images contain sacred power, which is subject to abuse, singers destroy paintings when the ceremonies end. Sandpaintings help the Navajo restore and maintain balance and harmony between the natural and supernatural worlds, which are intertwined in their traditional worldview.

The portrayal of cosmic images also serves a vital role in a number of Hindu and Buddhist traditions, but the most famous sandpaintings in these traditions relate to Tibetan Buddhist (Vajrayana) beliefs and practices. Although much of the Tantric Buddhist teaching remains esoteric to outsiders, the Dalai Lama, head of the Tibetan Buddhist community, has promoted their views by distributing knowledge about the most famous aspect of Tibetan Buddhism, namely, the *mandala*. The mandala (Sanskrit for a "circular" or "round" shape or container), often made of richly colored sands and other materials, conveys a wide range of symbolic significance. In its essence, the mandala is a picture or diagram of the universe, a representation of the deities that inhabit the cosmos, that serves as an aid to meditation for those on the path to Enlightenment (Nirvana). The ceremony surrounding the creation of a mandala, which includes music and chanting, has a purifying effect and plays an important role in the initiation of Tibetan monks and the pursuit of spiritual blessings. As a place of spiritual encounter—an actual sacred space and something more than a mere picture—the mandala channels positive energy to both beginners and experts in Tantric practices.

The Tantric artists refer to the sand mandala as *dul-tson-kyil-khor,* a mandala/diagram composed of colored powders (e.g., sands, plant materials, gemstones). The practitioners follow traditional patterns and carefully control the distribution of the mandala's tiny components with a small hand-held device. Depending on its size and complexity, monks can take up to several weeks to complete a sand mandala. The deities that populate the finished painting point to various aspects of the Buddhist quest and aid the contemplative process. One of the most famous mandalas, the so-called Wheel of Time (Kalachakra), reminds adepts about the transient nature of time. Like all such cosmic diagrams, the wheel helps contemplatives focus on the relation between the finite and the infinite. Like the Navajo artist/singer, Tibetan artists/monks also destroy the mandala after the ceremony ends—in this case by pouring its transportable components into a body of water. This destructive act distributes blessings from the mandala and vividly symbolizes the impermanence of life, one of the pivotal principles of Buddhism. According to Buddhist tradition, Siddhartha Gautama—the Buddha himself—taught his followers the value of sandpaintings.

Certain groups of Australian Aborigines also practice a form of sandpainting, often called "dot painting." With a patch of desert surface as a background, they use various materials (e.g., sand, stones, plant materials, and feathers) to depict various accounts (e.g., their creation account, clan history, sacred sites). Accompanied by ceremonies of song and dance, some dot paintings portray scenes from the most sacred history, what the indigenous Australians call "Dreamtime" or "Dreaming"—the time of Origins that remains immanent. In other words, these simple ground paintings have functioned as a primary medium to depict the sacred beginning of time and history, to connect Dreamtime with the present. While the designs perpetuate motifs in use from remote times, some artists now use new media for these images and have begun to market portable versions of these paintings.

Gerald L. Mattingly

See also Buddhism, Mahayana; Buddhism, Theravada; Buddhism, Zen; Dreamtime, Aboriginal; Navajo; Nervana; Pueblo; Totem Poles

Further Readings

Brauen, M. (1998). *The Mandala: Sacred circle in Tibetan Buddhism.* Boston: Shambhala.

Bryant, B. (2003). *The Wheel of Time sand mandala: Visual scripture of Tibetan Buddhism* (Rev. ed.). Ithaca, NY: Snow Lion.

Griffin-Pierce, T. (1995). *Earth is my mother, sky is my father: Space, time, and astronomy in Navajo sandpainting.* Albuquerque: University of New Mexico Press.

Kluckhohn, C., & Leighton, D. (1962). *The Navaho* (Rev. ed.). Garden City, NY: Doubleday.

Leidy, D. P., & Thurman, R. A. F. (1997). *Mandala: The architecture of enlightenment.* New York: Overlook Press.

Morphy, H. (1998). *Aboriginal art.* London: Phaidon Press.

Myers, F. R. (2002). *Painting culture: The making of an Aboriginal high art.* Durham, NC: Duke University Press.

Parezo, N. (1991). *Navajo sandpainting: From religious act to commercial art.* Albuquerque, University of New Mexico Press.

Reichard, G. A. (1977). *Navaho Religion: A Study of Symbolism.* Princeton, NJ: Princeton University Press.

Sankara, Shri Adi

Shri Adi Sankara was a philosopher-theologian of the Advaita Vedanta (nondual) school of Indian thought. His dates are disputed, although he probably lived and worked in the early 8th century. Besides his distinguished career as an influential thinker, he played several roles: Hindu reformer, founder of monastic centers, commentator on ancient texts, and author of original works of philosophy.

Medieval Indian culture recognized two types of time: linear historical time, often associated with dynastic rule, and cyclic cosmic time, which was depicted as four *yugas* (ages) of descending longevity. In the ancient Atharva Veda text (19.53–54), time is identified with the deity Prajapati. According to the Maitri Upanishad (6.14–16), the sun, a source and support for all living things, is also identified with Brahman, and time is, by extension, identified with Brahman, or the highest reality. In the cosmic level, time is a power that brings about the evolution and involution of the entire universe. Time is depicted in the Upanishads as cyclical, with an inconceivable beginning and end. Being described as all-inclusive and rolling on endlessly, time is conceived commonly as a destructive force. Time is, for instance, compared with the six seasons, which swallow up creatures, or cook all creatures, according to the Maitri Upanishad (6.15), making them ripe enough to be swallowed by death. Other metaphors of time depicted it as a noose that binds one and tightens as one grows older; time is imagined to be a winged horse that carries away all creatures, or time is like a ceaselessly revolving wheel. Moreover, time is connected to the cycle of birth, death, and rebirth, which is interpreted as an endless cycle of suffering that only ends with the attainment of liberating knowledge and status of one liberated while alive (*jivanmukti*).

The conception of time as four yugas is found in the worldview of the Puranic texts (c. 4th century CE). The term *yuga* is derived from the throws of dice and suggests that life is similar to a gigantic dice game. The primary or golden age is the *krita* yuga, which lasts 1,728,000 years, and it is represented by a four-legged mythical cow, which is a symbol of the social and cosmic order (*dharma*). The second age, the *treta* yuga, lasts for 1,296,000 years and is a period of time when the mythical cow stands on three legs. This silver age is followed by the copper age of the *dvapara* yuga, a period when the mythical cow stands on two legs and which lasts for 864,000 years. During the final age, or *kali* yuga, the mythical cow stands on one leg for a period that lasts for 432,000 years. During this last period, the mythical cow symbolizes the idea that humans can no longer perform good deeds during a final age characterized by strife, quarrel, dissension, war, and evil. Each cycle of the four yugas is called a *mahayuga* (great age), which represents a *kalpa* (eon) at the conclusion of which there occurs a dissolution of the world and return to cosmic nondifferentiation. After an unspecified period, the cosmos is recreated, and the cyclic process begins again with the dawn of a golden age and a repeat of the entire cycle.

These two notions of time were inherited by Sankara, who, among his other accomplishments, is arguably most renowned for his commentary on the Vedanta Sutras. Originally composed around the 2nd century BCE by Badarayana, the Vedanta Sutras were revived by Gaudapada and his disciple Govinda, who initiated Sankara into the text. During their transmission, the texts were influenced by ideas from the Vijnanavada and Madhyamika Buddhist schools, whereas Sankara attempted to purge the text of their distinctive Buddhist traits. Sankara's intention was to construct a philosophical edifice based on a direct interpretation of the older Upanishad texts that he considered part of the divine revelation to ancient Indian seers. These ancient revelatory texts helped Sankara to grasp reality, world, and the self from a nondualistic perspective.

Sankara makes a distinction between reality, appearance, and unreal. Reality is that which cannot be sublated by any kind of experience, whereas appearance can be sublated by reality, which Sankara identifies with Brahman. The unreal can never become a content of experience; it is thus that which neither can be nor cannot be sublated by other experience. For Sankara, sublation is a mental process in which an object or content of consciousness is cancelled because it is contradicted by a new experience. You perceive an object in your path, for instance, that you imagine to be a snake, but on closer inspection it turns out to be a piece of rope. Sublation represents a change of one's judgment because a new experience rectifies one's previous erroneous belief.

The notion of sublation in Sankara's philosophy possesses important implications for time, which is a category of empirical experience or only of the phenomenal world. Sankara recognizes six types of empirical or lower forms of knowledge: perception, comparison, noncognition (judgments of absence), inference, postulation (assuming of a fact in order to make another fact intelligible), and testimony (accepting as true information that one receives from a reliable person). The basic problem with these six instruments of knowledge is that they are all subject to ignorance because, in part, they presuppose a distinction between knower and object, which is a dualistic mode of knowing, and thus do not allow the individual to grasp the nondual nature of Brahman. The six forms of knowledge are valid as long as the intuitive vision of Brahman is not achieved by means of higher knowledge, which is an intuitive type of knowledge that is unique, immediate, and self-validating. The six types of empirical knowledge are rendered invalid because one can see that they are tainted by ignorance and are sublated by the higher form of knowledge.

This distinction between lower empirical knowledge and intuitive higher knowledge means that time is something to which everything is subject, and it is thus fundamental to the objectification of human existence. Simultaneously, it is our temporality that gives us a chance to know the eternal Brahman, which is defined as both time and eternity. Because of the notion of sublation, time is ultimately illusory for Sankara because it can never sublate Brahman.

Even though time possesses a lower reality when compared with Brahman, time is in us as pure subjects, and we are in time as empirical egos. The self (*atman*), which is identical to Brahman, is timeless, does not arise in time, is not subject to a present, and does not have an end in time. The self (*atman*) exists in an eternal now without past or future. Thus the phenomenal world, which can conceal and distort reality, is illusory and is produced by illusion, a metaphysical power (*sakti*) of Brahman. This illusion is beginningless, unthinkable, and indescribable, although time arises only within it. For Sankara, time is only real on the level of appearance, but it is ultimately unreal and illusory because it can be sublated by a higher reality.

Carl Olson

See also Cosmology, Cyclic; Now, Eternal; Time, Cyclical; Time, Illusion of;

Further Readings

Deutsch, E. (1969). *Advaita vedanta: A philosophical reconstruction.* Honolulu, HI: East-West Center Press.

Sankara. (1968). The Vedanta-Sutras with the commentary of Sankaracarya (G. Thibaut, Trans.). *Sacred books of the East* (Vols. 24 & 38). Delhi, India: Motilal Banarsidass.

Sankara. (1992). *A thousand teachings: The upadesasahasri of Sankara* (S. Meyeda, Ed. & Trans.). Albany: State University of New York Press.

Santayana, George (1863–1952)

Philosopher, poet, novelist, and critic Jorge Agustín Nicolás Ruíz de Santayana was born on December 16, 1863, in Madrid to Spanish parents and was brought to Boston at the age of 9 and educated at the Boston Latin School. He studied at Harvard University under William James and the idealist philosopher Josiah Royce. His academic career was also at Harvard, where he was a professor of philosophy. But he became progressively more estranged from American life and, once he could afford to do so in 1912, he left the United States and migrated to Europe. In 1924 he settled in Rome, where he remained for the rest of his life, dying there on September 26, 1952.

Santayana is best remembered for two works: *The Life of Reason* (five volumes, 1905–1906), which is deeply imbued with the ideals of the naturalism and humanism of ancient Greece, and his novel *The Last Puritan* (1936), a study of New England attitudes and values. Other important books he wrote include *Skepticism and Animal Faith* (1923), wherein he revised some of the ideas expressed in *The Life of Reason* and refined others. During World War I, he expressed support for critical realism, contributing to an important collective work called *Essays in Critical Realism* (1920). A feature of Santayana's work is his extraordinary fluency with prose writing. He has been described as the finest writer of philosophy since Plato.

Santayana's views on time altered imperceptibly as he got older. In *The Life of Reason,* he articulated a meliorist view of progress, which opened the possibility of things improving, but only with concerted human effort. As he got older he became more conservative in political matters and less sure that even the modest forms of progress he had endorsed as a younger man were either possible or desirable.

During the first half of his philosophical career, until about 1923, he was broadly naturalistic and humanistic. But after that date he felt the need for a more systematic exposition of his naturalism, one that inserted ontological categories he called "essences" into the fabric of nature. These essences had a negative effect on his notions of progress. Athough this second half of his career was more Platonist in style, it was still fundamentally naturalistic. But throughout his philosophical career he eschewed dualism and advocated what he called the Aristotelian principle: All ideals have a natural basis but all natural processes are capable of ideal fulfillment. By reason, Santayana simply meant a higher-order impulse.

Although he was an atheist and materialist, Santayana could see good in religion, when understood properly. He saw little value in literal belief and supernaturalism, but as a way of memorializing and celebrating what matters in life, religion was of inestimable value, he believed. Santayana's legacy is mixed. Ironically, it is in the United States, the country he felt least at home in, where he is best remembered and exerts the greatest influence, particularly among aestheticians and proponents of American philosophical naturalism.

Bill Cooke

See also Existentialism; Humanism; Materialism; Plato

Further Readings

McCormick, J. (1987). *George Santayana: A biography.* New York: Knopf.

Santayana, G. (1944). *Persons and places.* New York: Scribner.

Santayana, G. (1954). *The life of reason.* New York: Scribner.

Satan and Time

The term *Satan* (Hebrew: ןָטָשׂ, Greek: Σατανάς, Aramaic: אנטס, Arabic: ناطيش) comes from the Abrahamic religions Judaism, Christianity, and Islam, those derived from Semitic origins and traced back to the patriarch Abraham. Satan is often represented as an angel, minor god, or the Devil himself. Modern Christianity commonly conflates Satan with Lucifer and Beelzebub, among other malicious beings. In these traditions, Satan represents a force of evil within humanity.

Satan is a figure often designated by an assortment of aliases and roles. He has been called, variously, the Prince of Darkness, the Devil, the Accuser, the Prince of Hell, the Evil One, the Tempter, the Wicked One, Old Nick, Old Harry, the Dragon, the Fallen One, and Mr. Scratch and has been identified as the Ruler of Hell, Hades, the Lake of Fire, the Inferno, Styx, the Everlasting Fire, and the Realm of Pluto. These roles and names reflect the incorporation of demonic figures from several ancient religious and belief systems.

Islam's main devil figure, or Shaitan (Satan is the English equivalent), is Ibis, who was created out of smokeless fire by Allah (God). After the creation of humankind, Ibis was expelled from the graces of God to Jahannam, or hell, due to his self-pride and jealousy. In response to his pleading, Allah granted him the right to roam Earth, as the ruler of all jinns and tempter of humankind, to the end of his days. It was he who tricked Adam and Hawwa (Eve) into eating the forbidden fruit, but they repented and God removed their misdeed. Allah, after granting forgiveness, then warned them of the trickery of Ibis and the hell fires that await those who fall to the deceptions of the Devil. Unlike within modern Christianity and Zoroastrianism, Ibis is merely the servant of God, who is the supreme ruler and savior of all.

Within Zoroastrianism the figure Angra Mainyu, or Ahriman, is the opponent of the sole god figure, Ahura Mazda. According to Zurvanite Zoroastrianism, Ahriman, and Ahura Mazda were twins created by Zurvan (time). Today the Parsis of India hold that Mainyu is the "destructive product" of Mahura, and instead of battling Mahura himself, Mainyu battles the creative product Spenta Mainyu.

The Bahá'í Faith refers to Satan as a metaphor for the "insistent self" or the self-serving desire of humanity. Bahá'u'lláh wrote of the insistent self being the "evil one," the symbol of which is Satan. They hold that evil is simply the absence of goodness, making the existence of evil powers impossible. Consequently Satan is not evil personified in the world, but the evil ego and lower self of all of humanity.

Within the Hebrew Bible the prosecuting angel *Ha-satan,* the accuser, is the closest reference to Satan. Ha-satan is the one who questions man's loyalty and plagues Job with disease to test his faith. The Hebrew Aprocrypha also holds references to a Satanic-like figure being tossed from heaven.

It is this story of a rebellious angel being tossed from heaven which composes the mainstream understanding of Satan in Christianity. Satan's original name is said to have ended in *-el* like the great angels Michael, Raphael, and Gabriel. Having become consumed by pride, Satan challenged God for supremacy of heaven. God then cast him and other rebellious angels out of heaven. Due to his former stature, Satan became ruler of all Devils and disobedient souls. Christianity additionally regards Satan as the serpent in the Garden of Eden, the tempter of Christ, and the Dragon in the Book of Revelations. The common belief is that at the Apocalypse, Satan will wage a final war against Jesus, whereupon he will be defeated and banished into the Lake of Fire alongside all sinners. The Unification Church, however, believes that Satan will be returned to his former angelic form.

The Devil is supposed to be capable of taking any form to carry out his deceptions. As Martin Luther mentioned in *Table Talk,* the Devil holds two forms. He may appear as either a serpent (to scare us) or a lamb (to deceive us). Depictions of Satan have varied throughout the centuries. In the Middle Ages the common devil icon is that of a figure with horns, hooves, and a pointed tail. Medieval art depicts a figure with bat wings, a twist on the traditional angelic figure. Kabbalists, however, show him as a former angel with the moon upon his feet, denoting the ability to change. His wings are severed to show his fallen state, a star on his forehead denotes him as the former morning star, and he carries a torch symbolizing him as a destroyer. Some have depicted him in the form of an animal, such as a black dog, goat, or snake. These forms are often riddled with deformity due to his inability to duplicate God's work. Others have even depicted him as a beautiful creature, referring back to his former stature and ability to deceive humanity.

Many minor demons are commonly confused with Satan due to their nature. Lucifer is a leader of the rebellious angels who is expelled from paradise. He is commonly confused with Satan himself:

> "How art thou fallen from Heaven, O Lucifer, son of the morning!" (Isaiah 14:12)
>
> "I beheld Satan as lightning fall from Heaven." (Luke 10:18)

The demon Beliel or Beliar, commonly referred to as the Prince of Trickery, is another fallen angel. He is confused with Satan due to Saint Paul's decree:

> "What Concord hath Christ with Belial?" (2 Cor. 6:15)

Beelzebub, "the Lord of the Flies," is a former Philistine god. He is one of the chiefs in the nine hierarchies of hell, and is regarded frequently as second in command to Satan. The Evangelists Matthew, Mark, and Luke refer to Beelzebub as the chief of the demons, and in Matthew 12:24 Beelzebub is called the "Prince of Demons"; however, he is not Satan himself. Mephistopheles is a servant of Lucifer who is closely associated with Satan because of his role in the literary works *The Tragical History of Doctor Faustus* by Christopher Marlowe and *Faust* by Johann Wolfgang von Goethe.

Derik Arthur Kane

See also Angels; Bible and Time; Christianity; Devils (Demons); Evil and Time; God and Time; Goethe, Johann Wolfgang von; Islam; Judaism; Sin, Original; Zoroaster

Further Readings

Ashley, L. L. N. (1996). *The complete book of devils and demons*. Fort Lee, NJ: Barricade Books.

Collin de Plancy, J.-A.-S. (1965). *Dictionaire infernal.* London: Peter Owen.

Pagels, E. (1996). *The origin of Satan*. London: Allen Lane.

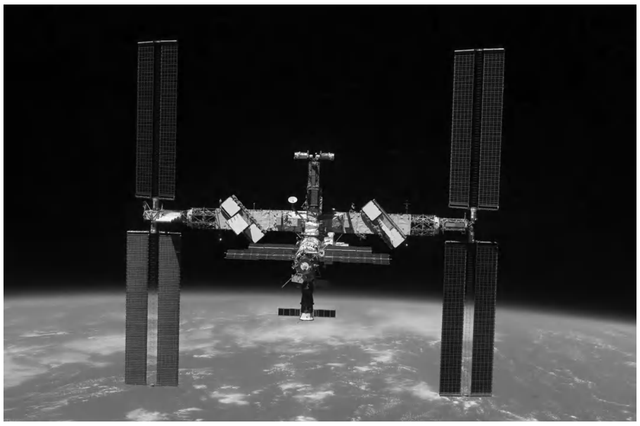
Satellites, Artificial and Natural

A satellite is a small or secondary body that revolves around a larger one in the solar system. There are both natural and artificial satellites, which revolve and rotate at different rates of speed. Consequently, they may be used to measure time on Earth and to determine extraterrestrial occurrences. In the future, time-measuring satellites will be used to aid space travel and to predict cosmic events.

Natural planetary satellites are classified according to either their composition or their type of orbit. Nearly 100 have thus far been observed and identified in our solar system, and a great deal is known about their size, composition, and other physical properties. Our moon is Earth's only natural satellite; some planets have many such objects circling them. Jupiter, for example, has 49 officially named satellites. The rotation of most natural satellites about their respective planets is west to east, the same as the rotation of their planets. Some outer satellites, however, rotate in the opposite direction.

Artificial satellites are human-made objects that typically orbit the Earth, gathering data that are used for a multitude of purposes. There are six main types: (1) scientific research, (2) weather, (3) communications, (4) navigation, (5) Earth observing, and (6) military. Because their design is dictated by their intended use, satellites come in a variety of shapes and sizes. Some artificial satellites also orbit the moon, the sun, asteroids, and the planets Venus, Mars, and Jupiter, gathering information about the bodies they orbit. All artificial satellites are subject to the same physical laws as their natural counterparts. The first artificial satellite, *Sputnik I*, was launched in 1957 by the Soviet Union; today, according to estimates by the National Aeronautics and Space Administration (NASA), more than 8,000 satellites are in orbit. All the major industrialized nations use satellite technology.

Satellite observations provide a unique vantage point from which to study Earth, and they have provided researchers with a critical means for studying the solar system. This is the only way to make in situ measurements of Earth's atmosphere, without having to contend with the affects of the atmosphere. Previously, such measurements could only be made on the ground or on ships or airplanes.



The International Space Station (ISS), the largest human-made object ever to orbit Earth, is shown here after separation from Space Shuttle Atlantis*, June 19, 2007.*

Source: NASA.

Most satellites are launched from rockets at fixed sites; in the United States many are launched from Cape Canaveral, Florida. Such sites provide logistical support for the assembly, check-out, and launching of satellites, and these sites possess the technology necessary to support these activities, including radar, optical tracking equipment, and meteorological equipment.

The launching of a satellite is achieved by propelling the object at a high velocity that allows enough energy to be imparted so that the object can remain in orbit without the need for additional energy. Orbits exist in a variety of shapes, from circular to highly elliptical and from high altitude to low altitude. A higher-altitude orbit leads to longer orbital periods (i.e., time required to complete one orbit). Satellites with a low-altitude orbit, on the other hand, orbit more quickly but are more likely to decay and enter Earth's atmosphere sooner than those orbiting at a higher altitude.

Artificial satellites are powered by solar cells, by batteries that often are charged by solar cells, and in many cases by nuclear reactors, or by generators in which heat produced by the decay of radioisotopes is converted into electricity.

Patricia West

See also Moon, Age of; Nebular Hypothesis; Planets, Extrasolar; Space Travel; Time, Measurements of

Further Readings

Chartrand, M. (2003). *Satellite communications for the nonspecialist.* Bellingham, WA: SPIE Press.

Montenbruck, O. (2000). *Satellite orbits: Models, methods, and application.* New York: Springer.

Parks, L. (2005). *Cultures in orbit: Satellites and the televisual.* Durham, NC: Duke University Press.

Pelton, J. N., Oslund, R. J., & Marshall, P. (2004). *Communications satellites: Global change agents.* Hillsdale, NJ: Lawrence Erlbaum.

Whipple, F. (1981). *Orbiting the sun: Planets and satellites of the solar system.* Cambridge, MA: Harvard University Press.

Scheler, Max (1874–1928)

Max Scheler was among the most prominent and widely discussed philosophers of the

German-speaking world in the early decades of the 20th century. Though Scheler did not explicitly outline a specific philosophy of time, the concept of "timelines" of life and being is important for his phenomenological and anthropological work and needs to be understood in the context of the general development of his thinking.

The Life

Born within a predominantly Jewish family background (his mother was orthodox Jewish, his father had converted from Protestantism to Judaism), Max Scheler developed an interest in Catholicism in his youth in Munich and formally became a member of the Catholic Church in 1899 at the age of 25.

After briefly studying medicine and psychology at the universities of Munich and Berlin, where he also studied under Wilhelm Dilthey and Georg Simmel, he changed to philosophy, which he continued to study in Jena. At the University of Jena he studied mainly under the philosopher and Nobel Prize winner (for literature) Rudolf Eucken (father of the later influential economist Walter Eucken). There Scheler also finished his Ph.D. and taught from 1900 to 1906. During that time he met Edmund Husserl and came in contact with the philosophical thought of the phenomenological circles, to which he became more closely connected after 1907 in Munich, where he had moved after a private crisis that forced him to leave the University of Jena in 1906. From 1907 to 1910 Scheler taught in Munich and was in close contact with phenomenological thinkers Alexander Pfaender, Dietrich von Hildebrand, Theodor Lipps, and others. After Scheler lost his position in Munich, he gave private lectures in Göttingen, where Edith Stein was among his students, and worked later for the German government. During that time Scheler published some of his major works, including *Phenomenology and Theory of Sympathy* and *Formalism in Ethics and Nonformal Ethics of Values*. Defending a value ethic and a view on humankind as characteristically related to a theistic-understood God (and creator), Scheler became one of the most influential Catholic intellectuals. After World War I the mayor of Cologne, Konrad Adenauer, later chancellor of Germany, was involved in Scheler's appointment as professor of philosophy and sociology at the refounded University of Cologne, where he taught beginning in 1919. In that time a major shift took place in Scheler's thinking; he turned from the Christian and Catholic tradition, denied the concept of a personal creator-god, and developed the idea of a god in the process of becoming, for which humankind is crucial (highly important for that concept is his famous *Man's Place in the Universe,* in which Scheler outlines his late anthropology). In 1928 he accepted a new position in Frankfurt but died early in that year. His work was actively suppressed under the Nazi regime, but in the postwar period it underwent a revival and has been translated into many languages.

The Work

Scheler did not explicitly outline a specific theory of time in his oeuvre, so that his comprehension of time needs to be understood in the context of the general development of his thinking. Despite the discontinuities in his thinking, Scheler emphasizes that the understanding of anthropology is the steady center of his interest and his philosophy. In his first important period he holds a specific phenomenological view, which leads him to an understanding of man as primarily an *ens amans,* a loving being, characterized by his *ordo amoris,* or order of love, that directs him to the sphere of values. This core dimension of human existence follows his own—intelligible—"logic of the heart." Prior to all other forms of cognition is the perception of value in a specific act of feeling (*wertnehmen*). Scheler distinguishes five strictly hierarchical ranks of values: (1) an absolute sphere of holiness; (2) a sphere of values of person, culture; (3) ethics, vital values; (4) values of utility; and (5)values of sensual pleasure. His ethical concept is based on the ethical good being realized by a creative process of intending the realization of higher values as preferred to values of the lower spheres, whereas evil results from a "disorder of preferences," mistaking lower values for the sphere of the absolute. In its leaning and orientation to the realization of value, human life is a *werde-sein* ("being in becoming") and the experience of time is primarily the medium of a process of becoming, developing, and growing. In his later period Scheler embedded his concept in the idea of a great "drama," in which a value-connected but originally powerless spirit forms and directs the vital *Drang* (urge, impulsion), both being original aspects of the ground of being. This process of *Durchdringung* (penetration) of spirit and vital *Drang* is the evolution of a yet unfinished, "becoming deity," which can be observed in the spiritual development of humanity.

In this context of his late philosophy, Scheler speaks of "absolute time" as the origin of the phenomenon of timeliness, which is given with this evolutionary character of being as a cosmic "becoming." The concept of absolute time results from this evolutive constitution of being (as *werdesein*) as a "space" for the process of development. Measurable, objective time, the "clock-time" of our day-to-day understanding, derives from the experienced phenomenon of "absolute time" by an act of extending the tendency to self-alteration and resistance against it to a general concept of reality.

Harald Jung

See also Anthropology; Husserl, Edmund; Merleau-Ponty, Maurice; Simmel, Georg; Time, Phenomenology of; Values and Time

Further Readings

Frings, M. S. (1997). *The mind of Max Scheler.* Milwaukee, WI: Marquette University Press.

Spader, P. (2002). *Scheler's ethical personalism: Its logic, development, and promise.* New York: Fordham University Press.

Schelling, Friedrich W. J. von (1775–1854)

Friedrich Wilhelm Joseph von Schelling was born on January 27, 1775, in Leonberg, Württemberg, Germany. He was perhaps the most important German idealist philosopher who lived after the time of Immanuel Kant and before G. W. F. Hegel. With them, he shared the principle of idealism, namely, that the essence of an object is the objectified essence of a subject.

In his *System of Transcendental Idealism* (1800), Schelling began by adopting the seminal notion of time as the intuition of inner sense, developed by Kant, but developed it into the doctrine that "the self itself is time conceived of in activity." In his metaphysics, Schelling identified "being" with "process," that is to say, to be is to produce. The self is the process that produces itself; that is, the self is simply the activity of producing its own world. This process is itself time and space, as they are nothing other than the process which creates them. The self begins unaware that it produces the world and only gradually becomes conscious of the fact.

Greatly influenced by Kant's late notion of "force" in *Metaphysics of the Natural Sciences,* Schelling developed an idealism that took into account the natural sciences. The resemblance between the theories of Schelling and Roger Joseph Boscovich is due to the fact that Kant largely adapted Boscovich's concept of force in *Metaphysics of the Natural Sciences.*

Schelling wrote in the verbose and dense terminology of the German idealists. He constructed a "system of transcendental idealism" in considerable detail, which cannot be entered into in this entry.

In *On the History of Modern Philosophy,* Schelling criticized his immediate forerunner in German idealism, Johann Gottlieb Fichte. Schelling had studied at the prestigious University of Jena, becoming close friends with the well-established and famous Fichte, who had already developed a subjective idealism of the ego. Schelling began as a follower of Fichte but moved on through a series of developmental stages. Beyond Fichte's subjective idealism, Schelling found his way to his own philosophy of nature and his own philosophy of identity. Another student at Jena and a close friend of Schelling, Georg Wilhelm Friedrich Hegel, was also an idealist in the manner of Kant, but Hegel eventually succeeded in surpassing Fichte and Schelling in logic and much else. Though his junior, Hegel seemed to mentor Schelling. In his *Lectures on the History of Philosophy* (Vol. 3), Hegel criticized, but also praised, Schelling. Still another Jena student, Arthur Schopenhauer, became an immediate lifelong opponent to Schelling, however. Much later, the University of Berlin gave Schelling a teaching appointment as a sort of counterbalance to the Young Hegelian movement there. Yet, Schelling's star never shone as bright as Hegel's, although Schelling had followers in Schleiermacher, Schlegel, and others.

Problem of Idealism

As was true of the idealists generally, philosophy was defined by Schelling as the history of self-consciousness. Schelling chose to divide this history into epochs. The first epoch is one from original sensation to productive intuition. The second epoch runs the course from productive intuition to reflection.

As his problem, Schelling took to explain how the self comes to intuit itself as productive. His "Solution III" in the *System of Transcendental Idealism* was derived from the nature of space and time. One cannot say of the self that it exists, it begins, precisely because it is being-itself.

Schelling continued by defining the self as the "eternal, timeless act of self-consciousness . . . which gives all things existence, and so itself needs no other being to support it."

The self bears and supports itself, instead. Viewed objectively, the self is "eternal becoming." And viewed subjectively, the self is a "producing without limit." One implication of this is that the self produces infinite time from itself.

Schelling observed that consciousness of an objective world is implied in every moment of consciousness. He concluded that something objective must already enter into the synthesis of self-consciousness from the beginning, meaning a stream of intuitions which comes, presumably, from outside the self.

This same stream of intuition must emerge as the developed form of the object, meaning that the intuitions issue forth as objects in a world of time and space. Indeed, time and space themselves come from a development of the intuition. But, Schelling asks, how does the philosopher know this second, constructive stream to be identical with the original, absolutely free one? When intuitions are structured into a world, in other words, how do they compare to the original sensations? For Schelling, this was the central problem of idealism. To do so involved him in problems about time and space.

Time and Process

Schelling rephrased, and attempted to solve, the problem of idealism in terms of time. If it is through self-consciousness that all limitation, and thus all time, originates, then this original act cannot itself occur in time. This is a problem stemming from Kant's metaphysics; the transcendental structures cannot be described as having any of the a priori categories, because they *are* those categories.

And so the structures cannot be spoken of in terms of "temporal sequence," and so on. The transcendental ego is, therefore, entirely outside time and space, Schelling argued. One can no more say that the transcendental ego has begun to exist, than that it has existed for all time.

The self as such is eternal, meaning outside time altogether. "The self, once transposed into time, consists in a steady passage from one presentation to the next; yet it remains, after all, within its power to interrupt this series by reflection. The absolute interruption of the succession is the beginning of all philosophizing. . . . Nothing else can arise for me save what comes about for me originally and beyond all time."

Retreating to a more comprehensible Kantian formula, Schelling founded his solution to the problem of idealism by claiming that "time is merely inner sense becoming an object to itself."

This "becoming an object" occurs when an awareness of inner and outer worlds arises, that is, when the self experiences what it considers to be an inner world while at the same time experiencing a world it considers to be outside itself.

Time is the inner intuition, whereas space is the outer intuition. Thus space and time arise from limiting each other. Again, as the self becomes aware of itself as such, a dual experience of the inner and outer objects arises.

The self is none other than the process of producing a time and space. "Time is not something that flows independently of the self," concluded Schelling, "the *self itself* is time conceived of in activity."

An object is nothing else but "fixated, merely present, time," and yet time is fixed simply and solely by the space occupied. Substance and accident, however, are attributed to the object. The philosophical observer sees that space and time may be distinguished in the self, and substance and accident in the object.

History as Sacred Time

Schelling's notion of history owes much to Fichte but also to Johann Gottfried von Herder. Even before the appearance of Kant, Herder had insisted that history is entirely sacred; there is no secular history and no secular time. History is not a pointless, merely human parade of events. Rather, history is the evident Divine Plan unfolding through human agency. Fichte had echoed these sentiments of Herder, and Schelling's philosophy of history further resonated with those tones.

Time as a Point

A fundamental problem remained, though. *How* does the self become an object to itself as inner sense? Ultimately, Schelling explained that the self becomes aware first of the space before it and, in reaction, comprehends its inner space, which is not the outer. At this point in his argument, Schelling insisted on distinguishing time as it is "already externally intuited" from time as a "mere point, a mere limit."

This latter notion is a moment in which the self knows itself as "*pure intensity,* as activity which can extend itself only in one dimension, but is at present concentrated at a single point; but in fact this uni-dimensionally extensible activity, when it becomes an object to itself, is time."

Aside from the rather circular form of his thinking here, Schelling has taken time to be a point and taken a line to be an extended point, whatever that may be. (He perhaps means, rather, that a line is a point in motion.) But unfortunately the entire use of geometry explained the obscure by the still more obscure. Or Schelling may be taken to merely *assume* that time is one-dimensional and unidirectional, though both seem suspect.

For Schelling, in this one dimension of time, the intensity of the self is infinite, pure intensity; that is, the self would produce infinite time out of itself if it were not constrained by space.

Time and Causality

Consider the simplest possible model of time, a succession of events A and B, in which the observer takes A to be prior to B and the cause of B. Because the observer judges the relation to be temporal, the observer takes it to lie in the objects themselves and not just in the observer's subjective locus of consciousness. That the succession is considered "objective," means, for Schelling, that "its ground lies, not in my free and conscious thinking, but in my unconscious act of producing. That the ground of this succession does not lie in us means that we are not conscious of this succession before it takes place; its occurrence and the awareness thereof are one and the same." Schelling took the succession, as well as the objects A and B, to be "independent" of our representations but also "absolutely inseparable" from them. More understandably perhaps, the observer's rational intuitions identically correspond with the events in things.

Evaluation and Influence

Schelling's works present a Gordian knot of logical flaws, including several concerning time. Most fundamentally, Schelling had committed the fallacy of circular argument. "If we begin with intellectual intuition," reasoned Hegel, "that constitutes an oracle to which we have to give way, since the existence of intellectual intuition was made our postulate." Instead, Hegel felt the point of idealism was to prove that intellectual intuition exists, not merely presume it: "It must be shown that the subjective signifies the transformation of itself into the objective, and that the objective signifies its not remaining such, but making itself subjective." Thus Schelling's advance was hardly one of logic, but rather in moving from Fichte's subjective idealism to a sort of objective idealism, the idealism of nature. Hegel took Schelling to have begun at the same point as Fichte, but without any dialectic to move from object to subject, and back again. As a corrective, Hegel developed his own system of absolute idealism, building on the advances of Schelling over Fichte.

Greg Whitlock

See also Causality; Fichte, Johann Gottlieb; Hegel, Georg Wilhelm Friedrich; Herder, Johann Gottfried; Idealism; Kant, Immanuel; Schopenhauer, Arthur; Time, Sacred

Further Readings

Hegel, G. W. F. (1995). *Lectures on the history of philosophy: Vol. 3. Medieval and modern philosophy.* Lincoln: University of Nebraska Press. (Original work published 1840)

Schelling, F. W. J. von. (1978). *System of transcendental idealism.* Charlottesville: University Press of Virginia. (Original work published 1800)

Schelling, F. W. J. von. (1988) Ideas for a philosophy of nature. Cambridge, UK: Cambridge University Press. (Original work published 1797)

Schelling, F. W. J. von. (1994). *On the history of modern philosophy.* Cambridge, UK: Cambridge University Press. (Original work published 1837)

Schopenhauer, Arthur (1788–1860)

Arthur Schopenhauer has been eclipsed in the history of philosophy by "the three evil geniuses of the nineteenth century," as Albert Camus called G. W. F. Hegel, Karl Marx, and Friedrich Nietzsche. Schopenhauer is rarely studied as an independent figure: The usual treatment is to consider him as an antipode to Hegel or as a precursor of Nietzsche, or as a Kantian (all three of which are partial truths). This oversight is far less common in Germany, where Schopenhauer is regarded not only as worthy of independent study but also as one of the nation's greatest philosophers; during the postwar period in Germany, he was widely held to be a greater thinker than Nietzsche.

Schopenhauer was born in Danzig on February 22, 1788, to Heinrich F. Schopenhauer, a wealthy merchant, and his wife Johanna, an exceptionally well-educated and renowned novelist. Schopenhauer studied medicine at the University of Göttingen, where he became acquainted with the writings of Plato and notably Kant, two authors who powerfully influenced his own ideas. Schopenhauer first became a philosopher in Göttingen, but in 1811 he left there for the University of Berlin, the newly founded hub of philosophy for the entire nation. He attended lectures by Johann Fichte and theologian Friedrich Schleiermacher. Schopenhauer was impressed by neither, and the former became one of his most frequent objects of attack. In his eyes, Hegel was a "clumsy charlatan," Fichte a "sophist" of "chicanery and nothing else . . . humbug"; they existed miserably among many unnamed "Hegelians and other ignoramuses."

When Napoleon's troops shut down the University of Berlin in 1812, Schopenhauer withdrew to Rudolstadt (in Thüringia) and independently wrote his thesis, *On the Fourfold Root of the Principle of Sufficient Reason* (published in 1813), which earned him a degree from the University of Jena. His idea of time may be found in its earliest formulation in his thesis. During this period, he also met Wolfgang von Goethe and conversed with that polymath concerning Goethe's recently published theory of color and vision. While in Weimar and its vicinity, he also met the Orientalist F. Mayer, who alerted him to the philosophy of ancient India. Schopenhauer found a Latin translation of the *Upanishads* soon afterward. Schopenhauer left the area around Weimar for Dresden, where he lived for 4 years. In Dresden he studied Indian philosophy and wrote the first version of his most famous work, *The World as Will and Representation,* which was published the next year. In this grand production, Schopenhauer's erudition encompassed Hinduism, Buddhism, the Roman and Greek classics, and much more, also reflecting a long-running interest in natural science.

When the cholera epidemic of 1831 swept through Berlin, killing Hegel among many others, Schopenhauer left for the university town of Frankfurtam Main, where he lived for 28 years (living 1 year, 1832–1833, in Mannheim) with his wife, Caroline Medon, the operatic singer, until his death.

While in Frankfurtam main, Schopenhauer published two books: *On the Will in Nature* (1835) and *Essays and Aphorisms* (1852). He also published two essays, one of which had won a prize from the scientific Society of Drontheim in Norway, as *Two Fundamental Problems of Ethics* (1841). But most importantly, he added 50 new chapters (Part II) to *The World as Will and Representation,* for a second edition, finishing that work as it is known today. His mature ideas on time may be found in Volume I, Chapter 4 and Volume II, Chapter 4 of his magnum opus. By 1853 the fame of the philosopher was ensured, when an anonymous article on him, titled "Iconoclasm in German Philosophy," appeared in the *Westminster and Foreign Quarterly Review.* But he lived to enjoy it for only 7 more years, dying in 1860.

Schopenhauer's General Orientation Toward Time

Schopenhauer came from the Kantian tradition, which interpreted time as the inner form of intuition (space being the outer form). These forms structure the "phenomenal world"; our experience of time and space comes from these transcendental ideal structures, along with a stream of sensations. Schopenhauer accepted Kant's theory of forms of intuition but took them to be under the control of the Will; or more precisely, the forms of intuition were developed for the purposes of the Will (to make sensations comprehensible). Schopenhauer accepted Kant's "thing in itself," too, but he identified it with the Will behind the transcendental idealist structures. Schopenhauer's thing in itself creates a world of representations for itself. The thing in itself, the Will, does so by a schema of structures transcendental to space, time, and matter: the a priori categories, forms of intuition, faculties of pure reason, practical reason, and judgment, and the faculty of representation or imagination (*Vorstellung*). The world perceived as an independent entity is an illusion that Schopenhauer identified with the *maya,* the "veil of deception," of the Vedic philosophies of India; the world only appears as an object independent of one's own rational processes.

Indeed, Schopenhauer was more at home with the Brahmins, ancient Greeks, and Romans than with his contemporaries, with the exception of the scientists, as he was well-read in science. As a product of his milieu, too, Schopenhauer inherited transcendental idealism from his fellow German Immanuel Kant, but without choosing the path of the many Hegelians around him. For him, the transcendental ideal structures connect the individual locus of consciousness with a universal Will identical to that of Divine Cosmic Will in the Hindu and Buddhist religions. And so, for Schopenhauer, these transcendental structures took on a deeply moral and religious significance that they did not enjoy in science. Time, space, and the whole material world are illusions that serve the purposes of the cosmic Will, he believed, though to the subjective locus of consciousness they seem entirely external and objective. Sooner would Schopenhauer believe in Shiva, the dancing god of destruction, than the rational unfolding of Hegel's Absolute Idea or the Christian God of love.

Schopenhauer's tenets, taken together, provide a clear and distinct image of a world created through rational processes in the intellect, given immediate sensation. Where time and space meet is in the object. Material objects are those interstices between space and time. Thus the material world, composed of countless objects, is all a construction of the cosmic Will within the individual. Time, space, and the entire material universe are subjective representations that the intellect constructs to understand its own sensations. Time does not exist in and of itself; it exists only as the internal form of one's rational intuitions. And more so, the rational sense of "time" does not apply to the Will in and of itself; questions as to its beginning or end, or lack thereof, simply make no sense.

This becomes a spiritual notion because the only liberation from suffering is through a realization that the intellect creates the world. Schopenhauer combined ancient Sanskrit wisdom with the German idealist principle that the essence of an object is the objectified essence of the subject. The essence of any object is the self, the subject, which projects itself onto the world and creates representations that are objectifications of its own inner workings. Thus it is not truly an object but the objectified essence of the subject.

When the individual ego finds its way to the transcendental ego, through the transcendental deduction, it experiences a transindividual rational process, which Kant identified as science, but which Schopenhauer identified as a largely irrational force, the Will. It is this realization that Hindus express as *tat tvam asi.*

As a creature of the intellect, time is merely a representation of sensations that cannot be interpreted otherwise. The Will-in-and-of-itself is not susceptible to the a priori categories of quantity, quality, relation, or modality. It lies beyond the distinctions between and within these categories.

Thus the cosmic Will can be known only immediately, directly as swirling chaotic sensation.

Time and the Principle of Sufficient Reason

Schopenhauer will forever enjoy an important place in the philosophy of time. He held these main tenets about time: (a) Time is a representation of a cosmic Will at work in the world. (b) Time and space intersect through matter, and matter is the perceptibility of time and space. (c) Time is the inner form of intuition. (d) Time is only the principle of sufficient reason. (e) Succession is the form of the principle of sufficient reason in time.

The "principle of sufficient reason" may also be referred to as the "law of causality": For every effect, there is a cause or causes sufficient for its actualization. The cause must precede the effect in time. Schopenhauer stipulated that causality occurs between states, not things. "It is not one thing which is the cause of another thing," he wrote, "but one state which is the cause of another state." This principle is the basis of the understanding, or more precisely, it is the understanding itself. The principle has a "four-fold root," for it is expressed equally well in knowing, being, willing, and judging. But relations of time are peculiar to willing and judgment.

Time is "the simple schema of all the other forms of the principle of sufficient reason, and this schema contains only what is essential; indeed time is the prototype of all finiteness."But Schopenhauer qualified this by noting that the relation of time has no meaning in the faculty of knowing ("before" and "after" make no sense to knowledge). Time is meaningful to the faculty of reason, instead. Nor does the relation of time find any place in geometry or arithmetic, because neither simultaneity nor succession applies to numbers (their being is determined by the "identity of indiscernibles" alone). At the root of being, time and space are representations that are sensuously perceived as matter. Time and space are pure intuitions and matter is the perceptibility of time and space. Schopenhauer alternately defined time in this regard, as "causality that has become objective," because we take these material bodies to be real objects. Matter is whatever cannot be reduced to subjective form; it is the "material from without," from "organs of sense."

Understanding and Empirical Reality

The function of the understanding alone constitutes the foundations of empirical reality. Empirical reality arises from the union of time and space. Time alone cannot represent coexistence, and so space is needed in addition. And space alone cannot allow for change, for there is alteration or change only in time. Thus Schopenhauer defined time in this regard as "the possibility of opposite conditions in the same thing."

The law of causality is "a mere form of understanding" by which the material world is constructed. In the understanding, space and time are so thoroughly mutually related that every part of one is conditioned by another part. Thus the understanding cannot grasp this complex as a whole, and space and time must be known by pure intuition a priori.

Time exists infinitely in the past, since a first cause is as incomprehensible as the limiting points of space. The law of causality concerns itself exclusively with changes. Each and every change is an effect.

Schopenhauer regarded change as taking place in time; like Aristotle, he argued that no change occurs instantly (as Plato had entertained in *Parmenides*). All change requires a certain time. Between any two points on a line, there is infinite divisibility and thus no immediate contact between points. A line may be constructed between any two points, but a certain space will always lie in between. Two indivisible things, such as geometric points, cannot be contiguous with each other. (To the extent that the imagination represents two curved boundaries touching, it represents the zero-dimensional point-three dimensionally.) Now the same principles hold in time. To the extent that we imagine time as a line, each point would correspond to a discrete "now." Yet these nows are not contiguous, and an infinitely divisible certain distance exists between them. As a change occurs over a range of these points, an infinitely divisible amount of time becomes the time of a change. Changes thus come about infinitely gradually and not instantly. Further, every entity coming into existence is made of an infinite number of parts, as Aristotle had deduced. As these parts change, time is required, which arrives gradually, and not instantly. Just as a line is not composed of indivisible discrete points, time is not composed of a succession of instantaneous nows. (This was the solution Aristotle had proposed in the face of Zeno's paradoxes.) What we must assume are two states, one the cause and prior in time, the other the effect, which gradually changes into the other. This chain of causality has no beginning or end, and is, in Schopenhauer's terminology, the "root of becoming."

Conclusion

Arthur Schopenhauer will forever enjoy a unique place in the history of the philosophy of time. It was obvious to him that a Will exists within and without each individual human being. This cosmic Will is universal, immanent, transcendental, and absolute; it is prior to all the qualities contained in the a priori categories. The Will within each human being is imperceptibly intertwined in a collective consciousness, or more precisely, the Will in and of itself is neither one nor many. And likewise the Will has neither spatial nor temporal attributes. The Will only creates representations of time internally and those of space externally. Schopenhauer always insisted that our intuitions are already rational; that is, we cannot know the ultimate nature or origin of those sensations. Time is the internal intuition of the self and world, whereas space is the external intuition of the world. Time and space intersect as material bodies. These are mere representations by the Will for itself, a process of reflection that creates its own subjective locus of consciousness. The Will operates to fashion a world out of time, space, and matter in order to understand its own stream of sensations. The world, therefore, is this foundational Will and its representations of time, space, and matter.

Greg Whitlock

See also Causality; Feuerbach, Ludwig; Hegel, Georg Wilhelm Friedrich; Hegel and Kant; Idealism; Kant, Immanuel; Nietzsche, Friedrich; Schopenhauer and Kant; Wagner, Richard

Further Readings

Janaway, C. (Ed.). (1999). *Cambridge companion to Schopenhauer.* New York: Cambridge University Press.

Schopenhauer, A. (1969). *The world as will and representation* (2 vols.; E. F. J. Payne, Trans.). New York: Dover. (Original work published 1815)

Schopenhauer, A. (1974). *On the fourfold root of the principle of sufficient reason* (E. F. J. Payne, Trans.). La Salle, IL: Open Court. (Original work published 1813)

Schopenhauer, A. (1995). *The wisdom of life* and *Counsels and maxims* (T. B. Saunders, Trans.). Amherst, NY: Prometheus. (Original work published 1890)

Schopenhauer, A. (1999). *Prize essay on the freedom of the will* (E. F. J. Payne, Trans.). Cambridge, UK: Cambridge University Press. (Original work published 1839)

Schopenhauer, A. (2004). *Essays and aphorisms.* New York: Penguin. (Original work published 1851)

Schopenhauer and Kant

Arthur Schopenhauer (1788–1860) was, at the turn of the 20th century, the most widely read philosopher in Europe. He exerted an influence on art, literature and psychoanalysis, and philosophy, especially with regard to Friedrich Nietzsche's and Henri Bergson's ideas of time. Even if he claimed to follow Immanuel Kant in his theory of time and space as being a priori forms of perception, there are also other lines in his thought on time that led to significant differences.

In his thesis *On the Fourfold Root of the Principle of Sufficient Reason*, Schopenhauer refers to Kant's transcendental idealism when he presents time and space as the class of objects that is ruled by the principle of sufficient reason. Time and space are the formal parts of representations. Whereas space is the form of outer sense, time is the form of inner sense. Neither can be perceived on its own; instead they are conditions of the possibility of perception which precede experience and are thus called a priori forms. So far, Schopenhauer's considerations agree with Kant's transcendental aesthetics. But during the preparation of his main work, *The World as Will and Representation,* he deviates from Kant's conception.

According to Kant, perception is completed by sensation as the matter of representation. Form and matter constitute human sensuality, which is the receptive part of our faculty of cognition. With regard to time this means that we perceive any impressions on our senses in time. Time itself, however, is merely a subjective condition and not a quality of things in themselves. Kant makes a sharp distinction between sensuality and intellect, which is the spontaneous part of the faculty of cognition. Therefore something must be given to the receptivity on which the intellect can act and complete the sense perception to an object of experience.

Schopenhauer refuses this distinction and combines sensuality and intellect to yield "intellectual perception": A complete representation, even an object of experience, is created by the intellect whose function is to connect time and space. Matter consists in this connection and is identical with causality. Nothing is presupposed that is given to the subject from outside, and the whole "world as representation" seems to be totally subjective, a "dream" or an illusion created by the "veil of Maya." But these considerations, which are based on Kant, stem from an abstraction in Schopenhauer's eyes; they have to be complemented by consideration of the "world as Will." According to Schopenhauer, Will is the thing in itself outside of time, space, and causality. Taking the concept of a thing-in-itself from Kant, Schopenhauer emphasizes that Will is subjective and is the one essence that objectifies itself in terms of time and space as a manifold of appearances; in that sense, time and space are the "principle of individuation." With this metaphysical assumption the fact corresponds that the function of the intellect in creating the world of representation as subject to the principle of ground depends on Will: The intellect is serving the Will supplying it with motives; if it does not, tormenting boredom arises. Already in the dissertation Schopenhauer had called time the "prototype" of all forms of the principle of sufficient reason because it has only one dimension and one direction: Every moment is caused by a previous moment. In his main work he writes that the principle of sufficient reason is "the most general form pertaining to all objects of cognizance that stands in the service of Will." By connecting time and space, the intellect places the present into a net of structurally defined moments that constitute past and future. With this, the present, which is the only true reality of existence, becomes the unextended and insubstantial boundary between past and future, immediately annihilated by the following moment. Thus temporality originates, which is the reason for pain, as any satisfaction of Will is always vanishing and making way for new desires, while having death in prospect. Temporality has an existential and ethical significance, for it is dependent on Will and there is a possibility for the intellect to resign from its service to Will. In such cases the present is viewed as eternal existence of the thing in itself (the idea) because it is realized that the difference between present, past, and future merely belongs to the form of perception. Eternity in that sense does not mean infinite time but that which is beyond time at all.

A concern with the ethical meaning of temporality can be traced back to the earliest manuscripts of Schopenhauer. Under the influence of his Pietist education and taking up Platonic and mystical elements he had developed the idea of "temporal" and "better consciousness." According to this thought, temporal or empirical consciousness is characterized by the fear of death and the striving for pleasure in order to make the most of whatever time remains. It causes pain not only because its striving is in vain in the face of the transitoriness of life but also because it tries to shift pain onto others and thus becomes morally bad. By contrast better or eternal consciousness has been relieved from all that through religious and moral conduct as well as through aesthetic contemplation. Later on Schopenhauer connects this idea with transcendental idealism, the doctrine that objects of experience are dependent on the subjective forms of perception and understanding and with the metaphysics of Will. Unlike Kant, for whom these subjective forms simply belong to the nature of human mind, in Schopenhauer they again have a condition in the will to live. Whereas temporality stands for the will to live and its correlate, the world as representation, the release from it now is formulated as denial of Will.

Transcendentalism remains basic, however, for Schopenhauer's theory of cognition: Even the philosophical cognizance of Will as thing-in-itself is dependent on time for we cannot grasp it immediately; we can only perceive singular acts of Will and interpret them as expressions of the timeless essence. Self-cognizance is therefore tied to the inference from bodily actions, which are the developed and elaborated appearance in time of a universal extratemporal act of Will. Using Kantian terms, Schopenhauer calls the latter "intelligible character" while the sum of the bodily actions make the "empirical character" of an individual.

In its maturity, Schopenhauer's thought on time emphasizes time's circularity and the insignificance of history, which is nothing but the return of the same in different modes. The crucial significance of temporality, which Schopenhauer identifies, by explicit reference to Christian tradition, with worldliness involves further conceptions, like that of temporal and eternal justice and a number of psychological considerations that anticipate modern thinking in several respects.

Matthias Kossler

See also Christianity; Idealism; Kant, Immanuel; Kant and Hegel; Nietzsche, Friedrich; Schopenhauer, Arthur; Time, Illusion of

Further Readings

Doerendahl, R. (2001). *Die Bedeutung der Langeweile in Schopenhauers erstem Band der* Welt als Wille und Vorstellung (The significance of boredom in Schopenhauer's first volume of *The World as Will and Representation*). *Schopenhauer-Jahrbuch, 82,* 11–29.

Gent, W. (1963). *Die Kategorien des Raumes und der Zeit bei Schopenhauer* [The categories of space and time in Schopenhauer]. *Schopenhauer-Jahrbuch, 44,* 180–194.

Janaway, C. (1989). *Self and world in Schopenhauer's philosophy*. New York: Oxford University Press.

Science, Progress in

See Medicine, History of

Scopes "Monkey Trial" of 1925

The epic "Monkey Trial" (*Scopes v. State*, 152 Tenn. 424, 278 S.W. 57 [Tenn. 1925]) pitted high school science teacher John Scopes and the American Civil Liberties Union (ACLU) against the Butler Act, a 1925 ruling that made it illegal to teach evolution in Tennessee schools. The resultant court battle received widespread public attention, in part, for the theatrical grandstanding of its participants, though today the trial is remembered for its impact on our understanding of human rights and development.

John Scopes's actual role in the "Monkey Trial" seems one of test subject more than actual defendant. The ACLU had sought out an educator to front its contesting of the Butler Act, which prohibited the teaching in Tennessee's public schools of ideas (including evolution) that disputed the Bible; Scopes answered the call. In actuality, there are questions as to whether or not Scopes truly taught evolutionary theory at the time. This aside, Scopes, defended by the ACLU, was charged with violating the Butler Act and quickly thrown into the circus of accusations and grandstanding worthy of reenactment in films such as *Inherit the Wind* (1960). The trial became a forum for a variety of concerns regarding civil rights of the few and religious beliefs in public education, as debated hotly by one of the prosecuting attorneys, William Jennings Bryan, former U.S. Secretary of State and three-time candidate for president, and prominent defense attorney Clarence Darrow. Ultimately, although Scopes was found guilty of violating the Butler Act, his conviction was overturned due to procedural errors tied to the establishing of Scopes's fine.

Sensational as the trial itself was, little was settled by the verdict although, arguably, its effects continue to reverberate in American culture. The ACLU failed in its effort to have the verdict overturned by the Supreme Court of Tennessee in the hope of refuting the Butler Act and similar pieces of legislation. Other states, Arkansas and Mississippi, subsequently passed laws forbidding the teaching of evolution, though similar bills were rejected by a number of other states. The trial also frightened some educators into avoiding further discussion of evolutionary theory within their classrooms for fear of losing their jobs or worse. Additionally, Scopes's trial stirred up national emotions regarding evolution versus creationism, two viewpoints exacerbated further by divisions within each respective camp and its place in time. The trial brought to light the right of individuals outside the majority to hold to their values and perspectives, scientific or otherwise. It has also been observed that the trial ultimately helped speed public awareness of evolutionary theory and its impact on our understanding of the progression of life on Earth.

Neil Patrick O'Donnell

See also Bible and Time; Darwin, Charles; Evolution, Organic; Genesis, Book of; God as Creator; Gosse, Philip Henry; Haeckel, Ernst; Huxley, Thomas Henry; Time, Planetary

Further Readings

Branch, G. (2006). Scopes, John (1900–1970). In H. J. Birx (Ed.), *The encyclopedia of anthropology* (pp. 2068–2069). Thousand Oaks, CA: Sage.

Clark, C. A. (2001). Evolution for John Doe: Pictures, the public, and the Scopes trial debate. *The Journal of American History, 87*(4), 1275–1303.

Larson, E. J. (1999). The Scopes trial and the evolving concept of freedom. *Virginia Law Review, 85*(3), 503–529.

Moore, R. (2001). The lingering impact of the Scopes trial on high school biology textbooks. *BioScience, 51*(9), 790–796.

Seasons, Change of

The Greek naturalist and mathematician Pythagoras, around 529 BCE, presciently believed the earth to be a sphere and divided it into five zones: two frigid areas, one at each pole; one torrid area at or near the equator; and two temperate areas, located between the equator and either of the poles. In this, Pythagoras was essentially correct. As we now know, with the earth's axis pointing toward Polaris, or the North Star, at a 23.5° angle from the perpendicular of its orbit, the sun's rays strike the earth's surface at various angles during its yearly revolution. The only area of the earth that receives direct rays from the sun is between 23.5° north latitude and 23.5° south latitude, known as the tropics, or the torrid zone. These parallels are known as the Tropic of Cancer and the Tropic of Capricorn, respectively. The march of the sun's direct rays between these two extremes sets up a seasonal variation within the tropics; that is, the rainy season and the dry season. It also tends to define the other climates of the world.

Climate and Geography

According to the Koeppen climate classification, generally torrid or tropical climates include the tropical rainforest, the tropical savanna and the tropical monsoon, all of which have rainy and dry seasons. The rainy season in the tropics tends to follow the sun's direct rays between the tropics of Cancer and Capricorn. The direct rays bring about convection currents in the atmosphere from the heating of the earth's surface, and as the heated air rises it cools. When the air cools sufficiently, condensation occurs and clouds form. Once the clouds become saturated enough with moisture, rain occurs, bringing with it the rainy season. At this time in other parts of the tropics, the dry season occurs; sometimes, depending on location, there are two dry seasons and two wet seasons. However, even during the dry season, varying amounts of rain will fall occasionally during the afternoon. The dry season (or seasons) in the tropics occurs where the sun is not directly striking the earth's surface, resulting in a significant decrease in convection currents and very little, if any, precipitation.

The temperate zones are located in the northern and southern hemispheres and vary with the position or angle of the earth as related to the sun. Thus, when it is winter in the northern hemisphere, it is summer in the southern hemisphere, and vice versa. The transitional seasons between winter and summer are spring and fall. The temperate zones as mirrored as the hemispheres exhibit several temperate climates. Nearer to the tropical zone, the humid subtropical, marine West Coast, and Mediterranean climates occur. The humid subtropical climate tends to have four seasons, with mild winters and hot summers. The marine West Coast climate is cool and rainy most of the year. The Mediterranean climate has a cool, wet winter and a hot, dry summer. Nearer to the polar zone, but only in the northern hemisphere, are the humid continental with a warm summer, the humid continental with a cool summer, and the Subarctic climate. The humid continental climates exhibit the well-known and typical winter, spring, summer, and fall seasons. Winter snows, spring rains, summer breezes and colorful falls dominate the landscape. The subarctic climate, adjacent to the polar tundra, is commonly known as the taiga biome, with stunted conifers that survive a harsh winter and a short growing season. The continental climate types do not appear in the southern hemisphere, where there is more water than land, the underlying reason being that water heats and cools more slowly than land.

Also in the tropical and temperate zones are the dry climates, brought about mostly by the position of the land in relationship to the oceans with cold currents. Here, the prevailing winds are cooled by the adjacent waters, resulting in deserts, or the distance from the oceans tends to produce deserts farther inland. Lastly, some deserts occur on the leeward side of mountain ranges. Among the most prominent deserts in the world are the Kalahari and Sahara in Africa, the Baja and Sonoran in North America, the Patagonian in South America, the Arabian in the Middle East, the Gobi in Asia, and the Great Sandy, among others, in Australia. Arid areas contain deserts as well as steppes, the latter being transitional areas between deserts and more humid areas. The steppes exhibit some precipitation during the warm period, whereas the cold period is very dry.

In the frigid zones, north and south, there are two polar climates: the polar tundra and the polar ice cap. Here, too, there are only two seasons as related to cool and cold, and day and night, respectively. In the winter there are 24 hours of darkness at one pole, while there are 24 hours of daylight at the other pole. Extremely cold weather occurs during the dark winters, with temperatures commonly below 0°F; during the warmest summer month, the average temperature is still below 50°F but above 32°F. Adjacent to the ice caps is the tundra biome, with its mosses and lichens—too cold and dry to support much vegetation.

In addition to the previously described climates and their related seasonal attributes are the highlands and the metropolitan areas of the world. Due to elevation, highlands take on a polar appearance. For example, the ice-capped Kilimanjaro on the equator in Africa and Mauna Loa on the island of Hawai'i show snow and ice year round. But like the glaciers, they are receding as the earth proceeds into another interglacial stage, tending to redefine climates and the seasons. Urban places tend also to modify climates and seasons. Commonly known as urban heat islands, the large cities, at least in the northern hemisphere, tend to be warmer and wetter in the summer and less cold in the winter compared to rural areas worldwide. The intensification of heat among streets and buildings in the city, compared with the adjacent rural areas, brings about this climatic and seasonal modification. How much these heat islands contribute to global warming is not known, although it is believed to have some effect.

Patterns of Seasonal Change

Throughout the world, native peoples tend to follow seasonal change. In the tropics, shifting cultivation or ladang ("slash and burn" cultivation) is practiced, as with each growing season there is a move to another location, usually on a 7-year cycle. The practice of transhumance in mountainous areas is well known, where summers are spent in the high mountain pastures and winters are spent in the valleys below. In the desert areas of the world, the nomadic peoples follow the seasons always seeking better moisture and vegetation. Farmers around the world plant their crops in the spring, cultivate during the summer, harvest in the fall, and hopefully provide a ground cover during the winter. There are many examples of adhering to seasonal changes, including the urbanites. The practice of taking vacations during certain seasons is common. Skiing in the winter, boating in the summer, watching or playing football in autumn, and planting gardens or at least window boxes in the spring are just a few seasonal rituals in which people engage. It is likely that people will respond, although perhaps slowly, to future seasonal changes, as well as changes within seasonal changes. As the earth continues toward a warmer global condition, weather conditions and patterns will tend to be more erratic, and climatic conditions and areas will change. Over time, some species will adjust more easily than will others.

Richard A. Stephenson

See also Earth, Revolution of; Earth, Rotation of; Ecology; Global Warming; Pythagoras of Samos

Further Readings

McKnight, T. L., & Hess, D. (2008). *Physical geography: A landscape appreciation* (9th ed.). Upper Saddle River, NJ: Prentice Hall.

Thompson, G. R., & Turk, J. (2005). *Earth science and the environment* (3rd ed.). Belmont, CA: Thomson Learning.

Sedimentation

In geology, sedimentation is the process of deposition of previously eroded and transported material (sediments), and it includes such processes as the separation of the rock particles from the source rock, their transportation to the site of deposition, the settling of the sediments in layers, and the diagenetic processes that occur until the sediment is lithified. The processes involved occur on a geologic timescale that spans millions of years. It was the meticulous and systematic observation of the layers, or strata, of sedimentary rock that enabled 18th- and 19th-century scientists to appreciate the immense age of the planet.

Sediment is any material that settles to the bottom of a fluid. *Sedimentation* describes the motion of particles in suspension or molecules in solutions as a response to an external force, and it takes place when the energy of the transport agent decreases (e.g., when a river reaches the sea). Water plays a major role in sedimentation in most areas, whereas wind is the main parameter in dry sedimentary environments such as deserts. Although sedimentation often takes place in minute reactions and quantities, its effects are magnified by time. Given sufficient time, the material accumulates layer upon layer in sedimentary basins after going through geological, physical, chemical, and biological processes. Sedimentation thus involves the erosion of rocks or minerals from the earth's crust, their transportation, and their recombination as sediments. After sediments are deposited, they are commonly compacted by the weight of overlying sediments, and they are altered or affected by *diagenesis*. Diagenesis is characterized by low pressure and temperature conditions, and it should not be confused with metamorphism. Because many diagenetic processes originate during transportation, the study of sedimentation also must include the analysis of lithification (conversion of loose sediment into sedimentary rocks). Geologic time is important in the study of sedimentary rocks: Although the rocks' properties may appear permanent at any time during the study, they are constantly changing through geologic time.

Mechanisms of Sedimentation

The four key physical aspects of sedimentation are *gravity* (force that acts to attract two masses, in this particular case, pulling a grain into the earth), *shear stress* (component of gravity acting along the surface), *normal stress* (component of gravity acting into the surface), and *friction* (acts parallel, but opposite, to shear stress; the coefficient of friction is a constant for a given surface material). Hydraulic physical properties of the mobile medium determine turbulence and current velocity, which control the composition, size, and shape of the sediments that will be eroded, transported, and settled.

The different minerals that form as weathering products have different characteristic grain sizes that determine the distances to which they are typically transported and the environments in which they are deposited. The size of the particles and the velocity of the fluid are combined in Hjulstöm's curve (Figure 1), which concerns the minimum shear stress to get a grain to move in a flow. This curve shows the mean flow velocity required to initiate movement on a flat, uniform bed, for a flow depth of 1 meter. Flow velocity required to sustain movement is less (Figure 1, lower curve). As a result of transport, there is a sequence of sedimentary rocks that represents the various weathering products of rocks and the distance that they can be transported from their source areas. Whereas coarse products (boulders, gravels) require fast-moving water to be moved, and they are not transported far from their sources, often retaining their source mineralogy and chemistry, intermediate-sized particles such as sands normally consist of quartz grains, which are relatively resistant to chemical weathering processes that affect the particles during their transport by rivers and wind and during their deposition at coasts or in deserts. The fine grains such as silt and clay are transported to off-shore environments and

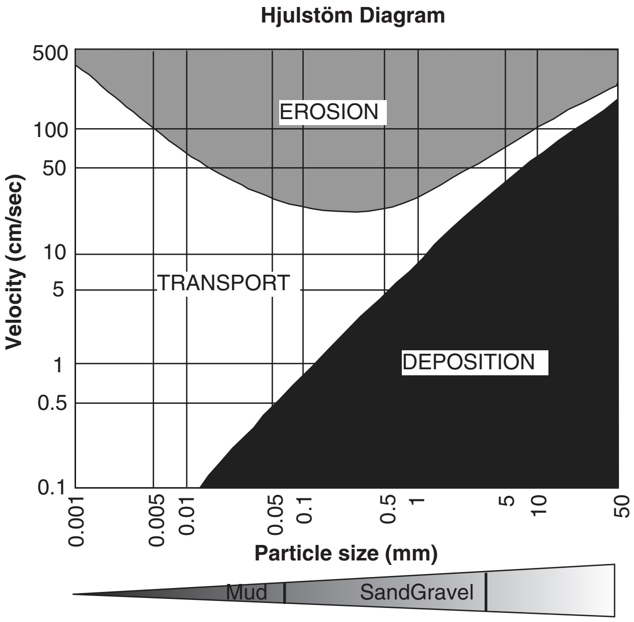


Figure 1 Hjulstöm's curve

Note: The Hjulstöm's curve illustrates the size of the particles and the velocity of the fluid.

consist of clay minerals resulting from weathering of feldspars and ferromagnesian minerals. Finally, the finest material is carried farthest in dissolution and deposited in evaporation areas as evaporites (e.g., calcite, gypsum, halite).

The geochemical aspects of sedimentation include the study of chemical properties of the mobile medium and the sedimentary particles, as well as the reactions that occur between them during sedimentation. Rates of sedimentary chemical reactions are greatly influenced by the temperature of the mobile medium. Biological aspects have an influence on, and are regulated by, chemical parameters, which control the abundance of nutrients or the metabolic functions.

The characteristics of sedimentary deposits depend on the nature of the mobile medium. When the mobile medium is the wind, rivers, or the sea, particles are settled when velocity decreases. When the mobile medium is ice, deposition takes place when the ice sheet reaches its maximum spatial extension or when it finds an obstacle.

There are two types of sedimentation or accumulation of sediments: *clastic* and *nonclastic*. The former consists of sedimentation of solid particles produced by weathering (e.g., formation of sands and sandstones), and it is controlled by physical parameters. Sedimentation takes place when the velocity at which particles settle is greater than the velocity of the mobile medium, and this situation happens when the transportation stops (in the sedimentary basin) or during transportation (selective sedimentation, which is a function of the dynamic conditions). Nonclastic sedimentation depends on chemical properties and corresponds to the deposition of dissolved material such as chemical or biological sediments, which are known as nonclastic sediments (e.g., limestone).

Sedimentary Environments

A different classification of sediments is used in geomorphology, depending on the characteristics of sediments that are deposited in continental or in marine environments. Continental sedimentation (glacial, fluvial, eolic, or lacustrine) originates coarse and angular sediments, and marine sedimentation (littoral, neritic, bathyal, or abyssal) results in finer and more rounded sediments.

The places where the sediments are deposited are called sedimentary environments, and their study provides information on the transport and erosion processes that affected the sediments, as well as on their origin. A sedimentary environment is a region on the earth's surface that is characterized by specific physical, chemical, and biological parameters. Although the surface of the earth is varied, there is a limited number of sedimentary environments. This allows us to define each sedimentary environment and its characteristics. The main physical parameters are precipitation, temperature, dominant transport agent and its velocity, currents and their direction; among the chemical parameters, the composition of the rocks and of the water is most important. The biological parameters refer to the flora and fauna and to their interaction with the sediments. Each sedimentary environment is unique and is affected, to a greater or lesser degree, by erosion, transport, and sedimentation processes. For example, sedimentation dominates in marine environments and transport dominates the slopes, whereas deltaic systems are dominated by sedimentation or erosion depending on the season and the precipitations, which determine the river flow. Sedimentation results in deposition of the sediments, originating the stratigraphic record. The successions of sedimentary rocks are studied by sedimentologists, who attempt to infer the sedimentary environments from the past, based mainly on the principle of uniformitarism, which holds that the present is the key to the past; that is, the present processes are similar to those that occurred in the past.

Laia Alegret

See also Earth, Age of; Erosion; Geological Column; Geologic Timescale; Geology; Glaciers; Stratigraphy; Time, Planetary

Further readings

Boggs, S., Jr. (2001). *Principles of sedimentology and stratigraphy* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.

McCrone, A. W. (1913). Sedimentation. In R. W. Fairbridge & J. Bougeois (Eds.), *Encyclopedia of sedimentology*. Stroudsburg, PA: Dowden, Hutchinson & Ross.

Senescence

Senescence, or aging, is a biological term deriving from the Latin root word *senex* ("old man" or "old age") and refers to the period following the development phase of a living organism, during which various processes cause it to age, deteriorate, and die. The period of senescence begins when an organism reaches sexual maturity and ends with the organism's death. For humans, senescence begins at about age 28 and ends at about age 85 under optimal living conditions.

The length of senescence is in large part genetically determined and is species-specific, correlating closely with the average life expectancy for any given species, with longer-lived species having a more prolonged period of senescence. One theory of aging states that this innate aging process is caused by the release of highly reactive molecules called "free radicals," which arise from the processes of normal metabolism as well as from such external sources as chemical exposure, sunlight, smoking, or other environmental damage. Over time, these unstable compounds interact and bind with other molecules in the organism, gradually and cumulatively causing irreversible harm to cellular DNA, mitochondria, and cell membranes.

Senescence occurs at the cellular level when cells lose their ability to divide, or suffer "replicative senescence," as the organism steadily loses the ability to respond to, or repair, damage caused by stress, injury, or disease. In humans this natural biological limit occurs after about 50 cell divisions, and is called the "Hayflick limit" in honor of the scientist who first observed this phenomenon in 1961. In contrast, for mice (a shorter-lived species than humans), cells typically divide only 10 times. In both plants and animals, each chromosome has at its end a specialized nucleoprotein complex (a "telomere"), which helps to protect, replicate, and stabilize the chromosome ends, allowing them to be repaired when damaged. Replicative senescence is thought to be caused in part because the telomeres at the ends of cells become shorter each time the cell divides, until it can no longer divide and replicate itself. Senescence progresses as more and more cells across the organism reach their Hayflick limits and the body's cells are increasingly unable to reproduce or repair themselves. The remaining length of an organism's telomere sequences at any given point in time therefore serves as a natural "clock" or measure of how far senescence has progressed for that individual.

In addition to being affected by inherent aging processes, the length of senescence is also affected by the level of cell and tissue damage (and resulting DNA damage) that an individual organism experiences during its lifetime due to such environmental factors as food availability, temperature or light changes, disease or injury, or predation. For all living organisms, then, better nutrition, shelter, treatment of diseases, and safety from physical injury will help to reduce cellular damage and to allow the upper natural limits of the senescence period for that species to be reached.

Helen Salmon

See also Aging; Amnesia; Consciousness; Decay, Organic; DNA; Dying and Death; Life Cycle; Longevity; Memory

Further Readings

Crews, D. E. (2003). *Human senescence: Evolutionary and biocultural perspectives.* New York: Cambridge University Press.

Harman, D. (2001). Aging overview. *Annals of the New York Academy of Sciences, 928*(1), 1–21.
Ranjan, R., Bohra S. P., & Asija, M. G. (2001). *Plant senescence: Physiological, biochemical and molecular aspects*. Jodhpur, India: Agrobios.
Zwaan, B. J. (2006, January). Aging: Genetics. *Encyclopedia of the life sciences* [Online]. Available from http://mrw.interscience.wiley.com

Seven Wonders of the Ancient World

In ancient times, monuments and structures with the power to redefine environments or landscapes gained renown. The classical era (roughly 8th century BCE to 5th century CE) produced seven of these, noted by travelers and sightseers of the times who roamed the shores of the Mediterranean. The ancient Greek poet Antipater of Sidon included the Seven Wonders of the Ancient World in a poem written around 140 BCE and is thereby credited with naming them: the Great Pyramid of Giza, the Hanging Gardens of Babylon, the Temple of Artemis at Ephesus, the Statue of Zeus at Olympia, the Mausoleum of Mausollos at Halicarnassus, the Colossus of Rhodes, and the Pharos or Lighthouse of Alexandria. Of these seven, only the Great Pyramid of Giza remains.

The Great Pyramid of Giza

Built by the Egyptians between 2650 and 2500 BCE and therefore the oldest of the Seven Wonders, the Great Pyramid of Giza is the only one that still stands. It is believed to be the tomb of the pharaoh Khufu or Cheops, who ruled between 2589 and 2566 BCE, the second pharaoh of Egypt's Fourth Dynasty. This dynasty is known for pyramid building, with its founder Sneferu—Khufu's father—commissioning at least three pyramids during his reign. At a height of 480 feet, the pharaoh Khufu's tomb remained the tallest structure in the world until 1300 CE, when it was surpassed by the soaring spire of the Lincoln Cathedral in England.

The Great Pyramid, or Pyramid of Khufu, rests on the Giza Plateau just outside Cairo, Egypt, in a complex called the Giza Necropolis. Included within the necropolis are the Pyramid of Khafre (Chephran) and the Pyramid of Menkaura (Mykerinus), as well as the lesser pyramids of queens. Watching over all, is the Great Sphinx, the head of which some current-day Egyptologists believe to be a representation of the pharaoh Khufu; others claim the likeness is of his son, Khafre. One of the smaller pyramids contains the tomb of Khufu's mother Hetepheres, who was both a sister to and a wife of Khufu's father, Sneferu.

Some believe that the architect of the Great Pyramid of Giza was Hemon (Hemiunu), who was Khufu's vizier. Typically, viziers were top executives in ancient Egyptian culture who controlled taxation. Considering the resources needed to construct a single pyramid, a vizier was perhaps in the perfect position to accomplish the task. Scholars and scientists estimate that Khufu's pyramid consists of more than 2 million blocks of limestone taken from a nearby quarry, with each block weighing an average of 4 tons and some weighing as much as 15 tons. Blocks of granite that weighed as much as 80 tons were brought from Aswan for the pharaoh's inner chamber. Although various theories have been proposed as to how these pyramids might have been built, not knowing how they actually came to be constructed does not diminish the finished masterpieces that resulted. The Great Pyramid was so brilliantly constructed that, to this day, even a piece of paper cannot be slipped between the stones. The fact that this wonder of the ancient world is both the oldest of the seven and the only one that has withstood the ravages of time speaks unequivocally to its prominence in the history of the world.

Hanging Gardens of Babylon

A woman's longing for the trees of her homeland may be the reason that the Hanging Gardens of Babylon made it to the Greeks' list of the Seven Wonders of the Ancient World. Near the present-day Iraqi city of Al Hillah, these gardens and the walls of Babylon were built around 600 BCE by Nebuchadnezzar II, reportedly for his wife, Amytis of Media, who left her Iranian home when she married the king of Babylon. Whether Amytis planted the seed or whether King Nebuchadnezzar simply followed his father's lead, he created more than gardens as he rebuilt Babylon, devastated by years of conquests and rebellions. In addition to constructing the terraces that held the Hanging Gardens of Babylon, the king restored temples, completed the royal palace, built a bridge over the Euphrates to connect citizens of Babylon, and built the Mede wall to protect citizens from any invasion of their northern borders.

Because the Hanging Gardens did not appear in documents that chronicle the history of Babylon, some have questioned whether the gardens were mythical. The earliest mention was in 4th-century BCE; subsequently, Greek historians Strabo and Diodorus documented their existence. They wrote that the terraced gardens were irrigated by water drawn from the Euphrates, and they mentioned stones, towers, and stairways, tiers of fully grown trees, lush plants that thrived in a theater-like setting. An earthquake is cited as the reason for the garden's destruction around 1 BCE. Recent archaeological excavations along the banks of the Euphrates show promise of revealing thick garden walls that may ultimately put to rest the question of whether the Hanging Gardens of Babylon were historical myth or fact.

The Temple of Artemis at Ephesus

Turkey is the site of this wonder of the world: the Temple of Artemis at Ephesus, a city of ancient Lydia. In Greek mythology, Artemis was a female twin of the male god Apollo; both were children of Zeus and Leto. As Apollo was associated with the sun, so was Artemis associated with the moon. Her counterpart in Roman mythology was Diana, the huntress, and Artemis, too, was often represented graphically with bow and arrows.

Begun by Croesus of Lydia, the Temple of Artemis was built over a 120-year period, completed in 550 BCE. Its architect was the Greek Chersiphron. Many Greek sculptors contributed works of art for the temple, including Pheidias, creator of the Statue of Zeus at Olympia. Made of marble, the temple overlooked a courtyard filled with activity—musicians, artisans, merchants, magicians—and was so stunning that, in the eyes of the poet Antipater of Sidon, it dwarfed all of the other wonders he named.

Its very beauty may have led to the beginning of the temple's demise: A disturbed young man named Herostratus chose to set fire to it in 356 BCE in an attempt to forever seal his fame. The Greeks put him to death and rebuilt the temple. Some historians claim that the temple was destroyed and rebuilt as many as seven times. Around 400 CE, the temple was eventually demolished.

The Statue of Zeus at Olympia

The Greek statesman Pericles, a general who led the city during the Peloponnesian War, commissioned this wonder of the ancient world from the Greek sculptor Pheidias circa 440 BCE: the Statue of Zeus at Olympia, Greece.

Olympia was one of four Greek sanctuaries, centers of culture and Greek life. Along with the sanctuary Delphi, Olympia hosted games and contests every 4 years in which the best Greek athletes would compete. As they did with Delphi, the games elevated Olympia's political prestige, and it became one of the most important sanctuaries in all of Greece and considered sacred to Zeus.

Although the only artistic representation of the Statue of Zeus that remains is on ancient coins, from them and from historians of the times it is known that Pheidias created the god Zeus in ivory on an ornate throne accented in gold. The statue was huge—40 feet tall—and crowded the temple that was built to house it. The construction was chryselephantine: built up on a wooden frame using ivory and gold leaf to form the image. In Zeus's hands, Pheidias placed an eagle atop a scepter and a likeness of Nike, the winged goddess of victory.

Zeus was not alone in his temple but was accompanied by his mythical son Herakles, a hero to local residents and considered the founder of the games. The 12 tasks of Herakles were depicted on friezes above the columns of the temple.

From early accounts, words failed to describe the statue's power when seen in person. It is not known for certain how it met its destruction. Some presume it was destroyed by an earthquake in 400–500 CE; others claim that armies carried it to Constantinople, where it was consumed by fire in 462 CE. Today, only fallen columns embedded in Greek soil mark the place where Zeus's statue watched over the Olympians' success at their Greek games.

The Mausoleum of Mausollos at Halicarnassus

As with the Hanging Gardens of Babylon, history credits a woman for this wonder. The Mausoleum of Mausollos was commissioned by Artemisia II of Caria, the wife and sister of King Mausollos, and built around 350 BCE in the ancient city of Halicarnassus, what is now the Turkish port of Bodrum. Artemisia's grief at her husband's death was so great that the tomb could be no less than splendid. Designed by Satyrus and Pythius, well-known Greek architects of the times, each of the four sides of the 135-foot-high-tomb showcased graphic relief works—primarily animals and armies in battle—created by prominent Greek sculptors and hundreds of lesser artists and workers. The monument to Artemisia's husband sat on a hill that overlooked Halicarnassus and became so famous among travelers and sightseers that the king's name is now an eponym for a grand and splendid final resting place: *mausoleum*.

The tomb was toppled by an earthquake in the 1490s. Crusaders used the remaining stones in 1522 to fortify their castles from Turkish attack. Today, visitors of the Knights of Malta's castles in Bodrum can see stones from the tomb in the castle walls. Visitors of Bodrum can view the tomb's remaining ruins as well.

The Colossus of Rhodes

Towering 110 feet over the Greek island, the Colossus of Rhodes was a statue of Helios, the Greek god representing the sun. It was built in 292 BCE by the citizens of the island of Rhodes, following their successful defense of the island when an army led by Demetrios Poliorketes invaded.

Chares of Lindos, a native of Rhodes who had studied under the sculptor Lysippos, was in charge of the statue's construction. Made of white marble and bronze, the statue Helios stood 100 feet tall. Its exact location has never been documented, although romantic notions place the Colossus astride the entrance to one of the many harbors of Rhodes. It existed only half a century before it was felled by an earthquake at the knee. Although offers came from abroad to pay for the restoration of the statue, the people consulted an oracle or prophet who forbade the reconstruction, and the Colossus remained where it fell for almost 800 years. In 654 CE, an Arabian army that had captured Rhodes disassembled what was left of the Colossus and sold off the pieces. In her 1959 poem "The Colossus," poet Sylvia Plath gave a voice to what is left of the ruin:

> No longer do I listen for the scrape of a keel
> On the blank stones of the landing.

The Lighthouse of Alexandria

Off the coast of Alexandria, Egypt, on the island of Pharos, the Lighthouse of Alexandria rounds out the Greek list of Seven Wonders of the Ancient World. Estimated to be as tall as 450 feet, the lighthouse was originally built around 250 BCE as a tower or pharos, a navigational landmark.

It was designed by Sostratus of Cnidus at the behest of Ptolemy I of Egypt, one of Alexander the Great's generals, although it was Ptolemy's son who actually saw to its completion. Legend has it that the son, Ptolemy Philadelphos, forbade Sostratus to inscribe his name on the tower when it was finished. Dutifully, Sostratus instead inscribed Ptolemy's name on the tower. Centuries later, erosion removed the inscription to reveal a second name and that of the true builder of the Pharos of Alexandria: Sostratus.

At the top of the tower, a mirror reflected the sun during the day and a fire lit at night. It is estimated that the light could be seen offshore as far as 35 miles. Early images of the lighthouse from Roman coins show a statue of the Greek god of the sea, Poseidon, at the top of the Pharos and a triton at each of the tower's corners.

Built of stone, the tower could withstand the sea's waves crashing against it and survived until 1303, when an earthquake damaged it. In 1323, another earthquake brought it down. Egyptian sultan Al-Ashraf Sayf used the remaining rubble to build a fort in 1480, and these stones can still be seen in the walls of Fort Qaitbey.

Likewise, stones from the collapsed lighthouse have been discovered in the sea just off the coast of Alexandria by archaeologist Jean Yves Empereur, director of the French Center for Alexandrian Studies.

The New Seven Wonders of the World

In 2007, a nonprofit organization dubbed New7Wonders conducted an extensive poll via the Internet and cell phone text messaging to update the Seven Wonders of the World list. Whereas the Seven Wonders of the Ancient World represented a consensus of Greek travelers who toured the rim of the Mediterranean Sea, today's newly named wonders represent locations around the globe. The New Seven Wonders are

- Great Wall, China
- Petra, Jordan
- Chichén Itzá (Mayan pyramid), Mexico
- Colosseum, Italy
- Machu Picchu, Peru
- Taj Mahal, India
- Statue of Christ Redeemer, Brazil

The people of Egypt protested the idea that the Great Pyramid of Giza needed to compete with modern wonders. The sponsors of the new list agreed, and the Great Pyramid retained its status as a wonder, remaining the oldest and only surviving member of the original Greek list.

C. A. Hoffman

See also Anthropology; Archaeology; Egypt, Ancient; Rome, Ancient

Further Readings

Gombrich, E. H. (2005). *A little history of the world.* New Haven, CT: Yale University Press.

Hamilton, R. (2006). *Ancient Egypt: Kingdom of the pharaohs.* New York: Barnes & Noble.

Kagan, N. (Ed). (2006). *Concise history of the world.* Washington, DC: National Geographic.

NOVA. Treasures of the sunken city (Companion Web site to the NOVA documentary *Treasures of the Sunken City*, aired February 27, 2007). Retrieved July 30, 2007 from http://www.pbs.org/wgbh/nova/sunken/wonders

Plath, S. (1981). *Collected poems.* New York: Harper.

Roberts, J. M. (2003). *The new history of the world.* Oxford, UK: Oxford University Press.

Santon, K. (2007). *Archaeology: Unearthing the mysteries of the past.* Bath, UK: Parragon.

Shakespeare's Sonnets

Time is a major theme throughout most of the 154 sonnets that William Shakespeare wrote. It is referred to variously as "ould Time" (Sonnet 19), "wastfull time" (Sonnet 15), "bloudie tyrant time" (Sonnet 16), "devouring time," "swift-footed time," Time's "cruell hand" (Sonnet 60), "Times sieth" (Sonnet 12, meaning time's scythe), "injurious hand" (Sonnet 63), "Ages cruell knife" (Sonnet 63), "Times theevish progresse" (Sonnet 77), "times spoiles" (Sonnet 100), "times tiranie" (Sonnet 115), and "fortie Winters" (Sonnet 2) indicating the passage of time.

It is important to note that Shakespeare's treatment of time is predominantly that of an antagonist. His love defies "devouring time." Time is the enemy that is overpowered by the eternal love he bears. It is also referred to as the time that takes away his beloved's beauty even though his love remains strong and defiant. Time is seen as a harbinger of death in which it culminates. As such, the theme of time as it hastens death is recurrent in several of the sonnets. The theme of time and death appears again in Sonnet 32, when the poet refers to his own death. Sonnet 13 also speaks of the decay that time brings and the rage of death's eternal cold, a throe of time.

Sonnet 15 shows time debating with decay to change youth to night. In this sonnet, Shakespeare defies time by "ingraft(ing)" (Sonnet 15) anew what time takes away from his love; by making her immortal with his pen even though the ravages of time might take over her physical self. He is constantly in war with time (Sonnets, 15, 16, 18, 19). Sonnet 55 refers to the end of time, doomsday, until when the Bard's beloved will be kept alive in these verses. Sonnet 60 once again returns to the theme of time as the destroyer of beauty and youth, as nothing can withstand the scythe of time except for the poet's verses singing praises of his lady love. Shakespeare makes a statement that time shall never succeed in erasing the memory of his beloved (Sonnet 63), even as in the very next sonnet he worries that time will take his love away (Sonnet 64). Even though he defies time, he continues to be haunted by it. This conflict continues in Sonnet 65, in which he is agonized by the thought of time wiping out impregnable rocks while his beloved's beauty was like a flower. Yet by the end of the sonnet he gains back his confidence that his love will remain in black ink despite the ravage of time. In Sonnet 100, the Bard compares the speed of his love's fame to be faster than the destructive pace of time. In Sonnet 115, the poet, fearing time's tyranny, expresses his love in the present as the best while he harbors doubts about the times to come when he might not be in a position to do so. However, in the next sonnet (116), he writes about the unchanging nature of love, which is not "Times foole." In Sonnet 123, he once again challenges time as not the one to bring about changes. Sonnet 126 refers to time's fickle hourglass and sickle.

In "When I do count the clock that tells the time" (Sonnet 12), Shakespeare considers the day, the spring, and the summer as times to rejoice, whereas night and winter have a negative connotation showing the onslaught of time, when nature is past its prime. In Sonnet 30, he refers to the passage of time bringing him sweet remembrances of the past. Sonnet 33 refers to his hour of glory. He also looks at time as the moment that love has come because the time is ripe, or "now is the time" (Sonnet 3). In Sonnet 57, the poet bestows all the time he has to the service of his love, much like a slave. Sonnet 49 shows him preparing for the time when his love might cast him away.

Throughout Shakespeare's sonnets, time is primarily looked at as cruel and cold in combination with death. It is a knife, a scythe, a cruel hand that mercilessly takes away the beauty of youth and of the spring. Though youth and beauty cannot withstand the ravage of time, the effect on nature itself is not permanent. For instance, he mentions that the sun is new and old every day, and so time has but a limited impact on this great gift of nature. Yet, unlike the sun, Shakespeare is aware that his love, time's best jewel, cannot lie hidden from time, for it will take its toll. Hence, Shakespeare tries to defy time by immortalizing his love through these sonnets. This defiance is so strong that it is repeated variously in several of his sonnets. In fact, he is aware and even admits that he is repeating himself, but he chooses to do so nevertheless. Immortalizing his love for the dark lady and Mr. W. H. is definitely the main theme of his sonnets. Less frequently, Shakespeare also refers to sad times, when his beloved is in the company of others. On a more positive note, time is looked at as a reminder of moments of glory or love, of sweet silent thoughts as he goes down memory lane, the day, spring and April, and the summer, as times to rejoice and cherish.

Vidisha Barua

See also Alighieri, Dante; Chaucer, Geoffrey; Donne, John; Eliot; T. S.; Goethe, Johann Wolfgang von; Poetry

Further Readings

Landry, H. (Ed.). (1976). *New essays on Shakespeare's sonnets.* New York: AMS Press.

Vendler, H. (1997). *The art of Shakespeare's sonnets.* Cambridge, MA: Belknap Press.

Willen, G., & Reed, B. V. (1969). A casebook on Shakespeare's sonnets. New York: Crowell.

Wilson, D. J. (1964). *An introduction to the sonnets of Shakespeare: For the use of historians and others.* New York: Cambridge University Press.

Shangri-La, Myth of

The search for paradise on earth has been a recurring theme in world mythology for thousands of years. People have always been drawn to the idea that there is a place where humans live in harmony with each other and nature and where the wisdom in the world is gathered for the benefit of all humanity. In paradise, the ravages of time are slowed or stopped, and peace is eternal.

Shangri-La is such a place. Shangri-La is a modern myth invented by James Hilton in his novel *Lost Horizon,* published in 1933. In the novel, a group of westerners are rescued from a plane crash in a remote valley. The exact location is never pinpointed in the novel, but the flight had been heading northeast from Afghanistan when Hilton pictured it landing in the unexplored western region of Tibet, surrounded by the highest mountains in the world. Shangri-La is an isolated community that has a lamasery (a monastery for Tibetan lamas) headed by a 200-year-old Capuchin lama. Time is slowed significantly in Shangri-La, making life spans of more than 200 years common. The lamasery is a repository for all human knowledge and cultural treasures, gathered for posterity when the outside world self-destructs. The inhabitants of

Shangri-La are peaceful, opposing all aspects of violence or materialism. The tale becomes a meditation on philosophy and how to best live one's life, as the travelers in the story meet the High Lama of Shangri-La and engage in many conversations.

The idea of a lost kingdom somewhere in the Himalayas has circulated for centuries. Europeans first found references to a mythical place called Shambhala in Tibetan texts at the court of the Moghul Emperor Akbar in the 1580s. The tale appears to date even further back in time, to 962 CE in India. Shambhala is said to be a land behind the Himalayas where a group of isolated people live in peace and harmony waiting to save the world after its destruction. The kingdom is in the shadow of a crystal mountain surrounded by a ring of snow-covered mountains shaped like the petals of a lotus. A crystal palace housing the current king lies at the very center. It is said that inhabitants of Shambhala have made huge advances in science and technology, as side effects of the intense study conducted to attain spiritual goals. While gaining deeper knowledge over their minds and bodies, inhabitants of Shambhala are said to have achieved the ability to cure themselves of illness. Other side effects of their study include telepathy and precognition. Although the inhabitants are not immortal, they live healthy, happy, extended lives of well over 100 years.

The prophecy of Shambhala states that a series of 32 kings will rule for 100 years each. The outside world will continue to deteriorate as each reign passes. The pursuit of power will continue to corrupt until one evil tyrant rises above the rest to oppress the entire world. As the world appears to be on the brink of total annihilation, the mists obscuring Shambhala will clear. The 32nd king of Shambhala will ride forth to lead a mighty army against the tyrant, establishing a Golden Age of Enlightenment and restoring peace and prosperity to the world.

It is easy to see the appeal in this type of tale throughout history. In times of political unrest and instability, the world can be a frightening place. Stories about the possibility of places like Shangri-La and Shambhala validate this fear. The future is uncertain, and it is comforting to think that something good from the past will endure through time, after the destruction of all that is familiar.

Jill M. Church

See also Elixir of Life; Longevity; Mythology; Youth, Fountain of

Further Readings

Bernbaum, E. (2001). *The way to Shambhala.* Boston: Shambhala.

Hilton, J. (2004). *Lost horizon.* New York: HarperCollins.

LePage, V. (1996). *Shambhala: The fascinating truth behind the myth of Shangri-La.* Wheaton, IL: Theosophical Publishing House.

Wood, M. (2005). *In search of myths and heroes.* London: BBC Books.

Shintō

Shintō is the indigenous Japanese religion, based on the belief in divinities called *Kami*, reverence of ancestors, and a combination of ritual purification and food offerings. Kami can best be described as impersonal manifestations of power. They have no shape of their own but can be summoned into vessels (often trees, banners, long stones) or be communicated with through a medium (often young women called *Miko*). Usually living in a world of their own, Kami can visit the human world at certain seasons. If cared for through the fulfillment of proper rituals and offerings, then they can bring material blessings to this world. If offended, for example, by pollution brought about by blood, dirt, or death, they might curse the offenders, thus bringing disease, disaster, or famine to the culprits. Shintō faith does not hold a unified concept of time. Instead, its myths present two different understandings of time and space.

There is no historical founder and no set of holy scriptures that define the content and practice of this faith. But two Japanese classics, *Kojiki* (Record of Ancient Matters, written in 712) and *Nihon shoki* (Chronicles of Japan, 720) contain the myths central to Shintō up to the present day. According to these works, three gods appeared out of the primordial chaos and disappeared, leaving no progeny behind. More generations of gods appeared and disappeared to no greater effect. Then Izanami and Izanagi (the first pair of gods with distinct sexes) appeared, married, and created the great eight-island country of Japan. In want of an entity that could rule the universe, they begot three gods: the sun goddess Amaterasu, the moon god Tsukiyomi, and the storm god Susanoo. Whereas Amaterasu and Tsukiyomi were sent to heaven, the unruly storm god was not seen fit for a position of equal power and sent to the netherworld.

The sun goddess then decided to send her august grandchild Ninigi to reign over the Central Land of Reed-Plains (usually understood to be Japan) and bestowed him with the Three Treasures (sword, mirror, jewel). Ninigi was sent to the Reed-Plain with the parting wish that his dynasty may prosper and, like heaven and earth, endure forever. He was successful in his quest, and one of his descendants became the first legendary emperor, Jimmu, who, according to Japanese tradition, is ancestor of the Imperial Family that reigns over Japan until this day.

History of Shintō

Although Shintō only crystallized as a religious system during Nara (710–784 CE) and Heian (794–1185 CE) times, early religious phenomena can be traced back well into prehistoric times. Agricultural rites developed first during the Yayoi period (250 BCE–300 CE), when the cultivation of rice was introduced from the continent. Numerous clans (*uji*) ruled smaller and larger areas of the country, gradually forming alliances and small states. The leaders of those clans traced their ancestry to the gods revered in their domain, combining political and religious power in their hands. By the 5th century CE, these states were unified around the powerful Yamato clan, which became the imperial lineage. Japanese religion by then already displayed two characteristics: It combined a strong local character (including manifold local legends and myths) with a supraregional cult, centered around the dominant clans' ancestral gods.

Import of continental culture went to a new level, when Confucianism, Buddhism, and Chinese Taoism reached Japan in the 5th and 6th centuries. Equally important for the further development of Shintō, the Chinese writing system was introduced to Japan, and the spread of literacy among the aristocracy set the foundations for Shintō to assume formal identity as an indigenous religion. Japan was modeled after the Chinese state and furnished with a Chinese-style bureaucracy as well as chronicles recounting its legendary and historical past. *Kojiki* and *Nihon shoki*, respectively, contain myths about the age of gods and the creation and history of Japan, starting with the legendary first emperor of Japan, Jimmu. But rather than retell the oral traditions of the people, these chronicles were compiled to serve as mythological literature of the ruling elite, integrating conflicting legends from different clans according to their present position at the court. The legendary beginnings of Japan were written down not only utilizing the Chinese writing system but also Chinese philosophy. Most prominently, the emperor system cannot belie its Chinese origin. It is in these chronicles that the word *Shintō* ("way of the gods") appears for the first time.

The 8th century brought with it strong tendencies to interpret Shintō from a Buddhist point of view. Understanding Kami at first as beings to be saved from the endless cycle of transmigration, Buddhists later took them to be incarnations of Buddhas and Bodhisattvas. It was only in the 15th century that the Yoshida school reversed this *honji suijaku* theory and paved the way for a national reorganization of Shintō. The Edo period (1600–1868) witnessed a shift of Shintō from Buddhism. While some scholars interpreted Shintō from a neo-Confucianist standpoint instead and stressed the concept of imperial virtues and national ethics, others turned toward the Japanese classics in search of a pure Shintō. The philological studies of the School of National Learning (*Kokugaku*) aimed to identify the original norms of Shintō as mirrored in the beliefs of former generations.

Although the imperial lineage had continued through the centuries, the emperor's position had been a rather powerless one for many centuries. The Meiji Restoration (1868) reinstated the emperor as head of state and renewed the bonds between state and Shintō. In 1870 the government proclaimed the separation of Kami and Buddhas (*Shinbutsu bunri*), turned shrines into instruments of the state, and made Shintō priests civil servants. State Shintō played an important role in Japan's imperialist efforts from the Sino-Japanese War (1894–1895) to the end of World War II.

Accordingly, state and religion were strictly separated, and the system of state-financed shrines was abolished in 1945 by the Allied forces. Although weakened by the memories and repercussions of its not yet distant past, the emperor continues to be a symbol of the nation, and Shintō still is a vital part of Japanese religious life.

Concepts of Time in Shintō

Shintō is not based on a set of scriptures, and it has not generally accepted a creed. It is concerned with detailed legends, practical questions of life, and proper rituals rather than abstract dogmas. Just as *Kojiki* and *Nihon shoki* in places recount several conflicting versions of the same legend, they also hold fundamentally opposing concepts of time and space. These can roughly be divided into a spatial and a linear image of time, each described by different layers of the Shintō tradition.

The spatial concept of time is often described as cyclical. Indeed the appearances and disappearances of the first gods are strongly reminiscent of an agrarian life cycle. They appear, grow, and finally disappear, only to be followed by the next generation in due time. Their disappearance is often understood to signify death. In this respect a story about the sun goddess Amaterasu "disappearing" (hiding) into a cave and appearing again out of the same cave at the sound of music and laughter gains a deeper meaning. It can be interpreted as rebirth of the goddess, which also leaves the possibility for other disappeared gods to be reborn.

Renewal and purification play a very important role in Shintō. Each visit at a shrine starts with a ritual purification of the believer, and New Year celebrations require a thorough cleanup of the house. During Shintō festivals (*Matsuri*) the locally revered god pays a visit to his shrine, thereby renewing the bond between him and his followers. If all necessary rituals like dancing and food offerings are observed, the god himself is strengthened by the worship. Most prominently, shrine buildings were usually rebuilt to purify the site and renew the materials used. Most of the larger shrines followed this tradition until the Edo period (1600–1868). Today it is only preserved by the shrine of the sun goddess (Ise shrine), which is still rebuilt at an adjacent site every 20 years.

Although several traditions and legends contain elements suggesting a cyclical image of time, spatial aspects are prevalent. Day and night, life and death, different seasons as well as present and past are not perceived as different times experienced in the same location, but as different worlds. The oldest Shintō traditions describe the world as divided into a land of the living and a land of the dead. The latter is called Tokoyo and is described both as a cheerful place for heroes and as a horrible place for the ordinary dead. It is located beyond the sea, in the mountains or in the woods. In many parts of Japan, the dead are believed to dwell on holy mountains (e.g., Mount Fuji) with a characteristic symmetrical and conic shape. They watch their descendants from a distance and visit them in the plains at certain seasons. Traditionally these visits were thought to take place at New Year and at harvest time. But today the Buddhist festival of O-Bon, celebrated in mid-July or mid-August, has become the central time to welcome the dead back in the land of the living in Japan.

Passage from one world to the other is perceived as a movement in space rather than time. Thus visiting the other world might be difficult, but is possible as such. *Kojiki* and *Nihon shoki* tell the story of a visit to the land of the dead. Izanami, the first female god, was also the first one to die. When her mourning brother and husband Izanagi arrived in *Yomi no kuni* (Hades), Izanami had already eaten the other world's food and thus had lost any chance of return. Ignoring his wife's order not to look at her, Izanami lit a torch and beheld her worm-eaten body. Disgusted at the sight, he had to flee from her wrath and only just reached the world of the living again. But even when in different worlds and separated by a rock, Izanagi and Izanami argued with each other. While an angry Izanami threatened to take 1,000 souls to Yomi no kuni every day, Izanagi promised to let 1,500 humans be born everyday in return.

Although the legend is not specific about the means to reach the other side, a passage is described to be possible. The two gods even argue with each other. Although in different worlds, they obviously are within earshot.

Probably due to continental influences, later myths divide the world into three realms. Gods live in the Plain of High Heaven (*Takama no hara*). The present world, or Middle Land (*Nakatsu no* *kuni*), is inhabited by the living, while the dead go to a world below (Yomi no kuni or *Ne no kuni*). Movement between these worlds is believed to be restricted but possible. Gods can easily cross the borders, while the living are usually confined to the Middle Land.

Until the end of World War II, the emperor was believed to be a living god (*ikigami*) descended from heaven. When a new emperor ascended the throne, the god was believed to descend from heaven only to ascend again at the emperor's death. Similarly, the myths speak of Izanagi's ascension to a palace in heaven after his death.

Souls of the deceased are free to leave their world at certain times and thus retain a strong connection with their descendants. When somebody dies a violent death or is thought to hold strong resentments when dying, his angry soul may haunt the world and bring disaster to any living person. Such souls have to be cared for cautiously to be pacified and are often enshrined as gods. If cared for properly, they might use their considerable power to help the people instead. The most prominent example of this practice is the Yasukuni Shrine in Tōkyō, Japan, which is dedicated to the souls of all people that once fought for the emperor, including several convicted war criminals.

Although the legends do not describe specifically the condition of the souls in afterlife, there is a strong belief in the return of the souls into the land of the living. Even a return to the body after death was once believed to be possible. In ancient Japan the souls were thought to leave the body at death and linger between the worlds of the dead and the living. During the time of mourning, the dead were laid out in a special building. The mourners lived with them, eating and drinking, dancing, singing, and crying in front of them, thereby hoping to persuade the soul to return to its body. In 686 the mourning for emperor Temmu continued for as long as 2 years. But the Buddhist custom of cremation had already started to take hold in Japan by then, and soon all burials followed Buddhist traditions.

Legends conveying a linear concept of time probably result from continental influences. The emperor system adopted from China in the 7th century CE left its traces not only in political practices but also in the religious traditions. In historical Japan the emperor's supremacy was backed by his supposed descent from the sun goddess. Ancestor gods of other leading clans were given importance according to their respective clans' power at the time of the compilation of the chronicles. This may partially explain the existence of conflicting legends within each of the chronicles. In particular, the unruly storm god Susanoo is depicted differently in several myths. Reverence for the smallest details of each legend and a strong opposition to unifying changes to the myths seem to be other reasons.

In the legends of *Kojiki* and *Nihon shoki*, Amaterasu's order for her august grandchild Ninigi to rule the Reed-Plain is the beginning of a long and unbroken line of emperors. With this legend, history starts to unfold. According to Amaterasu's wish, Ninigi's dynasty was to prosper forever. Although there is no promised land or final stage to be reached, history always holds the promise of eternal prosperity of the imperial linage. Although after World War II the Emperor Hirohito (posthumously Emperor Shōwa) renounced his status as a living god, the national anthem of Japan still refers to Amaterasu's promise. The lyrics were taken from a Heian period (794–1185) collection of poems and express the wish that the emperor's reign may continue for 1,000, even for 8,000, generations. As the imperial lineage started with the legendary Emperor Jimmu in 660 BCE, current Emperor Akihito being the 125th emperor, fulfillment of this wish would indeed hold a very long future still.

Marianne Sydow

See also Afterlife; Mythology; Religions and Time; Time, Cyclical; Time, Linear

Further Readings

Philippi, D. (1969). *Kojiki.* (D. L. Philippi, Trans.). Princeton, NJ: Princeton University Press.

Tsunoda, R. (Ed.). (1964). *Sources of Japanese tradition.* New York: Columbia University Press.

Simmel, Georg (1858–1918)

The pioneering German sociologist Georg Simmel spent most of his life as a private scholar, sustained by a small inheritance. Although he was permitted to lecture after receiving his doctorate in philosophy from the University of Berlin in 1881, his Jewish origins sufficed to deny him an academic chair until 1914, when he was offered a professorship at the University of Strasbourg. A penetrating thinker and brilliant essayist, Simmel is best known for his *Philosophie des Geldes* (Philosophy of Money, 1907); *Einleitung in die Moralwissenschaft* (Introduction to Moral Philosophy, 1893); and *Soziologie* (Sociology, 1908).

In his last work, *Lebensanschauung* (Life Views), Simmel broaches the issue of time in order to explicate his concept of *life*, which was of central relevance for all his work after 1908. According to Simmel, time (like life) is characterized by the notion of continuity. Therefore, the subdivision of time into past, present, and future is an artificial one. The present as such cannot be experienced, just as little as past or future. Rather, the present experienced by humans "is always composed of a little piece of past and a little piece of future," which means that the concept of the present is closely linked to the concept of the experienced timely moment (*Augenblick*), which is constituted by the vital functions of remembrance and anticipation. Simmel focuses especially on the former by analyzing how remembrance constitutes the past. According to Simmel, the previously experienced moments "live in us, not as a timeless content but bound to the very special point of time." Therefore, very much unlike the mechanistic concept of time, which Simmel often criticizes, these previously experienced moments are not absorbed and dissolved in the present as the cause is absorbed and dissolved in its effect. The mechanistic conception of causality destroys the cause by dissolving it, the vital notion of time, on the other hand, *stores* the experience. Simmel holds that the mechanistic concept of time leads into logical aporia because it remains unable to explain the "continuity of changing." Thus, Simmel's theory of time is one of the first approaches toward a conception of "organic time."

It is not only this criticism of mechanism but also the vital concept of time itself which Simmel adopted from his reading of the French philosopher Henri Bergson. In his essay titled "Henri Bergson," published in 1914, Simmel states that the mechanistic conception is principally timeless "because no formula, no state would change if all motions of the world would run two times as fast or a thousand times as fast or even slower than they actually do." Thus, the physical concept of time is a relational one. Time, understood as a physical term, can be contracted or expanded (or sometimes even be reversed) without changing the underlying physical processes. In contradistinction to that, the vital concept of time Simmel has in mind is characterized by the irreversible process of life for which the timely progress is essential because, according to Simmel, "to live means to age." Time, thus understood as the central category of life, transcends every given moment—on the one hand by remembering the past and on the other hand by fulfilling voluntary actions pointing into the future (in which way the past can be represented in an instant view, as analyzed in Simmel's book *Rembrandt*). Thus, according to Simmel, the distinction between past, present, and future is an artificial one and belongs to the physical concept of time.

A different focus on the concept of time is inherent in Simmel's criticism of modern culture. According to Simmel's discussion of time in his book *Philosophy of Money* and in many other essays, modernity focuses on time as goods, as "a value determined by usefulness and shortness." The individual measuring of time (by means of pocket watches) leads to a binding time schedule, which irrevocably corrupts the vital concept of time.

Dirk Solies

See also Bergson, Henri; Causality; Change; Nietzsche, Friedrich; Schopenhauer, Arthur; Time, Measurements of; Watches

Further Readings

Coser, L. A. (Ed.). *Georg Simmel*. Englewood Cliffs, NJ: Prentice Hall.

Frisby, D. (2002). *Georg Simmel*. New York: Routledge.

Simmel, G., & Wolff, K. H. (1964). *The sociology of Georg Simmel*. New York: The Free Press.

Sin, Original

Original sin is the Christian doctrine that all people have a general condition of sinfulness from birth inherited from the first humans—Adam and Eve—that separates humans from God. Original sin is also called hereditary sin, birth sin, ancestral sin, and person sin.

The term *original sin* applies to both the first sin and to the inherited nature of sin found in each human. Genesis chapter 3 describes the first sin of Adam and Eve, the first humans. Initially, Adam and Eve lived in a state of immortality and in close communion with God. The humans disobeyed God when the serpent deceived them into eating from the tree of knowledge of good and evil, a tree from which God had told them not to eat. By eating the fruit, Adam and Eve discovered the capacity to know and do evil; thus, they developed a sinful nature. This capital transgression condemned the first humans as well as the human race to a life of sin that ends in death. As a consequence of the first sin, everyone born afterward inherits this sinful nature, thus corrupting the human race. This first sin is often referred to as "The Fall."

The Christian tradition of original sin is based in part upon Paul's writings to the Romans. Romans 5:12 (New International Version) says, "just as sin entered the world through one man, and death through sin, and in this way death came to all men, because all sinned." This thought is repeated in subsequent verses. According to Paul, Christ's sacrificial death was the remedy for original sin.

Augustine, Bishop of Hippo (354–430), one of the early church fathers and an early Christian writer concerning original sin, believed that every human was born flawed, that is, evil with a sinful nature, and shared Adam's guilt. He based this belief on his understanding of Psalm 51:5. He believed one must be baptized in order to remove this guilt; even infants should be baptized because they are born with a sinful nature. Furthermore, Augustine believed that a person was predestined as to whether one would accept God's grace to overcome this nature and that a person could not overcome this sinful nature without God's help.

Not everyone agreed with Augustine's view of original sin. The Pelagians, a group following the teachings of a British ascetic named Pelagius (late 4th to early 5th century), believed one could reach perfection through a virtuous life. This group believed that Adam's sin was confined to Adam alone and that he was destined to die regardless of whether he had sinned. Augustine wrote against the Pelagians in *On Merit and Forgiveness* around the year 412. Orthodox Christianity condemned Pelagius's position at the Council of Carthage in 418.

Like Augustine, Anselm, Archbishop of Canterbury (1033–1109), saw original guilt and humanity's flawed nature to be passed on from parent to child; however, he saw original sin as original in each individual rather than as a reference to Adam and Eve's first sin. He argues that all people were present in Adam and actually sinned in Adam.

Thomas Aquinas (1225–1274), a scholastic theologian, defines humans as rational beings. Although he does not use the term *original sin*, he says the consequence of Adam's sin was that a person's ability to reason was no longer subjected to God's will. Therefore, the Fall does not involve the loss of human reasoning, an ability Aquinas connected with the image of God, but rather humans gained the ability to reason outside of what God would want. Aquinas's position influenced the theology of many modern theologians such as Karl Barth (1886–1968).

According to his writings in *Institutes of Christian Religion,* John Calvin (1509–1564), one of the Protestant Reformers, saw original sin as an internal, total depravity and corruption of human nature (II.i.5). He was greatly influenced by Augustine's work. Yet, he did not see original sin so much as heredity but rather as an ordinance of God. According to his position, Adam, a representative of all humans, sinned, and God ascribed this sin to all people. Then God judged all humanity because of this sin. For Calvin, sin pollutes all aspects of the human being; there is no goodness in humankind. Humans on their own accord have no option but to choose sin (i.e., humans have no free will). Like Adam, Christ, also representing all humans, overcame sin; therefore, all humans can be made righteous through him. According to Calvin, only those predestined to this salvation will receive it. Today, several modern denominations follow Calvin's position, including some Presbyterians and some Baptists.

Jacobus Arminius (1560–1609), a Dutch Reformed pastor and the head of the Arminian movement, believed that all people inherited the sinful nature; but he also believed that each person has the free will to choose God's grace and that God's grace overcomes this condition. Out of this tradition came the modern Methodist movement.

In the Jewish tradition, Adam and Eve's actions are those of individuals; thus the sin, which is disobeying God, is limited to them alone. By eating the fruit, humanity gained the capacity to know evil. Thus, they developed free will, the ability to choose to do good or evil. Sin in itself is the responsibility of each individual based upon each individual's choices. Thus Judaism does not have a doctrine of original sin as Christianity does.

Islamic tradition of the account of the first sin is similar to the biblical Genesis account. Islam blames both Adam and Eve for the sin. However, Adam and Eve are forgiven after they repent, and they are restored. Therefore, Islam does not have a doctrine of a sinful nature passing from parent to child. Islam holds that children are born in a state of purity without sin.

Terry W. Eddinger

See also Adam, Creation of; Anselm of Canterbury; Aquinas, Saint Thomas; Aquinas and Augustine; Augustine of Hippo, Saint; Barth, Karl; Bible and Time; Christianity; Devils (Demons); Genesis, Book of; God and Time; God as Creator; Judaism; Luther, Martin; Predestination; Religions and Time; Salvation; Satan and Time

Further Readings

Calvin, J. (1990). *Institutes of the Christian religion* (H. Beveridge, Trans.). Grand Rapids, MI: Eerdmans.

Fitzgerald, A. D. (Ed.). (1999). *Augustine through the ages: An encyclopedia.* Grand Rapids, MI: Eerdmans.

Wiley, T. (2002). *Original sin: Origins, developments, contemporary meanings.* Mahwah, NJ: Paulist Press.

SINGULARITIES

Singularities are points in spacetime that have infinite density and temperature. At these points, the known laws of physics break down or contradict each other. Singularities are found in three places: at the beginning of the big bang, at the end of the hypothetical big crunch, and at the centers of black holes. The singularity at the big bang is mathematically defined as the beginning of time, or "t = 0." Alternatively, singularities may be defined as points of infinite tidal gravity and chaotic spacetime curvature, or as being made of quantum foam, the bubbly substance governed by probability that constitutes space at the quantum level. Infinities usually identify an error or problem with a physical theory, so these definitions cannot properly describe singularities. The search for a complete grand unified theory was initiated because of this breakdown of physics.

Singularities warp the fabric of spacetime more than any other known phenomenon. Time slows to stopping at the event horizon of a black hole and ceases to have any meaning at the singularity itself. The warpage of spacetime around a regular black hole depends upon the hole's mass and circumference, according to Albert Einstein's general theory of relativity. The greater the mass and the smaller the circumference of the object is, the greater is the time dilation that results.

Black Hole Theory

In England in 1783, John Michell used Newton's laws of gravity to deduce, via a thought experiment, the possible existence of "dark stars," rudimentary black holes. Perhaps, Michell postulated, there are stars so massive that their escape velocities, the speed required to escape the star's gravity, were the speed of light. He imagined light rays, or photons, rising above the surface of the star, then being dragged back by gravity. Such a star would be invisible from a distance. Michell presented his idea to the Royal Society, which caused excitement. Around the same time, the Marquis Pierre Simon Laplace used nearly the same argument in his book *Le Système du Monde* (The System of the World), published in 1796. Without any apparent reason, Laplace later removed the reference. Because these dark stars could not be studied further, interest waned.

Some of the right tools with which to study black holes appeared in Einstein's general theory of relativity. This theory is built upon the principle of equivalence, which states that all reference frames are equally valid to view or study physical phenomena. This theory, to Einstein's chagrin, predicted a singularity at the big bang and the big crunch, despite his efforts to prove that singularities were impossible. He would not even countenance the possibility that stars many times the sun's size might implode near the end of their lives. Einstein was certain that some internal force would be found to balance the star's gravity.

More of Einstein's findings led to discoveries of singularities' properties. When researching the effect of curved spacetime, he realized that tidal gravity, the force that pulls all matter toward an object's center, was a sign of curved spacetime. His discovery explains the high level of tidal gravity near singularities; they also highly curve spacetime. Tidal gravity stretches the closest part of an object most and squeezes the sides perpendicular to the bottom. Objects that were originally moving parallel with respect to each other will collide when acted on by tidal gravity. The same mechanism can be seen looking at a globe, where longitude lines, parallel at the equator, cross at the poles.

Another advance in black hole theory was the discovery of stellar mass limits. Karl Schwarzschild, Subrahmanyan Chandrasekhar, and J. Robert Oppenheimer were primarily responsible for these discoveries. Schwarzschild created Schwarzschild geometry in 1916, which describes the degree of spacetime warpage for any spherical, nonrotating star. He calculated the critical circumference, better known as the Schwarzschild radius, at which the sun would become a black hole, about 18 1/2 kilometers. This number agreed with Michell's and Laplace's calculations. High magnitudes of spacetime warpage and densities were accepted in the physics community, but no one was willing to believe in infinities. It was known theoretically that infinitely redshifted photons were created at the horizon, which also meant that time stopped at the horizon. The amount of a wavelength shift equals the amount of time dilation resulting from the shift. This was considered unacceptable.

Sir Arthur Eddington's and R. H. Fowler's work on white dwarfs and the end stages of stars inspired Chandrasekhar. Using one of Eddington's books, he deduced the stellar mass limit for forming a white dwarf. Eddington encouraged Chandrasekhar to develop the idea. Most physicists had no interest in the subject at the time, and Eddington later attacked Chandrasekhar's ideas openly at a conference. Chandrasekhar sent his calculations to Niels Bohr for verification and was told that he was correct: No star more massive than 1.4 solar masses could settle into a white dwarf state. Another physicist, Viktor Amazapovich Ambartsumian, told Chandrasekhar that he would have to analyze known white dwarfs to prove his calculations. This Chandrasekhar did, finding all white dwarfs to be of less than 1.4 solar masses. He eventually moved into other areas of physics. Most scientists believed that by some method, stars greater than 1.4 solar masses would either eject enough mass to become white dwarfs or settle into some unknown intermediate phase between white dwarfs and neutron stars, a denser star form.

Oppenheimer was the next physicist to add to the stellar mass limits. He was intrigued by neutron cores, which when first proposed in 1933 were modern neutron stars buried inside regular stars. Upon analyzing this hypothesis, Oppenheimer found that neutron cores were not viable, but neutron stars were. Researching further, Oppenheimer found that these also had a maximum limit, somewhere between one half and a few solar masses. Above that size, a star would certainly form a black hole. Oppenheimer then investigated black holes. He discovered a paradox: From a distance, a forming black hole would appear to be a static star shrinking to the critical circumference and then freezing there. However, for an observer on the star, the star would continue to shrink to zero volume and infinite density. The curvature and tidal gravity would not, as previously thought, be infinite, but the light would be infinitely redshifted. These unusual findings encountered a great deal of skepticism, largely because in order to analyze the imploding star, Oppenheimer had been forced to make his model star very uniform and spherical, unlike most real stars. In 1958 John Wheeler said that black holes were unlikely, while acknowledging in the same breath that implosion was necessary for stars over two solar masses. Resistance continued, but these developments nevertheless led to advances in singularity theory.

Wheeler contributed an important insight to the study of singularities, labeling them the holy grail of the physics community. He found that quantum gravity, the name for the theory incorporating quantum theory and relativity, would entail quantum fluctuations. These fluctuations occur everywhere in the universe in two types: electromagnetic and gravitational. There are always some of these fluctuations, no matter how empty the surrounding space is. They contain no net energy, but any isolated area can temporarily have positive or negative energy. Quantum fluctuations become more vigorous in confined spaces, and gain crucial importance at the Planck-Wheeler scale, about 1.62×10^{-33} centimeters. At this length, space becomes quantum foam, which is what a singularity is actually composed of. The connection of singularities to quantum fluctuations was not made for years, however.

Singularity Theory

In 1961 Evgeny Lifshitz and Isaac Khalatnikov concluded that all known types of singularities are unstable when realistic random fluctuations are introduced into their vicinity. Instability would halt a star's implosion and avoid a singularity. However, the same researchers, with Vladimir Belinsky, discovered the chaotically oscillating singularity, a new type, 8 years later. This new singularity had random forces of alternating pressure and elongation that acted on matter falling through the black hole. As matter approached the singularity, the forces gained strength and oscillated faster, remaining chaotic in pattern. Matter was always stretched in one spatial dimension and squeezed in the other two dimensions. The oscillations were chaotic both spatially and temporally, so a human falling toward one of these singularities might have one leg being pulled down while an arm was stretched sideways. Another physicist, Charles Misner, had also found the chaotically oscillating singularity, and called it the "mixmaster oscillation" because of its ability to completely destroy and combine the constituents of matter.

Roger Penrose and Stephen W. Hawking developed singularity theory directly to a higher degree in one generation than anyone had before. Shortly after Hawking received his Ph.D., the two began working together. In late 1964, Penrose used the rules of general relativity and an obscure field of mathematics called topography to prove that there was a singularity in every black hole, and conversely, that no black hole could form without a singularity. The Russians Lifshitz, Khalatnikov, and Belinsky rejected this idea on the grounds that the known singularities would be unstable, until they found the chaotically oscillating type. This is considered to be the only kind of singularity that exists, based on their work. In the late 1960s, Penrose and Hawking proved that both the big bang and big crunch scenarios entailed singularities, which all matter and energy either exploded from or converged into. From the methods and theorems that Penrose had derived, coworkers like Hawking, George Ellis, and Robert P. Geroch created the "global methods," with which they described the early universe and the centers of black holes. In 1969, Penrose made a claim known as the "cosmic censorship conjecture," broadly meaning that the universe does not allow "naked singularities" (i.e., those without event horizons) to occur. The weak version of this conjecture protects the universe from the spatial and temporal unpredictability experienced close to the singularity; the strong version states that singularities are always either completely in one's future or one's past but can never actually be reached. Despite the security this conjecture would give the outside universe, Penrose has not successfully proven it.

The next winter, Hawking discovered that black holes have an event horizon that never decreases. When matter falls into the hole, the horizon increases. Singularities were eliminated from the universe by Hawking a decade later. His development of the "no-boundary" hypothesis made use of imaginary time, which is represented visually at right angles to ordinary time. Using the concept, Hawking could explain the singularities at the big bang and big crunch without the unknowns and infinities inherent in their definitions. They became normal points in spacetime, analogues of those at the north and south poles of the earth. Looking at the history of the universe in real time, there are still singularities, but it makes mathematical consideration of cosmology simpler.

A decade after Hawking made singularities optional, Werner Israel and Eric Poisson investigated the changes that occur in old singularities. Another theoretical physicist, Amos Ori, independently carried out the same calculations. They found that the chaotic oscillations deteriorate in intensity over time and may even disappear. This work suggests that if a person fell into an old black hole, he or she may not die on impact with the singularity, or may die much closer to the singularity than the individual would have if the hole had been new. However, the tidal forces are temporarily rejuvenated upon the intake of energy.

The most recent breakthrough in singularity theory was a computer simulation carried out at Cornell University by Stuart L. Shapiro and Saul A. Teukolsky. Through the history of singularity theory, an ongoing debate has raged over whether naked singularities can be seen from a distance. Even if they could, some have argued, the state would be very unstable, and an event horizon would form swiftly. Most physicists have sided with Penrose's cosmic censorship theory, but Shapiro and Teukolsky's simulations in 1991 created naked singularities from extremely misshapen stars, using calculations in the general theory of relativity.

Over the past 50 years, knowledge of singularities has grown exponentially. Gravitational waves carry away asymmetric matter from a collapsing star; when the star finally settles into its final state as a black hole, the singularity at the center is perfectly spherical. Both space and time stream directly to the singularity inside the horizon. A near-vacuum exists between the event horizon and the core of a black hole, due to the singularity's extreme gravity. Younger and smaller singularities destroy matter faster than do large or old holes. Atoms are pulled apart, as gravity overcomes even nuclear forces, and their constituent particles merge with the singularity. When this complete destruction happens, in 10^{-43} seconds or less, the still-incomplete theory of quantum gravity is supposed to replace current physical theory. When this occurs, time close to the singularity becomes separated from space and ceases to exist. Theoretical havoc ensues; probabilities are the only tool left to find the properties of this state. Space itself becomes frothy. It is believed that the electromagnetic vacuum fluctuations bombard a hole, ensuring that the singularity doesn't pinch spacetime off completely and drift away, creating a new universe.

There is still a great deal to learn, however, and perhaps to observe directly. Still unknown is whether or not a person would certainly die when he or she hits a singularity, especially a very large or old one. Also left to prove conclusively is whether Penrose's cosmic censorship hypothesis is correct. If it is, then there is nothing we can learn for certain about singularities, for they will always be hidden behind the event horizon. The expense of having naked singularities to study is the added danger for travelers of finding an unstable, gravitationally powerful singularity potentially around every corner.

The laws that govern singularities' activities (i.e., the theory of quantum gravity) are beyond the grasp of current physics as well. The rules and laws must govern tiny spaces and high densities satisfactorily. The theory should unravel the mysteries of the mechanisms and events that occur inside black holes and how the singularity causes them. Finally, it must settle the debate about whether a singularity can detach from its region of the universe and create a new universe.

Emily Sobel

See also Big Bang Theory; Big Crunch Theory; Black Holes; Cosmogony; Cosmology, Inflationary; Einstein, Albert; Hawking, Stephen; Laplace, Marquis Pierre-Simon de; Newton, Isaac; Relativity, General Theory of; Relativity, Special Theory of; Time Dilation and Length Contraction; Time Warps; Universes, Baby; White Holes

Further Readings

Gribbin, J. (1986). *In search of the big bang.* New York: Bantam.

Guth, A. (1997). *The inflationary universe: The quest for a new theory of cosmic origins.* Reading, MA: Addison-Wesley.

Hawking, S. W. (1996). *A brief history of time.* New York: Bantam.

Overbye, D. (1991). *Lonely hearts of the cosmos: The story of the scientific quest for the secret of the universe.* New York: HarperCollins.

Rees, M. (2000). *Just six numbers: The deep forces that shape the universe.* New York: Basic Books.

Thorne, K. (1994). *Black holes and time warps: Einstein's outrageous legacy.* New York: Norton.

Sisyphus, Myth of

Sisyphus is a character in ancient Greek mythology who defied death and then was condemned to an eternity of performing a repetitive, meaningless task. The myth exemplifies the concept of eternal recurrence, the notion that time in the universe is cyclical rather than linear, and that the universe recurs in the same form an infinite number of times. The myth of Sisyphus also became the foundation of a 20th-century book, *The Myth of Sisyphus, and Other Essays,* by the 20th-century French writer Albert Camus, about the meaninglessness and absurdity of life.

According to the Greek myth (partially recounted in Homer's *Odyssey*), Sisyphus was the founder and first king of Ephyra (Corinth) and the father of Odysseus. He is also credited with founding the Isthmian games in honor of Melicertes, whom he found dead lying on the shore of the Corinthian Isthmus. Legend holds that Sisyphus was a deceitful person and very crafty. He put Death in fetters when he came for Sisyphus, and thereafter no one died. Ares became frustrated because his enemies in battle would not die, so he came, released Death, and sent Sisyphus to Tartarus, a dungeon within Hades. Before Sisyphus died, he told his wife not to offer the normal sacrifice for the dead. The underworld complained that Sisyphus's wife had neglected him, so Sisyphus convinced Persephone to allow him to return and ask his wife to offer the sacrifice. She agreed and allowed Sisyphus to return to Corinth, but then he refused to go back to Hades. Eventually, Hermes took him back to the underworld. As punishment for his misdeeds and trickery (and for betraying Zeus by exposing his sexual misdeeds), Zeus bound Sisyphus to an eternity of frustration, forcing him to forever perform a meaningless task. Zeus forced Sisyphus to push a rock up a steep hill. However, just before he reached the top of the hill, the rock always rolled back down and he had to start over again. Today, people often use the term *Sisyphean* to describe a pointless or interminable task.

Sisyphus's eternal, repetitive labor serves as an example of the concept of eternal recurrence. According to this philosophy, the universe is cyclical and, over time, recurs upon itself. This was a common philosophy in the ancient world. The scarab in ancient Egypt symbolized recurrent life. This concept also appears in other Greek myths, such as the Demetrian myth of the cyclical, annual return of Persephone from Hades, a myth that explains the seasonal changes. In Western civilization, eternal recurrence lost its prominence with the rise of Christianity; however, philosophers such as Friedrich Nietzsche briefly revived the philosophy in the 19th century.

In 1942, Albert Camus wrote an essay titled *Le Mythe de Sisyphe*. Based on the myth of Sisyphus, Camus's treatise is a philosophy of the absurd and focuses on humanity's futile search for meaning in an unintelligible world without God or eternity. He concludes that such a life does not require suicide. He compares the life of absurdity with the struggle of Sisyphus to push the rock up a hill. He concludes that Sisyphus is an absurd hero, who has found happiness in his meaningless task. He is truly happy because the futility of his task is beyond doubt; therefore, any human can be content once he or she comes to terms with the absurdity of life.

Terry W. Eddinger

See also Eternal Recurrence; Eternity; Homer; Mythology; Nietzsche, Friedrich; Tantalus; Time, Cyclical

Further Readings

Camus, A. (1991). *The myth of Sisyphus, and other essays* (J. O'Brien, Trans.). New York: Vintage Books. (Original work published 1955)

Homer. (2006). *The Odyssey* (R. Fagles, Trans.). New York: Penguin.

Sleep

From time immemorial the ultimate function of sleep has occupied the attention of scientists, philosophers, and physicians, though little basic understanding emerged. In recent times, J. A. Hobson, a leading sleep researcher at Harvard University, succinctly observed that sleep is of the brain, by the brain, and for the brain. Recent approaches from the perspectives of efficiency of brain function and natural selection are unraveling sleep's long-standing mysteries, particularly how sleep is "for the brain."

One obtains the greatest insight into the rationale of a biological act or state through elucidating its evolution, namely, why, when, and how it came into existence. With this inherent advantage of an evolutionary perspective, sleep's ultimate function now presents little more mystery than many other phenomena of life that increasingly are yielding their secrets. In fact, it is now evident that time, in the sense of simultaneity, played a pivotal role in sleep's origin.

Time's Role in the Origin of Sleep

Merely from the fact of sleep's continued existence, an evolutionist would expect it to maintain an overall high level of efficiency of brain operation. Otherwise, how could sleep have survived the relentless pressures of natural selection? Such an overall highly efficient state of brain operation very likely has been achieved by the brain's postponing, until the new vigilance state of sleep, any nonurgent (low-priority) brain activities that conflicted with the urgent activities of wakefulness.

But which brain activities are nonurgent during waking and can safely be postponed until sleep? Here, neuroscientists have provided clear answers. The major, safely delayed brain activity carried out during sleep is memory processing, with the delay tolerated because synaptic decay rates are low. Three aspects are foremost. Enormous numbers of memory fragments, essentially meaningless taken individually, are reinforced during NREM (no rapid eye movement) sleep; new memories are "consolidated" and added to the brain's long-term memory stores; and already-stored long-term memories become "reinforced," or "refreshed," during REM (rapid eye movement) sleep.

Given that memory processing is the major nonurgent brain activity during sleep, why couldn't this processing have occurred safely and efficiently during a continuous state of wakefulness? In other words, why is postponement until sleep sometimes necessary or merely beneficial? To answer these questions, one has to turn back in evolutionary time to the early appearance of brains and relatively simple collections of nerve cells in nonsleeping invertebrates. At those times, natural selection would have favored animals whose simple brain tissues were versatile, that is, had evolved the capacity to carry out more than one function.

A given amount of brain tissue in such animals would have been able to carry out more processing than could the same amount in animals whose brain tissues were dedicated only to specific functions. These circumstances are now recognized as a fundamental dogma of neuroscience. According to this dogma, memories are stored in the same collections of brain cells involved in processing, analyzing, and controlling responses to the situations to be remembered. In a striking example of these circumstances, after severe damage to certain limited brain regions, some patients not only become blind to colors, they are unable even to remember what a color is. In other words, the damaged brain circuits were involved in both seeing and remembering colors.

While such circuits with multiple functional capacities were highly adaptive for animals with the simple, stationary lifestyles in which the circuits had evolved, this versatility could have led to conflict in a more complex, highly mobile existence. For example, if circuits were occupied with a high-priority function during waking, say the escape from a newly encountered predator, the same circuits might not have been able to carry out, simultaneously and efficiently, the lower-priority function of processing the memory of how the escape was achieved. That might have had to wait until the subsequent period of "restful waking," or primitive sleep, after the urgent escape had been accomplished.

Just such a conflict in highly mobile animals in complex environments—an inability of certain brain circuitry with multiple functional capacities to cope efficiently with more than one function at a time—is believed to have been the selective pressure that gave rise to earliest sleep, in other words, sleep's "ultimate cause." In this sense—of infeasibility of efficient occurrence of certain brain functions in the same neural circuitry at the same time—an aspect of time was responsible for sleep's origin.

Detailed Focal Vision's Role in the Origin of Sleep

The evolutionary progression toward primitive sleep is thought to have begun when animals were evolving increasingly complex, highly mobile lifestyles (control of which is one of the brain's main functions) and detailed focal vision (vision that recreates a complex scene). Such vision requires enormous amounts of neural processing. Thus, almost 50% of the neocortical neurons and circuitry (the most recently evolved portion of the brain) of the primate are devoted to representing the pictorial world. The processing is vastly more complex than for any other sense, even more so than for all other senses combined. Without focusing on any specific region of a scene, one becomes aware of the simultaneous, space-filling presence of almost limitless numbers of objects, of all sizes, shapes, orientations, positions, depths, textures, and colors—all involving tremendous amounts of information.

In those ancient times, as animals acquired detailed focal vision, their lifestyles would have become markedly altered. With sharper discriminations and engagement in multifarious new activities, including fast, wide-ranging movements and rapid actions and responses, it would have been crucial to retain greatly increased stores of memories for the long term.

In these circumstances, the parallel processing capacity of some regions of these animals' brains would have become severely taxed. It would have become increasingly difficult for brain regions with multiple functional capacities to meet demands associated with crucial, largely unpredictable hazards and routine but essential needs, while at the same time (the role of simultaneity of time) meeting needs to acquire and maintain large stores of long-term memories.

In essence, an adaptation that initially conferred great efficiency of brain operation, before the evolution of great mobility and detailed focal vision, would have become increasingly less efficient as highly mobile, more complex visual lifestyles evolved, had not compensating features evolved in parallel—first restful waking and, eventually, primitive sleep. Accordingly, the selective pressure for primitive sleep probably was the need to resolve these developing conflicts. This could have been achieved most readily through the provision of a period with a greater degree of brain unresponsiveness to outside occurrences than exists during restful waking, namely, primitive sleep.

By providing a portion of the 24-hour cycle when enormously increased needs for memory processing could be accommodated efficiently, primitive sleep obviated any possible conflicts with urgent waking brain activities, particularly the rapid processing and responding to increasingly complex and varied visual inputs.

It follows from this mode of origin of primitive sleep that entirely sessile and very slow-moving animals, such as mussels, sea anemones, starfish, and some worms, would have no need for sleep. It also follows that sleep would be engaged in only during that part of an animal's existence when danger was at a relative minimum and rapid movements usually were unnecessary, for example, during the night for day-active animals.

The long-sought ultimate function of sleep thus appears to be an "enabling" one. Sleep enables the brain to operate with high efficiency at all times. This was accomplished by the evolution of a vigilance state to which low-priority waking brain activities, particularly the enormously increased needs for memory processing, could be deferred.

This scenario for the origin and ultimate function of primitive sleep does not rule out the subsequent or accompanying evolution of secondary (proximate) functions that may have become essential. Indeed, several proximate functions besides memory processing now play important roles. These include rest and rejuvenation, as well as many deep-seated rhythmical changes that influence physiological processes.

Beyond the superficial, some occurrences that appeared to contradict this paradigm, and that long contributed to obscuring sleep's significance, are readily reconciled. These included a continuing need for sleep by blind animals and an absence of sleep in some fishes, despite their having excellent vision.

Actions of Brain Waves and States of Awareness During Sleep

Attention here is directed largely to the sleep of mammals and birds, in most of which both the REM and NREM states occur. Earliest sleep probably most closely resembled the predominantly slow-wave, arrhythmic, high-voltage spiking as it now occurs in cold-blooded vertebrates. REM sleep, which awaited the evolution of warm-bloodedness, is essentially a specialization of a portion of primitive sleep, in which certain fast and slow brain-wave components have come to predominate.

Both slow (≤ 14 cycles per second [cycles/s]) and fast (> 14 cycles/s) spontaneously generated electrical brain oscillations are present to varying degrees in human electroencephalograms (EEGs) during waking and NREM and REM sleep. The designations "slow waves" and "fast waves" for scalp EEGs are used only for convenience. It is often the global oscillatory brain states that are involved, of which slow and fast scalp-waves are merely superficial manifestations. These oscillations play roles at all levels of brain function.

The fast waves, which greatly predominate during REM sleep, are nonsynchronous, and of relatively low voltage (several-microvolt range). In most mammals the EEGs of this state are very similar to those of wakefulness, a sure indication that similar brain activities occur in both states. Not only does sleep have a role in the differing frequencies of slow and fast brain waves, but these waves likewise have a role in the origin of the cyclic alternation between NREM and REM sleep.

One of the keys to REM sleep's principal adaptive features in the adult, as in wakefulness, lies in the predominance and principal actions of the brain's gamma oscillations (30–100 cycles/s). Thus, REM oscillations in the gamma band predominantly participate in memory processing by actions first suggested by Christoph von der Malsburg. This processing is generally referred to as "temporal binding," or binding by synchrony.

In the temporal binding of a memory during sleep, the memory's circuit fragments, located in widely distributed neocortical regions, are mobilized and synchronously activated by the gamma oscillations. These actions usually result in reinforcement and transient recall of the memory. At the same time, all individual connections (synapses) between the fragments are reinforced (accomplished by their mere activation). In short, the gamma oscillations of REM sleep bring about the reinforcement of neocortical memories, often resulting in the "unconscious" awareness of them, which we call "dreaming."

This temporal binding by gamma oscillations also figures largely in the formation of waking thoughts and perceptions during cognitive processing, including their recall from long-term memory. In higher vertebrates, this formation of a memory by the temporal binding of its fragments can be regarded as the neural correlate of consciousness. However, the contents of unbound fragments of memories are meaningless.

The synchronous, relatively high-voltage (in a somewhat higher microvolt range) slow waves of sleep have three principal functions. In one function, during NREM sleep, they activate and reinforce only the synapses within the enormous numbers of memory-circuit fragments. Unconscious awareness (dreaming) of the contents of these fragments does not occur, because, as noted, without temporal binding, the contents are meaningless.

A second principal function of slow waves during NREM sleep is the consolidation of declarative memories, which involves the conscious recollection or explicit remembering of facts or events. In this process, known as "hippocampal replay," distributed hippocampal circuit fragments of recent short-term memories become established at distributed locations in the neocortex for long-term storage.

The third principal function of slow waves during sleep is carried out by highly synchronous hippocampal REM theta waves (4–8 cycles/s), the largest and most regular slow waves. It seems likely that these waves serially link selected groups of memories assembled by gamma oscillations. Groups of memories so linked often are manifested as continuous or narrative dreams.

As an example, the fragments of a visual memory would represent such characteristics as shape, size, orientation, color, texture, and so forth. Most of these fragments are distributed in the neocortex. Mobilizing and temporally binding them (which requires a period of 100–200 milliseconds) produces the conscious (awake) or unconscious (dreaming) visual memory.

Slow and fast waves are thought to act cooperatively in reinforcement during sleep. NREM slow waves reinforce synapses within enormous numbers of memory fragments and participate in hippocampal replay. REM gamma waves reinforce synapses between the specific combinations of memory fragments that yield the corresponding memories, and REM theta waves link these memories, often expressed as narrative dreams.

Predominantly slow-wave, arrhythmic, high-voltage spiking generally occurs during restful waking and sleep in reptiles. The fast and slow brain-waves that temporally bind memories and serially link the bound memories, make their appearance abundantly only during arousal and wakefulness. Reinforcement of memory fragments by slow waves during sleep probably occurs on a nightly basis. This would have been the principal primitive sleep–associated mechanism of memory maintenance in reptiles, inherited by mammals and birds as the chief action during their NREM sleep.

The stimulation of circuits controlling muscle contractions during the sleep of cold-blooded vertebrates and NREM sleep of mammals and birds reinforces the circuits but fails to produce contractions (which would disturb sleep) because the muscles have partially lost their tone. Stimulation of circuits for fragments of thoughts and perceptions in mammals and birds during sleep also reinforces the circuits but produces no awareness. To the minor extent that properties of REM sleep overlap those of NREM sleep, dreaming can occur, but the NREM dreams are mostly of the static or thoughtful variety.

While the gamma oscillations of REM sleep temporally bind circuits controlling skeletal muscle contractions, the muscles—excluding those of the diaphragm—do not contract then, either, because they are completely without tone. If, in abnormal circumstances, skeletal muscle tone is not lost, dreams are acted out with startling reality, sometimes with injury.

It follows that the most favorable time for reinforcing circuits controlling muscle contractions is during REM sleep. Further, during REM sleep there is a high degree of perceptual isolation from external stimuli, and behavioral responsiveness is reduced. Because of this, the temporal binding of fragments of motor circuitry and serial linking of the bound fragments during REM sleep do not produce contractions—only dreams.

NREM and REM Sleep Cycling

NREM and REM sleep alternate in roughly 90-minute cycles in human adults. The most efficient memory processing in most mammals and birds appears to be a multistep affair. First, memory fragments are reinforced by slow waves, primarily during NREM sleep, which accounts for 75% to 85% of total adult sleep time. The fragments then become temporally bound into memories by gamma waves, including reinforcement, during REM sleep—different ones on different nights. These, in turn, become linked by theta waves, often producing narrative dreams, also primarily during REM sleep.

The role that time plays in the occurrence of NREM–REM sleep cycling during a night's sleep can be elucidated as follows: It is reasonable to assume that some minimal time is required to achieve an effective measure of the characteristic actions that occur during each sleep state. Accordingly, one would expect 4 or 5 90-minute NREM–REM cycles occurring in sequence in humans, with the length of each sleep state fulfilling the minimum, to be more effective than one long biphasic period lasting 6 to 8 hours, with the length of each state greatly exceeding the minimum.

Because multiplication and reduction of physiological processes and structural elements are among the most common achievements of evolutionary processes, these circumstances would account for sleep having become partitioned into multiple NREM–REM cycles in most warm-blooded animals.

J. Lee Kavanau

See also Amnesia; Consciousness; Dreams; Hibernation; Memory; Psychology and Time; Rip Van Winkle, Tale of; Sandman

Further Readings

Buzsáki, G. (2006). *Rhythms of the brain.* New York: Oxford University Press.

Kavanau, J. L. (2002). REM and NREM sleep as natural accompaniments of the evolution of warm-bloodedness. *Neuroscience and Biobehavioral Reviews, 26,* 889–906.

Kavanau, J. L. (2005). Evolutionary approaches to understanding sleep. *Sleep Medicine Reviews, 9,* 141–152.

Sloterdijk, Peter (1947–)

Peter Sloterdijk was born on June 26, 1947, in Karlsruhe, Germany, to a German mother and a Dutch father. He studied philosophy, history, and German at the universities in Munich and Hamburg and received a Ph.D. in German literature in 1976. In 1983 he became the shooting star of German philosophy with the publication of his early main work *Die Kritik der zynischen Vernunft* (The

Critique of Cynical Reason), which is of particular importance for his views concerning time. It was translated into English in 1987. The most important work of his current period is a three-volume project titled *Spheres*. Since 2001 Sloterdijk has been the rector at the Staatlichen Hochschule für Gestaltung in Karlsruhe. With Ruediger Safranski he has been host of the television show *Philosophical Quartet* since 2002, in which leading intellectuals discuss topics of current importance. Together with Jürgen Habermas he is widely seen as the leading German philosopher alive today. Some academic philosophers regard him as a charlatan, however, claiming that he lacks academic rigor and deals with topics not normally discussed in academic philosophy. Yet, even Habermas reviewed Sloterdijk's *Critique of Cynical Reason*. Sloterdijk's views concerning time also stem from this work, still considered his most important.

Critique of Cynical Reason

Sloterdijk is a vehement critic of all abstract philosophical topics such as time; he regards it as futile to attempt to give a philosophical account of them. Only young people, outsiders, and clerics are supposed to be interested in them, according to him. Through such comments Sloterdijk's Nietzschean heritage becomes clear, as both thinkers argue against the plausibility of positions by reference to their origin. Neither of them commits the genetic fallacy, as they do not attempt to put forward the truth in correspondence with the world because they are skeptical of the possibility of grasping the truth in correspondence with the world. However, by putting forward this type of criticism, they try to undermine the plausibility of those beliefs against which they argue.

Sloterdijk's main contributions to the philosophy of time are his views concerning the Zeitgeist, the spirit of our times. In his *Critique of Cynical Reason,* he puts forward an interpretation of the Enlightenment similar to that of Nietzsche and Spengler. According to him, the Enlightenment brought about the end of the Christian domination of the Western world, a destruction of ideals, absolutes, or truths, with respect to both ontology and morality. In great detail he analyzes various types of critique with which the Enlightenment is connected: critique of revelation, religious illusion, metaphysical illusion, idealistic superstructure, moral illusion, transparency, natural illusion, and the illusion of privacy. According to Sloterdijk the history of criticism has been connected with laughter, gaiety, the affirmation of life, and the satiric tradition. However, the outcome of the Enlightenment brought about an attitude toward life that is different from that satirical tradition.

Cynicism and Kynicism

Our times are supposed to be dominated by misery, depression, and pessimism. Sloterdijk calls this attitude toward life "cynicism." He distinguishes between "cynicism" and "kynicism," and he is critical of the former but affirmative of the latter. Cynicism is enlightened false consciousness, and he regards it as a modern universal problem as it is supposed to be the dominant attitude toward life in enlightened countries. Kynicism, on the other hand, is also connected to an enlightened attitude toward life. In contrast to cynicism, it is an enlightened correct consciousness. Cynics are aware of the various types of criticisms. In addition, cynics see that they are part of institutions and bound to moralities that they cannot justify for themselves, given all the critiques of which they are aware. As a consequence, cynics are miserable. The philosopher and cultural critic Theodor Adorno (1903–1969) is seen as a prototype of a cynic by Sloterdijk. Kynics, on the other hand, are aware of the very same situation as cynics but, in contrast to cynics, kynics are able to say "yes" to it. Kynics are cheerful, life-affirming, full of vitality, and also cheeky, and they argue with the whole of their bodies, especially with its lower part, which is supposed to have been neglected throughout the history of philosophy. Diogenes is the role model of a kynic. Traditionally, the carnival, universities, and bohemians have been connected with the kynical tradition. By putting forward a critique of cynical reason, Sloterdijk tries to show why the kynical attitude is far more appealing and more appropriate for modern times than is the cynical one. In his descriptions of various cultures, Sloterdijk gives a poignant summary of the dominant Zeitgeist, and the presentation of such descriptions has been called Sloterdijk's greatest ability.

Stefan Lorenz Sorgner

See also Critical Reflection and Time; Enlightenment, Age of; Nietzsche, Friedrich; Zeitgeist

Further Readings

Sloterdijk, P. (1987). *Critique of cynical reason.* Minneapolis: University of Minnesota Press. (Original work published 1983)

Sloterdijk, P. (1989). *Thinker on stage: Nietzsche's materialism.* Minneapolis: University of Minnesota Press.

Sorgner, S. L. (2003). In search of lost cheekiness—An introduction to Peter Sloterdijk's *Critique of Cynical Reason*. *Tabula Rasa, 20*. Retrieved August 30, 2008, from http://www.tabvlarasa.de/20/sorgner.php

Smith, William (1769–1839)

William Smith was an English surveyor, canal builder, and amateur geologist who became known as the "father of English geology." His main achievement was the creation of the first geological map, using fossils as a tool for mapping rocks by their stratigraphical order.

Smith was born in Churchill, Oxfordshire, into a humble family, and he received a limited education, although his work as a land surveyor for Edward Webb gave him a deep knowledge of the rocks. While working in an estate's pit mine in Somerset, he noticed that the strata were arranged in a predictable pattern and that the various strata could always be found in the same relative positions. Moreover, he realized that fossils were arranged in order and regularly in strata, always in the same order from the bottom to the top of a section, each stratum being characterized by a particular type of fossils. These observations lead him to propose the principle of faunal succession, according to which strata could be traced and correlated by comparing the fossils that they contained. Smith was probably the first to suggest that strata and their fossils were displayed in a natural order of indefinitely wide extension.

While he was working as a surveyor for a canal-building company until 1799, and later unemployed or taking different civil engineering jobs, he tried to test whether the same succession of fossil groups from older to younger rocks could be found all over England and if the relationships between the strata and their characteristics were consistent throughout the country. As a result of his research, Smith produced the first large-scale geological map of the area around Bath, Somerset, showing the outcrops of the rocks and their boundaries, coloring each rock type with a different color.

In 1815, after traveling all over England, mapping and collecting samples for more than a decade, and in spite of financial problems in funding his research, he published his masterpiece, the first geological map of England and Wales. The map itself is 6 feet across by 9 feet high, representing tens of thousands of square miles, and it used John Cary's national topographic map as a base map. This geologic map helped Smith to demonstrate the validity of his principle of faunal succession. Additionally, in 1816 Smith published the "Geological Table of Organized Fossils," which completed the first map. Whereas Smith's map was overlooked by some naturalists, George B. Greenough and collaborators plagiarized it and sold it at a lower price, pushing Smith to bankruptcy and to debtor's prison in 1819. Released from prison, he worked as a surveyor for different employers, and conceived a more ambitious idea: the preparation of 60 geologic maps of individual counties in much greater detail, from which he finally prepared 21.

It was not until 1831 that his work was finally recognized. He was awarded the first Wollaston medal, the highest honor of the Geological Society of London. Afterward, his scientific achievements were widely appreciated; he was offered an honorary Doctorate of Laws by Trinity College and received a lifetime pension, awarded by King William IV. William Smith died on August 28, 1839, in Northampton, and he is buried in St. Peter's Church.

Laia Alegret

See also Earth, Age of; Fossil Record; Geological Column; Geologic Timescale; Geology; Hutton, James; Lyell, Charles; Stratigraphy

Further Readings

Phillips, J. (2003). *Memoirs of William Smith* (H. Torrens, Ed.). Bath, UK: The Bath Royal Literary and Scientific Institution. (Original work published 1844)

Winchester, S. (2001). *The map that changed the world: William Smith and the birth of modern geology.* New York: HarperCollins.

Solipsism

Solipsism (from the Latin *solus ipse* "[one]self alone") is the thesis that *I,* the one who is thinking, am the only one who really exists. The term is ambiguous, and can be taken in a metaphysical, ontological, epistemological, or methodological sense. The status of time with regard to solipsism varies depending on which sense is in use.

Metaphysical solipsism is the thesis that the world is dependent on *me.* In this case, it seems that time must be an unreal, purely subjective, phenomenon that is created by the solipsistic mind. The pragmatist George Santayana and early analytic philosopher Bertrand Russell both argue that, in order to remain consistent, any (metaphysical) solipsism must be "present-moment solipsism." If one is going to be skeptical about the induction that other minds exist, then one must be skeptical about the induction that one has a past or future too: Only the present moment is known.

The view that the structure of reality—that is, the way the world is categorized—depends on *me* is a subclass of metaphysical solipsism called ontological solipsism. This view is often associated with transcendental idealism, which was popular in later modern philosophy beginning with Immanuel Kant. The later transcendentalism of Ludwig Wittgenstein can also be understood in terms of ontology, although it may be conceived more properly as a semantic theory. For this type of solipsism, time is frequently thought of as a necessary, a priori condition for structuring the matter of the world either conceptually, as for Kant, or linguistically, as for Wittgenstein.

Epistemological solipsism holds either that *I* cannot know that my experiences do not exhaust reality or, more strongly, that *I* can justifiably believe that my experience is the only experience. This view may be taken with either of the views above in mind. Another, weaker form of epistemological solipsism is often associated with strong foundationalism: the view that the starting point for all knowledge is basic knowledge about one's internal world. This view does not seem to imply any particular view about time necessarily. Depending on how strongly one holds the position, one might claim that one simply does not know about the reality of time or that one knows it as a part of one's epistemically basic experiences.

René Descartes's method of doubt, as the forerunner of epistemological foundationalism, employed methodological solipsism. This is the view that one should suspend beliefs about the existence of other minds or other entities outside of one's own mind because this is the correct way to go about scientific or philosophical investigation. This view may be held independent of one's view about time. The investigation of time, however, would employ the method.

One of the most prominent attempts to reject solipsism is the pragmatic view that one simply cannot live as a solipsist—it is simply impossible to live without believing that other people and things exist. Other criticisms include Russell's rejection of present-moment solipsism and the later Wittgenstein's private-language argument.

Kyle Walker

See also Descartes, René; Epistemology; Husserl, Edmund; Idealism; Kant, Immanuel; Metaphysics; Ontology; Russell, Bertrand; Santayana, George; Time, Illusion of; Time, Nonexistence of; Time, Phenomenology of; Time, Subjective Flow of

Further Readings

Passmore, J. (1966). *A hundred years of philosophy* (2nd ed.). New York: Basic Books.

Pihlström, S. (2004). *Solipsism: History, critique and relevance.* Tampere, Finland: Tampere University Press.

Solstice

Solstice refers to the 2 days in the year when the length of daylight hours are either the longest or the shortest. The hours of daylight change because the earth's axis, an imaginary line drawn through the earth from one pole to the other, is not perpendicular to its orbit around the sun. The axis tilts from the vertical by 23.45°. As the planet moves around the sun and the earth rotates, there will be 1 day when the north pole will be pointing most directly toward the sun. A second day occurs when the south pole turns as closely as it can toward the sun.

As the north pole begins to point more directly toward the sun, the days grow longer. When the length of the daylight hours reaches maximum, this is the summer solstice. When daylight hours are at their minimum, it is the winter solstice. The times of sunrise and sunset at the winter solstice compared to the summer solstice can differ by nearly 3 1/2 hours.

In the northern hemisphere, the summer solstice occurs in June, marking the beginning of summer. At that time in the southern hemisphere, it is the winter solstice and the beginning of winter. Conversely, in December, in the north, when the day is the shortest, the winter solstice occurs. In the southern hemisphere, it is the beginning of summer. The exact days when these events occur vary between June 20 and 23 and December 21 and 22.

During the course of the year, as the time of solstice approaches, depending on whether summer or winter is coming and in which hemisphere, the sun will rise and set further and further north or south. There is a point at which, for a short period of days, this progression slows. The sun appears to rise and set in the same place. This accounts for the name given to the solstice events by the Romans, *sol stetit,* meaning the sun stood still. In primitive times, with the importance of agriculture, many cultures celebrated the summer and winter solstices.

Ancient stone structures such as Stonehenge (England) and petroglyphs (rock carvings) were ways of calculating the exact occurrence of solstices and other astronomical data. For example, at Chaco Canyon in New Mexico, a single blade of light bisects a carving called the Sun Dagger as sunrise begins on the summer solstice.

Today, most of the civilized world barely acknowledges the summer solstice. However, celebrations of the winter solstice live on in some of the traditions associated with Christmas and New Year's Day. Even the date of Christmas may have been moved from what was believed to be the Nativity (January 6) to December 25 in order to capitalize on preexisting pagan celebrations of the winter solstice.

Charles R. Anderson

See also Chaco Canyon; Earth, Rotation of; Equinoxes; Seasons, Change of; Stonehenge; Time, Measurements of

Further Readings

Heinberg, R. (1993). *Celebrate the solstice: Honoring the earth's seasonal rhythms through festival and ceremony.* Wheaton, IL: Quest Books.

Matthews, J. (2002). *The summer solstice: Celebrating the journey of the sun from May Day to harvest.* Wheaton, IL: Quest Books.

Space

The general history of the concept of space can be divided into two epochs: the Aristotelian period and the Newtonian period. A third epoch, which is a consequence of the rethinking of Newtonian spatiality, especially by Einstein in the early 20th century, can be identified with relativistic spacetime theory. In each epoch the physical concept of space rested upon geometrical as well as cosmological concepts of spatiality, which furthermore was set in a cultural context by which certain understandings of space were encouraged and others ignored or suppressed.

Early Concepts

The dominant spatial concept in antiquity was that of place (Greek *topos*). Within his epistemology the Greek philosopher Aristotle (384–322 BCE) first classified place as a linguistic category, by which anything can be described according to *where* it is. Subsequently in *Physics* he defined the place as the surrounding border of any material object: A place has in itself no extension and is invariable. According to Aristotle it is a pure modality of things being, therefore the place itself cannot be moved; only things can change their places. By this concept Aristotle tried to solve a problem that was posed by Zeno of Elea (c. 495–445 BCE), who argued that trying to physically describe the traversing of a given distance (which is the literal meaning of the later Latin word *spatium*) leads to certain paradoxes: especially to the one that an infinite number of points to which any distance can be reduced in geometrical respect makes it logically impossible to traverse all single "spots" (for their number is infinite). In turn Aristotle tried to emphasize the physical concept of becoming as a change (of place) and to separate the concept of place from a pure geometrical definition. Nevertheless, his concept also caused theoretical problems: If place was the location of things, where then is a certain place itself located?

This problem had already been discussed before Aristotle, namely, by his teacher Plato (427–347 BCE), who argued that there has to be something which "gives place" to any possible being (including locations). Plato called this the *chora:* He defined it as an instance that is in between the realm of the eternal ideas and the world of becoming. The concept of chora can be interpreted as a forerunner of the Newtonian concept of "absolute space" insofar as it is conceived as the horizon or context of any possible existence in the physical world.

Nonetheless Plato's concept had less impact on ancient physics as well as on medieval ontology, where the Aristotelian view prevailed. The reason for this was Aristotle's cosmology (which was the background to his physics), which called for a "first mover" (which in the Christian interpretation was identified with God), located at the edge of the outermost sphere from where God caused any physical process in the world. Aristotelian physics and its cosmological framework are nevertheless typical for ancient Greek philosophy, within which scientific reflection always began with the question of an origin (*arche*), or what being is in total. In this way many Presocratic philosophers evoked a certain concept of spatiality when they tried to answer these general questions: The first philosopher, Hesiod (c. 700 BCE), for example, defined the origin as an opening or abyss (*chaos*) and thereby anticipated Plato's concept of chora. Anaximander (c. 610–c. 546 BCE) defined the totality of being as that which is without a border (*a-peiron*) in the spatial as well as temporal sense. In the same respect Parmenides (early to mid-5th century BCE) conceived of totality as a spherical entity outside which nothing exists. Like Aristotle, many ancient theorists of space agree on the idea that within the (finite) world everything is of matter or substance and that nothing like a void exists. Exceptions can be found in atomistic concepts, for example, in Leucippus (late 5th century BCE) and Democritus (c. 460–c. 370 BCE), who argued that in between atoms, in order for them to be moveable, there is a void.

Aquinas and After

The fundamental change within the conceptualization of space presupposed a turning away from the cosmology of a finite universe, which especially was promoted by Thomas Aquinas (c. 1225–1274), who had adopted the Aristotelian worldview. Against it theologians like Giordano Bruno (1548–1600) and Nicholas of Cusa (1401–1444) posed the idea of the cosmos as something infinite, indeed the universe as one of an infinite number of universes. The perspective on the cosmos with the earth at its very center got qualified as only one possible perspective among others. Especially in early Italian Renaissance philosophy, this cosmological turn was of great impact: It coincided with the new and even modern ontology of the world as something that can only be perceived or described from a certain standpoint. Likewise, the technique of linear perspective painting became established as an adequate form of pictorial representation in which a certain point of view on the world was accepted as sufficient.

The decentralization of the earth as envisaged by Nicolaus Copernicus (1473–1543) thus can be considered a consequence of the perspectival and optical theory of representation: Even though Copernicus still denied the existence of empty space, he envisaged the possibility of a viewpoint from which the planets' movements might be described. However, the final impetus for a new concept of physical space came from a theological as well as an experimental side. Already before Copernicus, the Jewish philosopher Hasdai Crescas (c. 1340–1410) argued that the Aristotelian concept of space as place is inconsistent, because a reduction of space, which is seen to be quantitatively identical with the surface of an object, could lead to an increase of the object's place (e.g., taking away a piece from a spherical object increases the outline of that body). Crescas thereby actually did not only prove Aristotle's concept of space as place to be incorrect, but also his critique showed that the epistemological basis for ancient physics had begun to erode: The new understanding of space to emerge was that of volume as the (geometrical) product of a three-dimensional extension.

But in order for volume as the definition of space to be accepted, first of all the existence of empty space had to be proven. This was done by Otto von Guericke (1602–1686), who in the 17th century developed an air-pump and demonstrated the power of vacuum in his hemispherical experiments. Guericke's demonstration gave way to the procession of the Newtonian worldview, which rested mainly on the acceptance of space as void and stood in a strong contrast to the dominant theory of matter in the baroque era, which still was committed to Aristotelian ontology. Especially René Descartes's (1569–1650) theory of physical space as *plenum* gave a strong backing to this substantialism as he defined the external world as continuous and of a material character (*res extensa*).

Newtonian Space

Against the Aristotelian–Cartesian heritage, Isaac Newton (1642–1727) established a new understanding of space. Newton was trained in the Neoplatonic tradition of Cambridge, where his teacher Henry More (1614–1687) introduced him to the kabbalistic concept of space as *makom*. That expression could stand for the divine being, but as a concept it first of all meant "indivisibility," which became the core concept for the notion of absolute space. According to Newton, space in total cannot be divided; it is not the sum of all (relative) spaces, but is spatiality as such. This new concept finally overthrew the whole Aristotelian physics in which the universe was finite and spatiality bound to the locality of an object as well as its substance. From here the Platonic concept of chora can be interpreted as a forerunner of Newton's concept of absolute space, which now includes Nicholas of Cusa's and Bruno's idea of the infinity of the universe as well as the Copernican worldview. According to this view, the earth's movement is not only relative to the sun, but any position of any planet is relative to the others. For Newton there was no center of the universe, but also no end to it. What Newton named absolute space can thus be considered a matrix: It is the totality of all measurable relations between objects. By this there was no "place" in this universe anymore for a divine creator being the cause of all movement within it. Instead Newton supposed matter (as *mass*) itself to be the cause for movement by means of attraction.

Newton's concept was widely discussed, and he was especially accused of promoting an atheistic philosophy—physics. Anticipating that charge, Newton in some exemplars of his *Opticks* wrote that space is the organ with which God "perceives" the world, stating that he nevertheless believed God existed. It was Gottfried Wilhelm Leibniz (1646–1716), in a dispute with the Newtonian Samuel Clarke (1675–1729), who argued that such a concept is not only atheistic, but first of all that it is false. In contrast to Aristotle, who implied that location is the definition of space, Leibniz argued that not the topos in itself, but the relation between the topoi is what defines space. Leibniz thereby is a forerunner of a topological concept of spatiality, which was further developed by Leonhard Euler (1707–1783) in the 18th century, Johann Benedict Listing (1808–1882) in the 19th, and Jules Henri Poincaré (1854–1912) in the 20th century. A topological description of space (Leibniz called it *analysis situs*) thereby is less interested in physics or in the motion of matter, but furthermore in a transformation of Euclidian geometry into nongraphic algebra and process geometry purely by calculation.

This was the main reason why the dispute between Leibniz and Clarke could not be resolved in either of the two fields (geometry or physics) but only on a different stage of reflection. A solution to this dispute on space was developed by Immanuel Kant (1724–1804), who stated that definition of space as an extension measurable in three dimensions is the very and only condition of any perception by the external senses. In contrast to time, which rests upon the inner condition of (memorable) succession, space (extension) is something that underlies any possible appearance ("in space"). However, the Kantian concept of space did not (yet) imply the understanding of space as dependent on individual perception; rather, Kant talks about an imaginable space, a space that can be (geometrically) constructed independently from any given situation. Therefore Kant does not talk about the construction of space by individual cognition but about the general constructability of objects or the relations between them. In contrast to the approach of Leibniz, which considered the construction being a priori to the spatial appearance, Kant conceived of spatiality as something even prior to the topological construction of it.

Subjectivity, Non-Euclidian Space, and Einstein

It was not until the 19th century when Kant's concept of space was transformed into the concept of subjectivity as it is widely understood today. Subjectivity in the post-Kantian sense rests upon a physiological understanding of perception, which implies that spatiality is subject to the condition of each species or even of each individual. Especially in psychophysics and physiology with Gustav Theodor Fechner (1801–1887) and Hermann Helmholtz (1821–1894), space was qualified as variable according to different impressions and therefore became a question of experience in the strong sense.

It was at that time that non-Euclidian geometers tried to find an alternative basis for geometry, avoiding the parallel axiom. In psychophysics the new geometrical approach found a stronghold for the idea that space not necessarily has to be defined as an extensive realm in which each place can sufficiently be located by three coordinates. For what is missing is a parameter for describing the space as something that can also appear as curved, as is the case in individual perception. Even when the Cartesian system of coordinates enables one to describe all the locations in respect to a "point zero," none of the three values depicts the qualitative form of space, neither in perception (where the field of vision is curved in relation to the viewer) nor in geodetics (where the surface of the earth is measured as a curved one). Non-Euclidian geometry and modern topological approaches began to cause a rethinking of physical space, which until then was bound to Newton's concept of space, seen as homogeneous and as an entity separated from time.

Against the latter aspect Hermann Minkowski (1864–1909) argued that time and space cannot be seen as different entities but are two aspects of the same physical event. Just as time has an extension, space is of a certain age. Minkowski's student Albert Einstein (1879–1955) then developed a relativistic theory of space, in which he claimed Newton's difference of absolute and relative space fostered an image of space as a container. Einstein's argument was that the movement of a physical body, described on the level of absolute space, implies a movement of the relative spaces themselves. However, Einstein wanted to look on (absolute) space as being relative not to another space, but to matter, which furthermore is claimed to be determined by an electromagnetic field. In consequence, on the one hand, Einstein transforms the Newtonian notion of space by claiming absolute space itself to be relative; with this, on the other hand, former concepts in physics that had been superseded became reestablished—for example, as Einstein pointed out, in the concept of a field, Descartes's idea of space as a continuous plenum returns. By looking upon space as being of a certain age, space then cannot be infinite anymore, because since the big bang, it started to expand and was transformed within its temporal development. In recent cosmology, especially in string theory, space is not only conceived of as interweaved with time, but spacetime possesses at least 10 different spatial dimensions.

Space and Cultural Discourse

In contrast to scientific and also philosophical concepts of space, the notion of cultural or anthropological space as it can be found throughout the 20th century does not ask for a definition of the origin, the essence, or the true concept of space, but for spatial practices as well as for the production of spatiality. An important figure in the modern cultural discourse on space is Ernst Cassirer (1874–1945), who claimed that in anthropological terms, it is less useful to think about space as such than to look upon different structures that have constituted cultural and aesthetic spaces throughout history. His claim directly influenced the art historian Erwin Panofsky (1892–1968), who analyzed the pictorial presentation system of central perspective as a symbolic form that first of all constituted the idea of a homogeneous space in paintings as well as in architecture. Furthermore Cassirer influenced the anthropologist Claude Lévi-Strauss (b. 1908), who analyzed archaic cultures by looking at the way they structure their material world, such as in settlements, housing, and craftwork, in respect to the structure of the intelligible world, like a specific myth or the given rules for marriage. The cultural approach to space in cultural theory was later renewed by Michel Foucault (1926–1984) who applied the structuralist description of spatiality not only to different historical forms of space but also to scientific concepts of space, stating that they share the same "discourse" or paradigm, like the corresponding structure of a given culture does.

Stephan Günzel

See also Aquinas, Saint Thomas; Aristotle; Bruno, Giordano; Copernicus, Nicolaus; Descartes, René; Einstein, Albert; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Newton, Isaac; Nicholas of Cusa (Cusanus); Plato; Presocratic Age; Space; Space, Absolute; Space and Time; Spacetime, Curvature of; Spacetime Continuum; Space Travel; Time, Absolute; Zeno of Elea

Further Readings

Algra, K. (1994). *Concepts of space in Greek thought.* Leiden, Netherlands: Brill.

Casey, E. S. (1997). *The fate of place. A philosophical history.* Berkeley: University of California Press.

Grant, E. (1981). *Much ado about nothing. Theories of space and vacuum from the Middle Ages to the Scientific Revolution.* Cambridge, UK: Cambridge University Press.

Huggett, N. (Ed.). (1999). *Space from Zeno to Einstein. Classic readings with a contemporary commentary.* Cambridge: MIT Press.

Jammer, M. (1954). *Concepts of space. The history of theories of space in physics.* Cambridge, MA: Harvard University Press.

Koyré, A. (1957). *From the closed world to the infinite universe.* Baltimore, MD: Johns Hopkins University Press.

Wertheim, M. (1999). *The pearly gates of cyberspace. A history of space from Dante to the Internet.* New York: Norton.

Space, Absolute

In his 1687 work *Mathematical Principles of Natural Philosophy* Isaac Newton defines *absolute space* as something that is "without relation to anything external" and "remains always similar and immovable." In contrast to absolute space, *relative space* "is some movable dimension or measure of the absolute spaces; which our senses determine by its position to bodies; and which is commonly taken for immovable space" (Scholium II). Similar to his differentiation of "absolute time" and "relative time" in the same context, Newton's definition of two types of space fundamentally changed the basis for the physical description of movement in the field of mechanics: Until the 17th century, movement was defined as a change of place by an object. With Newton, a different definition was consolidated: Movement is movement through space. Newton defines relative space as everything that is in relation to a certain object moving and absolute space as the level of comparing two or more of these relations in relative space. Thereby both "spaces" are no longer conceived as substantial, but as a frame or matrix for describing movement. Mostly—and already by Newton's critiques—these conceptions were interpreted against the background of space as substance: Descartes in his *Principles of Philosophy* (1644), for example, defined space as *plenum;* in other words, as the substance of all things being (*res extensae*). The idea of space as void had already been considered by ancient philosophers but had not been accepted until experimental proof for its "existence" was given by Otto von Guericke, who invented the vacuum pump in 1650 and demonstrated the virtue of vacuum 13 years later by joining two copper hemispheres, from which he pumped out the air and showed that power of eight horses was insufficient to separate them. Consequently Newton did not intend to define absolute space as an absolute substance but, on the contrary, as the totality in which any substance is located and can be described according to its position. Newton was directly inspired by his Neoplatonist teacher Henry More in Cambridge, who introduced his pupil to the Kabbalist notion of *makom,* which defines space as something that is inseparable. That definition met on the one hand with the Platonic notion of space as *chora* (defined as that which "gives birth" to becoming) and on the other hand with Renaissance considerations that the universe is infinite. In accordance with this metaphysical grounding, absolute space gave Newton the framework for his interpretation of the causation of movement through gravitational forces (*actio in distans*) in between objects, or "physical bodies." From a theological perspective Newton's concept was criticized for either leaving no place for God or for turning space into a medium (*sensorium*) for God's perception of the world (as Newton himself tried to explain it in his *Opticks*). The model of absolute space subsequently became *the* concept of space in modern times. In particular, Kantian epistemology conceived of space neither as a holistic substance nor as the sum of singular spaces, but first of all as the possibility of perceiving as well as describing things spatially, that is, constructing and defining them geometrically. In the late 19th century, Newton's concept of space was questioned by physicists such as Ernst Mach and the mathematician Hermann Minkowski, who argued for the coupling of the concepts of time and space that were discussed separately in Newtonian mechanics. The resulting concept of *spacetime* then became the basis for the theory of relativity, with which Albert Einstein interpreted Newton's physics to be valid only as a special case.

Stephan Günzel

See also Descartes, René; Einstein, Albert; Kant, Immanuel; Mach, Ernst; Newton, Isaac; Space; Space and Time; Spacetime, Curvature of; Spacetime Continuum; Space Travel; Time, Absolute

Further Readings

Erickson, P. F. (2006). *Absolute space, absolute time and absolute motion.* Philadelphia: Xlibris.

Zaret, D. R. (1978). *Absolute space and space-time ontologies.* Ann Arbor: University Microfilm International.

Space and Time

Until the beginning of the 20th century, time and space were treated as two distinct modalities of being. It was only following the pioneering work of Albert Einstein that time and space were defined as inseparable with respect to physics, and consequently also in metaphysics. The separation of time and space can be pointed out in ancient philosophy as well as in classical physics and philosophy, namely in Aristotle, Isaac Newton, and Immanuel Kant. For all of them Einstein's physics of relativity meant a categorical break to the conception of matter in particular as well as being in total. All three conceptions of time and space rested upon a mechanical view of the world by which time was conceived as the duration a physical entity takes to traverse space. Thus, time furthermore was looked on as derivative of space, for only space allowed a definition of time in the sense of traversing a certain distance within space or to change place. For this reason, even though time and space were treated as different entities, the two concepts correspond strongly or even mirror each other.

In Einstein's era, alongside the new definition of an inseparable physical spacetime, time as such on behalf of metaphysics was then identified with lived (experienced or remembered) time. In early 20th-century philosophy, this led to a dominance of time over space, which from then on was correlated with the dead aspect of matter. This reevaluation of the former dominance of physical space over physical time started with Kant, who defined time and space as subjective forms of imagination. Until then, and in contrast to ancient physics, time and space both were still objective determinations: Aristotle defined time as the succession of a change of place—that is, the measurement of the states before and after. Even though he did not have a concept of space in the modern sense (as extension), time for him implied a form of spatial movement. Aristotle's concept of space was that of *topos,* or space as "place." Place hereby is not understood in the sense of coordinates (as in Cartesian geometry) but is defined by the surface inhered by an object: Every object is spatially identifiable by the place it occupies. In accordance, time is defined as the change of place, that is, the object occupying a different place at one moment compared to another moment. Through this, Aristotelian physics relies on the concept of "presence," which means that "being here" (in a certain place) and "being now" (at a certain time) are the two modalities of matter that cannot be explained even though they both explain what space (as place) and time (as change of place) are. To overcome this notion, the modern concept of space as volume had to be introduced into physics. Volume is described as a three-dimensional extension that is independent from an actual existence of matter in place.

Isaac Newton's concepts of time and space have to be understood against this background: Space is not the place of a certain object, but extension or expansiveness as such. Time then is the duration it takes for an object to move through space. Newton thereby defines time as well as space in two respects. Both time and space persist in a relative way as well as in an absolute way. *Relative space* is the observable space or the given extension through which an object moves. Likewise, *relative time* is the corresponding duration. Both are measurable, and relative space as well as relative time can be quantified. On the contrary, *absolute space* and *absolute time* are not measurable but are assumed to be the frameworks by which each spatial or temporal quantification is comparable. That further means that a certain time an object takes to travel a certain distance can be compared with the time another object takes to travel the same distance, or a different distance in the same time.

Since Newton, it has been heavily discussed whether absolute time and absolute space really exist. If especially absolute space were real in the sense of an endless volume ("void") there would be no place for God, who in Aristotelian cosmology was seen as the overall agent of all motion in the universe, being located at the edge of the world, and—by means of the concept of gravitation—to Newton, having no longer any physical function in the world. Even though in the long run the impact of Newton's physics indeed was to promote an atheistic worldview, the interpretation of absolute space as existent is somewhat misleading and was not intended by Newton. As Immanuel Kant pointed out, (absolute) time and (absolute) space according to Newton have to be presupposed in order for physical descriptions to be scientific, that is, universal and comparable. Kant thus defined time and space as the "pure forms" of perception or intuition by which they are a priori to any experience; that is, any experience is already spatial as well as temporal, no matter in what quantity or quality it appears. Nothing can be perceived or even imagined that is not of a certain volume and persists for a certain time. Kant never made clear whether the three dimensions of space (volume) and the dimension of time (duration) are anthropological conditions of humankind. He gives some hints that especially the three-dimensionality itself is dependent on the sense of directionality, which in turn is derived from the subjective standpoint. However, what Kant made clear is that he does not consider the number of spatial dimensions to be objectively given. Thereby Kant's theory of space as a form of perception can be seen as compatible with anti-Euclidian concepts of space, insofar as Kant distinguishes between the form and the concept that is derived from that form within physics.

Even though Einstein's concept of a spacetime continuum is interpreted as overthrowing classical physics, it was Newton's understanding of time and space that in fact was the beginning of a relativistic concept of space and time. The main difference is that, to Einstein, relative space and relative time are all that can be accepted by modern physics. To Newton, the concept of anything being absolute and free from the influence of matter—which was the root of gravitation—was wrong. Einstein, then, overturned the idea of a spatial and temporal framing and started with matter/gravitation as the benchmark for physical description: Time and space are not prior to matter, but the physical "event" affects a qualitative difference in spacetime.

Stephan Günzel

See also Aristotle; Einstein, Albert; Kant, Immanuel; Newton, Isaac; Space; Spacetime, Curvature of; Spacetime Continuum; Space Travel; Time, End of; Time Travel

Further Readings

Čapek, M. (Ed.). (1976). *The concepts of space and time. Their structure and their development.* Dordrecht, The Netherlands: Reidel.

Christensen, F. M. (Ed.). (1993). *Space-like time. Consequences of, alternatives to, and arguments regarding the theory that time is like space.* Toronto, ON, Canada: University of Toronto Press.

Earman, J. (1989). *World enough and space-time: Absolute versus relational theories of space.* Cambridge: MIT Press.

Spacetime, Curvature of

The concept of curvature can be approached through examination of two-dimensional surfaces. The floor of a room is flat, the surface of a ball or of the earth is curved. What does this mean more exactly? Let us imagine two wanderers going from place P to place Q along two different paths and carrying pointers which, in the beginning, were oriented in the same direction. Let the wanderers regulate the directions of their pointers in such a way that they do not change in the plane tangent to the surface of the earth (it is possible to envision this with the help of large-scale maps). It is easy to ascertain with the aid of a globe that, in the case of repeated meeting of the wanderers whose paths taken together enclose a large area, the directions of the pointers will be different (see Figure 1).

The path of a wanderer continuing in the initial direction of the pointer will be the most upright line on the earth's surface, the *geodesic.* Two initially parallel geodesics (principal circles on the spherical surface) will gradually approach each other and will finally intersect. But the direction of the parallel transported pointers would be independent on the path (see Figure 2), and the initially parallel geodesics would remain parallel in the case of flat, noncurved space.

Great mathematicians of the 18th and 19th centuries (Gauss, Riemann, Levi-Civita, and others) elaborated the concept of curvature and extended it to the case of spaces with arbitrary dimension. In the 20th century new, more abstract formulations succeeded, but in this entry the original, more intuitive definitions are retained.

Let us have in the space two "infinitesimally near" points P, Q with the coordinates x^i, $x^i + dx^i$. Let the vector (depicted by the arrow) have the component V^i, given in the point P. By its parallel transport into the point Q, the vector V^{*i} arises with the components

$$V^{*i} = V^i + DV^i = V^i \rightarrow \Gamma^i_{jk}(x^a)\, V^j\, dx^k. \qquad (1)$$

The coordinate dependent quantities Γ^i_{jk} are called the components of affine connection. Their prescription makes it possible to transport vectors in a parallel manner along an arbitrary path and to find the parametrically expressed geodesics (most direct lines) $x^i(\sigma)$ by solving the equation

$$\frac{d^2x^i}{d\sigma^2} + \Gamma^i_{jk}\frac{dx^j}{d\sigma}\frac{dx^k}{d\sigma} = 0. \qquad (2)$$

The geometrically natural request of closeness of infinitesimal parallelograms constructed by parallel transport leads to the symmetry of the components of the connection or, in the other words, to the zero value of the *torsion tensor* field

$$S^i_{jk} = \Gamma^i_{jk} \rightarrow \Gamma^i_{kj}. \qquad (3)$$

In the case of the *Riemannian spaces* with the infinitesimal distance ds defined as

$$ds^2 = g_{ik}(x^a)\, dx^i\, dx^k \qquad (4)$$

(g_{ik} are the components of the metrical field, or the metrics), it is natural to demand the inalterability of the lengths of parallel transported vectors and the angles between them. Thus in the case of zero

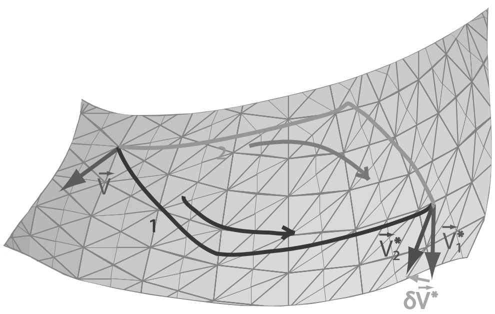


Figure 1

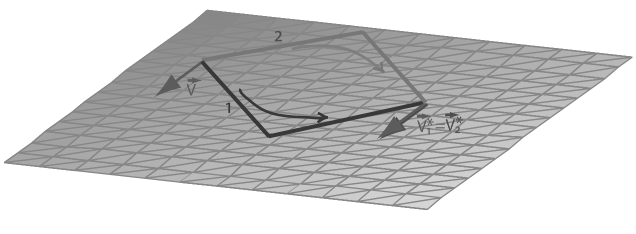


Figure 2

torsion (3), the relation can be derived

$$\Gamma^i_{jk} = \frac{1}{2} g^{is} \left(\frac{\partial g_{sj}}{\partial x^k} + \frac{\partial g_{sk}}{\partial x^j} - \frac{\partial g_{jk}}{\partial x^s} \right) \tag{5}$$

determining the components of the connection by help of the metrics (here, g^{ab} is the inverse matrix to the matrix g_{ab}). Then we speak about the Levi-Civita connection and the components of the connection (5) are called the Christoffel symbols. It is possible to introduce coordinate systems where these quantities are equal to zero in a prescribed point, with the effect that the equations of geodesics locally merge into the equations of right line. Such systems are "locally geodesic." Thus the Christoffel symbols do not determine the curvature of the space, only the curvature of the coordinate system.

To find the criterion of the curvature of the space, let us transport in parallel the vector V^i along the arms dx^i, dy^j of an infinitesimal parallelogram by both possible ways (see Figure 1). The difference of the transported vectors is given by

$$\delta V^{*i} = R^i_{jkl}\,(x^a)\, V^j dx^k dy^l \tag{6}$$

where

$$R^i_{jkl} = \frac{\partial \Gamma^i_{jl}}{\partial x^k} - \frac{\partial \Gamma^k_{jk}}{\partial x^l} + \Gamma^i_{nk}\Gamma^n_{jl} - \Gamma^i_{nl}\Gamma^n_{jk}\,. \tag{7}$$

Thus the curvature of the space is determined by the quantities R^i_{jkl}, which are the components of the curvature tensor field. Their zero values in the given point (or in some region) means that the space is flat here. They are constrained by some relations, which decrease the number of independent quantities. The one-dimensional space cannot be curved, and there are 2, 6, and 20 independent components in the two-dimensional, three-dimensional, and four-dimensional spaces, respectively.

According to Einstein's general theory of relativity, *spacetime* is the four-dimensional space of events with a special type of metrics, which allows the time coordinate to be distinguished from the space coordinate, and with the appropriate Levi-Civita connection. All relations and definitions presented above remain valid, but the square of the distance *ds* in the relation (4), now called the interval, can have a positive, negative, or zero square (which distinguishes the timelike, spacelike, and lightlike intervals). According to the general theory of relativity, spacetime is curved by its matter content in accordance with the Einstein equations (1915)

$$G_{ik} = R_{ik} - \tfrac{1}{2} R g_{ik} = (\kappa/c^2)\, T_{ik}. \tag{8}$$

Here κ is the Einsteinian gravitational constant, c is the speed of light, $R_{ik} = R^a_{iak}$ is the *Ricci tenzor,* $R = g_{ik} R_{ik}$ is the *scalar curvature*. The Ricci tensor and the scalar curvature are derived from the curvature tensor, but unlike the curvature tensor, they can be equal to zero even in curved space (or spacetime).

Thus the Einstein equations state the proportionality between the *Einstein tensor* G_{ik}, which has a purely geometric nature, and energy-momentum tensor T_{ik}, which describes basic mechanical properties of the content of spacetime—densities and flows of energy and momentum, pressures or tensions. (It is possible to include into it also the cosmological constant added later by Einstein and today usually related with the properties of a physical vacuum.) According to John A. Wheeler, "matter prescribes to spacetime how to curve itself" via the Einstein equations. The curvature of spacetime, caused by its matter content, represents the mathematical description of the gravitational interaction.

It follows from the Einstein equations that the particles of dust matter, subjected only to the gravitational influence described by the spacetime metrics and in this sense "free," trace by their motion geodesics in the spacetime (see equation [2]). So, according to Wheeler, "spacetime prescribes to matter how to move." The motion of light signals (or photons) corresponds to the geodesics of zero "length." The curvature of spacetime can be observed as changing distances of originally parallel geodesics or, physically expressed, as relative motions of free particles. In curved spacetime, one particle moves with respect to the other with relative acceleration. Consequently, gravitational influence causes the deformation of bodies. On the earth's surface, the well-known manifestation of tidal forces are marine tides. In strongly curved spacetimes in the nearness of massive bodies, the tidal forces manifest themselves more violently (the observer falling to the horizon of a black hole is deformed by them into a strip). Similarly, the influence of spacetime curvature on light rays causes an effect somewhat reminiscent of the functioning of a lens. The common gravitational force acting on bodies at the surface of the earth does not represent a manifestation of the curvature of spacetime. It is given by Christoffel symbols in equation (2), and consequently it can be "canceled" in the local geodesic system, that is, in a freely falling system from the physical point of view.

In the framework of spacetime geometry, it is also possible to consider the curvature of "space" as the three-dimensional section of spacetime. In some approaches to quantum gravity theory, three-dimensional geometries are considered as states of the quantum universe, and the task of theory is to determine the probabilities of transition between these states. In these approaches, time is a secondary construction.

In the field of cosmology, the curvature of the universe is often understood to be the curvature of three-dimensional space in a given moment of the evolution of the universe. Because this space is (on a large scale) homogeneous and isotropic according to standard cosmology, its curvature is completely determined by the scalar curvature.

The curvature of spacetime does not exhaust its unusual properties as possibly realized in spacetime. Non-Euclidean topology can be considered, with the impossibility of finding a mutually continuous map between spacetime and Euclidean space and, in such a way, to cover spacetime by one coordinate system. In spacetimes fulfilling the Einstein equations, singularities can arise, not allowing the prolongation of spacetime through them. These properties of spacetime could be important in astrophysics and in cosmology.

The concept of connection is logically independent of the concept of metrics. It is possible to consider connected curved spaces without metrics, with a connection related to metrics in another way as the Levi-Civita connection (5), or with a connection with nonzero torsion (3). Also nonsymmetric metrics ($g_{ik} \neq g_{ki}$) and various modifications of the Einstein equations have been considered.

These possibilities intrigued Einstein and other physicists and mathematicians (including Eddington, Schrödinger, Bach, Cartan, Hlavatý, and Moffat) after the rise in popularity of the theory of general relativity. They placed much hope in them: extension of the geometrical description of gravity to the other interactions (at first, mainly electromagnetic); exclusion of the phenomenological, not strictly determined energy–momentum tensor from the Einstein equations; or inclusion of the spin of matter among its fundamental properties. Many versions of unified theories of physics and of generalized theories of gravitation were derived, but—in contrast to the theory of general relativity—none of them was able to reach a satisfactory experimental corroboration. Currently, theories positing a larger number of spacetime dimensions seem to offer a hopeful direction for unifying the theories of physics.

Thanks to the work of É. Cartan (1923), Newton theory of gravity also was formulated in geometric language with the use of the concept of connection. Consequently, Newtonian gravity also can be understood as a manifestation of the curvature of spacetime.

Jan Novotný

See also Cartan, Élie Joseph; Chronometry; Cosmogony; Einstein, Albert; Relativity, General Theory of; Relativity, Special Theory of; Space; Space, Absolute; Space and Time; Time, Absolute; Time, Relativity of

Further Readings

De Felice, F., & Clarke, C. J. S. (1990). *Relativity on curved manifolds.* Cambridge, UK: Cambridge University Press.

Islam, J. N. (1992). *An introduction to mathematical cosmology.* Cambridge, UK: Cambridge University Press.

Misner, C. W., Thorne, K. S., & Wheeler, J. A. (1973). *Gravitation.* San Francisco: Freeman.

Schrödinger, E. (1985). *Space-time structures.* Cambridge, UK: Cambridge University Press.

Stephani, H. (1990). *General relativity.* Cambridge, UK: Cambridge University Press.

Wald, R. M. (1984). *General relativity.* Chicago: University of Chicago Press.

Spacetime Continuum

The mathematician Hermann Minkowski, in his groundbreaking 1908 paper "Space and Time," stated that "henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality." Minkowski's insight referred to the fact that until the late 19th century, space and time in physics were treated as two separate entities. This was because traditional approaches used different ways of describing space and time, which again was a heritage of the dualistic ontology of the modern era.

Such ontology can be found especially in the work of René Descartes, who identified space with the outer realm and objects as matter (*res extensa*) in opposition to the rational interior (*res cogitans*). To Descartes the outer world furthermore was characterized as a *plenum,* which means that in his opinion there is no void, but that anything is of a certain substance: Anything that exists in the object world occupies space, because it is extended. The concept of *plenum* is not equal to space itself, but to the continuity of matter, which fills space. Descartes thus adheres to an antique notion of substance that can be found as early as Aristotle and the nonatomistic philosophies, which denied the existence of the void.

After Descartes, in Isaac Newton's physics, the concept of "absolute space" no longer implied a materialistic concept of space. Newton conceived of (absolute) space as the frame for any possible description of movement (in space), and as such the void is just as continuous as the plenum of Descartes. Furthermore, "absolute time," according to Newton, can also be continuous in the sense that there is the theoretical possibility of an endless movement—not limited by either space or time. Here the concepts of space and time include the continuity of each one, but not a continuity of both of them together.

Subsequently, Immanuel Kant, with the most serious consequences, combined Newton's physics with Cartesian dualism and defined space as the condition of the possibility (spatiality) of any perception or construction of things present to the outer senses by means of uniformity and, in opposition to that, time as the condition of the possibility (temporality) of any perception or construction of things changing shape or place—that is, the concept of movement. For more than 200 years after Newton and Kant, not only were space and time treated as separate entities, but space became identified with the unchangeable and was even attributed as "dead," whereas time, as the specific mode of inner perception, became identified with the principle of life; as such it can be found in Henri Bergson's concept of the *élan vital* and the notion of time as *durée* (duration).

Minkowski's enterprise therefore was neither purely mathematical nor physical; it thereby aimed at the heart of the predominant worldview, according to which time and space are strictly separated entities. Minkowski's student Albert Einstein interpreted this in a chiefly psychological respect: In his view, time and space are both forms of lifeworld abstractions from physical instances, as can been seen in the concept of space as a container (three-dimensional) or time as a line (fourth dimension). But the possibility of describing these abstractions in respect to space (volume) or time (interval) suggests a false understanding of matter, which is always spatially situated and is always moving. To overthrow this misinterpretation Einstein suggested defining space as something that is of a certain "age" as well as to define time as something that is extended. Therefore not only time and space are continuous in themselves, but they together form a space–time continuum: Each location in the universe therefore is a single manifold, which is qualified by the impact of gravity. In consequence the description of a manifold is no longer relative to an observer but is defined as a (four-dimensional) reality in its own, which has no gaps but rather is a "smooth" space. Any object moving in spacetime can thus be depicted according to a "world line" that is describing its unique path through the universe in respect to time as well as to space, whereby the three dimensions of space are condensed to one. Hence, in a two-dimensional diagram, all four dimensions can be represented.

Surprisingly, Einstein in his idea of continuity of space (and time) refers back to Descartes, whom he respected for not having accepted the idea of space as void. On the contrary, Einstein takes the concept of "plenum" as a forerunner of the concept of the electromagnetic "field" as it was developed by Michael Faraday and James Clerk Maxwell in field theory. Instead of defining points in a coordinate system, a field defines a homogeneity, which is caused by electromagnetic forces. According to Einstein the movement of a body is not a movement through space and time anymore but a change of states of a gravitational field, by which an object is then defined quantitatively. Thus, to Einstein the idea of plenum can even be traced back to ether theory, insofar the ether is defined as a medium of movement. But in contrast, the modern theory of a spacetime continuum takes into account that there are different qualities of several continua, which Einstein identifies as "inertial systems." In those systems a physical instance cannot be defined in spatial and temporal respects separately, but must be conceived of as an "event" in spacetime. Today Einstein's concept of the continuity of spacetime has been further developed in string theory, which defines spacetime as a continuum that is structured according to at least 10 spatial dimensions. However, dimensions higher than four only have effects on the subatomic level.

Stephan Günzel

See also Bergson, Henri; Descartes, Rene; Einstein, Albert; Kant, Immanuel; Newton, Isaac; Relativity, General Theory of; Relativity, Special Theory of; Spacetime, Curvature of; Spacetime Continuum; Time, Linear

Further Readings

Butterfield, J., Hogarth, M., & Belot, G. (Eds.). (1996). *Spacetime*. Aldershot, UK: Dartmouth.

Ferraro, R. (2007). *Einstein's spacetime. An introduction to special and general relativity.* New York: Springer.

Friedman, M. (1983). *Foundations of space-time theories. Relativistic physics and philosophy of science*. Princeton, NJ: Princeton University Press.

Space Travel

Space travel, the act of sending objects and humans beyond Earth's atmosphere, includes both orbiting Earth and traveling far beyond Earth's gravity. The fringes of outer space were explored as early as 1949, but only since 1957 have humans had the ability to send objects permanently beyond our atmosphere. Controlled motion in space requires the accurate use and measurement of time; the laws of physics dictate that there is only one best path from one place to another, a path available only by using precise timing. Thus, to travel successfully in space requires both an exact departure time and a way to measure time intervals with great precision.

To travel in space we must leave behind our Earth-centric concepts of time intervals and grapple with the concepts of relative planetary time and absolute time. The common definitions humans use for the passing of time on Earth change depending on the location in space. When communicating between planets, the orbits and rotations of each planet affect the success of those communications. The timing of those motions is critical to find the optimum moment to send and receive messages.

The distance between the planets of the solar systems places them minutes and hours apart. When communicating with objects in space, near-instantaneous communication changes with distance to asynchronous messages and responses. The universe is so immense that time in the form of the light year is used as a measure of distance in space travel. To travel beyond our solar system, it will take a very long time to get any place if we cannot travel nearly as fast as light.

Motion in Space

Although at extremely high speeds the theory of relativity is invoked, the basic motions of space travel are governed by Newton's laws of the motion of bodies and Kepler's laws of planetary motion. Newton and Kepler showed that orbital motions are predictable both backward and forward through time. Through careful recording of where objects in space have been, it is possible to plan the optimum moment for a future launch of a space vehicle.

Space travel is possible because of the "clockwork" nature of the universe in classical physics. Everything in the universe interacts primarily via gravity. All destinations of any significant size are traveling in specific regular orbits. These orbits behave for the traveler as asynchronous clocks. Each object revolves in a regular orbit with a regular period, but every object has its own period. Navigation in space is therefore concerned with finding the optimal time to travel from one orbit to another.

Orbital mechanics dictates that there are an infinite number of possible free-flight paths between two objects. Space navigators are concerned with the trade-off between the path that requires the least fuel and time spent in transit. Operating within these limitations has meant that, from the beginning, space travel has been associated with certain time-specific terms such as *countdown*, *launch window*, and *mission elapsed time*.

A practical example of the timing needed would be predicting the optimum time to leave Earth for the Moon. This is referred to as a launch window or orbital window. The Moon revolves around the Earth in an elliptical orbit, so there is an optimal time of the month to launch when the Moon's orbit brings it closest to Earth. The calculation also should consider that the Earth rotates on its axis. Every 24 hours there is an optimum time for the rocket to leave Earth pointing at the moon. The interaction of two cyclic clocks gives a best time and day every month to launch. The planner also needs to account for the motion of the Moon during the rocket's time of transit, aiming for where the Moon will be when the rocket reaches lunar orbit path.

To go to another planet in the solar system, the planner must consider the orbital periods of different objects around the sun. For a launch to Mars the best orbital window occurs only once every 2.2 years when both Mars and Earth are on the same side of the sun. Also, most orbits are elliptical, and so where each planet is at its apogee (greatest distance) and perigee (closest distance) in relation to the sun also can dictate the optimum time to travel the least distance. The Voyager probes in the 1970s took advantage of a so-called grand alignment, when Jupiter, Saturn, Uranus, and Neptune were all on the same side of the sun. The fortunate timing of the "window" is evident when you consider this alignment only takes place every 176 years, because these planets' orbital clocks all run at such different rates.

As we continue to travel in space, other cyclic phenomena will influence the timing of rocket launches. A short list includes the approximately 11-year solar cycle of flare activity, the orbits of various comets and asteroids, the behavior of planets with multiple moons, and the motions of other solar systems around the core of the Milky Way.

A last, now common, use of time and predictable orbital motion in space is in global positioning system (GPS) satellites. The fundamental properties of a satellite regularly orbiting Earth allow an observer on the planet to determine his or her location. An observer with an accurate clock and the knowledge of the transit time for signals from four satellites can determine location. The transmitter compares its internal clock with the ultra stable and accurate atomic clocks on each of the four satellites. The difference between the five clocks is influenced by the motion and location of the satellites and can be used to calculate a location and altitude on the planet very accurately.

Relative Planetary Time

Space travel shows that many of our common time measurements are relative to Earth. As humans travel in the solar system, they will need to redefine what terms like *noon, day, month*, and *year* mean. The case of Mars is particularly illustrative because we contemplate colonization there at some future time. Travelers in space will face the problem of choosing their own definitions. Whether the defined terms will be of where they departed, their destination, or some standard time is still not clear.

Humans have a local interpretation of when noon is. We tend to think of noon as "solar noon, when the sun is highest in the sky. That also matches with "mean noon" (what the clock says) within plus or minus 16 minutes because Earth has a very regular orbit around the sun. We experience only minor differences throughout the year. Mars, however, has an orbital eccentricity that is considerably larger, which means that the lengths of various Martian seasons differ considerably. On Mars the time of day when the sun is highest in the sky varies throughout the year. On Mars, because of its orbit, mean noon and solar noon can be plus or minus 51 minutes apart through the seasons.

A sidereal day on Earth is 23 hours and 56 minutes, and on Mars it is 24 hours 37 minutes. For an explorer on Mars this will require only a moderate adjustment. When operating missions remotely from Earth, however, more planning will be required. During missions that last weeks and months, the days on Earth will become out of sync with those on Mars. The Jet Propulsion Laboratory team running the Pathfinder missions had to modify their schedules to the Martian day in order to coordinate probe observation times with daylight on Mars, regardless of what the daylight time was on Earth. They coined the term *sols* to describe mission times and events on Mars. Any future residents of Mars will have to develop their own clocks to cope with this subtle change.

On Earth a month is defined by the motion of the Moon around the Earth every 27.3 days. With 12 to 13 orbits per year, months on Earth are 1/12 of a year. Other planets, however, may have no moon, or several moons. Residents will need to create a new calendar, with new definitions of the length and name(s) of the months. What will define a month on Mars? It has two moons, Deimos and Phobos, that whip around it every 1.3 and 0.3 days, respectively, making for very frequent months.

We define a year as 365 days, 5 hours, 48 minutes, 46 seconds (the time for Earth to revolve around the sun). In our solar system, years vary in length more than 1,000 times, from 88 Earth days on Mercury to 90,777 days on Pluto. Living year-round on Mars would require adjustment for residents to the Martian year of 687 days. Because we measure our lives in these "Earth standard" units of time, how will such basic concepts as birthdays and age change? Exploration in space will mean either being tethered to a single planet's definitions or developing new ways of naming how time passes.

Communication Timing in Space

Communication distances in space are another way that time and space travel are tied together. Objects in space are separated by huge distances, which translate into being separated by time. We need precise clocks to communicate across these distances.

Radio waves, like all forms of electromagnetic waves, travel at the speed of light. The time it takes for a message to travel a given distance can be calculated using the equation $t = d/v$ (t = time, d = distance, v = speed of light). Our Moon is so far from Earth that light (and radio waves) takes 1.3 seconds to get there. Communications between these bodies have this 2.6-second gap between when a message is sent and when the reply is received. For human conversation this is merely annoying, but for an operator remotely driving a robotic vehicle, this 2.6-second gap could be disastrous.

An additional problem is that Earth is constantly revolving and traveling in its orbit. These motions move the transmitters and receivers apart, so multiple sets are needed over the surface of the Earth to have continuous communication with an object in space. The problem is increased when communicating with probes on or orbiting around other planets which are moving too.

Consider, as an example, a robot explorer on Mars. The round trip for communications to Mars when Mars is closest to Earth is 20 minutes. When the Earth and Mars are at opposite sides of the Sun, the round trip is 40 minutes. Additionally, both Earth and Mars revolve on their respective axes, so the transmitters and receivers on their surfaces are moving constantly. Similar to orbital windows for launching, there are optimal communication windows when the communicators are facing each other. The clocks between these transmitters and receivers need to be precisely synchronized. For most space missions there are communication blackout times when communication is impossible because the transmitter and receiver do not have "line of sight."

Each planet exists within a "time island," separated from the others by the gap it takes communications to go between them. This time gap functions as an isolating element when doing real-time tasks like communicating between computers. If we choose to explore the outer solar system, the gap for round-trip communication between Earth and a moon of Saturn would be 2 hours and 12 minutes. In our world of networked computing and Internet communications, this is an unseen barrier to human colonies in the solar system. Each colony will need its own computer network and will communicate with outside systems though a built-in delay. This has had implications for remote control of exploratory probes, leading to an increase in the ability of probes to be autonomous of a human controller. For time-critical maneuvers, like entering or leaving orbit, instruction sets are sent for the robot to carry out, and highly accurate clocks are required.

As we move farther from Earth the gaps become more significant. Human and robot explorers become travelers isolated from timely assistance or instructions. An explorer on Pluto would have a round-trip communication gap of more than 9 hours. Exploration beyond the solar system will have communication gaps of weeks and months. Travelers to the nearest star (4.2 light years away) would experience a gap of almost 8 1/2 years between a sent message and a reply. Any meaningful dialogue will be reduced to asynchronous communication spread over decades. As we contemplate life in other solar systems, this gap suggests we may never be able to have a dialogue with other intelligent life, only a series of exchanged monologues.

Distance in Space

Time is used in space travel as a measure of distance. The known universe is so vast that we need a very long measuring stick to conceptualize it. The commonly used measure of space distances is the speed of light. Light is the fastest phenomenon we know of, moving at approximately 30 centimeters (approximately 1 foot) per nanosecond. In fact, the current definition of the meter is the length of the path traveled by light in a vacuum during a time interval of 1/299,792,458 of a second. In a year (31,557,600 seconds) light travels 9.46×10^{12} kilometers or about 5.88×10^{12} miles.

We can conceptually measure the relative size of space with light. In our solar system, the Moon is 1.3 light seconds from Earth, the sun is 8.3 light minutes away, and Pluto is 4.4 light hours away. The nearest star to Earth, Alpha Centauri, is 4.3 light years away (273,000 times the distance from Earth to the Sun), the center of our galaxy is 32,000 light years from Earth, and the nearest galaxy to Earth is 75,000 light years away. These distances remind us that the events we see in space are minutes, hours, and years separated from what is actually happening at a given location.

Travel Times in Space

Distances between solar systems are so large that there have been only a few objects sent beyond the solar system. *Pioneer 10* was launched in 1972 and left the solar system in 1983, aimed at the star Aldebaran, about 65.1 light years away. At its present rate of speed it will take it more than 2 million years to reach there. *Voyagers 1* and 2, launched in 1977, have also left the solar system. Because of their gravitational assists during their mission, they are traveling at a much higher velocity than is *Pioneer*. *Voyager 1* is traveling at a speed of 61,799 kilometers per hour (.000057 the speed of light) covering about 538,465,972 kilometers a year. Even at those speeds, as of February 2008, *Voyager 1* was "only" 15.7 billion kilometers from the sun.

Voyager 1 is traveling faster than any other spacecraft humans have launched, yet it will not be "near" another solar system for 6,600 years when it passes 4 light years from Barnard's Star. The closest *Voyager 1* will get to another solar system in the next 300,000 years will be 1.7 light years, 38,000 years after launch. From that point, at its present speed if it could fly straight to the system, it would take it an additional 30,000 years.

The distances in space are daunting without some way to reduce the travel time. Velocity in space is related to the amount of force one can produce and the amount of time needed to produce it. Space travel is essentially frictionless, so once a velocity is achieved, an object will continue at that speed indefinitely. An important implication is that the object will not slow down at its destination without the application of an equal and opposite force.

One solution would be greater rocket velocities with improved rocket propellants. Rocket propellants are compared by the specific impulse (Isp) they provide. Specific impulse is measured in "seconds," or the number of seconds during which a rocket engine can produce 1 pound of thrust from 1 pound of propellant. The velocity a vehicle can achieve is directly proportional to the specific impulse. Current chemical rockets such as the NASA Space Shuttle have a specific impulse of 450 seconds (burning liquid hydrogen and liquid oxygen). To achieve greater velocities for longer times, we will need to explore experimental propulsion systems like nuclear (900–1,200 seconds) and ion propulsion, which has a specific impulse of 2,000 to 20,000 seconds. The ultimate would be an engine with a specific impulse of 30,000,000 seconds (approximately the speed of light).

One of the fascinating outcomes of relativity theory is the idea that, at very high speeds, time is distorted. The amount of time that passes for a passenger is reduced as the velocity of the spaceship is increased to larger fractions of the speed of light. This effect is of interest because the time it would take to reach another solar system would be reduced for the passenger. If we could attain greater speeds, we could achieve a kind of time travel for passengers, allowing them to experience less time passing than would observers on Earth.

The second way to tackle the long to extreme travel times between planets and solar systems is to slow the passage of time's effects on human passengers. There is speculation that the existence of "hibernation" genes within mammals or the development of "suspended animation" technologies would allow the engineering of humans to travel in a state of reduced metabolism. This suspension would allow essentially little or no time to pass for the traveler as well as reduce the number of supplies the craft would need to carry or recycle. It also may be possible through advances in biotechnology to engineer humans for extended life spans allowing "near-by" flights within a human life span. Finally, science fiction has explored the concept of "colony" ships, which would carry humans for several generations.

John Sisson

See also Light, Speed of; Newton, Isaac; Spacetime, Curvature; Time, Planetary; Time, Relativity of; Time Travel; Twins Paradox; Wormholes

Further Readings

Belbruno, E. (2007). *Fly me to the moon: An insider's guide to the new science of space travel.* Princeton, NJ: Princeton University Press.

Kemble, S. (2006). *Interplanetary mission analysis and design.* Berlin: Springer.

Launius, R. (2008). *Robots in space: Technology, evolution, and interplanetary travel.* Baltimore, MD: Johns Hopkins University Press.

Rogers, L. (2008). *It's only rocket science.* New York: Springer.

Spitzmiller, T. (2006). *Astronautics: A historical perspective of mankind's efforts to conquer the cosmos.* Burlington, ON, Canada: Apogee Books.

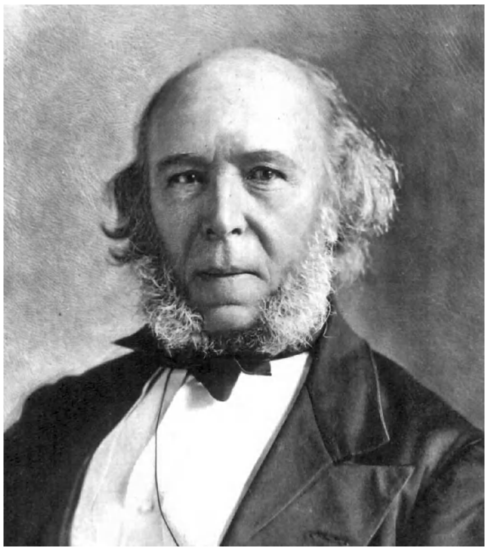
Tinder, R. (2007). *Relativistic flight mechanics and space travel: A primer for students, engineers, and scientists.* San Rafael, CA: Morgan Claypool.

Spencer, Herbert (1820–1903)

Herbert Spencer was an English philosopher, evolutionist, and political theorist, whose theories treated the universe and time in general with scientific minuteness and a synthesis of speculation and positivism. He is often cited with coining the popular expression "survival of the fittest," which later would be used frequently by social Darwinists.

Spencer was born in Derby, England, on April 27, 1820. His early influences were chiefly his father and uncle, both of whom were teachers well acquainted with the natural sciences. Initially gaining a job as a civil engineer, to cultivate the skills learned from his father and uncle, Spencer went on to become a subeditor for the *Economist,* a newspaper noted for its liberal tone. During this time, Spencer was able to pen *Social Statics* (1851), which supported the popular notion of laissez-faire economics. In 1858, however, Spencer set out to create a synthetic philosophy, which aimed to unite the disciplines of biology, sociology, psychology, and ethics under the physical notions of time, space, matter, motion, and force. This was first presented in the 1862 work *First Principles.*

Spencer's philosophy rests upon the insolubility of the nature of reality and something he called "the unknowable." One such question that would fall into the unknowable is the idea of who created the universe. Because this is something that



In 1862 Spencer began his 10-volume System of Synthetic Philosophy*, which expanded Darwin's theory of evolution to include the entire field of human knowledge. Spencer coined the expression "survival of the fittest."*

cannot be comprehended, as it is not within one's own intellectual power to ascertain, Spencer instead concentrated on the knowable, which he believed was governed by the unified physical notions, which in turn preclude knowledge of the unknowable. These powers, too, are not completely known without a complete grasp of the unknowable.

From this, Spencer applied the idea of force as the key to understanding all other knowledge. Force is responsible for evolution to take place, of which he defined as "a change from a state of relatively indefinite, incoherent homogeneity to a state of relatively definite, coherent homogeneity." Evolution was not only a biological or cultural force to Spencer, but a cosmic force, which pervaded the time–space continuum. As life and the individual on Earth were evolving, so was the cosmos.

After Spencer laid the groundwork for his conception of evolution, he succeeded *First Principles* with the *Principles of Biology* (2 vols., 1864–1867), *Principles of Sociology* (3 vols., 1876–1896), and finally *Principles of Ethics* (2 vols., 1892–1893). Before *First Principles,* Spencer wrote the *Principles of Psychology* (1855), which was marked by Spencer's position that individual characteristics develop as a result of evolution. In *Principles of Biology,* Spencer used the expression "survival of the fittest," referring to organisms that were able to reproduce due to their self-sufficiency and ability to adapt and survive in a changing environment.

Principles of Sociology was one of Spencer's celebrated works in which he likened the progression of society to the progression of a biological organism. His use of the term *superorganic* differentiated a society as something that exists above the nature of reality, yet like an organism, it is mutually dependent and follows the process of evolution. The society evolves from being relatively insufficient and undifferentiated (homogeneous) to being self-sufficient and differentiated (heterogeneous).

Spencer also weaved his thread of evolution into the *Principles of Ethics.* Though there are stronger individuals in societies, it should be the goal of humankind to promote the longevity of our species. Instinctively, the human race has garnered certain "good" behaviors through the evolutionary process that have contributed to the survival of the species. Thus, the good behavior is one that contributes to the healthy maintenance of the species, whereas the bad behavior is conducive to the destruction of the species. This same idea would be applied to Spencer's ideas of economics; that is, the laissez-faire approach to the economy is best because there are no regulations from outside influences that would dissolve the economy.

On December 8, 1903, Spencer died, leaving behind a body of work that was to influence many later scholars and writers. He had been honored a year earlier with a nomination for the Nobel Prize in Literature (1902). His synthetic philosophy allowed writers such as H. G. Wells in *The Time Machine* to develop his themes of evolution. Charles Darwin would also use Spencer's phrase "survival of the fittest," in the fifth edition of his *On the Origin of Species* (1869). Spencer's philosophy of the universe will be remembered as both groundbreaking and diverse.

Dustin B. Hummel

See also Cosmology, Cyclic; Darwin, Charles; Evolution, Organic; Haeckel, Ernst; Huxley, Thomas Henry; Kropotkin, Peter A.; Wells, H. G.

Further Readings

Francis, M. (2007). *Herbert Spencer and the invention of modern life.* Ithaca, NY: Cornell University Press.

Spencer, H. (2002). *First principles* (6th ed.). Honolulu, HI: University Press of the Pacific. (Original work published 1862)

Whitney, S. (2006). Herbert Spencer. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (pp. 2123–2124). Thousand Oaks, CA: Sage.

Spinoza, Baruch de (1632–1677)

Spinoza, a Dutch philosopher, is considered one of the greatest rationalists of the 17th century and one of the founders of modern Bible criticism. His works encompass metaphysics, ethics, political philosophy, and epistemology. With regard to his theory of time, the most striking feature of his ontology is the emphasis on eternity. Although the philosophical investigation of physical time plays only a minor role in Spinoza's work, he highlights the inherent striving of each thing to stay in existence for an infinite time.

As a member of a Sephardic Jewish family living in Amsterdam, Baruch (also known as "Benedictus") de Spinoza enjoyed a classical biblical–talmudic Jewish education. Because of his sympathy for the rationalistic Cartesian philosophy and due to his critical Bible studies, he came into conflict with the Jewish community, from which he was expelled in 1656. In his philosophical work he initially follows Descartes. Spinoza presents Descartes's main philosophical ideas in the fashion of the geometrical method. In his *Theologico-Political Treatise,* published in 1670, he develops a political doctrine that aims at freedom of speech and at a limitation of the power of religion and churches. In his posthumously published chief work *Ethica,* he (again in a geometrical fashion) develops an ontology, which states that there is only one substance called "God or Nature" (*deus sive natura*). Individual beings therefore do not have a separate existence of their own but rather are modes of God.

Spinoza was a Dutch philosopher of Portuguese–Jewish heritage whose independent thinking led to his expulsion from the synagogue in 1656. His philosophy was deductive and rational, as expressed in his book Ethica *(1677).*

Source: Library of Congress, Prints & Photographs Division, LC-USZ62–122962.

The striking absence of a theory of time in Spinoza's *Ethica* is characteristic of his philosophical approach. His main interest lies in the understanding of the timeless structure of the universe, insofar as all of its parts express the eternal essence of God. In Spinoza's pantheistic worldview, all finite things are encompassed in God. Everything within this world needs a reason (*causa*) for its existence; only God exists through its own power (*causa sui*). According to Spinoza there are therefore two main ways of looking at things: either as existing in relation to a given time and place or as contained in God and following necessarily from his divine nature (cf. *Ethica,* Part V, Prop. 29, Note). Thus the temporal order is only one way of looking at things that also has the disadvantage that it does not reveal the eternal truth. While the imagination is mainly directed at the spatial-temporal order, reason is the capacity to look at the relation of the individual concepts to God's infinite and eternal essence under a form of a timeless, eternal perspective (*sub quadam specie aeternitatis;* cf., Part II, Prop. 44, Cor. 2).

With regard to the concrete physical time of objects, Spinoza states that all objects are either at rest or in motion. Motion occurs at different speeds, so that our notion of time is derived from the experience of things moving at different velocities (cf., ibid., Cor. 1, Note). Spinoza ascribes to each thing the endeavor (*conatus*) to persevere itself in its being (Part III, Prop. 6). In principle every finite thing would exist for an unlimited time. It is only through external causes that it can be destroyed. So just as well as everything needs a cause to come into existence, it also needs an external cause to vanish from existence.

Andreas Spahn

See also Descartes, René; Ethics; God and Time; Leibniz, Gottfried Wilhelm von; Metaphysics; Ontology

Further Readings

Alexander, S. (1921). *Spinoza and time.* London: Allen & Unwin.

Spinoza, Benedictus de. (1989). *Ethics* (G. H. R. Parkinson, Ed.; A. Boyle, Trans.). London: Dent.

Spontaneity

That which develops or occurs without apparent external influence, force, cause, or treatment manifests spontaneity; a spontaneous event is one that occurs as if by chance. This phenomenon seems to permeate every facet of life. Concerning its role for existence, and in hypothesizing on what may have functioned as a catalyst to the spark of life, Charles Darwin states that a "warm little pond, with all sorts of ammonia and phosphoric salts, lights, heat, electricity, etc. present, so that a protein compound was chemically formed ready to undergo still more complex changes" may have existed in some rudimentary form. Continuing, he states "at the present day such matter would be instantly devoured or absorbed, which would not have been the case before living creatures were formed." As such, Darwin believes that the search for life must take place within sterile conditions of a laboratory, for intensely evolved present-day life would overpower the most basic of creations.

Perhaps the most fundamental, primordial case of spontaneity informs the big bang theory, which purports to explain the emergence of substance and ultimately life within the universe. In brief, the theory, as advanced by American astronomer Edwin Hubble, speculates that approximately 15 billion years ago, a tremendous explosion occurred, giving rise to all the energy and matter of the universe from one infinitesimally small point. The event was not like a conventional explosion, but rather one in which all the particles of the embryonic universe rushed away from each other, this creating—and still forming—the constantly expanding universe that exists today.

With such tremendous force of energy, the universe was, in these very early moments, unfathomably hot. As it expanded and thus cooled, at around 10^{-43} seconds after creation, there existed an almost equal yet asymmetrical amount of matter and antimatter. As these two materials originated together, they inadvertently collided and destroyed each other; luckily for us, there was an asymmetry that favored matter, and this incredibly small advantage—about one part per billion—eventually matured into an environment receptive to material growth, the commonly referred to "plasma soup" of existence. Over billions of years, abnormalities, quirks, and external factors contributed to the increased complexity of this matter, to the point where life as we know it may well trace an elongated yet ultimately undetached line back to this condition.

Another famous instance involving the question of the origins of life—abiogenesis—is the now debunked 15th-century concept of spontaneous generation, which held that life of a more complex species could be traced to the breakdown of decaying organic substances. Perhaps the best-recognized example of this idea is the erroneous belief that maggots are created from the decaying meat of a once living creature, given that they are often viewed on such material yet never on the living creatures themselves. As a result of experimentation in the mid-1800s, Louis Pasteur discredited this idea with a demonstration that only when flying, burrowing, or crawling insects are permitted access to the dead matter in which they lay eggs does the meat give rise to living creatures.

Daniel J. Michalek

See also Big Bang Theory; Darwin, Charles; Evolution, Organic; Life, Origin of; Time, Emergence of; Universe, Origin of

Further Readings

Darwin, F. (Ed.). (1887). *The life and letters of Charles Darwin, including an autobiographical chapter.* London: John Murray.

Trinh, X. T. (1993). *Birth of the universe: The big bang and after.* New York: Abrams.

Stalin, Joseph (1879–1953)

Joseph Stalin was the supreme ruler of the Soviet Union from 1924 until his death in 1953. Upon his accession to power, he quickly established himself as the unequivocal leader of the state and chief ideologue of world communism. Although Stalin's legacy remains marred by controversy, his significance as a historical figure is undeniable, as there have been few politicians in the history of the world who have wielded comparable power, attained such a reputation for ruthlessness, and so deeply affected the lives of millions.

Joseph Stalin was born Iosif Vissarionovich Dzhugashvili on December 21, 1879, in a poor village in the Republic of Georgia. The omnipotence Stalin would enjoy throughout the latter stages of his life had its roots in his very upbringing. Soon after his father died in 1891, Stalin was sent to the seminary in the capital of Georgia, Tiflis (now known as Tbilisi). He never took to religious studies, however. A shy and self-centered teenager whose face had been permanently disfigured after a bout with smallpox, Stalin always felt inferior to his peers and, from an early age, developed a strong sense of contempt toward intellectuals, which years later would result in his merciless persecution of the Soviet intelligentsia. Driven by his lifelong desire for greatness and recognition, Stalin quickly found himself immersed in Tiflis's vibrant revolutionary life as he eagerly joined the city's burgeoning Marxist underground movement.

It did not take Stalin long to become a convinced Marxist, and he quickly rose through the party ranks. When Russian Marxism later split into two factions, he identified himself with the Bolsheviks. As loyal a Bolshevik as Stalin was (organizing Georgian and, later, Azerbaijani workers, distributing illegal literature, dodging arrests, and even robbing trains and banks), he still kept a relatively low profile within the party through the early 1900s. It was in 1913 that the young Georgian revolutionary changed his name from Dzhugashvili to Stalin (literally meaning "man of steel" in Russian), under which he became known as one of the most notorious tyrants of all time.

Although Stalin played a relatively inconspicuous role in the preparation for the Bolshevik Revolution of October 1917, his zeal and obvious organizational talents drew the attention of the party leadership. After the fall of the Romanov Dynasty and the subsequent execution of the czar and his family, Stalin was appointed in 1922 to the position of general secretary of the Communist Party's Central Committee in recognition of his work as a military commissar during the Civil War (1918–1921). As general secretary, Stalin gained control over the entire party apparatus and, within months, established himself as the second most important figure in the government after Lenin. During Lenin's last illness and after his death in 1924, Stalin's power rose even further while he served as a member of the three-man committee that conducted the affairs of the party and the country.

That formation, the *troika,* was arguably the last instance of pluralism that Stalin allowed. His nearly paranoid obsession with keeping every affair under his personal control led to the eventual destruction of the Bolshevik party as a political organism and ruling class. Through labor camps, political repressions of the late 1930s, elimination of free thought and market enterprise, treason trials and brutal executions of Communist cadres, Stalin accomplished the creation of an elaborate, completely centralized bureaucratic mechanism for the command and control of the Soviet society.

Already the leader of an unlimited autocracy, Stalin in the 1940s further solidified his political prowess when he declared himself commander in chief of the entire Soviet military establishment during Hitler's invasion. Thus, the one-party system had completely given way to a one-person system. Stalin carefully cultivated and enhanced his personality cult up until his death on November 5, 1953.

During his three-decade-long reign, Joseph Stalin greatly strengthened and stabilized the young Soviet state, transforming a country ravaged by war and famine into one of the world's most literate and industrially developed societies. Under Stalin, the German invasion of the Soviet Union was eventually turned back and the Allied powers, including the Soviet armed forces, ultimately defeated Hitler's Nazi military. For the Soviet Union, however, these economic and geopolitical victories took an unprecedented toll that many contemporary scholars consider excessive.

During his rule, Stalin's oppressive machine proved extremely powerful and overwhelmingly efficient. The imprint it left on the collective consciousness of the Soviet people was so deep that, even several years after his death, Stalin was still widely considered a national hero. It was not until 1956 that the new first secretary, Nikita Khrushchev, spoke openly of the terrors of Stalinism at the Twentieth All-Union Party Congress, thereby beginning a new chapter in Soviet history.

Stan Trembach

See also Attila the Hun; Genghis Khan; Hitler, Adolf; Nevsky, Saint Alexander

Further Readings

Bullock, A. (1998). *Hitler and Stalin: Parallel lives.* London: Fontana Press.
Conquest, R. (1993). *Stalin: Breaker of nations.* New York: Viking.
Overy, R. (2004). *The dictators: Hitler's Germany, Stalin's Russia.* New York: Norton.
Rayfield, D. (2004). *Stalin and his hangmen: The tyrant and those who killed for him.* New York: Random House.

Star of Bethlehem

The traditional account of the Star of Bethlehem has puzzled historians and astronomers for 2,000 years. Opinion remains divided as to whether accounts of the star are based on an actual astronomical phenomenon or instead represent a fiction intended to situate the birth of Jesus within the context of prophecy. The first appearance of the star in literature occurs in the Gospel of Matthew as it guides the Magi (or "wise men") from the East to Jerusalem. Upon arriving, they are informed of the prophecy in Micah 5:2–4 that a Jewish Messiah would be born in Bethlehem. They journey to the birthplace and worship the newborn Jesus of Nazareth as "King of the Jews." The early Christian writer Luke, however, does not mention the star in his nativity account, leading some to call the portent legend. Many nonetheless accept Matthew's text as a reliable account of historical events, and countless scholars have tried through the years to identify what stellar phenomenon motivated the trek of the Magi. Exactly what event inspired Matthew's account may never be known with certainty.

Within generations of Matthew's testimony, many exaggerations arose. Ignatius's Epistle to the Ephesians, for example, claimed the star exceeded all others, even the sun and moon. This counters the idea that King Herod and his court had no knowledge of the star prior to the Magi's arrival. In an effort to sort true events from the fantastic and identify the star, modern scholars study history and Matthew's text alongside ancient astrology and astronomical records. It is hoped that this method, paired with advances in technology and astronomy, will allow researchers to establish which theories fit the existing data most closely.

The Star of Bethlehem, if successfully identified, could help elucidate a more exact time for Jesus's birth. Current scholarly consensus restricts this event in a 10-year time frame, between 12 BCE and 2 BCE, with many considering the 5-year frame of 9 BCE to 4 BCE highly probable. Reaching a more specific date for Jesus's birth helps scholars identify dates of other significant biblical events, including Herod's death, Jesus's crucifixion, and the conversion of the early Christian missionary Paul.

Some, as previously noted, relegate the Star of Bethlehem to the realm of fantasy; others elevate the occurrence over the natural, claiming that only a miraculous event can suffice. In between these views range many diverse theories. Common suggestions include simple explanations, such as the planet Venus or a comet.

The planet Venus, however, was well known and recorded as early as the Assyrian Venus Tablet, circa 1700 BCE—hardly a unique astral portent that might inspire a voyage to bring tribute. Likewise, comet theories usually receive little credit from scholars. Unlike short-lived meteors, comets provide a lengthy display. Most ancient historical writings, however, attributed comets to be signs of disaster. An appearance of Halley's comet in 12 BCE, for example, was recorded by the Romans, who applied it to the death of statesman-general Marcus Agrippa. Some nonetheless propose the comet to be Bethlehem's star, suggesting a date of 12 BCE for Jesus's birth.

Other theories have proliferated. Some have argued that the sign triggering the Magi's journey could have been a conjunction of planets or an occultation of a planet by the moon. Novas and supernovas also add to the possibilities, as the sudden appearance of a "new" star might encourage the idea of a king's birth and would undoubtedly be noticed by ancient stargazers. Most researchers consider these theories too simple but admit several simple signs occurring in close proximity might have motivated the Magi's pilgrimage.

Recent scholarly works on the subject, not surprisingly, propose significantly differing theories.

Most attempt to pull together and analyze the many existing theories and then propose a new solution. These theories are often more complex than previous attempts to explain the Star of Bethlehem. One, for example, concludes that a series of events including Jupiter and Saturn, with a triple conjunction and planetary massing, constituted triggers for the Magi, proposing that the acronychal rising of Jupiter on September 15, 6 BCE, was the exact star.

Another explores candidates such as Venus, planetary conjunctions, and meteors. The conclusion of this study argues that a long series of events may have set the Magi on their journey. The triple conjunction including Jupiter around 6 BCE may have caught the attention of astrologers. Soon after, the massing of multiple planets in certain zodiacal signs and the occultation of Jupiter twice may have led up to a nova in 5 BCE as the culmination. Supporters of this view even offer a specific nova, DO Aquilae, which might serve as the Bethlehem star.

Others have put forth the idea that the eclipse of Jupiter by the moon on April 17, 6 BCE, could serve as the long-lost star. On the basis of data from the fields of astrology, astronomy, numismatics, scripture, and history, some claim this lunar occultation of Jupiter would point ancients to a new king born in Judea, much like a horoscope. A unique side of this argument is the thesis that Ares is the zodiac of Judea, not Pisces, as most previous studies claimed.

Nevertheless, scholars know many natural occurrences that can explain the Magi's journey to Bethlehem and have added astronomy to the fields that help identify a more specific date for Jesus's birth.

Jared N. Peer

See also Bible and Time; Christianity; Comets; Gospels; Meteors and Meteorites; Time, Sacred

Further Readings

Finegan, J., Vardaman, J., & Yamauchi, E. M. (Eds.). (1989). *Chronos, Kairos, Christos: Nativity and chronology studies presented to Jack Finegan.* Winona Lake, IN: Eisenbrauns.

Hughes, D. (1979). *The Star of Bethlehem: An astronomer's confirmation.* New York: Walker.

Kidger, M. (1999). *The Star of Bethlehem: An astronomer's view.* Princeton, NJ: Princeton University Press.

Molnar, M. (1999). *The Star of Bethlehem: The legacy of the Magi.* New Brunswick, NJ: Rutgers University Press.

Stars, Evolution of

Observing a single star through its evolutionary process with conventional time would prove to be inefficient. Instead, scientists have observed star clusters, where numerous stars of different masses, but close in age, reveal different stages of stellar evolution. The length of a star's existence, and whether its death is violent or more peaceful, is dependent upon its mass. Scientists have mapped the different stages of stellar evolution in the Hertzsprung-Russell (HR) diagram. The Hertzsprung-Russell diagram was named after its creators, astronomers Ejnar Hertzsprung and Henry Norris Russell.

Origins of a Star

Stellar evolution begins with the gravitational collapse of a cosmic cloud of gas and dust. Over a range of tens of thousands of years, the gas cloud

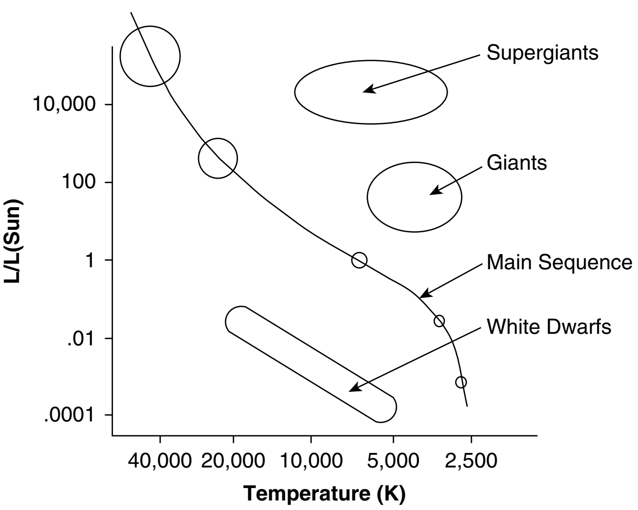


Figure 1 Hertzsprung-Russell diagram

contracts and becomes denser. If the mass reaches temperatures greater than 10 million Kelvin, it will ignite and begin a nuclear fusion reaction where hydrogen is transformed into helium. As the gas cloud continues to collapse and density builds, atoms move faster, colliding harder and more frequently, building pressure against the contracting cloud. These turbulent motions create a spin to the cloud, building the star's angular momentum. If the angular momentum is too high, this protostar, or potential star, might split off into two stars that revolve around each other and become what is known as a binary star system. If the angular momentum is too low, a nebula, or gas cloud, will form. The dust of this nebula may eventually create a planetary system that revolves around the star, similar to that of our solar system.

As the star stabilizes, the pressure inside will prevent the walls from contracting any further, and the star will settle into the evolutionary stage known as the "main sequence," where it will live out most of its existence. This is where our sun has been for the past 5 billion years and will remain for another 5 billion years. The more-massive stars burn brighter and hotter and will remain in the main sequence stage for a short amount of time, whereas less-massive stars are cooler and less luminous, conserving fuel supplies, and will stay in the main sequence stage of evolution for a longer period of time.

The mass of stars is measured in solar masses, a measurement comparative to our sun. A star that is equal in mass to our sun is said to be 1 solar mass. A star that is 8 times more massive than the sun is said to be 8 solar masses, or a solar mass of 8. A star with less than 0.08 solar masses will fail to reach a temperature required to commence a nuclear fusion reaction and become a brown dwarf, or a failed star.

Life on the Main Sequence

A star's life span is dependent upon the mass of the star. Higher-mass stars burn through their fuels much quicker than do lower-mass stars, thus going through the stages of stellar evolution faster. Stars of 1 solar mass take several million years just to reach the main sequence. This is but a blink of an eye for a star this size, for it will exist another 10 billion years. Stars of 8 solar masses will take approximately 100,000 years to reach the main sequence, with a stellar life expectancy of only 100 million years.

Throughout its rather uneventful existence on the main sequence, a star will burn through its fuel supply, transforming four hydrogen atoms into a single helium atom with energy as a by-product. Once the hydrogen is exhausted, the star will begin to collapse under its own gravitational force. The temperature of the star will begin to rise as this happens, causing the star to become more luminous. The outer gaseous layer of the star will expand, and the star will begin to cool and energy output to decrease. The star then will begin its move off the main sequence and upward to the red giant stage. For a star of only one solar mass, this move away from the main sequence will take 100,000 million years. As it moves into the red giant stage, the star's temperature will increase to 100 million Kelvin, triggering a triple-alpha reaction in which the helium will begin transforming into other elements.

If the star is massive enough, it may continue to burn its fuel supply, creating a successive chain of different elements. This cycle, if conditions allow for it, ends with the creation of iron in the core. Each successive element will require a shorter period of time to create, as well as more mass and higher temperatures, than its predecessor. A star that produces iron may exist for a day to a week. The cycle ends with iron because the creation of iron requires more energy than the process produces. The star will fail to create the amount of energy required to sustain its current needs, and it will rapidly collapse.

Death of a Star

The most-massive stars will explode violently, where as lower-mass stars will burn out quietly. Stars that are roughly the size of our sun will peacefully burn out. As the sun-sized star exhausts its fuel supply, it will begin to cool, decreasing in luminosity, and compress, becoming what is known as a white dwarf. A white dwarf is a densely compacted star composed primarily of carbon and oxygen. Over the next billions of years, the white dwarf will continue to cool and fade until completely burned out, at which point it will be nothing more than a cold, dark mass known as a black dwarf. The universe is currently too young, and not enough time has passed for the formation of black dwarfs.

A star that is greater than 5 solar masses, as it creates heavier elements during the final stages of its nuclear fusion process, will swell beyond the red giant stage and become what is known as a supergiant. As it expands, it may explode off its outer layer and may lose up to 80% of its mass. The core mass left behind, if less than 1.4 solar masses, would form into a white dwarf, and the outer layer would become a glowing cloud of unused hydrogen that surrounds the white dwarf. This spectacle is known as a planetary nebula, despite its having nothing to do with a planet.

If the core of the star is greater than 1.4 solar masses, it will form something other than a white dwarf. These massive stars violently expel their outer layer in what is known as a supernova. What is left behind is a core that compacts itself into either a neutron star or a black hole. If the core is between 2 and 3 solar masses, it will become a neutron star, a phenomenon so dense that a single teaspoon would weigh 400 million tons. Some of these neutron stars may emit pulsating radio emissions that flash in all directions, similar to a lighthouse beacon. These pulsating neutrons are known as pulsars.

If the core is greater than 3 solar masses, the star will continue to collapse in on itself until all of its mass reaches a state of infinite density, or a singularity, creating a black hole. Due to the high density of a black hole, not even light can escape from its gravity.

Mat T. Wilson

See also Black Holes; Nebular Hypothesis; Stars, Evolution of; Sun, Age of; Time, Sidereal; Universe, Age of; Universe, Evolving

Further Readings

Chaisson, E., & McMillan, S. (2004). *Astronomy today: Vol. 2. Stars and galaxies* (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Nicolson, I. (1999). *Unfolding our universe.* Cambridge, UK: Cambridge University Press.

Statute of Limitations

The statute of limitations is a statute that originated from the common-law system, which set forth time limits on legal action in certain cases. The deadlines for filing vary, in accordance with the type of case (criminal or civil) and the circumstances surrounding the case or claim. The periods of time also vary from state to state and country to country. Statutes of limitations apply to all cases filed in courts, including state and federal courts.

The limits of time for court action is predicated on an idea of equity or fairness. There is a prevalent belief that the best time to bring a civil lawsuit or prosecution of a criminal case is as close to the event as possible, in order to have the best evidence. The more time a case or claim sits dormant, the more likely memories fade and important evidence may be lost. Also, diligence is expected by an injured party or government entity to pursue an action in a timely manner.

Most jurisdictions examine the time frame of a legal action by thoroughly scrutinizing the circumstances of the individual case and tolling the amounts of time limitations. For example, in the case of medical malpractice, in which the doctor's mistake is not immediately known, tolling of time does not take place until there is a discovery of an actual injury or harm. Minors as injured parties are also afforded extra protection in most jurisdictions: The tolling of time often does not begin until after the minor turns 18 or the age of majority.

At any time, a party to a case can assert the statute of limitations as a defense. If the statute of limitations has expired, the case is no longer litigated. In the United States and Great Britain, there is no statute of limitations for murder. An individual suspected of committing the act of murder may be prosecuted at any time with no expiration date. However, other countries do not permit the prosecution of murder suspects after certain time periods have elapsed. For example, in Japan, a murder case must be brought before the court within 25 years of the victim's death. Japan extended its 15-year statute of limitation for murder in 2005, but the new time frame of 25 years does not apply retroactively. Only new crimes committed after the time period was extended may assert a statute of limitations beyond the original 15 years.

There are a few exceptions to the strict time limits of the courts. For example, parties may extend or limit the life of a case in civil and private matters if the litigants are in agreement. The Uniform Commercial Code allows for contracts of the sale of goods to be limited in time to 1 year; however, the code does not allow the parties to shorten the time limit beyond a 1-year period. The Uniform Code of Military Justice has a 5-year statute of limitations for almost all cases, excluding those cases for which a punishment of death is a possibility.

The statute of limitations as a concept illustrates the notion of time as a means to achieve justice for an individual. Both the injured party and the accused are afforded protections through the application of time limits to a case.

Jennifer R. Fields

See also Ethics; Humanism; Law; Morality; Values and Time

Further Readings

Levy, A. J. (1987). *Solving statute of limitation problems.* New York: Kluwer.

Simon, P. N. (1996). *The anatomy of a law suit.* Charlottesville, VA: Michie.

Steno, Nicolaus (1638–1687)

A respected anatomist, crystallographer, and priest, Nicolaus Steno (Danish: Niels Steensen) is hailed as one of the founders of modern geology. Through his dissections, laboratory experiments, and field observations, Steno was one of the first natural philosophers to recognize the organic nature of fossils and explain how sedimentary rocks were formed. His discoveries indicated that the earth has a dynamic history and is not a static body that has changed little since its formation, as was widely assumed at the time.

Born in Copenhagen in 1638, Steno was raised in a devout Lutheran household. He was a sickly youth, spending most of his formative years indoors reading science and philosophy and experimenting in his father's goldsmith shop. At the age of 18 Steno enrolled in the University of Copenhagen to study medicine but terminated his studies amidst war. He later continued his academic work in Leiden, where he earned a medical degree and set out on a successful career as an anatomist. Steno quickly became recognized as an expert on the human heart, brain, and glands. As a medical student he was the first to identify the duct of the parotid gland, which supplies saliva to the mouth. He would later impress audiences in Paris with his legendary dexterity with a scalpel, and in 1665 he published *Discourse on the Anatomy of the Brain,* a detailed anatomical description of the human nervous system, combined with a discussion of his philosophy of science.

In 1666 Steno traveled to Florence, where he befriended Ferdinando II de Medici, the scholarly Grand Duke of Tuscany who years earlier had established the Accademia del Cimento, the world's first academy dedicated to experimental science. Soon after his arrival, Steno was commissioned by Ferdinando to dissect the head of a giant 2,800-pound shark that landed near the port city of Livorno. In what was one of the first careful dissections of a shark, Steno noticed an uncanny resemblance between the creature's teeth and "glossopetrae," a type of odd stone common on Malta that was thought to have curative and magical powers. Other experts had previously noted the resemblance but were at a loss to explain how petrified sharks' teeth were found on land, often on mountains thousands of feet above sea level.

Steno explained this paradox in his 1669 *Prodromus to a Dissertation Concerning Solids Naturally Enclosed in Solids,* now recognized as a pioneering attempt to describe the earth in terms of natural science. Noting that glossopetrae resembled modern shark teeth in every regard, Steno wrote that these odd stones must be the remains of once-living organisms. This conclusion was generalized to other fossils, such as bones and shells, and was the first coherent argument that fossils were organic. Steno also realized that since sharks are aquatic, the sediments that encased glossopetrae must have formed in the sea. Based on field excursions in Tuscany, Steno recognized that many rocks are found in layers made of different materials. This observation formed the basis for Steno's Principles, three basic laws that are taught to every beginning geology student: (1) Sedimentary rocks are deposited from a fluid in originally horizontal layers; (2) in a series of layers, younger layers lie on top of older ones; and (3) sediments are deposited as laterally continuous sheets and later truncated by erosion. These principles demanded that the earth a dynamic history in which different rock layers are formed in temporal sequences, not as part of a single event such as the Biblical Flood.

Despite his philosophical break from traditional religious and scientific authority, Steno remained piously religious and attempted to reconcile his principles with scripture. Although Steno never departed from a young-earth viewpoint, his ideas would later be used by James Hutton, Charles Lyell, and other geologists to argue for an ancient earth. Steno converted to Catholicism in 1667, was ordained as a priest in 1675, and gradually withdrew from the scientific community. In 1677 Steno was ordained as the titular Bishop of Titiopolis, an office without a see whose main duty was to minister to remnant Catholic populations in Germany and Scandinavia. As a bishop Steno took a vow of poverty and frequently fasted, a devout lifestyle that gradually destroyed his health. Steno died in 1687 at the age of 48 and is today interred at the Basilica of San Lorenzo in Florence.

Stephen L. Brusatte

See also Earth, Age of; Geological Column; Geologic Timescale; Geology; Hutton, James; Lyell, Charles; Sedimentation; Stratigraphy

Further Readings

Cutler, A. (2003). *The seashell on the mountaintop: A story of science, sainthood, and the humble genius who discovered a new history of the earth.* New York: Dutton.

Laudan, R. (1987). *Mineralogy to geology: The foundations of a science, 1650–1830.* Chicago: University of Chicago Press.

Steno, N. (1968). *Prodromus to a dissertation concerning solids naturally contained within solids.* New York: Hafner. (Original work published 1671)

Sterne, Laurence (1713–1768)

Laurence Sterne, among the most prominent English novelists of the 18th century, is best known for *The Life and Opinions of Tristram Shandy, Gentleman,* a novel that mocks traditional literary conventions. In contrast to an ordinary presentation of time as a linear process, Sterne emphasizes the relativity of time in human experience by means of exuberant digressions.

Sterne was born in Clonmel, Ireland, the son of an impoverished infantryman. On account of his father's profession, Sterne spent his early childhood in various barracks moving from place to place. The future novelist was sent to school at the age of 10. From there he proceeded to Jesus College, Cambridge, where he first encountered the works of the philosopher John Locke.

In 1738 Sterne took holy orders and became vicar at Sutton-on-the-Forest. Three years later he relocated to York, where he assumed the position of prebendary. In the same year the clergyman married Elizabeth Lumley, who suffered several miscarriages before their daughter Lydia was born in 1747. Despite the birth of Lydia, Sterne's family life was not happy. In addition, he and his wife suffered from pulmonary tuberculosis. To recover from the quarrels in his private as well as in his public life, Sterne took an interest in painting, played the violin, read widely, and spent much of his time in the company of other women.

The author lived in Sutton for 20 years. It was at the end of this period that he began to work on his most famous novel, *Tristram Shandy.* Between 1759 and 1767 the work was published in nine volumes. The first version of volumes one and two was rejected by the London printer Robert Dodsley, so Sterne had to revise them. They were finally published in 1759 in London. These and the remaining seven volumes were highly successful although they aroused indignation among some contemporary literary critics (among them Samuel Johnson).

The aggravation of his tuberculosis forced Sterne to leave England. In January 1762 a journey to the south of France was arranged which engendered Sterne's second novel *A Sentimental Journey Through France and Italy.* After his wife and his daughter had followed him, the family went to

Toulouse where they settled for 1 year. In 1763 the Sternes visited Aix-en-Provence, Marseilles, and Montpellier. One year later the writer returned to England and finished the seventh and eighth volumes of his masterpiece, *Tristram Shandy.* Elizabeth and Lydia preferred to stay in Montpellier. In 1765 the writer left England again and set out for France and Italy, a trip that supplied him with further material for the *Sentimental Journey.* The work was published early in 1768. In March of the same year Sterne fell ill with influenza and died.

The author's literary career began late. Between 1742 and 1750 Sterne wrote letters, sermons, essays on local politics, and experimented with satire. *A Political Romance* (the title was later changed into *The History of a Good Warm Watch Coat*) was published in 1759. It was Sterne's major publication prior to *Tristram Shandy* and gave evidence of his power as a humorist.

Yet, Sterne's career as a novelist could be said to begin only with the publication of *Tristram Shandy.* The success of Sterne's masterpiece is based on its highly experimental structure that results from the ironic parody of traditional literary conventions. The writer composed his novel as a fictional autobiography, that is, as a biography of the main character Tristram told by himself. In contrast to the title the reader ironically learns little about Tristram's life and knows even less about his opinions at the end of the novel. There is no consistent plot or conclusion because the primary line of narrative is constantly interrupted by florid digressions. By means of digression Sterne is able not only to mock the generally accepted form of autobiography (*Tristram Shandy* starts with the procreation of its protagonist) but also to invert the ordinary flow of time: Paradoxically the more Tristram tells about his life, the more he will have to tell because the narrator-protagonist dwells upon endless excursions about his family and friends while his own life is constantly proceeding but remains undocumented. Apart from parodying autobiography and experimenting with time, *Tristram Shandy* explores the limits of typography by including marbled and entirely black pages as well as sketches of the plot.

Many of the innovations Sterne introduced in his masterpiece influenced modern as well as postmodern writers, for example, James Joyce, Virginia Woolf, Thomas Pynchon, and David Foster Wallace. Although Sterne's literary œuvre is quite small when compared to the work of other 18th-century authors, *Tristram Shandy* continues to exert an influence on contemporary writing.

Verena Kammandel

See also Joyce, James; Mann, Thomas; Novels, Time in; Postmodernism; Proust, Marcel; Woolf, Virginia

Further Readings

Campbell Ross, I. (2001). *Laurence Sterne: A life.* London: Oxford University Press.
Cross, W. L. (1929). *The life and times of Laurence Sterne.* New Haven, CT: Yale University Press.
Fluchère, H. (1965). *Laurence Sterne: From Tristram to Yorick. An interpretation of* Tristram Shandy. London: Oxford University Press.

Stonehenge

The prehistoric megaliths of Stonehenge, believed by many to correlate to a calendar or other device for calculating and/or monitoring time, have held firmly to people's imaginations for centuries. Likewise, the site itself has been studied and reported on by countless archaeologists, historians, astronomers, and other enthusiasts eager to unravel the mysteries embedded in the stone edifices, embankments, and human remains found there. The results of these collective investigations have been a broad understanding of the site's stages of construction, an appreciation for the feats of Stonehenge's architects, and a hint of Stonehenge's astronomical implications. At the same time, a multitude of unanswered questions remain.

Location and Stages of Construction

Stonehenge is a multicomponent site situated in the present-day town of Amesbury, located in the county of Wiltshire in southern England. Covering several acres, the site of Stonehenge includes earthen mounds and a ditch along the site's periphery, a series of pits constructed at multiple stages over time, and megaliths of sedimentary and igneous rock, some of which were extracted

Stonehenge as it might have looked in prehistoric times. There have been many theories about who built Stonehenge and much speculation as to its function.

Source: Fortean/Topham/The Image Works.

from locations that would have required Stonehenge's architects to travel over 100 kilometers to acquire them. Although Stonehenge was long believed to be a Bronze Age construction, radiocarbon dates indicate that the oldest sections of Stonehenge date further back in time to the end of the western-European Neolithic era, circa 5,000 years before the present, and were followed by multiple stages of construction during the 1,500 years that followed.

The first recognized stage of construction at Stonehenge included the formation of embankments and a ditch, all of which were positioned toward the periphery of the site. Additionally, a series of various-sized pits encircling the interior of Stonehenge's embankments were excavated, presumably during the first stage of construction. These "Aubrey holes," which were named after the man who discovered them, are believed to have served as postholes, although questions remain as to their exact purpose and date of origin.

The second major stage of Stonehenge's construction was completed during the half-dozen centuries following the first stage's activities and saw the filling of Aubrey holes with cremated remains and the partial filling of the ditch erected along the site's periphery through natural processes and human activity. Cremated remains were also placed elsewhere at the site during this period.

The third stage of construction at Stonehenge, ending roughly 1,500 years after the initial stage of construction began, saw the erection of the megaliths that form the heart of what most people envision when they think of the site. The actual stone used for the construction of the megaliths included sandstone and "bluestone," the latter being an assortment of blue-colored igneous and sedimentary stones, including sandstone, dolerite, and limestone variants. Unfortunately, stones used in the site's construction have been rearranged, removed, and damaged throughout the centuries. Consequently, questions remain as to the original arrangement of Stonehenge's megaliths and what their purpose was initially.

Time and Stonehenge

The specific purpose of Stonehenge remains unclear, even after countless researchers have examined its burials, mounds, and megaliths. With a particular focus on the alignment of Stonehenge's main avenue in the northeastern quadrant and megaliths to celestial bodies, investigators have hypothesized that the site may have served as an observatory to calculate eclipses, track lunar cycles, and unravel the movement of other celestial objects in relation to the earth and Stonehenge itself. Of central importance to many researchers' quests to prove such assertions is the position of Stonehenge's Avenue, Heel Stone, and additional megaliths in relation to the rising midsummer sun. To date, investigations of the site have questioned all such inquiries because the alignments of Stonehenge's components to celestial objects are not exact. Owing to loss, damage, and relocation of many of Stonehenge's fixtures over time, as well as the destruction and misplacement of collected artifacts and bone material through poor management and various catastrophes, it is difficult to ascertain what precisely was the aim of the site's creators.

Recent Research

Loss and repositioning of portions of Stonehenge's fixtures pose a challenge to determining the site's role in making temporal and astronomical measurements. Yet, numerous studies have uncovered information providing suggestions that appear promising. In 1996 John North completed and published his comprehensive research, which includes a detailed study of the placement and alignment of Stonehenge's earth and stone works. North's work also considers the possible purposes behind the site's construction and its connection to other sites. In 2001 Mike Pitts published results of his extensive research of multiple sites, including Stonehenge. Pitts's text also reviews the research on Stonehenge undertaken by scholars from multiple fields. Complete with diagrams detailing the stages of Stonehenge's construction and the alignment of the Heel Stone, appendixes documenting radiocarbon dates secured for Stonehenge, discussions of previous research initiatives of and excavations at Stonehenge, and systematic photographs of the site, Pitts's book provides a thorough analysis of Stonehenge as well as other megalithic sites. It is hoped that these efforts and those of other researches will help to further clarify the ancient site's temporal significance.

Neil Patrick O'Donnell

See also Anthropology; Archaeology; Equinoxes; Observatories; Planetariums; Solstice

Further Readings

North, J. (1996). *Stonehenge: A new interpretation of prehistoric man and the cosmos*. New York: The Free Press.

Pitts, M. (2001). *Hengeworld*. London: Arrow Books.

Young, P. A. (2006) Stonehenge. In H. J. Birx (Ed.), *The encyclopedia of anthropology* (pp. 2130–2132). Thousand Oaks, CA: Sage.

Stratigraphy

Etymologically, the term *stratigraphy* (from the Latin *stratum* and the Greek *graphia*) means "description of strata." The word *stratum* (plural, *strata*) was introduced by Nicolaus Steno in the 17th century to describe a layer of rock or sediment that is delimited by horizontal surfaces with lateral continuity and which represents a unit of time of deposition. The meaning of a stratum deals not only with the geometry of the stratified rocks but also with their genesis, assuming that it is a sedimentary unit deposited under constant physical conditions. Therefore, stratigraphy is not just a simply descriptive science, but it also deals with problems related to the genesis of the strata, the description of rock successions, and their interpretation in terms of a general timescale. Stratigraphers study all attributes of rocks as strata (e.g., form, distribution, lithologic composition, fossil content, geophysical and geochemical properties) and infer their origin and geologic history.

The origin of stratigraphy has its roots in scientists trying to determine the age of the earth. It was first introduced in the geological nomenclature by Alcide d'Orbigny in the 19th century, as a consequence of the need to order processes in time, so as to establish a geological chronology. Since Amadeus W. Grabau published the first treatise on stratigraphy in 1913, the term *stratigraphy* has been used to refer to a geological science that studies the order and the relative position of the strata, the stratified rocks being its main focus. The sequence of layering of the rocks, together with the evolution of life, is the basis of the relative timescale. In addition, stratigraphy can yield information about the processes affecting the deposition of sediments, which can result in a complex layout of the strata. Thus stratigraphers study and interpret the processes recorded in the sedimentary successions in order to determine the nature and arrangement of the stratified rocks, correlate rocks and events, and order the sequences of rocks and events in a relative timescale.

Since 1917 the improvement of radiometric techniques has allowed scientists to determine the absolute age of rocks and to work out the duration of the intervals of geologic time that had been previously established by means of fossils. The development of the oil industry between 1920 and 1940 led to a significant improvement in the knowledge of lithostratigraphy and the geometry of stratified sedimentary bodies. Until the mid-1900s the French school supported a historical meaning of stratigraphy, whereas the North American school focused on a dynamic concept of this science and on the interpretation of the geometries of sedimentary bodies. It was this second concept that was more broadly accepted within the scientific community. Afterward, the advent of plate tectonics led stratigraphers to concentrate their studies on the mobility of sedimentary basins and their evolution through time. Data from international research programs on marine geology, such as the Deep Sea Drilling Project, the use of paleomagnetism, sedimentary geochemistry and seismic stratigraphy, together with the improvement of the biostratigraphical methods and the abundant studies on radiometric dating, contributed to the current meaning of stratigraphy as a science and to its subdivision into several branches. The most important of these are *lithostratigraphy* (study of the geometrical bodies of stratified rocks, their geometry and genesis), *biostratigraphy* (study of the temporal distribution of fossils in the stratigraphic record), *chronostratigraphy* and *geochronology* (determining the age of the stratigraphic units and establishing a worldwide stratigraphic scale), *magnethostratigraphy* (establishing a scale of changes in magnetic polarity through time), *chemostratigraphy* (analysis of stable isotopes and chemical elements in the stratified rocks), *sequence stratigraphy* (recognizing major events recorded in the stratigraphic record), and *basin analysis* (reconstruction of the spatial and temporal distribution of each unit of stratified rock within a sedimentary basin).

Principles of Stratigraphy

The practice of stratigraphy is based on the application of five main principles. Nicolaus Steno proposed three of them in the late 1600s, when he attempted to explain sediment accumulation. The *principle of superposition* states that in any succession of strata not severely deformed, the oldest stratum lies at the bottom, successively younger ones above; this is the basis for establishing the relative ages of all strata and of the fossils that they contain. The *principle of original horizontality* suggests that because sedimentary particles settle from fluids and experience the influence of gravity, stratification is originally horizontal and when steeply inclined must have suffered subsequent disturbance. In addition, the *principle of original lateral continuity* states that a rock unit continues laterally unless there is a structure or change to prevent its extension, such as the edges of the depositional basin. In the late 1700s, William Smith suggested that strata could be traced and correlated by comparing their fossil content, proposing the *principle of faunal succession*. Finally, in recent decades, the *principle of simultaneity of events* was proposed to explain the catastrophic events (e.g., earthquakes, volcanism, meteorite impacts, climatic changes, sea-level changes) recorded in the sedimentary rocks globally. These catastrophic events are excellent correlation criteria, even at a global scale.

These principles, together with the *principle of cross-cutting relationships* (a structure that cuts another is younger than the structure that is cut), the *principle of inclusion* (a structure that is included in another is older than the including structure), and the *principle of uniformitarism* (the present is the key to the past; i.e., processes operating in the past were constrained by the same "laws of physics" as operate today), proposed by James Hutton in the mid-18th century to compare the present-day rock cycle to the past rock cycle, help to achieve the main objectives of stratigraphy. These include the identification of sedimentary rocks (lithology, textures, structures, geophysical and geochemical properties, fossil content), delimitation of the lithostratigraphic units (and of their lateral and vertical polarity) and their relationships (conformities, unconformities), interpretation of their genesis (sedimentology), stratigraphical logging, correlation, and introduction of time (bio- and chronostratigraphical units). Finally, the main target of stratigraphy is the reconstruction of the basin, which is the main source of information for historical geology. Apart from providing a basis for historical geology, the principles and methods of stratigraphy have found application in such fields as petroleum geology and archaeology.

Stratigraphy is closely linked to other geological sciences, such as sedimentology, historical geology, petrology, mineralogy or paleontology (especially with the biostratigraphy and paleoecology), among others. Nowadays, stratigraphy is a modern science that is actively contributing to multidisciplinary studies such as plate tectonics or so-called event-stratigraphy.

Laia Alegret

See also Chronostratigraphy; Dating Techniques; Earth, Age of; Erosion; Geological Column; Geology; Hutton, James; Lyell, Charles; Sedimentation; Smith, William; Steno, Nicolaus

Further Readings

Blatt, H., Berry, W. B. N., & Brande, S. (1991). *Principles of stratigraphic analysis*. Boston: Blackwell.
Hedberg, H. D. (Ed.). (1976). *International stratigraphic guide*. New York: Wiley.
Weller, J. M. (1960). *Stratigraphic principles and practice*. New York: Harper.

STROMATOLITES

Stromatolites are a distinctive group of layered structures that form in aquatic environments through the activity of microbial communities. They are the earliest known examples of complex life on Earth, and provide evidence that life started relatively soon after the planet's formation. The dominant form of life on Earth for most of its geological history, stromatolites are now quite rare. A few colonies still eke out a precarious existence in limited and unusual habitats.

The term *stromatolite* is derived from the ancient Greek (meaning "layered rocks") and is used to describe the laminated mineral deposits produced by certain microbial communities. Like coral reef systems, they can cover quite a large area. Stromatolites range in size from flat films to domes and columns several meters high. Some types are renowned for their distinctive "living rock" appearance and aura of quiescent antiquity. A stromatolite is not a rock, however, but a thriving colony of highly specialized microbial species. There may be many species in the system, including cyanobacteria, photosynthetic bacteria, anaerobic bacteria, and even diatoms, tied to each other by a web of symbiotic relationships.

Most stromatolites are divided into several vertical zones, each containing different groups of species. The outside or growth surface is composed predominantly of filamentous and motile photosynthetic cyanobacteria. Just beneath this layer is a thin zone of photosynthetic, anaerobic bacteria called the undermat, protected from oxygen by the growth surface and adapted to use only those wavelengths of light that pass through the cyanobacteria. Together the two populations use light energy to build up organic matter near the growth surface. Beneath the undermat, there is an oxygen-depleted zone inhabited by bacteria and archaea. These organisms feed on the remnants of organic matter produced by the layers above.

The Hamelin Pool in Western Australia is one of only two places in the world with living marine stromatolites, or "living fossils."
Source: iStockphoto.

New layers are added in response to changing environmental conditions, especially those concerning the quantity of available sunlight. The photosynthetic cyanobacteria secrete a sticky mucus, which traps and binds any passing sediment into layers of inorganic particles, predominantly carbonate. Being motile, they will then move to grow up and over the sediment layer to reach the sunlight. The space created beneath them allows the underzones to move upward as well. A new layer of carbonate forms each time the photosynthesizers move to remain on the outer surface, and the whole process causes the distinct laminations found in stromatolites.

Most stromatolites can be classified into four groups based on their shape, similar to the genera used in biologic nomenclature: the flat-layered *Stratifera,* domed *Cryptozoon,* conical *Conophyton,* and columnar *Colonnella* and *Gymnosolen.* The shape of a group is thought to be governed mainly by the conditions of its habitat. Mats and flat-layered varieties form in quiet, shallow environments such as lagoons and marshes. The conical and domed stromatolites form in more energetic environments or deeper waters, where the competition for sunlight is more intense.

Stromatolites are relatively rare but still can be found at a few sites scattered around the world. Because they have few defenses and take an extremely long time to recover from damage, they tend to be found in environments that are relatively hostile to other forms of life. Bodies of water with low nutrient levels, seasonal desiccation, extreme temperatures, or strong currents may play host to these colonies. Because stromatolites utilize minerals such as calcium carbonate, they also tend to grow in alkaline waters or regions where the groundwater is rich in minerals.

The age of fossil stromatolites has long been questioned and debated; some appear to be at least several billion years old. The oldest specimens yet found come from the ancient, well-preserved rocks of the eastern Pilbara craton, near Marble Bar in western Australia. Isotopic analysis of volcanic rocks associated with the stromatolites has precisely dated some specimens to 3,490 million years in the past. These are but one excellent example from more than 30 archaean stromatolite sites discovered worldwide. Some of these structures have been attributed to inorganic processes, such as soft sediment deformation and chemical precipitation. While this may be true of some sites, the evidence for the biological origin of stromatolites has been mounting. The Pilbara stromatolites, for example, have such a complex morphology that inorganic chemical processes are unlikely to have formed them. Furthermore, their features are inconsistent with fold structures and other physical deformations, indicating a nonbiogenic sedimentary origin.

Perhaps most importantly, fossil stromatolites possess some structural details that resemble exactly those seen in living stromatolites. They can have lens-shaped layers, for example, which are thicker over the apices of cones and flanks of columns. Serendipitously, world-class examples of living stromatolites can be found at Shark Bay, only a day's drive from the stromatolite fossil localities of the Pilbara region in western Australia. It is astonishing but convincing to see living versions of these multibillion-year fossils.

Fossil stromatolites provide evidence that life appeared on Earth relatively early, within 1 billion years of its formation. Stromatolites then grew increasingly widespread and abundant, peaking during the latter half of the Proterozoic era. During this period the atmosphere included a significant amount of methane and carbon dioxide and so was unsuitable for complex life as we know it today. Earth supported an immense population of anaerobic microbes and cyanobacteria at this time, some living in stromatolites and some floating free in the oceans. These organisms converted some of the atmosphere into free oxygen, paving the way for later stages of evolution and ecological change. In this way, stromatolites played a tremendously important role in shaping the course of Earth's history. Somewhat ironically, this change in the atmosphere also heralded the decline of the stromatolites. This has been attributed to the evolution of more complex life forms, including predators, and to a range of climatic and environmental challenges resulting from the evolution of tectonically segmented continents.

Discerning the environmental factors behind the emergence of a new species is a difficult proposition at best. In the case of stromatolites, the usual obstacles are almost insurmountable because of vast gaps in the fossil record. It may be speculated that a key adaptation was the ability to accumulate carbonate layers and thereby form an anchored structure. This led to the emergence of permanent colonies, enabling further specialization and differentiation of individual microbial species. A stromatolite provides a stable platform from which microorganisms can maximize their exposure to visible sunlight while limiting their exposure to potentially damaging ultraviolet light. Meanwhile, its laminated structure allows each species to more efficiently utilize the environment. Although their outer forms and physical structures have changed little over their long history, the microbes that build the stromatolites have never stopped evolving and specializing. Indeed, their successful history on geological timescales indicates that stromatolites have been adaptable enough to withstand many serious extinction threats.

Stromatolites have revealed many fundamental and significant facts of early life's evolution on Earth. Through them we know that at least some forms of life required sunlight to survive. Their form and composition also provides information on the early environment, telling us about water levels and energy and the gaseous composition of both water and air. Finally, they reveal that fully fledged ecosystems of food producers and consumers existed in the most ancient habitats now known to have existed on Earth.

Stromatolites have taught us to distinguish the subtle signals of ancient life from similar, nonbiological structures. These skills are now being applied to the search for life on Mars and other planets. Stromatolites have led us to recognize that a wide range of environments can harbor life, improving our chances to succeed in one of humanity's most fundamental quests.

Mark James Thompson

See also *Archaeopteryx*; Dinosaurs; Earth, Age of; Fossil Record; Fossils, Interpretations of; Life, Origin of; Trilobites

Further Readings

McNamara, K., & Long, J. (2007). *The evolution revolution: Design without intelligence.* Carlton, Australia: Melbourne University Publishing.

Schopf, J. W. (1999). *Cradle of life: The discovery of earth's earliest fossils.* Princeton, NJ: Princeton University Press.

Tidwell, W. D. (1998). *Common fossil plants of western North America.* Washington, DC: Smithsonian Institution Press.

STRUCTURALISM

Almost every science has witnessed the development of the intellectual movement called *structuralism.* Ranging from logic and mathematics, to natural science, to social science and the humanities, structuralist research programs have moved in different directions depending on the objectives, aims, and methods of the various sciences. Yet the diverse structuralisms have important properties in common, the first of which is their reference to a formal concept of structure. A crucial question that always arises when a structuralist approach develops in some science is how aspects of time can be described structurally, since most critics regard structures as static entities that cannot capture the dynamic properties of scientific objects.

It is most appropriate to start a discussion of structuralism by introducing a formal, even mathematical concept of structure. The structuralist movement in mathematics has been driven forward particularly by a group of, for the most part, French mathematicians that facetiously baptized itself "Nicolas Bourbaki." Since the 1930s the Bourbakists have been working on a systematic treatise of modern mathematics, the *Elements of Mathematics,* whose general architecture is constructed according to the idea that the objects of mathematical research are structures. Bourbaki defines a structure most generally as follows. Let us start with different sets $A, B, C, \ldots$ of elements whose internal constitution is unspecified. We generate another set M containing subsets and product sets of $A, B, C, \ldots$. Each element of M has relational properties, that is, properties it has only in relation to one or more other elements (e.g., being smaller/greater than or being contained in/containing). These properties can be used to define subsets of M: An element of M having a particular relational property belongs to the subset of M that contains all elements of M having this property (e.g., all elements that can be related to each other by a "smaller/greater than" relation). If an element of M has more than one relational property, it belongs to each of the respective subsets.

Let S be the intersection of all those subsets of M. The propositions that express the relational properties of elements of M according to which the subsets of M have been defined are called "axioms of S": They contain the complete information about all relational properties the elements of S have. Now a structure of species S is definable in two equivalent ways. Either we give the scheme of how we construct the set M from the sets $A, B, C, \ldots$, or we specify the axioms of S. To the theory of S-structures belong all propositions that are deducible from these axioms—or, more succinctly, from the proposition "s is an element of S" since s

can be completely characterized by its relational properties. In this sense, an element *s* of *S* defines on *A, B, C, . . .* a structure of species *S*.

Against the backdrop of Bourbaki's abstract concept of structure, the objection of some critics of structuralist thought, such as the philosophers Jacques Derrida and Jürgen Habermas, that structuralism blends out the dynamic properties of reality, seems to be plainly true. To define a structure of a certain species *S*, we start with given sets of *A, B, C, . . .* of internally unspecified elements, and for the construction of the sets *M* and *S* we use the given elements of *A, B, C, . . .* and predetermined relational properties of the elements of *M*, respectively. If we apply the concept of a structure on a real system, how can we capture the temporal change of the components of this system and of their relations?

In this respect it is remarkable that the founder of structuralism in the humanities, the Swiss linguist Ferdinand de Saussure, was an Indo-European scholar and developed a structuralist approach for the reconstruction of the history of Indo-European languages. The French ethnologist Claude Lévi-Strauss, arguably the most important structuralist in the social sciences, developed de Saussure's approach further to investigate an object of research—cultures that do not know writing—about the history of which records did not come down to us from earlier times. Lévi-Strauss considers a structure not only as a set of elements that are relationally definable but also as a hierarchical system in which the change of an element has, according to its hierarchical position, specific effects on other elements. A structure is, thus, a member of a class of hierarchies that can gradually be transformed into each other. For Lévi-Strauss, a structure is nothing but a snapshot of a process in which the relational properties of structural elements, and thereby the structures themselves, are changing at different velocities. A structuralist analysis must describe also the transformational rules these changes follow, as structures whose elements remain unchanged for a certain period of time. Thus emerges a conception of history, developed particularly by the French historian Ferdinand Braudel, as a hierarchy of structures whose levels differ in their rate of change. The semiotician Roman Jakobson captured the intrinsically historical nature of structures by his concept of dynamic synchrony: The structural analysis of a system cuts through its history to sketch an idealized picture of one of its states but does so only to determine, in form of structures of transformational rules, the forces that led to this state and will again change it.

If we do not want to consider temporal change—and in particular irreversible temporal change, that is, history—as the effect of a supranatural force that cannot be objectified by scientific methods, structuralism should still be an important starting point of our search for a general theory of historical systems. Current scientific approaches to phenomena of irreversible change, such as complexity theory and the theory of self-organization, analyze the dynamics of natural and artificial systems by means of structural concepts whose application is not restricted by traditional distinctions between ontological levels or regions of our world. This is the reason why those research programs are more and more often called "structural sciences." Their importance for the explanation of historical processes can be exemplified by a young science called "artificial life," which is the analysis of evolutionary processes in the world of the living through use of computer simulations of the origin and development of systems that have general properties of organisms, such as self-reproduction, variation, and metabolism. This method is of utmost importance for biology because biologists are in a similar, if not even in a more difficult, position as Indo-European scholars and ethnologists: Not only do they have an incomplete record of the evolution of life on Earth, but they also know, at least at the moment, only one specimen of an evolution of life in our universe. Because we also cannot restart the evolution of life-as-we-know-it from its beginnings to test experimentally how a second run would differ from the first one, we are dependent on virtual evolutions of life-as-it-could-be in the computer. In the future it might be possible not only to understand the general principles of evolution of life but also to reconstruct some processes in the real evolution of life on Earth by computer simulations.

Stefan Artmann

See also Anthropology; Derrida, Jacques; Evolution, Organic; Information; Life, Origin of

Further Readings

Artmann, S. (2003). Artificial life as a structural science. *Philosophia naturalis, 40*, 183–205.

Corry, L. (2004). *Modern algebra and the rise of mathematical structures* (2nd rev. ed.). Boston: Birkhäuser.

Ladyman, J. (1998). What is structural realism? *Studies in History and Philosophy of Science, 29*, 409–424.

Lane, M. (Ed.). (1970). *Structuralism: A reader.* London: Jonathan Cape.

Robey, D. (Ed.). (1973). *Structuralism: An introduction.* Oxford, UK: Clarendon Press.

Sufism

The English term *Sufism* (whose Arabic equivalent is *Tasawwuf*) refers to the diverse body of religious beliefs and practices that encompass the mystical dimension of Islam. In spite of this remarkable range of doctrines and outward expressions—the product of variables in history, geography, philosophy, and psychology—Sufis have shared a common goal, namely, a direct experience of Allah (the Real, the Absolute), not normally pursued through a more exoteric Islamic orthopraxy. Some Muslim factions from medieval to modern times have criticized the Sufis' more esoteric approach, with its strong emphasis on the interior life; some Muslims have doubted that Sufism represents an orthodox expression of Islam. Nevertheless, Sufism has won adherents from all branches of Islam and appealed to people from all walks of life. Indeed, throughout its history, Sufis played a significant role in the spread of Islam across parts of Africa, the Mediterranean Basin and Middle East, and other parts of Asia. Some Sufi practices made their way into what scholars often call "folk Islam." In modern times, Sufism has also won adherents in the West, though some advocates and practitioners who claim Sufi affiliation fall outside the authentic Sufi tradition. With their emphasis on union with God (Absolute Being who transcends time) and various rituals that enhance this interior quest, Sufi teachers and writers have concentrated on ways to bridge the divine–human gap, an agenda that considers critical aspects of reality and eternity and identifies the relation between the spiritual and the temporal. To appreciate Sufism's spiritual creativity, one must understand something about its historical development, distinctive teachings, and important teachers and writers.

The designation *Sufi* probably derives from the Arabic word *suf* ("wool") and alludes to the clothing that some early Sufi ascetics wore as part of their spiritual quest. Sufism looks to the Prophet Muhammad and his successors as foundational mystical exemplars, who also sought close personal relations with the Divine. This emphasis on the interior life developed, in part, as a reaction to the materialism that accompanied Islam's rapid expansion and establishment of the Umayyad caliphate. Some scholars attribute Sufi ideals and practices to Neoplatonic, early Christian, Gnostic, and/or Buddhist and Hindu influences. Such contacts and exchanges of ideas undoubtedly took place, but the Qur'an itself supplied the main elements of Islam's mystical approach, claiming that Allah is both transcendent and immanent. The Sufi tradition places greater emphasis on God's nearness and stresses the possibility of an intimate relation between the human and the Divine. Indeed, pivotal Quranic passages emphasize God's proximity and desire for communion and worship, and the Sufi intellectuals and poets discussed this perspective in technical theological treatises and sublime poetic masterpieces, always interacting and (occasionally) conflicting with the law (*Sharia*) and the scholarly authority of Sunni and Shi'ite traditions (*ulema*). By the 12th century, Sufi orders, which eventually numbered in the hundreds, began to form around charismatic, beloved teachers (*shaykhs*) who advocated the standard practices of Islam and emphasized their own approaches to union with God. Emphasis on this chain of transmission (*silsilah*) remains a strong feature of Sufism's appeal.

The Sufi "way" or spiritual "path" (*Tariqah*) refers to affiliation with a particular religious order or fraternity and to their distinctive doctrinal and practical emphases. All Sufis have taken the Islamic mandate of *dhikr* (remembering God's name) very seriously, as they regard such recollection as the way to achieve union with the Divine. They perform some dhikr rituals (e.g., repetition of a Quranic phrase or one of the names of God) that promote remembrance in public, while other practices remain private. These communal, liturgical gatherings (Arabic *sama*) consist of music, recitation of poetry, and dance, including the famous "whirling dervishes" of the Mevlevis (*Mawlawi Tariqah*). In this instance, the dancing symbolizes the movements of various parts of the Creation and can induce ecstasy. By focusing on the Divine through such meditation, chanting, and dancing, Sufis hope to approach or see God by leaving the corruptible behind and relying on Divine love and grace.

The most important breakthrough that leads to union with the Real results from *fana* and *baqa*. The former refers to "annihilation" or "extinction," that is, a state of trance in which the mystic's earthly ties pass away through absorption into God. Although a Sufi communes and unites with the Divine, thereby restoring "unity of Being," the mystic returns to the world but always maintains union with God. Sufis use the term *baqa* to refer to the "residue" or "remainder" that maintains this special relationship with God but still allows the Sufi to maintain individuality. They often describe the interior journey to union and a return to separate identity as "intoxication" and "sobriety," respectively. The unity achieved by the worshipper removes the temporal from the eternal as the Sufi "puts on immortality" by experiencing a new manner of existence in God. Throughout their history, Sufis have held a variety of views as to what this union means, and different emphases stimulated debates about its nature and the relation between the Oneness and the mystic's individuality. Of course, many scholars have compared *fanaa* with the goals of Hinduism and Buddhism—*moksha* and *nirvana,* respectively.

A number of Sufi leaders (theologians and charismatic leaders) made significant contributions to this more mystical approach of Islam; orders (Tariqahs) or schools of thought developed around their thoughts and examples. For example, Rabia of Basra (d. 801), one of the most famous and earliest Sufi saints, achieved almost legendary status as a female poet. Her poetry emphasizes the importance of love for God above all other concerns. Junayd of Baghdad (d. 910), one of the greatest of all Sufi teachers, claimed firsthand knowledge of mystical "intoxication" but also communicated the principles of Islam while in a state of "sobriety." On the other hand, the most famous Sufi martyr, Al-Hallaj (d. 922), seemed to cross the line between orthodoxy and heresy because of his emphasis on union with God. After claiming that he had become Truth (*ana 'l-haqq*), his theological and political enemies in Baghdad accused him of blasphemy (saying that he had claimed Divinity for himself), and he was executed.

Al-Ghazali (d. 1111), a leading theologian in Baghdad, found that Sufism offered a perspective on Islam that surpassed reason alone. He combined the interior path of the Sufis with a careful observance of basic Islamic beliefs and practices. Ibn 'Arabi (d. 1240), remembered as a great Sufi mystic and saint, was another respected theologian and scholar of Islamic law. Many other theologians have reacted to the extensive body of prose works he left behind, with some accusing him of heresy because he emphasized the close relation between God's attributes and nature.

The famous Persian poet Rumi (d. 1273) fell under the influence of a mysterious wandering dervish, Shamsi Tabriz, and became the focal point of a fraternity of pupils, whose spiritual descendants have survived until today. This Turkish order, known as Mevlevis, named after their "master" Rumi, have achieved notoriety as the "whirling dervishes" because of their ceremonial dancing. In addition to this distinctive devotional technique, Rumi left behind major poetic works that emphasized love for the Divine Beloved, as Rumi sought to loosen himself from the earth's glue and become one with God.

Gerald L. Mattingly

See also Islam; Mysticism; Qur'an; Religions and Time

Further Readings

Arberry, A. J. (1950). *Sufism: An account of the mystics of Islam*. London: Allen & Unwin.

Awn, P. J. (2005). Sufism. In L. Jones (Ed.), *Encyclopedia of religion* (2nd ed., Vol. 13, pp. 8809–8825). New York: Thomson Gale.

Chittick, W. C. (1995). Sufism. In J. L. Esposito (Ed.), *The Oxford encyclopedia of the modern Islamic world* (Vol. 1, pp. 102–109). New York: Oxford University Press.

Knysh, A. D. (2000). *Islamic mysticism: A short history.* Leiden, Netherlands: Brill.

Lewisohn, L. (2006). Sufism. In D. M. Borchert (Ed.), *Encyclopedia of philosophy* (2nd ed., Vol. 9, pp. 300–314). New York: Thomson Gale.
Nasr, S. H. (Ed.). (1987, 1990). *Islamic spirituality* (Vols. 1 & 2). New York: Crossroad/Herder & Herder.
Schimmel, A. (1975). *Mystical dimensions of Islam.* Chapel Hill: University of North Carolina Press.
Sedgwick, M. J. (2000). *Sufism: The essentials.* Cairo, Egypt: American University of Cairo Press.
Trimingham, J. S. (1998). *The Sufi orders in Islam* (2nd ed.). New York: Oxford University Press.

Sun, Age of

The sun, the star of our solar system, is approximately 5 billion years old and midway through its stellar life cycle. In another 5 billion years, the sun will exhaust its supply of fuel and collapse in on itself. As with all stars, it will go through the stages of stellar evolution before finally cooling into a cold, dark mass, in which state it will remain for the rest of time.

The sun formed from a slowly spinning cloud of dust and gas. The cloud eventually began to collapse under gravitational force, compressing itself into a smaller form. As this happened, the cloud began to spin faster, as stated by the law of conservation of angular momentum. The cloud of dust, as it continued to compress, began to flatten, forming a bulge in the center. This bulge formed the sun, making up 99% of the mass in our solar system. Meanwhile, the flattened, outer areas of the cloud surrounding the sun amalgamated, forming the planets and spatial debris (the remaining 1% of our solar system) while maintaining their spin, or rotation, around the sun.

After the first 400 million years in its existence, the sun entered the stage known as the main sequence. The sun will spend the majority of its existence as part of the main sequence, where it is today. After its becoming a star on the main sequence, gases and debris around the sun formed planets, becoming our solar system, roughly 4.6 billion years ago.

In about 3 billion years from now, the change that continuously occurs in the sun's core will be seen on its surface. Its main fuel supply will be exhausted and will switch to a secondary fuel, burning brighter at hotter temperatures. This will be the beginning stages of the sun transforming into a red giant. As the sun transforms into a red giant, the sun's mass will decrease as it emits stronger solar winds.

In 5 billion years, the sun's temperature will rise to 100 million Kelvin (K). The sun will expand beyond the orbit of Mercury and Venus, and life on Earth would be rendered impossible. The outer shell enveloping the sun will be blown off, and the debris and gases will surround the collapsed sun, creating a planetary nebula. The sun, now a white dwarf, will be the size of Earth, and will continue to consume its fuel supply over several billion years. Once the fuel supply is exhausted, our sun will become a frigid, black mass known as a black dwarf.

Scientists have measured the age of the sun by observing seismic waves on the surface. These seismic waves carried information about the sun's core to the outer surface. By observing these oscillations, scientists can compare information about the sun with theories of stellar evolution and stellar structure to give an estimate of the sun's age. It was dated at roughly 4.5 billion years, which corresponds with the age of the solar system through other studies such as nucleocosmochronology.

Mat T. Wilson

See also Aurora Borealis; Eclipses; Light, Speed of; Nebular Hypothesis; Stars, Evolution of; Sunspots, Cycle of

Further Readings

Golub, L., & Pasachoff, J. M. (2001). *Nearest star: The surprising science of our sun.* Cambridge, MA: Harvard University Press.
Tayler, R. J. (1997). *The sun as a star.* Cambridge, UK: Cambridge University Press.

Sundials

A sundial is a device used to display time. The position of the sun in the sky produces a shadow on a flat surface corresponding to a specific time of day. Although only functional during daylight hours and in direct sunlight, sundials can be very accurate. The majority of sundials measure apparent solar time, time determined by the angle of the sun's shadow. As the earth rotates, causing the sun to appear to move across the sky from east to west, the sun's shadow, in the northern hemisphere, moves in a clockwise direction around the object. This phenomenon is responsible for the direction that the arms of clocks spin. The longitudinal position of the sundial must also be known to accurately measure solar time because the earth tilts on its axis. As the earth revolves around the sun, it tilts either the northern or southern hemisphere toward the sun at approximately 6-month intervals, giving the earth its seasons. Because of this tilt and the curved shape of the earth, the speed at which the shadow rotates around an object is not uniform. To solve this, the *gnomon*, the part of the sundial that casts the shadow, is aimed north. As a result, the hour marks on the sundial do not fluctuate throughout the year; this makes sundials remarkably accurate.

The earliest sundials appeared in ancient Egypt around 3500 BCE. These tall, narrow, four-sided stone monuments were known as obelisks. (The Washington Monument in Washington, D.C., is an example of a modern obelisk.) Its moving shadow allowed the Egyptians to determine the time of the day. In addition, the length of the shadow at midday allowed the Egyptians to roughly determine the seasonal date. The pyramidal top of the obelisk gave the end of its shadow a point. The position of this point at midday showed the degree of the axial tilt of the earth. Although the ancient Egyptians likely did not understand this concept, they did recognize the significance of the length and angle of the shadow from the obelisk. It is from the Egyptians that the modern divisions of the day into 12 hours, the hour into 60 minutes, and the minute into 60 seconds are traced.

Over time, advances in science and mathematics led to a plethora of variations of the sundial. The simplest sundial is the equatorial sundial, which consists of a disk with a bar through its center. The bar is positioned so that it is parallel with earth's axis of rotation, making the disk parallel with the earth's equatorial axis. This style of sundial indicates both the time of day, with the gnomon, and the date, with the nodus. The *nodus* is the tip of the gnomon. Another common type of sundial is the garden sundial. Although similar to the equatorial sundial, it instead uses a disk that is parallel to the ground. This allows the garden sundial to display time all year long. The gnomon is positioned so that it is parallel with the earth's axis of rotation and therefore will cast its shadow on the hour-marked flat disk. Many forms of sundials exist, including the vertical sundial, the analemmatic sundial, the portable diptych sundial invented during the Middle Ages, the ring sundial, and the equatorial bow sundial. Sundials have even entered the modern age with the digital sundial. The two types of digital sundials are the fiber-optic sundial and the fractal sundial. Using no electricity and having no moving parts, the digital sundial displays the time with numerals formed by sunlight hitting them. As technology continues to develop, the future for sundials seems bleak, but their impact on human history is remarkable. Their simplicity affords them the ability to display time from the surface of any planet in the universe where an angle exists between it and its sun. So even though it may seem that time has passed the sundial by, its universal application may be called on again in the future.

Michael F. Gengo

See also Hourglass; Time, Measurements of; Timepieces

Further Readings

Breasted, J. H. (1962). The beginnings of time-measurement and the origins of our calendar. In *Time and its mysteries.* New York: Collier Books.

Millikan, R. A. (1962). Time. In *Time and its mysteries.* New York: Collier Books.

Stewart, I. (1991, August). What in heaven is a digital sundial? *Scientific American*, *265*(2), 89–91.

Waugh, A. (1973). *Sundials: Their theory and construction.* New York: Dover.

Sunspots, Cycle of

Sunspots are areas of the sun that appear relatively dark when viewed by astronomers using special techniques. These regions are approximately 2500°F cooler than the rest of the photosphere, which gives them their darker appearance. Sunspots have strong magnetic activity that inhibits its normal convection, resulting in the lower surface temperatures. Seventy-five percent of sunspots appear in groupings of two or more. They range in size from the smallest, called pores, which are less than 100 miles in diameter, to those that are more than 100,000 miles in diameter.

Sunspots have a fairly regular cycle of activity. The German astronomer Heinrich Schwab identified a 10-year cycle of activity while studying sunspots during the years 1826 and 1843. Rudolf Wolf, a Swiss amateur astronomer, used old astronomical records going back as far as 1700 to establish a sunspot cycle database and, in 1948, refined the sunspot cycle to 11.2 years.

A period of maximum activity, in which more than 100 spots may be visible, is referred to as the sunspot maximum. The sunspot minimum, the period of lowest activity, can have few or no spots visible for weeks at a time. At the initiation of the sunspot cycle, sunspots are more frequent at higher latitudes, generally appearing at 40°. As the sunspot maximum approaches, usually within 4 years after the initiation of the cycle, the sunspots will have moved toward the equator with the majority lying at 15° latitude. Near 5° latitude they begin to fade out with new spots forming at the higher latitudes. This movement is referred to as Sporer's law. However, the activity cycles will vary. For example, sunspot records show a period of 70 years, beginning in 1647 when activity was minimal. This era was called the Maunder Minimum, after the British astronomer E. W. Maunder, who was credited with the discovery.

The earth regularly reverses its magnetic polarity, and this change induces changes in the sun's magnetic field. The reversal occurs every 11 years. Using this information, George Ellery Hale suggested that the sunspot cycle is actually 22 years and encompasses the two polar reversals of the earth's magnetic field. Horace W. Babcock proposed a qualitative model for the dynamics of the solar outer layers. The Babcock model explains the behavior described by Sporer's law, as well as other effects, as being due to magnetic fields that are manipulated by the sun's rotation. Thus, the sunspot cycle may actually be a 22-year cycle, which includes two sunspot maximums and two polarity flips of the earth.

Sunspots are correlated with various events. Intense magnetic activity, such as coronal loops and reconnection, occurs with high sunspot activity. Large sunspot groupings produce magnetically active regions from which most solar flares and coronal mass ejections originate. Magnetic storms and auroral displays are more frequent and intense during periods of maximum sunspot activity. The Maunder Minimum clearly corresponded with an era of low temperatures and longer-than-normal winters. Correlations to other events, including such things as cycles of the stock market and baseball statistics, although hypothesized, have not been demonstrated.

Beth Thomsett-Scott

See also Aurora Borealis; Galilei, Galileo; Light, Speed of; Observatories; Planetariums; Sun, Age of; Telescopes; Time, Sidereal

Further Readings

Garlick, M. A. (2004). *Astronomy: A visual guide*. Richmond Hill, ON, Canada: Firefly Books.

Washburn, M. (1981). *In the light of the sun*. New York: Harcourt Brace Jovanovich.

SYNCHRONICITY, GEOLOGICAL

Synchronicity is the state of being synchronous or simultaneous; of occurring, existing, or being formed at the same time. The term *synchronicity* is applied to the co-occurrence of any geologic features or events in time, which are called synchronous events, or to rock surfaces on which every point has the same geologic age. Rocks formed in the same part of geologic time, which have identical or nearly identical geologic ages, are called *synchronogenic*. Synchronicity of events in multiple cores across a wide area has been used, for example, to identify turbidites as seismically generated (and therefore present at the same time in different settings) and to distinguish them from other types of turbidites.

A stratigraphic surface in which every point has the same geologic age is called a *synchrone:* a zone representing equal time. Chronostratigraphy, a brand of stratigraphy that deals with the age of the geologic strata and their time relations, is the use of chronostratigraphic correlation to demonstrate correspondence in age and chronostratigraphic position between geologic units. Chronostratigraphic correlation uses *chronohorizons* (chronostratigraphic horizons). Each chronohorizon corresponds to a stratigraphic surface or interface that is everywhere of the same age, and theoretically it has no thickness. However, it commonly corresponds to a very thin and distinctive interval that is essentially isochronous over its whole geographic extent and thus constitutes an excellent time-reference or time-correlation horizon. Many biohorizons, bentonite beds, and coal beds are valuable horizons for chronostratigraphic correlation, although the most geographically widespread horizons are those marked by magnetic reversals or those caused by global events, such as the red-rusty layer with impact evidence that is commonly found at the Cretaceous-Tertiary (K-T) boundary. To explain the origin of this layer, most authors agree that a large meteorite impacted the Yucatan Peninsula in Mexico at the K-T boundary, triggering catastrophic mass extinctions, as well as an anomalous enrichment in the element iridium and other extraterrestrial impact evidence such as shocked quartz grains or nickel-rich spinels in the boundary sediments globally. The meteorite impact and the deposition of the layer with impact evidence are thus synchronous events that occurred in an almost instantaneous geological period of time, and the K-T boundary layer can be used as an excellent chronohorizon, allowing chronostratigraphical correlation globally. Therefore, this layer can be considered as an isochronous (synchronous) surface having everywhere the same age within a body of strata. Magnetic reversals are also recorded globally in the stratigraphic record, as the magnetic field has its origin in the melt core of the planet, and magnetic reversals have occurred throughout earth history.

Other methods of chronostratigraphic correlation are based on biostratigraphy, philogeny, biomagnethostratigraphy, ecobiostratigraphy, quantitative and statistical studies of fossil assemblages, chemostratigraphy, cyclostratigraphy, and event-stratigraphy. Biostratigraphical correlation compares the stratigraphic distribution of taxa in different areas. Integrated biostratigraphy is one of the main tools of bio- and geochronology; it consists of the biostratigraphical study of different fossil groups, which provide different biozonations that can be combined allowing correlation of different biostratigraphical scales, increased resolution of the scales, as well as recognizing the diachronism of some biostratigraphical boundaries.

Two of the main problems in correlation are the paleoenvironmental and paleoecological effects, such as the local appearance or disappearance of species, or the Lazarus effect (discontinuous biostratigraphical distribution of a species caused by its local disappearance in a paleogeographic area, due to sudden paleoenvironmental changes, and by its reappearance in a more recent period of time). To minimize the paleoecological problems of biostratigraphical analyses, correlation methods based on the analysis of phylogeny have been developed. Biomagnethostratigraphical methods combine the reference isochrons of the magnetic reversals, which offer synchronous horizons, with the necessary correlation provided by the biostratigraphical scales. Ecobiostratigraphical methods organize or arrange the strata into units (ecozones) based on paleoecological and paleoenvironmental data; each ecozone is characterized by purely ecological assemblages that lived together in the same area. Ecozones allow high-resolution correlation, although their validity is local. Quantitative and statistical analyses of fossil assemblages improve the resolution of the biostratigraphical correlation, minimizing the subjectivity of identification of single species and of the data processing, and providing quantitative stages that allow correlation. Chemostratigraphical methods include stable isotope analyses, which allow scientists to identify global climatic, paleoceanographic, and eustatic events. These global events can be correlated and integrated into chronostratigraphical scales. Cyclostratigraphical methods are based on the variations of Earth's orbital parameters, which are reflected in the sedimentological, geochemical, and paleontological cycles, and therefore in the paleoclimatic and paleoceanographic record in the deep sea. These orbital cycles are expressed in terms of eccentricity, obliquity, and precession cycles, called Milankovitch cycles, which trigger cyclic climatic variations. Cyclostratigraphers try to identify and correlate cyclic variations in lithology, sedimentology, isotopes, paleomagnetics, mineralogy, or in the paleontological record. Finally, event-stratigraphers aim to establish a succession of global events (eustatic, cosmic, paleobiological, paleoclimatic, paleoceanographic events) in the geological record. Event-stratigraphy plays a main role in stratigraphical correlation, as events can be globally recognized and correlated in the stratigraphical record, where they are commonly recorded as chronohorizons. From a chronostratigraphical point of view, paleobiological events are some of the most important global events because they are usually unrepeatable and respond to global causes, therefore marking isochronous horizons. In this sense, mass extinction bioevents are probably the most isochronous events worldwide. The catastrophic mass extinctions recorded at the K-T boundary, together with other sedimentological, mineralogical, and isotopical evidence, mark one of the most synchronous chronohorizons and best documented global events in the earth's history, which can be easily correlated worldwide.

Synchronous boundaries delimit chronostratigraphic units, or bodies of rocks defined to serve as the material reference for all rocks formed during the same span of time. Each chronostratigraphic unit serves as a basis for defining the specific interval of time, or geochronologic unit, represented by the referent. Chronostratigraphic units are (in order of decreasing rank): eonothem, erathem, system, series, and stage. A formal chronostratigraphic unit of unspecified rank is a chronozone, which represents a body of rocks formed anywhere during the time span of a chron, which is the temporal equivalent of a chronozone. A chronozone corresponds to an isochronous unit, and it can be based on biostratigraphic units (biochronozones), lithostratigraphic units (lithochronozones), or magnetopolarity units (polarity chronozones).

Laia Alegret

See also Chronostratigraphy; Geological Column; Geology; Hutton, James; K-T Boundary; Lyell, Charles; Sedimentation; Steno, Nicolaus

Further Readings

Gradstein, F. M., Ogg, J. G., & Smith, A. G. (2004). *A geologic time scale 2004.* Cambridge, UK: Cambridge University Press.

McCrone, A. W. (1913). Sedimentation. In R. W. Fairbridge & J. Bougeois (Eds.), *The encyclopedia of sedimentology.* Stroudsburg, PA: Dowden, Hutchinson & Ross.

Synge, John Lighton (1897–1995)

J. L. Synge, an Irish physicist and mathematician, made important contributions to science, especially with respect to the theory of relativity. During his career he worked in various universities and scientific institutions in Canada, the United States, and Ireland. In the period 1948–1972 he was professor in the School of Theoretical Physics at the Institute for Advanced Studies in Dublin, which would grow, thanks to him, into one of the most prominent centers for the study of relativistic physics.

Synge was the author of numerous books and papers marked by a noteworthy originality in thinking. For example, he was the first physicist to seriously consider the interior of black holes. In 1950, he showed that the surrounding of the central singularity in the Schwarzschild solution (the centrally symmetric gravitational field with a "point" source) represents two separated regions, the black hole and the white hole, the first of them denoting the end and the second denoting the beginning of the time for all objects occurring there. Synge's books *Relativity: The Special Theory* (1956) and *Relativity: The General Theory* (1960) are counted among the best monographs on the subject in question. They are distinguished by their original approach, philosophical depth, and brilliant literary style.

In his books and articles, Synge presented an important contribution to the understanding of the meaning of time and its measurement. According to him, chronometry presents an essential part of the theory of relativity. The determination of the geometry of spacetime consists in the measurement of lengths of sections of world-lines performed by ideal clocks and in the measurement of intervals between the emission and the reception of light signals, which allows the synchronization of clocks in different places and the measurement of spatial distances. In this way, ideal clocks and light signals are sufficient for the determination of the metrics of spacetime and there is no need for measuring rods. Synge believed that many physical and geometric notions (e.g., mutual orthogonality of spacetime vectors) could be expressed chronometrically.

It was Synge's special distinction to have devised and popularized the use of spacetime diagrams (in, e.g., his *Relativity of Time*), which helped to make the explanation of many relativistic subjects more vivid and understandable.

He also showed the effectiveness of the use of the world function in relativistic calculations. This function assigns to every pair of events half the square of the length of the section of geodesic joining of these events. Thus, in the case of causally connected events, the world function is equal to the half of the square of the maximal time elapsed between them.

Jan Novotný

See also Black Holes; Chronometry; Relativity, General Theory of; Relativity, Special Theory of; Spacetime, Curvature of; Time, Measurements of; Time, Relativity of; White Holes

Further Readings

Florides, P. S. (1996). Obituary. Professor John Lighton Synge, FRS. *Irish Mathematics Society Bulletin, 37*, 3–6.

Synge, J. L. (1956). *Relativity: The special theory.* Amsterdam: North Holland.

Synge, J. L. (1960). *Relativity: The general theory.* Amsterdam: North Holland.

T

Tantalus

Tantalus is a character in ancient Greek mythology who is condemned to an eternity of being tempted without a way of gaining satisfaction. His name (meaning "most wretched") and myth transcend time by serving as the etymology for the English word *tantalizing,* meaning to tease or torment someone by tempting without actually rewarding him or her.

The specific details of the myth of Tantalus are disputed; however, scholars and ancient writers agree on the gist of the myth. Tantalus, perhaps the son of Zeus or Tmolus, was the king of Sipylos in Lydia, or of Argos, or of Corinth (location disputed) who had three sons: Pelops, Niobe, and Broteas. Because he was an intimate friend of Zeus, the gods allowed him to attend the Olympian banquets of ambrosia and nectar. However, one day Tantalus stole some of the divine food and shared it with mortals. He also tried to share the secrets of the gods with mortals. Then, before the gods discovered his wrongdoing, Tantalus committed a worse crime. Having called the gods to a banquet, he found himself in the dilemma of not having enough food. To rectify the problem, Tantalus killed his son Pelops, cut him into pieces, placed them in a stew, and served it to the gods. Another version of the myth says that Tantalus committed this act to test the omniscience of the gods. This action incurred the wrath of the gods, who would not eat the stew, except for Demeter who, being distraught by the loss of her daughter Persephone, ate his shoulder. The gods punished Tantalus by bringing his kingdom to ruin and assigning an ill fate to his family. They also restored the body of Pelops and gave him an ivory shoulder to replace the section that Demeter ate. Zeus killed Tantalus for his ghastly crime.

After his death, Zeus condemned Tantalus to Tartarus, a gloomy dungeon and place of torment within Hades. Here, he stood in a lake with a depth varying from waist to chin deep while hanging from the limb of a tree that teemed with perfect fruit. Any time he tried to lean over to drink the water, the water receded leaving only black mud. If he did manage to get water in his hands, it ran through his fingers before he could get it in his mouth. When he reached for fruit from the tree, a gust of wind blew the fruit so that it moved just out of his reach. Thus, he was forever "tantalized" by the water and fruit while condemned to hunger and thirst. Moreover, a large stone loomed over the tree, threatening to crush the tree and Tantalus. This constant threat was punishment for another crime, one of stealing a gold dog, which he swore by Zeus that he had not stolen.

The myth of Tantalus demonstrates that ancient Greeks abhorred human sacrifice and cannibalism, practices that once had been acceptable. Also, it teaches against deceit, especially when it is carried out against the gods.

In addition to being the source of the English world *tantalizing,* Tantalus is the namesake for the atomic element called tantalum, a gray metal that is nonreactive to acids and is used in electronics and surgical instruments. Also, American astronomer

Charles Kowal discovered an asteroid in 1975 that he named Tantalus. During World War II, the U.S. Navy had a landing-craft repair ship named the *USS Tantalus*.

Terry W. Eddinger

See also Eternal Recurrence; Mythology; Sisyphus, Myth of

Further Readings

Buxton, R. (2004). *The complete world of Greek mythology.* London: Thames and Hudson.
Graves, R. (1960). *The Greek myths* (Vol. 2.). New York: Penguin Books.

Taoism (Daoism)

Taoism is an indigenous religious and philosophical tradition of China. It has no single founder, no holy scriptures, and no single key message. Central to it is the belief in the existence of a mysterious power (Tao), unchanging in itself, but source of perpetual creation and decay in the world.

The term *Tao* (or *Dao* as the Chinese character can also be transliterated) translates as "way" or "path," but can also be used to describe a school or teaching. It corresponds to the Chinese words *Daojia* ("Dao family" or "school of the Dao") and *Daojiao* ("teachings of the Dao"). Both terms came into use during the Han dynasty (206 BCE–220 CE) to describe the philosophical and religious traditions of early Taoism, respectively.

History of Taoism

The beginnings of Taoism lie in Chinese antiquity, when this stream of thought first took shape. It was an oral tradition at first, transmitted and developed by masters, but not yet recognized as a religion of its own. The first written works, ascribed to Laozi and Zhuangzi, emerged around 400 BCE. But it was not until the 2nd century BCE that historians listed Taoism (*Daojia*) as one of six religious schools in China.

The first successful attempt at organizing a Taoist religious system started in 142 CE, when Laozi appeared to the hermit Zhang Daoling to announce the end of the world, which would be followed by an age of great peace (*taiping*). Zhang founded a movement known as the "way of the Celestial Masters" (*Tianshi Dao*) that successfully established a "Celestial Master state" during the later Han dynasty. The rulers of the Wei dynasty (220–280 CE) broke up the state, thus dispersing Celestial Master followers throughout China and setting a foundation for the movement's enduring strength. More individualistic Shangqing Taoism ("way of highest clarity") and Buddhist-influenced Lingbao Taoism were other important movements of this period.

During the Tang dynasty (618–906 CE) Taoist philosophy assumed a leading role. The imperial family venerated Laozi as one of their ancestors, ordering his veneration by imperial decree. Taoists attempted to attain immortality or longevity through the ingestion of herbs and minerals (external alchemy). These studies led to the death of numerous followers and to the invention of gunpowder as a side effect.

Taoist philosophical tradition also provided the foundation for the reception of Buddhism in China. Buddhists' ideas such as the concept of karma, rebirth, and hell were accepted into Taoism, and the Buddhist sect of Chan (in Japanese, Zen) shows strong Taoist influences.

As Confucianism grew stronger during the Five Dynasties (907–960) and Song periods (960–1279), the different religions interacted increasingly. Taoists tried to harmonize the "three teachings" (Taoism, Buddhism, and Confucianism), most prominently in the Taoist Quanzhen school ("complete perfection school") founded by Wang Chongyang (1113–1170). Taoists created monasteries and started to adopt monastic ways of life as displayed by Buddhist monks.

Instead of external alchemy, Quanzhen Taoists turned to internal alchemy in their pursuit of longevity. Through internal cultivation, the followers tried to harmonize themselves with the Tao, thus postponing or even avoiding death.

The relationship between Taoism and the Chinese state remained strong during the Five Dynasties and Song periods. Throughout the empire, a tightly knit network of temples was created; they served religious as well as political needs. The temples' Taoist masters did not confine themselves to religious studies and teachings but also served as government officials.

Favorable treatment of Taoism by the state ended during the reign of the Mongol emperor Kublai Khan (who reigned from 1260 to 1294). Buddhism was used to weaken the Taoist position of power. When the Taoists were defeated in a number of debates by the Buddhists in 1281, numerous Taoist texts were burned. Laozi's classic was the only work to be exempted.

After the expulsion of the Mongols and the establishment of the Ming dynasty (1368–1644) the Taoists regained a position of power. The Taoist canon (*Daozang*) was compiled under the patronage of the Yongle Emperor between 1408 and 1445. Almost 1,500 texts of great importance to Taoist faith were chosen, including texts on medicine and astronomy, as well as works that displayed Buddhist or Confucian influences.

The decline of the Ming Dynasty also marked a decline in fortune for Taoism and its followers. The Manchurian tribes that founded the Qing Dynasty (1644–1911) were influenced by conservative Confucians. The Celestial Masters, who had held a position of power at the Dragon and Tiger Mountain, lost their influence at the court. Taoism had exerted remarkable influence over the Chinese elite until this time. Now its impact on popular religious culture became more noticeable.

In the 1780s Christian missionaries arrived in China and started to spread their faith among the people. Around 1847 Hong Xiuquan, who claimed to be Jesus's younger brother, founded a Christian millenarian sect. In 1851 he proclaimed himself king of the Kingdom of Great Peace (Taiping). Government officials now were tested on the Bible instead of the ancient Chinese classics, and Hong's army destroyed Taoist temples as well as texts. But even after the defeat of the Taiping army, the decline of Taoism continued. By the beginning of the 20th century, almost all copies of the Daozang had been lost or destroyed.

The Great Proletarian Cultural Revolution (1966–1976) under Chairman Mao Zedong constituted another attempt at the destruction of Taoism. Temples were destroyed, and Taoist masters were killed or reeducated. In 1979 the overt suppression of Taoism ended. Many temples have been rebuilt since, and Taoist traditions can be openly practiced once more.

Concept of Time in Taoism

Taoism saw many changes and developments in its philosophical as well as religious traditions over the centuries. What was considered to be essential to Taoism at one point in history might have been contradicted squarely only a few years later. The classics by Laozi and Zhuangzi as well as works by the Celestial Masters were not even included in the first Taoist canon. Taoists have never agreed on any common teaching. But they share basic concepts in their understanding of the universe and of all life within.

Like many Asian religions, Taoism conceives the material world as ever-changing. Creation and decline follow cyclical or rhythmic patterns. Beneath this surface, there exists a timeless reality, the source of all being and nonbeing. This concept of reality is also reflected in the Taoist cosmology, which distinguishes two aspects of the Tao. The apparent aspect can be recognized in the order of the universe. The world and all plants and creatures emerge from the timeless Tao only to return to it when their time has come. The second aspect is often called the Absolute Tao. It is the source of all creation, the underlying essence immanent in the whole universe.

All people should try to adapt to the apparent aspect of the Tao, to create harmony and find fulfillment. To live in harmony with the world and be with the Tao, people have to accept the course of events around them, taking effortless action (*wu wei*) only. Wu wei literally translates to "without action" but implies the ability to decide when to act and the insight not to hinder natural developments.

Common people as well as the rulers should try to live in harmony with the Tao, but the failure to do so has by far more severe repercussions for emperors than for commoners. In ancient China the first emperor in each dynasty was believed to be chosen by heaven. Morally upright rulers are issued a mandate of heaven (*tian ming*) to direct the course of earthly events. As the dynasty's history grows longer, later emperors enjoy the luxuries available, starting to neglect their duties. Their government turns corrupt, and the empire sinks into chaos. Floods, diseases, and other calamities devastate the country. Heaven then withdraws its mandate again, thus ending the dynasty. Positive signs would then declare the new choice of heaven, appearing in the vicinity of a morally upright person chosen to be the new ruler.

Underlying this belief in a direct linkage between emperors' deeds or characters and natural disasters is the acceptance of certain features of yin and yang cosmology into Taoism. According to this worldview, the world consists of one cosmic energy called *qi*. This energy manifests itself in the two phases of yin and yang. They are not mutually exclusive but constantly move into each other. The stages of this continuous development are associated with five different elements (wood, fire, earth, metal, water), by which names they have come to be known. As yin and yang move into each other, the elements change into one another in cycles perceived as destructive or productive.

Taoism adopted this cosmology and formulated the basic law of impulse and response, according to which all things in the world are closely connected with each other. Not only do different events occurring in one place over the centuries influence each other, but simultaneous events in different places are also closely interrelated. Therefore, if one manages to adjust to the flow of reality and becomes one with the Tao, because of the close linkage between all living creatures and natural phenomena, this will bring forth greater harmony in the whole world. A corrupt government thus echoes on the natural world, causing earthquakes, floods, and other natural disasters. There is no other way to bring harmony to the world than to aim at inner cultivation. If evil is fought, new evil arises out of the force applied. And even peaceful actions strengthen it again, solely through the attention paid to evil.

Many cultures have brought forth millenarian movements, which believed in a better world to come. Most of them display a lineal understanding of time, waiting for or passionately working toward the realization of a future paradiselike state that is believed to continue until the end of times.

Although there were some millenarian Taoist movements, the belief in the nearing end of this world and the coming of a better one always accepted the possibility of a cyclical decline of the future world and a repeated renewal. The onset of this awaited world would be marked by the decline of the current dynasty. It would be another new beginning with every possibility of decline once the time for change came. Not even the millenarian sects believed in the existence of a paradiselike world that would last forever.

Just as the endurance of a dynasty is decided by Heaven, the human life span also is allotted to every person by celestial forces. Heaven watches over the people, judging them by their righteous or evil deeds. According to these observations, the length of each life is measured. The number of gods Taoists believe in and their powers and characters vary greatly according to the teachings of each sect. But most picture the spirit world as a heavenly version of the Chinese imperial bureaucracy. So the decision to end a life can be viewed as a bureaucratic act, death is its enactment.

Although Taoists of different schools accepted a variety of perspectives on death over the centuries, many tried to prolong life and avoid death. Generally the ancient Chinese philosophers are believed to have accepted death as the natural end to each person's life cycle. But even the famous work of Zhuangzi mentions immortals. Later religious Taoists often devoted their activities to practices promising longevity or even immortality.

The immortals (*xian*) mentioned in the Zhuangzi are spirit beings equipped with magical powers, such as the power to fly, who dwell on mountains in the Eastern Sea. But already in the Han period they were believed to live in a distant paradise (Kunlun, a high mountain in Central Asia, or Penglai, a paradise located in the Eastern Sea), which cannot be accessed by mortals without great difficulties. One way to attain the state of an immortal was to ingest a magical substance from the isle of Penglai. Some emperors sent ambassadors to the east to obtain this substance—thus Japan was discovered. Other Taoists studied alchemy or experimented with meditations, ecstasies, breathing exercises, and other longevity practices.

In Han cosmology the human body was believed to consist of two kinds of qi. Whereas primordial qi connects the body to the Dao, the earthly qi is connected to physical everyday survival. Sickness, healing, longevity, immortality, and death are different stages on a continuum of waning or abundant qi. If all primordial qi is lost, death occurs. But if all qi can be transformed into primordial qi through the practice of longevity techniques, the qi turns to spirit. Then even the end of the body has no impact on the spirit of the deceased, which then will reside in paradise.

Just as the body consists of two kinds of qi, in Chinese antiquity every person was believed to be made up of a spirit soul (*hun*) and a material soul (*po*). The souls of celestial and earthly origin join before birth and separate again when death occurs. For the first years after death, they are in contact with the living world. While the material soul needs proper care to prevent it from returning as a ghost, the spiritual part resides in the ancestral heaven and is worshipped at the family's home. Ultimately both souls will merge back into their original elements. The cycle of creation and decline, of birth and death, goes on. From this background it becomes obvious that the immortality Taoists strive for is not physical immortality but a transformation and strengthening of the spirit soul. The immortal still lives in a secluded part of this world. It is not removed to a completely different dimension but has reached a higher level of existence.

Little importance has been given to ordinary time in Taoism. This becomes obvious in the lack of chronicles and historical events recorded by Taoists. Laozi's work, the *Tao Te Ching,* is exemplary in this respect, as it contains no dates and mentions neither proper names nor anything else to connect it with any historic time or place. This pervading ahistoric attitude is also mirrored in other texts of the Taoist canon. Beneath all worldly events, all creation and decline, lies a timeless reality that remains unchanged. The goal of Taoists is to transcend the flow of these worldly events and to become one with the underlying timelessness. Dimension such as time and space have to be left behind to enter eternity.

Marianne Sydow

See also Cosmogony; Cosmology, Cyclic; Religions and Time; Time, Cyclical; Universe, Contracting or Expanding

Further Readings

Fagg, L. W. (2003). *The becoming of time: Integrating physical and religious time.* Durham, NC: Duke University Press.

Huang, C-C., & Zuercher, E. (1995). *Time and space in Chinese culture.* Boston: Brill.

Kirkland, R. (2004). *Taoism—The enduring tradition.* New York: Routledge.

Kohn, L. (2004). *Daoism and Chinese culture.* Cambridge, MA: Three Pines Press.

Taylor, Frederick W. (1856–1915)

In the field of organization studies, the American engineer Frederick W. Taylor is recognized as a pioneer in scientific management, a set of techniques for analyzing how any given job is performed, devising a more efficient way of performing it, and then training workers in the use of the new, improved method. Taylor's own academic training as an industrial engineer and his practical experience in factories as a machinist, foreman, and plant manager enabled him to develop a methodology that, over the course of a century, has not only directly influenced the way in which most manufacturing operations are performed but also helped to shape the very background of modern thinking about how organized human activities are to be managed and, consequently, about the way in which most people view time.

The cornerstone of Taylor's career was the commonsense recognition that in the performance of any task, certain methods will prove more efficient than others. The worker who, each time after assembling a machine component, must pause to fetch another set of parts from a bin on the other side of the factory will of course produce fewer units per day than will a worker who can simply extend a hand and pick the next set of parts from a moving conveyor belt. The worker who must stop to change the bit in his drill press twice to machine a single workpiece correctly will be less productive than if the component itself were redesigned to eliminate the need to change drill bits.

In serving industrial clients, Taylor and his associates, armed with notebooks and stopwatches, would carefully observe each routine step in a manufacturing process, analyze the task down to its smallest details, and discuss the job with the workers who actually performed it. Next, they would reengineer the task so as to eliminate all wasted time and motion and, finally, assist managers in retraining workers to use the new, more efficient method. In later years, Taylor would use the new technology of motion picture cameras to record on film the way industrial jobs were being performed, the better to analyze each movement and identify instances of wasted time and motion.

Such exercise of managerial control over the smallest aspects of workers' performance has been strongly criticized for removing the chief source of satisfaction from workers' lives, placing workplace knowledge in the hands of management and thereby alienating laborers from their own work. The effect, critics say, has been to devalue the acquisition and practice of traditional craft skills and to replace these with mind-numbing and inhumanly repetitive tasks. Also noted by critics is that from the capitalist's standpoint, an unskilled labor pool has the advantage of being quickly trained, cheaper to employ, and, if necessary, easier to replace. Thus, Taylor's methods would seem ideally suited to the purposes of modern capitalism, in which the desire to maximize profit requires the exercise of strict economic rationalism. As the German economist and sociologist Max Weber (1864–1920), a contemporary of Taylor, noted, the Protestant work ethic historically has understood the striving for profit as divinely ordained and the accumulation of wealth as an end in itself. To waste time is thus to be sinful, whereas the rationalizing of time, together with its increasingly precise quantification, serves as the instrument for increased productivity and the ever greater accumulation of capital.

It would be unfair, of course, to hold Taylor responsible for any abuses to which his methodology has been put since his demise. If he was worldly enough not to see the interests of workers and factory owners as identical, neither did he view them, like Karl Marx, as by definition antagonistic. In his 1911 book *Principles of Scientific Management,* he fully acknowledges the value of workers' capacities for insight and creativity in designing better ways to accomplish the desired end of greater productivity, whose benefits would in turn accrue—albeit with perhaps less than perfect equity—to workers, managers, capitalists, and the marketplace alike.

Sanford Robinson

See also Marx, Karl; Time Management; Weber, Max

Further Readings

Clegg, S., Kornberger, M., & Pitsis, T. (2005). *Managing and organizations.* Thousand Oaks, CA: Sage.

Taylor, F. W. (1967). *Principles of scientific management.* New York: Harper. (Original work published 1911)

Weber, M. (2000). *The Protestant ethic and the spirit of capitalism.* Los Angeles: Roxbury. (Original work published 1904)

Technology Assessment

Technology assessment (TA) is the systematic study of the conditions and societal and environmental consequences of predominantly new technologies. One should, of course, keep in mind that there are several very different approaches in the field of TA, ranging from the classic TA model embodied by the Office of Technology Assessment (OTA, U.S. Senate, 1972), which warns against technology-related risks and subsequent political blunders in the form of an early-warning system, to the Constructive Technology Assessment (CTA, Netherlands Organization for Technology Assessment), which attempts to accompany, describe, and assess the technology development process. In contrast to ethics, however, TA is more descriptive than evaluative.

The Temporal Structure of Technology Assessment

TA has a temporal structure. It is future oriented in that it develops various scenarios of a possible future state of the world depending on the implementation or nonimplementation of new technologies. This future orientation has its roots in the experiences of previous decades. The realization of the horrifically destructive potential of atomic energy as seen in World War II by the dropping of two atomic bombs on Hiroshima and Nagasaki and the still imminent danger of the annihilation of the entire planet as the result of a nuclear war has made most people aware of the fact that technical knowledge is more than just theoretical. Technical knowledge put into practice is ambivalent. Like the atomic bomb, it can be used to wipe out hundreds of thousands of people in one fell swoop. Likewise, even if it is used for peaceful purposes, it can get out of control as shown by the example of the Chernobyl nuclear power plant meltdown.

On the other hand, this technology could help reduce carbon dioxide emissions and thereby slow down global warming, which is itself largely the result of technological developments. These technological developments have improved our daily lives in many ways: For example, new technologies in modern medicine have, on the one hand, significantly increased our life expectancy but on the other are also partly responsible for the dramatic growth of the world population. When we consider the modernization of agriculture, we see a similar tension: On the one hand, it has helped prevent countless famines, but on the other, it has caused serious damage to the environment. Looking at modern information technology, the same can be said: It has made daily life much easier, but not without new demands and dangers, for example, to the private sphere. The rapid improvements in transportation from the car to the airplane are no different, because together with the World Wide Web they have given rise to globalization as we know it today with its opportunities and risks.

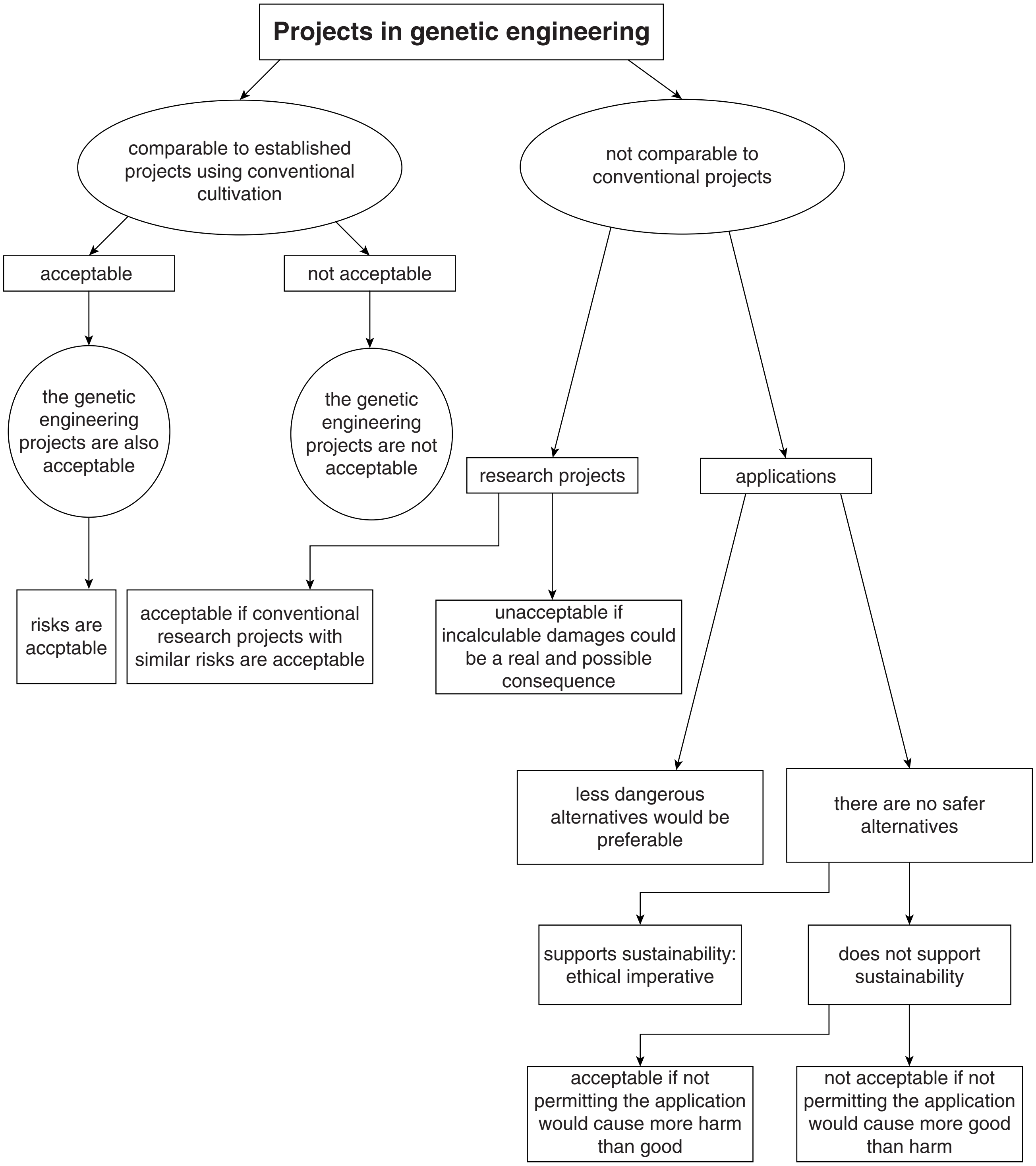
Against this very background, philosophers such as Martin Heidegger have already warned against an ambiguous understanding of technology and have called for a new attitude toward technological possibilities. TA has made it its task to consider prospective technological possibilities as a transdisciplinary collaboration. These considerations are directed at prospective consequences: TA does not want to put all technological possibilities under general suspicion. Instead, it is about trying to make sure that the future is still worth living in for the projected 9 billion people who will inhabit it in 2050 and that global catastrophes that could result from the misuse of technology are avoided.

Important Principles, Their Problematic Nature, and Decision Trees

The so-called precautionary principle and the principle of sustainability are key principles for every future-oriented TA. The philosopher Hans Jonas, inspired by discussions in the Club of Rome in the 1970s as well as by elements of the German legal tradition (*Vorsorgeprinzip*), formulated the central idea of the precautionary principle, with its imperative responsibility. His core belief is that the future of humankind is fundamentally threatened by current technological possibilities. This threat can be successfully faced only when technologies that could cause major and irreversible damage are not realized. The precautionary principle should function here as a kind of maxim principle: Conduct yourself in such a way that the conceivably worst consequences of a possible technology are minimized. It could, of course, turn out that we have to completely do without a given technology. In accordance with Jonas, environmentalists, for example, have called for an end to nuclear power and also a partial ban on genetic engineering in the agriculture sector, or at least a very controlled and cautious implementation of this technology.

With all of this in mind, the fundamental issue at the heart of every TA addresses the fact that because we cannot predict the future and, therefore, have to make decisions bound together with risk or uncertainty, the position of the precautionary principle as a maxim-principle cannot hold water in practice. Theoretically, the speculative risk of any technology, which could in the long run lead to catastrophe, is conceivable. Furthermore, Jonas overlooks a very essential defect of overcautiousness. A cautious person could also inhibit the development and implementation of technologies that could be very useful for humankind. For this reason, we have to work with hypothetical risks and, therefore, develop a decision tree. Using the decision tree, we can decide whether technologies that are in line with the precautionary principle and function under the principle of sustainability—meaning that they at the very least provide ecological, economic, or social advantages without putting one at risk for the sake of the others—should be developed.

The example of genetic intervention in agriculture can serve to illustrate this point: Are there conventional cultivation methods comparable to the new possibilities of genetic intervention? Are we dealing with research purposes or with an application? In the case of the former, how much do we know about the extent of potential damage? In the case of the latter, we need to ask whether harmless alternatives are preferable with regard to application. A decision tree for a TA in the case of green genetic engineering could look like this:



Political and Temporal Dimensions of TA

Recently, the precautionary principle and the principle of sustainability have gained considerable significance on a national and international level (1987 Montreal Protocol; the numerous international treaties and declarations reflected in the 1992 Rio Declaration on Environment and Development, which was signed at the United Nations Conference for Environment and Development; and the Kyoto Protocol). As long as individual countries can ignore international agreements without the threat of sanctions, the political influence based on findings from TA will remain limited. For this reason, one could say that the egoism of some groups of people living today threatens the future of coming generations. When someone ignores the fundamentally temporal structure, namely the consequences for the future caused by current technologies, he or she violates the aforementioned principles. So technology assessment is grounded in a serious concern because of the temporal structure of our changing the world.

Nikolaus J. Knoepffler

See also DNA; Ethics; Globalization; Heidegger, Martin; Morality; Values and Time

Further Readings

Jonas, H. (Ed.). (1985). *The imperative of responsibility: In search of an ethics for the technological age.* Chicago: University of Chicago Press.

Kunzmann, P. (2006). Technikethik. In N. Knoepffler et al. (Eds.), *Einführung in die Angewandte Ethik* (pp. 249–266). Freiburg, Germany: Alber.

Sunstein, C. R. (2005). *Laws of fear: Beyond the precautionary principle.* New York: Cambridge University Press.

Teilhard de Chardin, Pierre (1881–1955)

Since his student years in the Auvergne region of central France, Pierre Teilhard de Chardin was devoted to both science and religion; he specialized in geology and paleontology. After teaching the natural sciences in Egypt, he studied theology in England where he later became a Jesuit priest. As a result of reading Henri Bergson's *Creative Evolution* (1907), Teilhard embraced the sweeping temporal perspective of organic evolution. After becoming ensnared in the infamous Piltdown man fossil discovery (this specimen was later proven to be a hoax), he returned to France to become a stretcher bearer during World War I. He had several mystical experiences in the trenches and would later have a mystical experience of planetary scope while doing research in the Ordos Desert of Inner Mongolia. His ongoing dedication to historical geology more and more convinced him of the necessity to take organic evolution seriously in both his scientific and religious reflections.

Teilhard sought to reconcile evolutionary science with Christian theology. But, as a consequence of now introducing evolution into his own lectures and writings, he was silenced by the Roman Catholic Church. Briefly, his scientific view of time was not compatible with the religious conception of creation. However, with fortunate irony, his Jesuit superiors exiled him to China where he had to limit his academic activities to geological investigations and scientific publications.

While a geologist at the Cenozoic Laboratory of the Peking Union Medical College, Teilhard became involved with the excavations in the western hills near the village of Zhoukoudian. At this site, he participated in the discovery of the fossil remains of Peking man (*Sinanthropus pekinensis*), a hominid form that existed in China about 350,000 years ago. This evidence strengthened Teilhard's commitment to organic evolution in general and human evolution in particular. His numerous articles increased his growing reputation as a prominent geopaleontologist. Likewise, Teilhard became very concerned about the far-reaching consequences of human evolution for understanding and appreciating the true place of our own species within cosmic time and earth history.

Now having ample time to rigorously reflect on his unique experiences as a Jesuit scientist, Teilhard decided to write a book that would present a comprehensive view of the meaning and purpose of evolving humankind within this unfolding universe; he had expanded his vision to encompass the remote past and the distant future. The result was his major systematic work, *The Phenomenon of Man* (first published in 1955 in a French edition). It offered a philosophical worldview that boldly attempted to reconcile science and theology within an evolutionary framework. The Vatican and the Jesuit order were so alarmed by his unorthodox ideas about God, evil, free will, original sin, and personal immortality that Teilhard's book was not published until after his death.

Taking the vastness of evolutionary time seriously, Teilhard saw this universe as a cosmogenesis; creation was not a single event that happened in the past but is an ongoing process of creativity in terms of ever-increasing complexity and ever-centralizing consciousness. He maintained that the unity of this universe is ultimately grounded in units of spiritual energy that have been becoming more and more concentrated throughout cosmic history. Actually, his cosmology is essentially a planetology grounded in a spiraling sequence of global spheres.

Focusing on the finite and spherical earth, Teilhard interpreted our dynamic planet in terms of emergent layers of matter, life, and thought: Geogenesis had produced the geosphere, biogenesis has created the biosphere, and noogenesis is now forming the noosphere. He saw converging and involuting evolution resulting in a future layer of collective consciousness. Guided by a meta-Christianity, this human noosphere will eventually detach itself from the earth, transcend space and time, and become united with a personal God at the Omega point. This end-goal of planetary evolution is a mystical union of human and divine spirit.

Teilhard's bold vision had taken seriously the new perspective that emerged as a result of evolutionary time. Going beyond outmoded ideas and traditional beliefs, and despite his personal conflicts with myopic thinkers, Teilhard's optimistic concern for the survival and fulfillment of humankind still remains an inspiration to enlightened individuals in science, philosophy, and theology.

H. James Birx

See also Becoming and Being; Bergson, Henri; Christianity; Evolution, Organic; God and Time; God as Creator; Mysticism; Teleology; Whitehead, Alfred North

Further Readings

Aczel, A. D. (2007). *The Jesuit and the skull: Teilhard de Chardin, evolution, and the search for Peking man.* New York: Riverhead Books.

Birx, H. J. (1991). *Interpreting evolution: Darwin & Teilhard de Chardin.* Amherst, NY: Prometheus.

King, U. (1996). *Spirit of fire: The life and vision of Teilhard de Chardin.* Maryknoll, NY: Orbis Books.

Teilhard de Chardin, P. (1975). *The phenomenon of man* (2nd ed.) (B. Wall, Trans.). New York: HarperCollins.

Teleology

In philosophy, teleology is the attempt to comprehend and explain the universe in terms of ends or final causes. Teleology is based on the proposition that the universe has design and purpose, that its effects are in some manner deliberate, and that in order to understand it completely, one must take into consideration final causes. Teleologists admit that physical causes may be deterministic and agree that the object of scientific research is to discover universal laws of phenomena can be rationally explained when adequate causes are assigned to them—if the conditions of their occurrence are known. Teleology states that this determinism reveals a "direction" in nature; that is, the universe is headed toward a goal or completion. Thus, teleologists feel there is little question regarding whether the cosmos has a final cause; rather, the question should be whether humanity has the ability to see it.

Teleology emphasizes the concept that a final cause or purpose is inherent in all humanity. There are two types of such causes—intrinsic and extrinsic finality. *Extrinsic finality* consists of someone realizing a purpose outside him- or herself, primarily for the welfare of others. *Intrinsic finality* consists of someone realizing that a purpose exists within him- or herself by means of a natural tendency directed toward the perfection of its own nature. For instance, an atom obeys quantum principles that did not evolve but nonetheless are "givens." In addition, one's life is intended to play out in a specific manner, so that one's existence protects itself from death and disease.

When extrinsic finality is overemphasized, a likelihood exists that anthropic principles might be attributed to supernatural intervention or superstition; for example, God was angry at the world so he sent a flood to destroy all terrestrial life. Intrinsic finality provides the basis for the teleological argument that God exists and for the intelligent design debate regarding how human life evolved. Teleologists feel that relying solely on Darwin's principle of natural selection is faulty, because evolution focuses exclusively on the immediate causes and mechanisms of events, never looking for a rationale that explains the synthesis of different facts. Hence, if a clock is dismantled, one discovers nothing but springs, pivots, levers, and gears; on the other hand, if the mechanism causing the watch to work has been correctly formulated, could one not say that the clock was designed for the purpose of keeping time? Moreover, many philosophers state that biology is profoundly concerned with questions concerning causation and how constraint functions have affected the structure of life—Darwin's theories did not upset this thesis. For instance, when Darwin saw the various beaks of Galapagos finches, he thought that due to the area's scarcity of birds, one could surmise that a single species had been modified for different ends. This is a most un-Darwinian statement.

Historically, teleology has been associated with Aristotle, while the rationale of teleology was studied by Immanuel Kant and, again, made central to speculative philosophy by G. W. F. Hegel and the various neo-Hegelian schools, including that of Karl Marx. In Hegel's opinion, individual human consciousness, as it attempts to reach for autonomy and freedom, has little choice but to deal with an obvious fact—humanity's collective identities (the multiplicity of worldviews, ethnic, cultural, and national identities) that separate members of the human race both now and in the past and that always have and always will set different groups of people against each other in violent conflict. Hegel speculated that the "totality" of mutually antagonistic worldviews and life forms in history was best seen as being driven toward the completion of goals. In other words, a time would come at an end point in history when the "objective contradiction" of "subject" and "object" would eventually change into a form of life that has left all violent conflict behind.

Many individuals think that there is only one teleology, but there are many. Following are brief descriptions of each:

- *Philosophical Teleology.* Aristotle felt that the explanation of, or justification for, something was to be found not only in its functions or possible use but also in its final goal; that is, the reason for which the phenomenon was created. Every object in the universe (from subatomic particles to stars) is composed of some type of substance, has an efficient and final cause, and so on. Both Platonic and Neoplatonic theories of creation fit this kind of teleology.
- *Theistic (Dualistic) Teleology.* Monotheistic creationism (Judaism, Christianity, Islam, etc.), which posits the belief in an existence of an all-powerful God that created the world, represents dualistic teleology. According to Christian beliefs, teleology symbolizes a simple argument regarding the Creator's existence—that is, the order and efficiency found in nature is not accidental. If world design indicates order, then by necessity God exists, as there is no way of explaining how human beings (as well as other complex species) could have arisen by chance alone.
- *Natural Teleology.* Science, overall, dismisses teleology, though some scientists are believers in "natural teleology." It has two parts:

  In *bounded* natural teleology, a particular state of being is reached, regardless of the environment.

  In *unbounded* design or contingent teleology, the end of something is unknown; rather, it is the consequence of making a selection when several alternatives are on hand.
- *Process Teleology.* This belief states that the directional development of creation arose neither by chance nor because a beneficent God loved the universe but from the snail-like progress of evolution.

Cary Stacy Smith and Li-Ching Hung

See also Aristotle; Darwin, Charles; Design, Intelligent; Eternal Recurrence; Hegel, Georg Wilhelm Friedrich; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Marx, Karl; Nietzsche, Friedrich; Progress; Teilhard de Chardin, Pierre; Time, Arrow of; Time, Linear; Universe, Evolving

Further Readings

Fitzpatrick, W. (2000). *Teleology and the norms of nature.* New York: Routledge.

Johnson, M. R. (2006). *Aristotle on teleology.* New York: Oxford University Press.

Lenoir, T. (1989). *The strategy of life: Teleology and mechanics in nineteenth century German biology.* Chicago: University of Chicago Press.

McFarland, P. (1971). *Kant's concept of teleology.* New York: Columbia University Press.

Teleportation

The term *teleportation,* widely used in science fiction literature, may be broadly defined as the act of transferring an object from one location to another without the actual movement of the object through the space separating the two locations. This implies, therefore, that not only is the space required for travel eliminated from the process, but also the time of travel is eliminated, or nearly so. Several theories have been put forward to explain how such movement of persons or inanimate objects would take place. These include movement by psychic means, or through manipulation of the spacetime vacuum or geometry, or even through parallel universes. At present, the reality of teleportation is somewhat different from the definition given above, which arose partly out of decades of science fiction lore. This entry explains why this is so, followed by an outline of the general steps currently being employed in teleportation schemes in the scientific world, along with some of the actual experiments performed in the past decade and a half.

The steps required to facilitate the teleportation of an object may be generalized as follows: The exact composition of the original object is identified, after which the object at that location is disassembled. The details of the object's makeup are then transmitted to the final location and an exact copy of the original object is constructed. Despite what has been portrayed in current and past works of science fiction, teleportation of macroscopic objects is not yet part of the foreseeable future. Teleporting a human, for example, would first involve analyzing approximately 10^{28} atoms that are found within the human body. Storing the information obtained would require vast amounts of space. At present (and even in the foreseeable future), there is no computer technology available to handle that capacity of data, while even with the best possible technology, accessing and transmitting this information would take millions of centuries. In 1982, another problem arose from Dennis Dieks, William Kent Wootters, and Wojciech H. Zurek's no-cloning theorem, which, as its name implies, states that it is impossible to make an exact copy of any quantum particle. The major reason, however, for the impracticability of macroscopic teleportation is the violation of one of the key principles of quantum physics, Heisenberg's uncertainty principle. This principle states that it is impossible to know simultaneously all the properties of a quantum particle. The problem that arises is that in replicating the original object, all the information about each particle in the object must be known. The uncertainty principle makes this impossible.

While teleportation of macroscopic objects is not yet a reality in the scientific world, in 1993 a team of six international scientists (Charles Bennett, Gilles Brassard, Claude Crépeau, Richard Jozsa, Asher Peres, and William Wootters) proposed a mechanism for another type of teleportation (quantum teleportation) that obeyed all the laws of physics. Quantum teleportation may be defined as the transfer of quantum information from one particle to another some distance away; the state of a system, and not the system itself, is transferred. It uses a feature of quantum mechanics known as *entanglement,* along with the transmission of classical information, to transfer an unknown quantum state to some arbitrary location. Entanglement, also known as the Einstein-Podolsky-Rosen effect, is a property exhibited by quantum systems that are correlated with each other in some way, even though they may be separated spatially. States that are entangled are often regarded as one quantum system because of the strong correlations that exist between them. Entanglement is essential to any teleportation protocol, because it allows the state being transferred to remain unknown; there is, therefore, no violation of the Heisenberg uncertainty principle.

The following gives a general idea of the protocol employed in quantum teleportation. Alice, the sender, wishes to teleport the state of a quantum system, particle *c,* to Bob, the receiver. (Alice and Bob are not real people; they are systems that transmit and receive the state teleported.) Because this state is unknown to Alice, the Heisenberg uncertainty principle is obeyed. To facilitate the teleportation scheme, Alice and Bob require two channels, one for the entangled particles *a* and *b* and one for the transmission of the necessary classical information. In this way, Alice can divide the full information that describes the state of particle *c* into a purely classical part and a purely quantum part, and then send them to Bob via the two channels. They begin by sharing a maximally entangled state (this state is one of four possible states known as Bell states) comprising particles *a* and *b;* Alice is given particle *a* and Bob is given particle *b*. This can be done at any time before the teleportation process. For them to remain in a coherent entangled state, however, they must be kept isolated from their environments. At this stage, there is no classical or quantum correlation between particle *c* and the entangled particles *a* and *b*. Particle *c* and the entangled pair therefore exist in what is called a pure product state.

Alice initiates the interaction of particles *a* and *c* and performs a complete measurement on the two particles in the Bell basis. This results in one of four Bell-state possibilities that are equally probable. Because *a* and *b* are initially entangled, there is an immediate change in particle *b* that is based on the interaction of *c* with *a*. Particle *b* is now in one of four possible pure states that depends on the outcome of Alice's particles and is related to the original state of particle *c*. Alice then performs measurements on the joint properties of her pair of particles and transmits this information via the classical channel to Bob. The act of measuring destroys the quantum state of particle *c* such that particle *c*, as it originally was, no longer exists. This is expected, because the no-cloning theorem must be obeyed. Based on the classical information sent to Bob, he is then able to perform the necessary operations on *b* to transform it into an accurate replica of *c*.

Quantum teleportation requires the transfer of both quantum and classical information. However, unlike the transfer of quantum information in the teleportation process, classical information transfer is not instantaneous, because any such communication that is faster than the speed of light would violate the laws of relativity. Therefore, quantum teleportation cannot take place instantaneously.

Theoretically, quantum teleportation allows for the perfect transfer of the state of a system from one location to the next so that the final state of Bob's particle is an exact copy of the state teleported by Alice. However, in reality, imperfections in the initially entangled pair (in Alice's measurements and in Bob's transformations) tend to limit the fidelity of the teleportation process.

Experiments and Future Prospects

Several teleportation experiments have been performed since 1993 and, with exciting breakthroughs over the years, have come a long way from the teleportation of the polarization state of a photon in 1997. These experiments include the teleportation of squeezed states of light (1998), the teleportation of a laser beam (2002), the teleportation of photons over relatively long distances (2003–2004), the teleportation of states of trapped calcium and beryllium ions (2004), and the teleportation of a laser beam, in which information was embedded, into a cloud of atoms (2006).

Quantum teleportation is considered to be one of the most promising applications of quantum entanglement. However, there has also been the proposal of another teleportation protocol (2007) that does not require sharing an entangled state between Alice and Bob. Instead, an optical field is used to transmit the quantum state of the "object" from the sender to the receiver, at which point an exact replica of the object is constructed. Proponents of this scheme claim that it will result in greater teleportation fidelity, because the extent to which particles *a* and *b* (as mentioned before) are entangled is a limiting factor in the teleportation process. They also claim that their method will result in an increase in the distances achieved by current teleportation techniques, because light is used as the medium of transfer.

Quantum teleportation has become an important mechanism in the transfer of quantum information from one place to the next. It is a key resource in long-distance quantum communications and in quantum computation protocols. It is thought to be the quantum wiring for futuristic ultrafast computers and for the execution of operations at points, such as quantum logic gates, that are separated spatially. In nearly a decade and a half, quantum teleportation has developed from a theoretical proposition to experimental reality. With the progression of time, there have been gradual increases in the sizes and in the complexities of "objects" being teleported and in the distances over which teleportation occurs.

How far quantum teleportation or other such schemes will advance the conventional concept of teleportation remains to be seen.

Andrea Tricia Joseph

See also Quantum Mechanics; Space Travel; Time Travel

Further Readings

Clegg, B. (2006). *The god effect: Quantum entanglement, science's strangest phenomenon.* New York: St. Martin's Press.

Darling, D. (2005). *Teleportation: The impossible leap.* Hoboken, NJ: Wiley.
Kaku, M. (2008). *Physics of the impossible: A scientific exploration into the world of phasers, force fields, teleportation, and time travel.* New York: Doubleday.
Paul, H. (2004). *Introduction to quantum optics: From light quanta to quantum teleportation.* Cambridge, UK: Cambridge University Press.

Telescopes

Throughout human history, humankind has longed to reach beyond its physical limits. With the rise of the empirical sciences, people learned to question and expand the range of their senses with the help of optical tools, and telescopes have literally changed our worldview. Telescopes have served in the discovery and cartography of our planet; they have revolutionized the arts of navigation and war; they have taught us about the lifetime of a star, how galaxies looked at an early time of their existence, and how celestial bodies can be applied as chronometers. More than once, telescopes have thus redefined the borderline between science and religion, as illustrated, for example, by the well-known dispute between Galileo and the church.

In order to understand how much telescopes have contributed to our knowledge, it is necessary to follow their advancement through time. The use of telescopes has both benefited from and pushed ahead the development of state-of-the-art optical technology, materials, and fabrication techniques. Leading astronomers were often known as the manufacturers of the best lenses and mirrors of their times. The rise of the telescope was paralleled by the flourishing of optical theory, which gave insight into imaging principles, diffraction phenomena, and aberration, and which is connected to the work of great physicists like Christiaan Huygens, Isaac Newton, Joseph von Fraunhofer, and Ernst Abbe. Today, cutting-edge telescopes contain mirrors 8 meters in diameter and are located on top of isolated mountains, such as the Very Large Telescope in Chile, or even sent into space, like the Hubble Space Telescope. Those instruments collect light from objects of ever increasing distance—light emitted billions of years ago—and hence allow us to literally observe the evolution of the universe through time.

Precursors and Early Optics

The history of the telescope starts long before people began to assemble lenses and mirrors into tubes. Ancient civilizations, including those of the Babylonians, Egyptians, Chinese, and Assyrians carried out systematic observations of the night sky and created their own worldviews as a mixture of physical law, religious belief, and myth. At that time, lenseless observation tubes were used for aiming at particular regions of interest, helping to follow the motion of celestial bodies and to screen off disturbing light sources. The oldest known lenses, presumably used as magnifying glasses and for lighting fires, are dated back to the Assyrians of the 7th century BCE.

A first heyday of astronomy can be located during the Greek era. In his *Optica,* the father of geometry, Euclid (c. 365–c. 300 BCE), was the first to describe the linelike propagation of light. The Greeks (e.g., Hipparchus of Nicaea, 140 BCE) composed star maps of surprising accuracy. Also, the first detailed studies on the properties of reflection and refraction were performed by the Alexandrians Heron and Ptolemy during the 1st and 2nd centuries CE. Ptolemy is known best for his geocentric worldview, which placed the earth at the center of the universe and all other sidereal bodies on circular orbits around it.

During medieval times, much of the precious scientific knowledge of the Greeks was lost again—and the earth regained its disk shape. We can thank the Arabs, who themselves were skilled astronomers with their own observatories and precise star catalogues, that Ptolemy's work was preserved in translation.

In the 13th and 14th centuries, the dissemination of magnifying glasses and spectacles in England and northern Italy were the stimulus for many new experiments. Among others, Leonardo da Vinci mentions in his diaries the idea of "glasses for the eye to see the moon large." It was not until the 17th century that the first real telescopes were constructed; still, even without them, a number of major astronomical works was to announce the arrival of a new scientific era. In 1543, Copernicus released his book *Concerning the Revolution of Celestial Bodies,* which turned out to be a revolution itself, though of the (hitherto very anthropocentric) sciences. The Copernican system could avoid many of the Ptolemaic difficulties, especially the counterintuitive *epicycles,* by identifying the sun as the center of the universe and the earth as just one of the planets orbiting around it. But still not all discrepancies between the calculated and the observed planetary motion were resolved, and it was another 65 years until Kepler, using the outstanding observation records of his former teacher Tycho Brahe, found the solution to be elliptical orbits.

Revolutions: The First Tube Telescopes

The construction of the first telescope is commonly ascribed to the Dutchman Hans Lippershey, who applied for a patent for his invention in 1608. This request was rejected because in the following months, other people with similar instruments and claims appeared. One of the first and best-known people to use telescopes for astronomical observations was Galileo Galilei, who had heard rumors about the Dutch invention in 1609 and immediately started to build his own telescopes. The early Galilean telescopes consisted of a 60-centimeter tube holding a convex objective and a concave ocular (see sidebar). Among the numerous important discoveries by Galileo are the moon's craters, sun spots, the discrimination of the hazy Milky Way into single stars, and the first observation of Jupiter's inner satellites. Encouraged by his findings, he became a great defender of the Copernican worldview: If objects were found to revolve around other planets, then clearly the earth is not the center of everything. His strong stance was answered by the church with an inquisitional trial and verdict.

When Johannes Kepler, arguably the most advanced optician of his time, heard about Galileo's discoveries, he started an excited correspondence with the Italian. Although he had never envisaged a telescope, he published groundbreaking works on the fundamental principles of optics and telescopy, including the geometrical relations of imaging ("paraxial approximation") and the principles of the pinhole camera. He also suggested new types of telescopes (see sidebar) and multiple lens combinations to reduce aberration errors.

Following the Stars: Navigation and Timekeeping

Beyond their purely astronomical use, telescopes always had an earthbound purpose for geodesy and navigation. Especially with the rise of the seafaring age, the reliable determination of one's own coordinates from the stars became imperative. While the latitude could be derived easily by measuring the altitude of the pole star, the longitude required following the position of the stars through time. Because no precise chronometers were available, the relatively swift motion of the moon on the background of the stars was commonly used as a clock, which presupposed very accurate star maps. With the improvements of telescopy at hand, the Royal Observatory in Greenwich was founded under the auspices of Isaac Newton in 1675 to create exact star catalogues for sea navigation.

The different purposes of telescopes resulted in two standard mounting setups, which correspond to different astronomical coordinate systems. The first is the *altazimuth style,* which can be rotated about a vertical axis and a horizontal axis to determine the spherical angular coordinates *altitude* and *azimuth* of the celestial sphere. The second—the *equatorial* or *parallactic setup*—aligns one rotation axis along the earth's rotation axis and thus features observation planes parallel to the equator and thus parallel to the movement of the stars along the sky. In this setup, the tracking of a star is reduced to one rotational degree of freedom, which simplifies matters from an observer's point of view.

The exploration of celestial motions with telescopes also improved human timekeeping abilities. With the sun as the natural basis, the periodic rotation of the earth defines our "solar time," which has led to the demarcation of longitudinal time zones. The arbitrary zero point is set at the longitude of the Royal Observatory at Greenwich, England, the basis for Greenwich Mean Time (GMT). However, due to the ellipticity of earth's orbit around the sun and its nonuniform velocity, the day length varies periodically over the year on a minute scale. Furthermore, as the earth continues on its orbit, the rotation between two consecutive noons (i.e., the sun passing an observer's meridian) is larger than 360°. These effects can be neglected in everyday life; however, for astronomical purposes, more advanced time measures are required.

Most straightforwardly, the fixed position of the stars can be used as a frame of reference for the earth's rotation, defining the *sidereal time.* A related, more complex system is that of a *universal time,* which is calculated from a formula based on the varying position of the earth relative to the sun, as well as the precession of the earth's polar axis. Another measure, *heliocentric time,* takes into account also the difference in propagation time of sunlight to the different positions of the earth throughout the year. Finally, it was discovered that the earth's rotation is intrinsically irregular, and hence a linear time flow cannot in principle be defined accurately with respect to the earth's motion. Therefore, a flexible time measure—the *ephemeris* or *dynamical time*—was introduced, which links the time units to their use in gravitation theory and updates them regularly according to the measured position of the sun, the planets, and the moons.

A Race Toward the Infinite: Refractors Versus Reflectors

As people tried to increase the power of telescopes, they soon encountered physical limits. In order to minimize spherical aberration (see sidebar), the magnification had to be realized by means of lenses with small curvatures. This fact promoted the use of lenses with great focal lengths and diameters, leading to bizarre-looking constructions. Around 1650, Hevelius of Danzig built several lengthy wooden telescopes, the largest of which measured an incredible 45 meters in length.

Christiaan Huygens, father of the wave theory of light and the pendulum clock, also constructed large telescopes, ranging from 3.6 to 38 meters in length, with which he made the first observation of Saturn's rings and its moons.

Newton was one of the first to conceive of correction setups for dispersive effects by combining different optical materials (predecessors of the later *achromates*). However, Newton believed that these chromatic aberration errors (see pp. 1234–1235) were an insurmountable obstacle of refractors, and in 1671 he turned his efforts to a new type of telescope: the reflector. The idea to use mirrors as the primary optical element had been around almost as long as telescopes, but it was thought that mirrors were in principle inferior to the perfection of lenses—a grave mistake. By 1720, the quality of mirrors could compete with good refractors. Also, different layouts for reflectors had appeared, and the *Newton* and *Cassegrain* styles (see pp. 1234–1235) took a leading role. Both are still used in most telescopes today.

The final breakthrough of reflector telescopy is owed to Wilhelm Herschel, a German musician who engaged in astronomy after settling to England in 1757. Herschel's aptitude allowed him to increase the size of his parabolic mirrors gradually to 1.2 meters, bringing him fame and royal honors. He discovered Uranus, some of Saturn's satellites, and a huge number of double stars and star clusters; he resolved details of the Great Orion Nebula and thousands of stars of the Milky Way, whereupon he even correctly guessed the Milky Way's flat profile and our position in it.

Another milestone was a huge and rather unmanageable reflector finished in 1845 by the wealthy Earl of Rosse; it was named "Leviathan" for its gigantic appearance. The 4-ton mirror with a 1.8-meter diameter and a focal length of 16 meters superseded all previous endeavors and revealed, among other things, the shape of spiral galaxies. However, by the time of "Leviathan's" operation, large refractors also had become available and in fact fashionable due to a series of discoveries. In particular, Neptune had been spotted in 1846 with the excellent Fraunhofer 24-centimeter refractor, after its existence was famously mathematically predicted from Uranus's nonideal orbit. The second half of the 19th century can be considered the pinnacle of refractor telescopy; it yielded such great instruments as the Russian Pulkova telescopes, the Potsdam double refractor, and the outstanding 1-meter Yerkes refractor conceived by George Ellery Hale.

This success was made possible by the work of one man—Joseph Fraunhofer, the father of optical technology and quality control. In addition to other scientific abilities (e.g., he worked on far-field diffraction and the analysis of the solar spectrum), Fraunhofer possessed an unrivaled practical knowledge about geometrical-optical properties and glass chemistry. He created accurate charts of the refractive indices of optical materials and suggested how to combine them as achromates. Also, he replaced the *Pröbel* ("trial and error") technique of lens making with reproducible manufacturing procedures. Before his early death in 1826, he constructed a couple of measurement telescopes on equatorial mounting of unprecedented precision; almost-identical copies were made by his successors for many decades. A comparable comprehensive expertise in optical technology was not achieved until 1900, when the lucky constellation of the optician Ernst Abbe, the glass chemist Otto Schott, and the industrialist Carl Zeiss coincided in Jena, Germany.

Nonetheless, by the turn of the 20th century, refractors finally gave way to a new generation of reflectors, which held advantages in terms of color correction, aperture size, mounting stability, and a short tube length. Large-scale reflectors were erected around the world, such as the Crossley reflector at Lick observatory (1904) and the Zeiss telescopes at Hamburg-Bergedorf (1911), Berlin-Babelsberg (1915), and Uccle (1932). The leading telescopes of that time were the 1.5-meter (1908) and the 2.5-meter (1917) reflectors at Mount Wilson observatory, initiated by G. E. Hale. Mount Wilson was home to several decades of cutting-edge observations, including Hubble's discovery of the redshift of distant galaxies.

Modern Telescopy

The modern history of telescopy starts in 1948 with the Mount Palomar observatory in California, which was conceived of by G. E. Hale and later named after him. The observatory is located a height of 1,700 meters and houses a 5-meter Cassegrain reflector. The 15-ton mirror with its 19-ton bearing was encompassed by a clever "horseshoe" mounting, which was actually designed for much smaller amateur telescopes. With the optical power available, astronomical interest was finally shifted to extrasolar research. In 1962, quasi-stellar radio sources, the so-called quasars, were discovered. Other major results achieved at Mount Palomar include the typology of Cepheid stars, which led to a revision of the Hubble constant and hence to a recalculation of interstellar distances, resulting in an increase of the estimated size of the universe by factor of two to three

The Russian telescope at Mount Pastukhov (1976), with its 6-meter mirror, was the first to use altazimuth mounting again. The return to this "simpler" setup was made possible by the recent development of computer steering. The telescope itself is gigantic: It measures 42 meters from the bottom angular bearing to an observer cabin at the top of the tube, and it comprises about 700 tons of movable parts, which are steered with arc-second accuracy. The telescope achieved its full performance only after the installation of a new main mirror.

A significant contribution to telescopy was made by Bernhard Schmidt, who developed a method to use spherical mirrors instead of parabolic ones. Spherical mirrors can be fabricated much more easily but are subject to inadmissible distortions when used as focusing optics, even though the difference between a paraboloid and a sphere for a 5-meter mirror is less than 0.14 millimeter. Schmidt removed certain errors (*coma* and *astigmatism*) by inserting a limiting aperture at the center of the sphere, and he took care of the *spherical aberration* (see sidebar) by augmenting the

The 2-meter Zeiss reflector of the Thüringer Landessternwarte "Karl Schwarzschild" in Jena-Tautenburg, Germany. This is the world's largest Schmidt telescope. Schmidt telescopes use a spherical mirror in combination with a correction lens.

Source: Image courtesy of the Thüringer Landessternwarte (www.tls-tautenburg.de).

Astronaut Story Musgrave anchored to the end of the remote manipulator arm. Musgrave is preparing to be elevated to the top of the towering Hubble Space Telescope to install protective covers on magnetometers. Astronaut Jeffrey Hoffman assisted Musgrave with the final servicing tasks (February 1993).

Source: NASA Marshall Space Flight Center (NASA-MSFC).

aperture with a large, weakly deformed correction lens with a tricky profile. The enormous advantage of a Schmidt telescope is its increased field of view, which makes a real scanning of the sky feasible. This makes the Schmidt telescope a good complement to the high-resolution telescopes. The world's largest Schmidt system (2 meters in diameter) is located at the Karl Schwarzschild Observatory in Jena-Tautenburg, Germany; the next largest is the 1.8-meter "Big Schmidt" at Mount Palomar.

In addition to the mere technical limitations of building ever-larger mirrors for telescopes, the cost to fabricate large scopes rises by a factor roughly proportional to the third power of the diameter. Addressing both of these issues, two new techniques were tried at the construction of the Mount Hopkins observatory in Arizona in 1979. The telescope conjoins the foci of six separate Cassegrain reflectors, realizing the first multiple mirror telescope (MMT). Together, the six 1.8-meter mirrors gathered as much light as a 4.5-meter mirror, but construction costs were less than one third of what they would have been for a telescope with a 4.5-meter mirror. For several reasons, the groundbreaking MMT was later replaced by a telescope with a single 6.5-meter mirror, which was the first to be manufactured with the so-called spin-casting technique: During the cooling process, the hot glass liquid is rotated constantly such that the centrifugal force naturally pushes it into the correct parabolic form. Spin casting is used today for the most advanced telescope mirrors and has helped to reduce the fabrication time, the material effort, and hence the costs of large mirrors.

Since the 1960s, telescopes for nonvisible wavelengths have also been playing an increasing role in the study of astronomy. For example radiotelescopes (suitable for wavelengths of a few meters) have made many important scientific contributions based on the radio signals from quasars, pulsars, and nebulae and are greatly involved in the SETI (Search for Extraterrestrial Intelligence) program. The largest single-reflector radiotelescope—which has become popular through the movie *Golden Eye*—is located at Arecibo, Puerto Rico. It has a diameter of 305 meters, and it contains about 39,000 aluminum tiles. Today, radiotelescopes are often linked together using interferometry, the coherent superposition of waves from different reflectors, to form so-called arrays. From such an artificially increased detection surface, much higher resolutions can be obtained.

An outstanding observatory site is located on top of the 4,200-meter Mauna Kea, Hawai'i where clouds and atmospheric turbulence rarely disturb the view. Mauna Kea has been the home of many telescopes, including the 3.6-meter Canada-French-Hawai'i (CFH) reflector (1977), the 3.8-meter United Kingdom Infrared Telescope (UKIRT, 1979), the James Clerk Maxwell Telescope (JCMT, 1987) with its 15-meter reflector for the submillimeter wavelength regime, and two Keck telescopes (1992, 1996). The Keck telescopes were funded by a $140 million grant from the Keck foundation and were involved in the discovery of the oldest known galaxy. Each carries a 10-meter mosaic mirror composed of 36 hexagonal tiles, each of which is adjustable separately with 4 nanometers accuracy, somewhat reminiscent of the MMT technique.

In the early 1990s, the European Southern Observatory (ESO) erected a large telescope facility on the extremely remote Mount Cerro Paranal

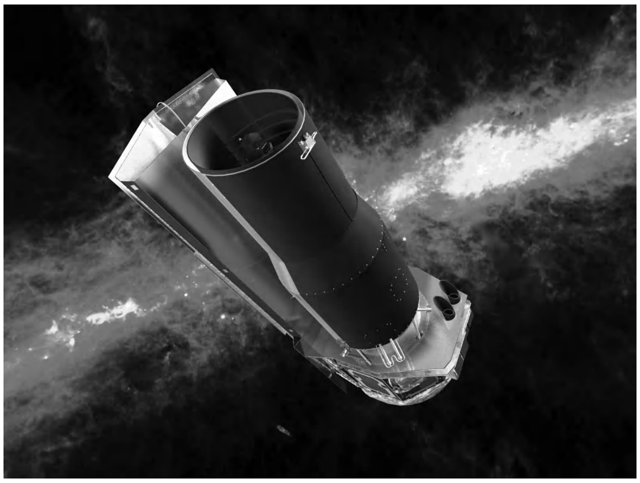
(2,635 meters) in the dry Chilean Atacama Desert. Paranal is home to the famous Very Large Telescope (VLT), which consists of four identical 8.2-meter reflectors that can be combined interferometrically to work as one ultralarge telescope. The four telescopes feature adaptive optical elements in the collimated part of the beam that activate several hundred times per second to counteract the negative effect of atmospheric turbulence on what the observer sees. The adaptive optic is adjusted with the help of an artificial, laser-produced "star" in the upper atmosphere. The VLT was the first telescope to spot an exoplanet.

Ambitious new telescopes—such as the Japanese Subaru telescope on Mauna Kea with its 8.2-meter mirror (1999) and the Large Binocular Telescope (LBT) with a doublet of two 8.4-meter mirrors on Mount Graham, Arizona (2004)—have marked the way into the next millennium, and exciting results can be expected from them.

Space-Based Telescopy

The idea of circumventing the limitations that the atmosphere puts on viewing the heavens by placing a telescope in an orbit around the earth dates back to German rocket science in the 1920s and was greatly promoted by Lyman Spitzer in 1946, after the first successful launching of small spectrometers into the upper atmosphere. The rapid development of space technology and satellites soon proved the unique quality of pictures recorded from space, so that finally in 1977 a project for a space-based observatory was started. The completion of the project took NASA 13 years (in part it was delayed by the *Challenger* catastrophe in 1986), and the projected cost of $450 million tripled to $1.5 billion, part of which was funded by the European Space Agency (ESA). The observatory was named the Hubble Space Telescope (HST) in honor of Edwin Hubble, and it features a 2.4-meter main mirror and several cameras and detectors to identify waves from UV to IR wavelength. It orbits the earth 600 kilometers above the ground at a speed of 27,000 kilometers per hour, taking 1.5 hours for one revolution.

When the HST was first launched in 1990, it turned out that the main mirror was deficient—it deviated from the ideal parabolic shape by



NASA's Spitzer Space Telescope (artist rendering). The Spitzer space telescope was launched into space by a Delta rocket from Cape Canaveral, Florida, on August 25, 2003. During its mission, Spitzer will obtain images and spectra by detecting the infrared energy, or heat, radiated by objects in space between wavelengths of 3 and 180 microns (1 micron is one millionth of a meter). Most of this infrared radiation is blocked by the earth's atmosphere and cannot be observed from the ground.

Source: NASA/JPL-Caltech.

2 micrometers, resulting in major distortions of the image. In an amazing space repair mission, the defect was corrected. The HST data are transmitted via a network of satellites, and many thousands of papers have been published on HST data. By now, the HST has delivered many images of objects that would not be accessible otherwise, like close-up views of other planets and their moons, or evidence of black holes at the center of galaxies. Assuming that no collision occurs, the HST's lifetime may well exceed another 15 years before it decays from its orbit into the atmosphere. The HST is supported by other space telescopes focusing at different wavelengths, like the Infrared Spitzer space telescope and the Chandra X-ray observatory.

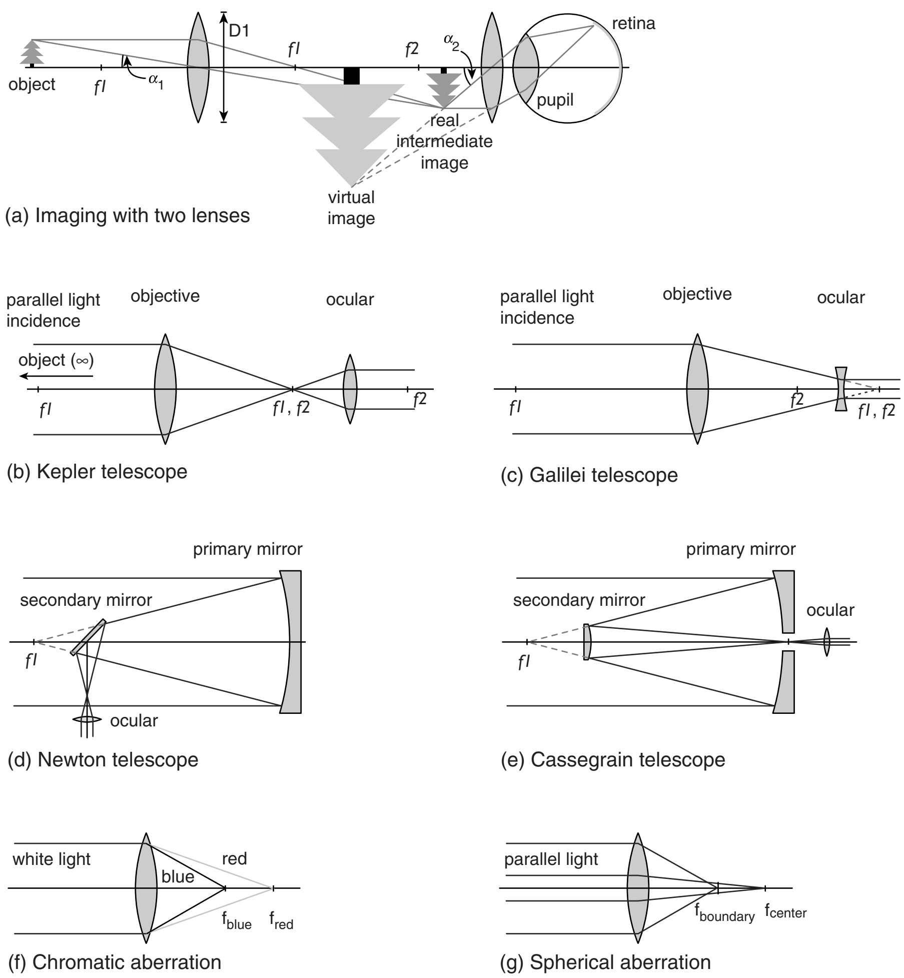
Watching the Past Happen

The information obtained through a telescope—for example the position, size, spectrum, and brightness of a star—is derived from the light that this very star emits. This light takes time, of course, to reach us. Light travels at the constant

The Physics of the Telescope

A telescope is an optical instrument designed to create a magnified image of a distant object on a detector (such as the retina of the human eye). Similar to microscopes, telescopes consist of at least two lenses. Figure (a) displays the image formation with two convex lenses, observing an object at a finite distance. The dark gray lines delineate the light path of the image formation in the eye.

The function of a telescope relies on the principles of geometrical optics, where rays that are parallel to the optical axis in front of a convex lens will intersect its focal point after they pass through it, and beams that run through the center of a lens are not deviated. The primary lens, the *objective,* generates a real, inverted image at an intermediate plane. For that purpose, the original object has to be located outside the focal length *f1* of the primary lens. The real image appears within the focal length *f2* of a secondary lens, the eyepiece or *ocular,* which causes the observer to see the object with a certain magnification. Together, the ocular and the pupil of the eye work exactly like a magnifying glass. The resulting apparent object size can be determined from the backward projection of the rays passing through the secondary lens (dashed lines), thereby forming a virtual image.



(a) Imaging with two lenses

(b) Kepler telescope

(c) Galilei telescope

(d) Newton telescope

(e) Cassegrain telescope

(f) Chromatic aberration

(g) Spherical aberration

The difference between a microscope and a telescope is that the latter aims at comparably large objects at great distances (e.g., stars) rather than at tiny but very close objects (e.g., cells), which requires the focal length of the primary telescope lens to be much larger. In fact, the distance to the object can typically be considered *infinite* without making any huge error. This means that the angle between the two rays leaving the object in figure (a) can be assumed to be approximately parallel. In this case, the intermediate image appears exactly at the focal plane *f1*. If *f1* furthermore coincides with *f2* (*confocality*), then the rays leave the ocular parallel again, and the eye is fully relaxed (no adaptation needed). In figures (b) and (c), Kepler and Galileo telescopes are shown, respectively; the infinity and confocality assumptions were made with both. Note that because the retina image is flipped once more by the human brain, the Kepler telescope produces an upside-down impression of the object. The Galilean telescope avoids the inverted intermediate image by using a concave ocular, so that one perceives an upright impression of the object.

Today, most telescopes used in astronomy are reflectors. In a reflector telescope, a concave mirror (followed typically by a secondary "catcher" mirror) is substituted for the objective or primary mirror. Nonetheless, the imaging process remains basically the same, involving an intermediate image and a magnified observation through an ocular. Mirrors avoid the difficulties associated with lens errors and can be fabricated with considerably larger dimensions, which allows them to collect much more light and obtain a higher resolution. This advantage compensates for the fact that refractor telescopes typically block a fraction of the incident light with their optics.

Figures (d) and (e) display the layout of Newton and Cassegrain telescopes. The Newton telescope possesses a 45° mirror on the optical axis and a characteristic side viewport, whereas in the Cassegrain setup, the beam is "folded" twice and sent through a hole in the main mirror along its initial direction. Nowadays, the final image is often recorded with sensitive electronic detectors like CCD (charge-coupled device) cameras, which allow for long-time illumination and also cover spectral ranges invisible to the human eye.

Three central entities for the characterization of a telescope are the magnification, the resolution, and the field of view. For all telescopes, the *magnification M* is defined as the ratio between the angle of observation with and without the additional optical aid, $M = \alpha_2/\alpha_1$, as indicated in figure (a). In the case of an infinite object distance and a confocal setup, this is equal to $M \approx f1/f2$, the ratio of the two focal lengths. For example, a Kepler telescope with focal lengths of $f1$ = 2 meters and $f2$ = 2 centimeters attains a magnification of 100x. For large Newtonian reflectors like the Herschel telescopes from the 1780s, where $f1$ = 2.1 meters and $f2$ = 0.5 millimeter, magnifications of 4,000x or larger are achieved. However, it is not desirable to increase the magnification indefinitely: No matter how large the magnification, a natural limit for the *resolution*—which determines the smallest structure that can be seen sharply—is set by the finite diameter of the primary lens or mirror, at the boundary of which the incident light is diffracted. A pointlike light source, for example, a distant star, is thus not imaged as a point, but as a set of concentric rings with a certain intensity distribution. Two stars can be separated only if centers of the corresponding ring structures do not overlap. According to the *Rayleigh criterion,* the minimum resolvable angle $\Delta\alpha_{\min}$ between two light sources is given by $\Delta\alpha_{\min} = 1.2.\ \lambda/D1$, where λ is the wavelength of the emitted light and D1 the diameter of the primary lens or mirror. For example, the Hubble Space Telescope with its 2.4-meter mirror attains $\Delta\alpha_{\min} = 2.5\times10^{-7}$rad at $\lambda = 500$ snm, which corresponds to a spatial resolution of 96 meters on the moon's surface (that is, at 380,000 kilometers distance). Such a resolution cannot be obtained by earth-based telescopes without additional measures of compensation, because fluctuations in the atmosphere limit the angular resolution to about $\Delta\alpha_{\min}^{earth} = 5\times10^{-7}$ rad.

A second, practical restriction for the highest reasonable magnification is the reduced *field of view*—or *solid angle of observation* Ω. The further one looks into the sky, the smaller the observed fraction of the sky becomes, and hence the motion of the stars becomes more difficult to follow. Ω is proportional to the ratio between the diameter and the focal length of the primary optical element squared, $\Omega \sim (D1/f1)^2$. Because the diameter D1 also determines the amount of light collected, a large Ω facilitates the detection of faint or more distant objects, though at the expense of magnification; if one wants to improve the magnification by increasing $f1$, one has to increase D1 accordingly in order to warrant the same illumination.

However, the use of large lenses or mirrors is accompanied by certain problems. In addition to the increasing difficulties of fabrication and mounting, large optics are typically subject to considerable imaging errors. For example, the refractive properties of lenses depend on the wavelength of the transmitted light, so that light rays of different colors will be focused at different positions [figure (f)]. Because stars do not emit at a single wavelength but with a characteristic spectrum, an image produced with a lens microscope will be "smeared out" over several image planes, which is called *chromatic aberration.* But even for monochromatic light, aberration errors occur: Rays refracted or reflected by a circular surface (i.e., by a lens or a spherical mirror) arrive at different foci depending on their incidence distance to the central optical axis [figure (g)]. This effect of *spherical aberration* can be counteracted by using "flat curvatures," that is, by using the central parts of lenses or spherical mirrors only, or by using parabolic mirrors, which avoid spherical aberration altogether. Other imaging errors include *coma, astigmatism,* and *distortion.*

finite speed of 299,792 kilometers per hour, which is the maximum possible velocity in our universe and the upper boundary for the transmission of information, as Albert Einstein posited in his theory of relativity. The distances in the universe are so huge that they are measured with light-years (the distance light travels in one year), or even millions and billions of light-years. This implies that the light from distant stars has traveled a very long time before it reached us, and the information it provides is in fact that of the star at an earlier time. When we use the light to determine the age of a star, this star might even have already ceased to exist.

The more remote an object is, the further we look into the past. Light from the sun takes about 8 minutes to reach the earth. The next star closest to our sun, Proxima Centauri, is already 4.2 light-years away, and the next galaxy is the Andromeda nebula at 2.7 million light-years. Probably the most distant object observed so far is a very faint galaxy behind the massive galaxy cluster Abell 2218. For the observation, Abell 2218 functioned as a magnifying *gravitational lens,* thus allowing observers to collect more light due to the light-bending effects. The faint object was detected with both the Hubble and the Keck telescopes, and it is approximately 13.4 billion light-years away; its light is the oldest light ever recorded. The pictures revealed a tiny galaxy of only 2,000 light-years in diameter, containing about a million stars that are only a few million years old; in contrast, a typical galaxy contains hundreds of billions of stars, and an "average" star like the sun is 4.8 billion years old. The evidence suggests that this galaxy is being observed at a time when star formation has just started, 750 million years after the big bang, which agrees with previous estimations of a 14-billion-year-old universe, as known from the recession velocity of the expanding universe.

By giving us the very possibility of peering at the past, telescopes have enabled us to formulate the central cosmological questions, theories, and models about our universe. Having framed humankind's way through time toward a modern scientific worldview, telescopes continue to teach us a humble perspective against the infinity we are encountering through them.

Sebastian Pfotenhauer

See also Astrolabes; Cosmology, Inflationary; Galilei, Galileo; Light, Speed of; Newton, Isaac; Observatories; Planetariums; Planets, Extrasolar; Time, Measurements of; Time, Sidereal

Further Readings

Birney, D. S., Gonzales, G., & Oesper, D. (2006). *Astronomical optics* (2nd ed.). Cambridge, UK: Cambridge University Press.

Ellis, R., Santos, R. M., Kneib, J.-P., & Kuijken, K. (2001). A faint star-forming system viewed through the lensing cluster Abell 2218: First light at z ≅ 5.6? *Astrophysical Journal, 560,* L119–L122.

King, H. C. (2003). *The history of the telescope.* Mineola, NY: Dover.

Moore, P. (1997). *Eyes on the universe—the story of the telescope.* London: Springer.

Wilson, R. N. (2002). *Reflecting telescope optics.* London: Springer.

Terrorism

In the past decade or so, terrorism has become a prominent topic of Western security agendas. Up to the 1970s, terrorism had been regarded as a merely internal problem of nation-states. In the 1980s, the Reagan government suspected the Soviet Union of collaborating with international terrorist organizations. Terrorist organizations were acknowledged as actors in world politics. However, rather than as independent actors, they were seen as puppets of the Communist leadership. In the 1990s, however, after the fall of the Berlin Wall, terrorism gradually came to be acknowledged as an autonomous force in international relations. By now, it is considered one of the most pressing dangers, if not the single most important security problem of the West. An important aspect of the terrorist threat to Western societies lies in the terrorist's "seizure" of time. After a brief general introduction into the concept and history of terrorism, this entry discusses the special time-relatedness of terrorist violence, which can be described as an acceleration of warfare.

War on Terror

Since the terrorist attacks on the United States of September 11, 2001, the place that the Soviet

Union and the "Eastern bloc" had left vacant after the dissolution of the Communist empire in the late 1980s has been taken by international terrorism and its state allies. From today's point of view, the period from 1989 to 2001, which had begun with President George H. W. Bush's optimistic vision of a more peaceful "new world order," appears as a mere interim phase between the era of the Cold War and the current era of the "war on terror."

Opinions diverge on how useful it is to equate the current threat of terrorism with that of former security challenges. Whereas the U.S. government drew a parallel between the 9/11 attacks and the strike on Pearl Harbor, most political scientists have been more cautious about citing historical precedents. Nevertheless, by and large they have joined in the official U.S. assessment that the 9/11 attacks mark the beginning of a new era, in which international terrorist organizations, alongside hostile state actors characterized as "rogue states," form the major threat to state security. The UN Security Council has subscribed to this view in its Security Council Resolution 1373, in which the terrorist aggressions of September 11 are classified as an "armed attack"—a term that has hitherto been reserved for belligerent state conduct. As a consequence, in the light of the new events, the natural right to individual and collective self-defense that the UN Charter has codified in Article 51 is widely considered to extend to cases in which a state is the victim of a terrorist attack that is comparable in size and impact to a regular armed attack.

Although there is a relatively broad consensus among state actors and international security organizations on the strategic and political necessity of responding to the threat of terrorism as a new form of political violence, there is much less agreement on the crucial question of how terrorism can be countered. At the core of the difficulty of reaching common ground in the debate on antiterrorism strategies lies the elusiveness of the term *terrorism*. Because "terrorism" is such a contested and highly ideological subject, the term has to be clarified before the specific relationship between terrorism and time can be addressed.

Historical Origins

It is by no means evident where the origins of modern terrorism can be found in the history of the strategic use of violence. Some historians trace terrorism back to the antique practice of tyrannicide. In ancient Greece, natural right allowed or even demanded the overthrow of an illegitimately usurped regnancy. In the city-state of Athens, for example, to commit tyrannicide and thus help reconstitute a legitimate government was a civic duty. The Roman Republic took over from the Greeks the doctrine of a natural right to resistance against despotism. The most famous politically motivated murder committed with reference to this doctrine was the assassination of Julius Caesar by Marcus Brutus and his associates in 44 BCE. Although the right to resistance was abrogated in the Roman Empire, Christianity reestablished the doctrine of resistance with recourse to the fifth book of the Christian New Testament, Acts of the Apostles, and to their claim that the religious duty to obey God's orders trumps the civic duty to obey the worldly sovereign.

The doctrine of resistance is not confined to Western thought. The Assassins, a radical Shiite sect that fought against the Christian crusaders from 1090 to 1272, serve as an early example of violent resistance in the Muslim world. In light of the recent Islamist terrorism, the Assassins have been considered precursors of the contemporary terrorist fight against the "West." Yet, despite a few similarities concerning the apocalyptic dimension of their ideologies and the idea of martyrdom, the Assassins fundamentally diverge from modern terrorists in that their violence was directed only against the invaders and spared civilians.

Although the justification of the use of violence with reference to God's commands is quite common among present-day fundamentalist terrorists, and despite the fact that ethnic or secessionist atrocities are usually exculpated in the name of a natural right to resistance, one must be careful not to take these self-portrayals at face value. Two things have to be considered. First, while violent resistance against a government may be legitimate if the government is tyrannical and if no other nonviolent means are at hand, terrorism is in principle illegitimate as a means of violent resistance. As will be argued in more detail below, the distinction between other forms of political violence and terrorism cannot be drawn by merely considering the aims of violence (its finality). Acts of resistance that have an unjust cause are not necessarily to be classified as terrorist acts—although the government under attack is likely to do so. Rather, the difference between mere violent resistance and terrorism becomes apparent when one looks at the way in which the violence is carried out and the targets at which it is directed (its modality). Mere violent resistance is directed against political and military leaders and may affect civilians only secondarily, whereas terrorist violence has civilians as its primary target. If terrorism is analyzed in light of the doctrine of resistance, the focus is inevitably on the question of the legitimacy of ends. This question, however, is always open to political debate and blurs the difference between justifiable and unjustifiable modes of violence.

The comparison between terrorism and regicide is misleading for a second reason. It obscures the fact that terrorism as a challenge to the modern territorial state emerged only in the 19th century and must therefore be regarded as a distinctively modern phenomenon.

As opposed to classical accounts of political violence, terrorism does not directly challenge an established order by way of the elimination of its representatives. Rather, it tries to undermine the territorial state's promise of securing the life of its citizens through the monopolization of the legitimate use of physical force. Thus, terrorism presupposes the modern conception of the state as a guarantor for the security of its citizens, which is due to Thomas Hobbes's political philosophy.

The rise of international terrorism is a more recent phenomenon still. Its origins lie in the 1960s and 1970s, when left-wing terrorists attempted to build coalitions across Europe, and when German members of the Red Army faction started to collaborate with Palestinian terrorist groups.

The Concept of Terror

The term *terror* is of Latin origin and means "fear." In Roman criminal law, the threat or execution of torture is meant to cause terror in the convicted. Although the current use of the word *terror* for an extreme form of fright and horror has its etymological roots in early history, the political use of the term dates back only to the French Revolution. In 1793, in order to cope with a state of national emergency, the Jacobins, a radical democratic faction, established a dictatorship that they called "régime de la terreur" (reign of terror). Contrary to contemporary usage, this characterization was meant to have positive connotations. For the Jacobins, terror was a necessary means for making possible the "reign of liberty," which was threatened by domestic opponents and foreign enemies (e.g., counterrevolutionary uprisings, the antirevolutionary coalition of European monarchies). In times of crisis, terror was thought to serve the moral task of educating the people and eliminating its enemies. On the Jacobin account, it was an emanation of political virtue.

Although, in the case of the Jacobin reign of terror, violence was directed against civilians by the state and was thus meant to strengthen and not to weaken the state's power, the Jacobin conception of terror as a distinctively political instrument bears more resemblance to modern terrorism than do the previously cited forms of resistance. Despite the crucial difference between state terror and (antistate) terrorism, three features of the Jacobin terror stand out as characteristics of subsequent forms of political terrorism as opposed to other forms of political resistance.

First, the political aim of terrorism cannot be accomplished by means of physical violence alone. In order to be effective, the terrorist attack has to disseminate fright and terror among the population. What is at stake is not primarily the physical annihilation of enemies but the silencing of opposition. Therefore, the permanence of potential terror has to stand out as an implicit threat to the established societal and political order. Second, the use of violence is justified at the moral rather than at the strategic level. Terror is not understood as a necessary evil but as a political principle that serves some higher ideal. Terror derives its legitimacy directly from the highest ends. Third, terror is not satisfied with replacing the "tyrant" as the embodiment of disorder but aims at reshaping the entire political system and society.

Toward a Definition

If terrorism as a distinctively modern form of political violence is to be distinguished from other forms of political resistance, how then can terrorism be defined? So far, no universally accepted definition of terrorism has been found, despite numerous attempts in the General Assembly of the United Nations. As former U.S. president Ronald Reagan put it with an eye to the war in Nicaragua (1980–1990), "One man's terrorist is another man's freedom fighter." Yet, if the focus is shifted from the (supposed) ends of violence toward its means, a definition of terrorism can be approached. As a first step, it is useful to contrast terrorism with closely related phenomena in order to detect what it is not.

First, terrorism is not war. Unfortunately, in the context of the so-called war on terror, the distinction between terrorism and war has been somewhat blurred. Sir Peter Ustinov's comment that "terrorism is the war of the poor, and war is the terrorism of the rich" reflects the contemporary tendency to conflate these different categories. However, three crucial differences have to be taken into account: (1) War is a conflict between states. Any other use of the term *war* (war on crime, war on terror, etc.) is metaphorical. (2) Because war is a conflict among states, it involves the mutual recognition of the warring parties as sovereigns. To be sovereign, on the classical pre–League of Nations account of international law, is to have a right to go to war. In the famous words of the Prussian historian of war, Carl von Clausewitz, "War is the continuation of politics by other means." Thus, conflicting states need not condemn one another as morally evil. The aim of war proper is the submission of the political adversary, not the annihilation of the enemy. Hence, although war in the technical sense is a violent conflict among states, the two ideologically laden world wars must be seen as departures from the classical concept of war. (3) Because the warring parties usually accept each other as equals, war has been a concept of international law since the formation of the modern international system. Far from being a legally unregulated space, war is governed by international law from its formal opening to its ending. The most important regulation of the laws of war (*ius in bello*) is the distinction between combatants and noncombatants (civilians). It is imperative for military conduct in war that civilians never be targets of attacks.

Second, terrorism is not guerrilla war. Guerrilla warfare, which was established as a paramilitary practice in the Spanish resistance to the Napoleonic occupation and which has been a successful strategy in the anticolonial wars, is directed against a state army by nongovernmental private actors. Guerrilla fighters resemble terrorists in that they fight against an enemy that is superior in size and war machinery. Therefore, they resort to the tactics of ambushing regular troops. But contrary to terrorists they more or less respect the difference between combatants and civilians. They may attack politicians and leading figures of the economic system, but only insofar as they are taken to be representatives of the hostile system. Furthermore, guerrilla war can be seen as a subtype of war, because it entails a military strategy. Terrorism by contrast is characterized by the psychological strategy of terrifying the population. Last, guerrilla war is defensive insofar as it can only be fought on domestic territory and requires the logistic and moral support of the domestic population. Mao Zedong reminded guerrilla fighters that they were "fish in the water, and the water is the people." Terrorism, conversely, is offensive. Terrorist acts of violence can be carried out abroad. Support of the population is not a prerequisite of violence, but its projected consequence.

Third, terrorism is not mere crime. Although it employs criminal means, it is to be distinguished from criminality by its political motivation. The aim of terrorist activity is not primarily personal enrichment, but the good of a political unit. Furthermore, emphasis is put not only on the immediate outcome, but on the long-term consequences of the terrorist's deed. More important than its instrumental use is its symbolic value, which is to be found in the demonstration that the state cannot fully guarantee the security of its citizens.

Having distinguished terrorism from war, guerilla war, and crime, an attempt at a positive definition can be made. Terrorism, then, is a form of irregular, organized, and politically motivated use of violence, not directly motivated as resistance to concrete suppression, that is systematically directed toward civilians and whose desired effects are accomplished not through strategic success but through the psychological consequences of terrifying.

Terrorism and Time

In what follows, the relation of terrorism to time will be considered from five different angles. First, it will be inquired what it means for the terrorists' self-understanding as political actors to be situated in the context of modernity and of modernity's specific conception of historical time. Second, the concept of different "generations" of terrorism will be explored. Third, it will be argued that three types of terrorism can be distinguished according to the account of historical time in which they situate themselves. Fourth, some attention will be given to the importance of time management for the terrorist's mode of action. And fifth, it will be pointed out what this sort of terrorist time management means for the state military and for politics.

1. Whereas in former epochs history was conceived of as a cyclical movement, the modern understanding of history is that of a linear progression that either moves toward an end that can be accomplished in history (teleological conception of history) or aimlessly moves toward an ever receding horizon. Whether aimless or not, the conceptualization of history as a linear process renders society a potential object of directed political planning. In the Middle Ages, feudal society was seen as a reflection of the immutable divine ordering. The enlightenment's philosophy of history, however, conceptualized history as the succession of different types of societies. Since then, the ideas that society is man-made and that the task of politics is not to fulfill some prescribed plan but to bring order to the otherwise disorderly or even anarchical human affairs have become constitutive for the modern self-understanding.

This conception of society as a political project is an integral assumption of early terrorist violence as opposed to more classical forms of violent resistance. Whereas in antiquity and in the Middle Ages resistance was justified as bringing about a return to the natural state of affairs that had been overthrown by the tyrant, the Jacobins resorted to terror in order to create a modern republic of virtuous citizens. Jacobin terrorism is not about the replacement of political personnel but about the creation of something entirely new.

The social-revolutionary terrorists who played an important role from the 1960s to the 1980s inherited the future-directed Jacobin conception of historical time. They sought to bring about a social revolution that was deemed the next step in the historical evolution. By contrast, ethnonationalist terrorists who seek the secession or autonomy of an ethnic group often stick to backward-looking perspectives. Independence and liberty are often portrayed as ideals that have to be regained rather than first achieved. A third category of present-day terrorism can be characterized by its outspoken hostility toward the cultural aspects of modernity and its conception of politics. The terrorism of Muslim fanatics draws on the relatively widespread resentment in the Islamic world that is directed against the modern ideals of secularism and emancipation. The fundamentalist's sense of being oppressed by the West is a reaction to the perceived acceleration of history, in the course of which the Islamic world, which had been culturally preponderant for centuries, seems to have been overtaken and finally left behind by the West. The most threatening form of terrorism that Western civilians and governments currently have to face thus has its roots in the perceived desynchronization of history in the era of globalization.

2. Terrorism scholars usually distinguish three "generations" of terrorism. First-generation terrorism in its early forms dates back to the 19th century. It bears some resemblance to other forms of armed resistance, like guerrilla war, in that it confines its actions to a special territorial conflict. Terrorism of this sort aims at the secession or autonomy of an ethnic group that its adherents deem suppressed. The fight of the Zionist Irgun against the British occupants in the then Ottoman province of Palestine from 1943 to 1948, which resulted in the foundation of the state of Israel, falls into this category, as does the Algerian National Liberation Front's (NLF) fight against French colonial rule from 1954 to 1962. Although first-generation terrorism has been succeeded by second- and third-generation terrorisms, it still exists in the present. The Irish Republican Army (IRA) in Great Britain, which has only recently renounced armed resistance, and the enduring fight of the Basque Euskadi Ta Askatasuna (ETA) in Spain are current examples of first-generation terrorism.

Terrorism of the second generation has a wider range of action. Although focused on a local conflict, it agitates on a regional or even global level. By transcending the boundaries of locality, it aims at drawing regional or global attention to a local conflict. Although attempts at the internationalization of conflicts can be traced back to the militant Zionism of the Irgun and to the Algerian terrorism, the "founding" of second-generation terrorism is usually attributed to the Popular Front for the Liberation of Palestine (PFLP), which in 1968 hijacked a plane of the Israeli airline El-Al on its way from Rome to Tel Aviv. Irrespective of their ethnic backgrounds, passengers were turned into victims of the terrorist attack. The hijackers demanded that Palestinian political detainees be liberated and coerced the state of Israel to start bargaining with the formerly ignored political representation of the Palestinian people, the Palestine Liberation Organisation (PLO). Another example is the taking of Israeli athletes as hostages during the Olympic games in Munich in 1972 by the organization Black September (a splinter group of the Fatah, which is another military arm of the PLO). In internationalizing its group of potential victims and its area of operation, terrorism had achieved a new dimension.

In contrast to second-generation terrorism, terrorist groups of the third generation, of which Al-Qaida is the most well known, do not act on behalf of a specific political group. Unlike the two formerly mentioned Palestinian second-generation terrorist organizations Fatah and PFLP that are affiliated with the PLO as the political representation of the Palestinian people, third-generation terrorist organizations do not have a political representation. Like second-generation terrorist groups, they act on the global scene. Unlike second-generation terrorism, however, they do not have fixed logistic bases. Although they do in fact need the support of so called safe havens (states that support or sponsor terrorists) in order to erect and maintain terrorist camps, their organizational structure is less dependent on that of states than is the case for second-generation terrorist groups. This territorial flexibility is due to a network structure that allows the terrorists to decentralize the preparation and execution of attacks. A terrorist network consists of small units, so-called cells that are autonomous to a large degree and thus capable of planning and carrying out terrorist attacks independently from the other associated terrorist cells.

3. The distinctions among the three generations of terrorism highlight the fact that terrorist strategies have changed over time (although first generation terrorism is still a present phenomenon). But beyond that, different types of terrorism can also be distinguished according to their different time horizons and their construal of the relationship between terrorist action and historical time. If terrorist action is undertaken in the name of an ethnic group (as is always the case in first-generation terrorism and more often than not in second-generation terrorism) terrorists have a near- to medium-term time horizon. Although the struggle for succession, independence, and so forth may take a long time, the aims of ethnonationalist terrorism can in principle be achieved in the here and now. A raising of awareness and a shift in the balance of power must be brought about by the terrorists, but there is no need for a new epoch in history in order for the terrorist aims to be accomplished. The ethnonationalist terrorist acts within a given historical context; he does not act upon history itself.

To act upon history is precisely the mission of the social-revolutionary terrorist, who carries out violence on behalf of a seemingly suppressed social class. Referring to the strategy of modern guerrilla war developed by Mao Zedong and the leader of the Cuban Revolution (1956–1959), Che Guevara, social-revolutionary terrorism took shape in Latin America during the 1960s and was then adopted by the violence-prone part of the extreme left in several European countries. The most prominent social-revolutionary terrorist group was the German Red Army Faction (RAF), which was active in the Federal Republic of Germany from 1968 to 1998.

The social-revolutionary terrorist conceives of his agitation as a trigger to a social revolution, which he sees as the dawning of a new epoch in history. Typically against the background of the Marxist philosophy of history, he is convinced of the necessary collapse of the antagonistic bourgeois society. Marx and Engels had placed their emphasis on the analysis of the self-defeating dynamics of the capitalist economic system and neglected the political question of how the transition from capitalism to socialism and communism might be brought about. Disappointed at the failure of the Marxian prophecy that a social revolution will take place in the most advanced bourgeois societies, social-revolutionary terrorism addresses this crucial question, albeit in a way that must be seen as a departure from classical Marxism. First, while Marx and Engels had been skeptical about the influence of violence on the course of history, social-revolutionary terrorism makes terrorist attacks the primary ingredient of its revolutionary strategy. Violence is meant to force the government to a repressive overreaction, which will in turn heighten the class awareness of the suppressed people. Second, in focusing its strategy around violent attacks, social-revolutionary terrorism favors an elitist conception of social revolution. The overthrow of the capitalist regime will not be the result of popular uprisings alone. Rather, as Che Guevara pointed out in his so-called theory of focus, these uprisings must be instigated by the revolutionary elite in the first place.

The principal idea behind this conception of terrorist agitation is that of an acceleration of historical time. If the time is not yet ripe for a social revolution to happen naturally, it may nevertheless be brought about by terrorist activity.

This idea of the acceleration of history is taken up by a third type of terrorism, which speaks on behalf of neither an ethnic group nor a social class, but of a religious sect. Central to most forms of religiously motivated terrorism is an apocalyptic dimension that culminates in the idea that the world is destined to fall. Because the fundamental ills of human existence cannot be healed, the best a religiously motivated terrorist can do is accelerate the decline of the world. The aim of terrorism, then, is not to enter the final staircase of the teleological historical development, as in social-revolutionary terrorism, but to terminate world history as such. The end of time is what has to be accomplished through terrorist activity.

The apocalyptic dimension of the terrorism of religious sects is clearly apparent in the Japanese sect Aum Shinrikyo (1987–1995), which in 1995 released deadly sarin nerve gas into the Tokyo subway system and thus committed the first successful terrorist attack ever with weapons of mass destruction. Initially the group sought to prevent an apocalypse, but after the failure of its political agitation—which the leader of the sect, Shoko Ashara, had professed would save the world—the sect prepared for the inevitable Armageddon. In light of the obscure ideology of Aum, which is based on the predictions of the French astrologer Nostradamus (1503–1566), the nerve gas attacks appeared as the cult's way of hastening the advent of apocalypse.

4. If one abandons the long-term historical perspective and takes a closer look at the practice of terrorism, a threefold time-relatedness of terrorism becomes apparent. First, the tactics of ambush and sudden retreat, which account for the elusiveness of terrorism, accelerate and fracture the combat at the same time. In turn, these tactics of acceleration and fracturing lead to the slowing down of war on the part of the state that engages in antiterrorism. Mao Zedong has characterized guerrilla war by the extension of war in time and space. This characterization holds true for the war on terror, too. Like guerrilla fighters, terrorists cannot be defeated in a decisive battle (*Entscheidungsschlacht*). Similarly, terrorists cannot be defeated all at once if terror cells are organized in a network-like fashion. The very term *war on terror,* therefore, raises the specter of an endless war.

Second, modern terrorists are masters of timely synchronization. The shocking and terrifying effect of the 9/11 attacks is due in part to the terrorists' symbolic take on time. Beyond the sheer number of victims, it was the perfect synchronization of the assaults on the Pentagon and the World Trade Center that made the 9/11 attacks an unprecedented event in the history of terrorism.

Third, the terrorists' tactics of time management extend to the reception of the attack. They take into consideration the worldwide simultaneity of mass-media reporting. Had the attacks of September 11 not been broadcast live throughout the world, they would not have shaken the global public to the same degree. It is a commonly known phrase among terrorism scholars that terrorists do not necessarily want many people dead; they want many people watching. Terrorism, as has been pointed out above, is primarily a strategy of communication and only secondarily a military strategy. As such, its effectiveness is a matter of mass-media reporting that nowadays extends to the farthest corners of the world instantaneously.

5. Terrorists' tactics of accelerating and fracturing combat and their symbolic seizure of power through careful time management and simultaneity pose a serious threat to contemporary states. The French urban planner and philosopher Paul Virilio, who has dedicated his life's work to exploring the connections between speed, military strategy, and politics, points out that every military and political confrontation is fundamentally a struggle for the power of movement. It can be discerned throughout history that the party that turns out to be quicker and more flexible is destined to prevail over

its slower and more static opponent. Yet, whereas in former times the tendency toward acceleration was regulated by inert physical and moral forces (like ramparts or moral bans), which moderated the speeding up of warfare, the Industrial Revolution of the 19th century was followed by a dromocratic (*dromos* = "run") revolution that gave birth to an age of unrestricted acceleration, or so Virilio's argument goes. Since then, according to Virilio, chronopolitics has taken the place of geopolitics. In line of this argument, the struggle for military and political power is primarily a struggle for speed.

Sociologists of time like Hartmut Rosa distinguish two waves of acceleration. The first significant speeding up of nearly all spheres of life took place around 1900. As a consequence of the technical innovations in the aftermath of the Industrial Revolution, such as the development of the telephone and the automobile, daily life accelerated, as likewise did military strategy (introduction of airborne strikes, etc.). A second push of acceleration can be perceived since the 1970s with the path-breaking developments in microelectronics and the digital revolution, which have been accelerating the speed of our communication and transport systems enormously.

Modern terrorists, who are highly dependent upon modern accelerating technologies like the Internet, are themselves part of the acceleration in the military sphere. Against the background of this brief outline of the history of acceleration, one major threat of modern terrorism can be identified in its capacity to speed up strategic and political processes.

The terrorist tactics of acceleration and fracturing challenge not only the military. Worse than that, they put pressure on the democratic political system. As Virilio and Rosa emphasize, democratic politics cannot be accelerated boundlessly. Deliberation as the foundation of democracy necessarily requires time. In order for a general law to be considered just, it has to be the outcome of rational discussion. Therefore it is not surprising that the measures that the U.S. government (and to a lesser degree the European governments as well) has taken in order to prevent further terrorist attacks—the set of regulations that have become known as the Patriot Act—have been criticized for putting the democratic rule of law at risk.

Generally, the executive branch is strengthened and seizes power in times of crisis. The classical necessity clause—the understanding and use of implied powers to solve political crises and emergency situations—has been a constituent feature of the politics of the constitutional state since its beginning. In the state of emergency, the powers have to fulfill their functions; otherwise there is no time left to deal with the pressing dangers. Because the parliamentary process of legislation is by its nature time-consuming, the executive branch is strengthened in times of turmoil.

However, the critics of the current war on terror maintain that the extraordinary measures that were taken after September 11 cannot be justified as emanating from the necessity clause. The degree to which ad hoc measures have taken the place of general laws in post-9/11 antiterrorism legislation indeed seems alarming. Liberal critics argue that by limiting civil rights in order to enhance the information-gathering capacity of the government so that it can react quickly in case of emergency, politics undermines the very basis of the constitutional state. Whichever position one takes, it is striking that the attempt to keep up with the terrorist logic of acceleration brings politics into conflict with the law.

The conflict that arises between law and politics in situations of crisis can be discerned in international law as well. In reaction to the 9/11 attacks, the *National Security Strategy* (NSS) has put forward the doctrine of preemptive strikes (the so-called Bush doctrine). According to this strategy paper, the harboring of terrorists by states should be categorized as an imminent threat that is a sufficient ground for legitimate preemption. According to international law, in order to allow for preemption, a threat must be imminent and overwhelming, leaving room for no other means and no time for deliberation. However, faced with an enemy that does not have to mobilize in order to strike and can thus attack unexpectedly, the NSS argues that a preemptive strike can be legitimate even if the traditional criteria are not met. The latest war against Iraq (2003) has been justified by reference to this doctrine of preemption. The international community, however, has not subscribed to this view. Again, one is confronted with a split between the law and a policy that tries to keep pace with the terrorist logic of acceleration.

It is an open question whether the Bush doctrine of preemptive strikes will prevail. The answer depends in part on the future of terrorism itself. If terrorist organizations manage to acquire weapons of mass destruction, seize hold of global information networks, or simply continue to threaten the civic life in Western societies, it is likely that politicians will be willing to give up existing standards of international law and civic liberties in order to keep pace with the terrorist logic of acceleration. Therefore, inquiries as to how terrorism can be fought within the boundaries of law are of primary importance. One crucial aspect of such theorizing is the analysis of the relationship between terrorism and time.

Florian Weber

See also Caesar, Gaius Julius; Clock, Doomsday; Engels, Friedrich; Humanism; Law; Marx, Karl; Peloponnesian War; Weapons

Further Readings

Fromkin, D. (1975). The strategy of terrorism. *Foreign Affairs, 53,* 683–698.

Hoffmann, B. (2006). *Inside terrorism* (Rev. ed.). New York: Columbia University Press.

Klink, B. v., & Lembcke, O. (2007). Can terrorism be fought within the boundaries of the rule of law? A review of recent literature in political philosophy. *Rechtsfilosofie & Rechtstheorie, 36,* 9–26.

Münkler, H. (2003). Asymmetric force. Terrorism as a politico-military strategy. *Goethe-Merkur, 1,* 5–13.

Münkler, H. (2003). The wars of the 21st century. *International Review of the Red Cross, 85*(849) 7–22.

Rosa, H. (2005). Speed of global flows and the pace of democratic politics. *New Political Science, 27,* 445–459.

Rosa, H., & Scheuerman, W. E. (Eds.). (in press). *The acceleration of society. conceptions—causes—consequences.* New York: Verso.

Virilio, P. (1986). *Speed and politics. An essay on dromology* (M. Polizzotti, Trans.). New York: Columbia University Press.

Virilio, P. (2002). *Desert screen. War at the speed of light* (M. Degener, Trans.). New York: Continuum.

Virilio, P. (2005). *City of panic* (J. Rose, Trans.). Oxford, UK: Berg.

Thales (c. 624–c. 548 BCE)

Thales is the person often credited with being the world's first philosopher, a claim first made by Aristotle. He belongs to the Presocratic group of philosophers, a grouping of people who had little in common except having lived before Socrates was born. His dates of birth and death are unknown, but the least unreliable estimates place him between 624 and 548 BCE. Little is known about the life of Thales, except that he was a native of the Ionian city of Miletus and that he traveled widely in the eastern Mediterranean. He is customarily associated with, and thought to have been the tutor of, Anaximander and Anaximines. These Milesian philosophers are the earliest of the Presocratics. Nothing written by Thales has survived; his thoughts are known only from later writers who paraphrased them. In addition to his work in philosophy, Thales was credited with significant work in mathematics, astronomy, politics, and economics. A theorem in geometry still bears his name. Whatever the truth about his actual contribution, he was clearly thought to be outstanding. Aristotle's pupil Theophrastus credited Thales with being the first "to reveal the investigations of nature to the Greeks." Thales was regularly counted among the seven sages of classical Greece.

The contribution of Milesian philosophers like Thales was their seeing the need for finding a single source that could serve as a general explanation for the natural world. Their world abounded with supernaturalist explanations and explanations we would now describe as mythological. But these were insufficient for the thinkers of Miletus. Where Homer attributed the origin of all things to the god Oceanus, Thales taught that water was the prime element in all things. Aristotle—our source for this information—speculated on some reasons for this teaching, including the primacy of water on the earth, its core nutritive function, and the moist nature of most things when reduced to their core elements. This is not to say that Thales had no role for the gods at all. Aristotle alluded to Thales's conviction that all things are full of gods, which he gave as an explanation for the ability of a magnet to move iron. Most commentators interpret Thales at this point to mean some variation of a vital principle when he speaks of the gods.

Another important anecdote about Thales comes from Herodotus, who reports him predicting a solar eclipse. It took place during a battle between the Medes and the Lydians, who promptly abandoned the contest and fled in disorder. The eclipse has been traced to May 28, 585 BCE, a date the American physicist Victor Stenger has given as the day science was born. As Stenger argued it, Thales got the date right because his mathematics and his science were right, not because he divined the gods or conferred with oracles. Others have expressed some skepticism that Thales made anything more than an inspired guess.

Other information about Thales comes in the form of anecdotes. Plato tells of Thales tumbling down a well while engrossed in study of the stars, much to the amusement of a Thracian maidservant. And Aristotle tells of Thales buying up all the olive presses in winter, when they were cheap and unused. This occasioned much scorn among the locals and confirmed them in their suspicion that philosophers were an unpractical lot. But his knowledge of the stars and the seasons meant he knew the spring promised a bumper olive crop. When this duly transpired, the people had to come to Thales and hire the equipment from him at whatever rate he asked. This showed, Aristotle wrote, "that philosophers can easily be rich if they like, but that their ambition is of another sort."

Bill Cooke

See also Anaximander; Anaximines; Empedocles; Heraclitus; Parmenides of Elea; Presocratic Age; Pythagoras of Samos; Xenophanes

Further Readings

Burn, A. R. (1972). *Herodotus: The histories* (Rev. ed.). London: Penguin.

Burnet, J. (1958). *Early Greek philosophy,* London: Adam & Charles Black.

Long, A. A. (1999). *The Cambridge companion to early Greek philosophy.* Cambridge, UK: Cambridge University Press.

Stenger, V. (1988). *Not by design: The origins of the universe.* Amherst, NY: Prometheus.

Wilbur, J. B., & Allen, H. J. (1979). *The worlds of the early Greek philosophers.* Amherst, NY: Prometheus.

Thanatochemistry

Thanatochemistry (from the Greek *θάνατος,* Thanatos, the personification of death in Greek mythology) is broadly defined as the chemistry and chemical aspects of those sciences related to mortuary practice. In particular, modern thanatochemistry encompasses *embalming,* the temporary preservation of human remains that enables them to be presented intact at a funeral ceremony. Thus, the objective is to overcome the effects of decay, a natural consequence of time.

One of the earliest manifestations of embalming was mummification, developed by the ancient Egyptians several thousand years before the common era. The Egyptians were motivated by spiritual or superstitious notions that after death, preservation empowered the soul of the deceased, which would then return to the corpse. The abdomen was opened and all the organs removed. The emptied body was then coated in natron (hydrated sodium carbonate), which facilitated drying. When in contact with moisture, it gives alkaline solutions, which provide a hostile environment to putrefying bacteria. The treated corpse was then wrapped in linen and canvas, and put to rest inside a tomb.

Mummification of a corpse need not necessarily involve any deliberate intervention. Naturally occurring, albeit extreme, environmental conditions have resulted in similar preservation, as evidenced by recent discoveries of naturally mummified remains; for example, the colloquially named Ötzi the Iceman, discovered in a glacier of the Ötztal Alps, 1991, and the Tollund man found buried in a peat bog on the Jutland Peninsula in Denmark in 1950 were both found in remarkable sates of preservation due to anaerobic and very cold and acidic conditions, respectively.

Shortly after the conclusive identification of the chemical formaldehyde by German chemist August Wilhelm von Hofmann in 1867, its preserving properties were discovered, and it is now the basis of contemporary methods of embalming. Aqueous solutions of formaldehyde (with trade names such as Formalin or Formol) kill living cells, both tissue and bacterial, by dehydration of cytoplasmic fluids and coagulation of the constituent proteins by their reaction with the primary amine groups of peptides in the formaldehyde. Aesthetically, color changes produced during this reaction can give the appearance of blood flowing under the skin. The moisture within the cell is replaced with a rigid gel-like material, which allows the embalmed tissue to retain its structural integrity. Moreover, the tissue can resist any subsequent bacterial attack.

Embalming fluids are injected directly into the arteries of the deceased. A concentrate of *arterial chemical* (based on a mixture of formaldehyde, glutaraldehyde, or in some cases phenol) is diluted and mixed with nonpreservative ingredients to give a case-dependent solution of *embalming/arterial fluid,* which is administered. The proportion of arterial chemical is dependent on the required longevity of preservation. Some additional *coinjectants* include water modifiers to maintain optimum alkalinity of the solution; dyes; humectants, which give dead tissue a hydrated and natural appearance; and cell conditioners to prepare for fluid absorption and to remove blood clots.

Despite its success as a preservative, formaldehyde has been shown to be a potent carcinogen. With many other ingredients of embalming fluids also known to be toxic, the search for safer arterial chemicals is ongoing.

James V. Morey

See also Chemistry; Decay, Organic; Dying and Death; Evolution, Organic; Mummies

Further Readings

Dorn, J. M., & Hopkins, B. M. (1998). *Thanatochemistry: A survey of general, organic, and biochemistry for funeral service professionals* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

Mayer, R. G. (2000). *Embalming: History, theory and practice* (3rd ed.). New York: McGraw-Hill/Appleton & Lange.

THEODICY

The problem of evil arises in most religions in some form or other, although it is most acute (and therefore most discussed) in the Abrahamic religions. It consists of the problem of reconciling the nature of God (or of the gods) with the nature of the world; in particular, a creator's goodness, power, and knowledge are held to be in conflict with the evil that is found in the world. One of the main sorts of approach to the problem is theodicy: the attempt to reconcile the existence and nature of God with the nature of the world. Time plays a part both in the way that the problem is understood and in some of the approaches to it.

The notion of evil varies from tradition to tradition, generally falling into one of a number of categories—two concerning the source and two the nature of evil:

- *Suffering*—physical and psychological pain
- *Metaphysical Evil*—contingency; that is, matters such as death and the shortness of life.
- *Natural Evil*—the result of the way that the world is (the laws of nature, through natural disasters)
- *Moral Evil*—the result of the actions of intentional beings

Time is involved primarily with metaphysical evil, though what is at issue is more what happens within time than the nature of time itself. That is, the process of aging, the shortness of life, and so on. In the Buddhist tradition, for example, Prince Siddhartha gave up his life of luxury (the Great Renunciation) when for the first time in his life he encountered old age, sickness, and death, and found that suffering (*dukkha*), founded in impermanence (*anicca*), is the universal human condition. This notion of evil is highlighted by recent discussions of what is known as "evolutionary theodicy," which focuses on the fact that pain, suffering, and extinction are an essential part of the evolutionary process.

Time also plays a role in the discussion of defenses against the problem of evil, with regard to God's nature. If God is eternal—that is, a nontemporal being, outside time—then God must create the world "all at once"; its beginning, middle, and end exist, all equally known to God, though from within the world the future (and much of the past) is unknown. There seems on this account to be no room for free will, or even for contingency: God, being essentially benevolent, omnipotent, and omniscient, creates the best; therefore this world is the best of all possible worlds (however odd that may seem to the creatures who live in it), and it is logically impossible that things should have been otherwise. That I might have been a politician or a serial killer rather than a philosopher might seem to be a genuine possibility, but in fact God necessarily created this world, in which I am a philosopher. Thus the free-will defense is challenged.

If God exists temporally, and if the world has not always existed, then God created it at a particular time; the world's future development is thus open (especially if genuine contracausal free will exists). This account allows for the freedom of the will, and if we take the future to be unreal, it allows us to say that God created the world without knowing what we would make of our free will. (For if the future does not exist to be known, then it is logically impossible to know it.) This raises, however, problems about the timing of Creation. It also raises the specter of ways the world might have turned out that are much worse than the actuality; although God created the world without knowing what the consequences would actually be, God knew that they might be horrendous, and this can be argued to conflict with divine benevolence.

Peter King

See also Evil and Time; God as Creator; Last Judgment; Leibniz, Gottfried Wilhelm von; Morality; Satan and Time; Sin, Original

Further Readings

Leibniz, G. W. (1985). *Theodicy: Essays on the goodness of God, the freedom of man, and the origin of evil.* Chicago: Open Court.

Leibniz, G. W. (1989). *Philosophical essays.* Cambridge, MA: Hackett.

Theology, Process

Process theology (PT) posits the idea that God has two natures (is bipolar) and that he is an inherent part of the countless processes taking place throughout the universe. God's nature is primordial or transcendent (he is perfect, thus, he never changes), as well as immanent. (He is part of the cosmic process itself and hence cannot be separated from the cosmos.) This process is called *epochal;* that is, it does not occur due to quantum mechanics or any other branch of science, but by creative experience, which continually influences itself in temporal sequence.

The method of PT is more philosophical, rather than biblically or confessionally based, though many feel that it is a better method for understanding, and expressing, Christian traditions. Moreover, the PT method stresses the significance of science in understanding God. Thus, PT is akin to natural theology and is associated with the American, empirical theology tradition whose adherents include Shailer Mathews, D. C. Macintosh, and Henry Nelson Wieman, all of whom felt that using inductive reasoning and the scientific method should be the primary tools for theology. PT shares many ideas with the evolutionary thinking of Henri Bergson, Samuel Alexander, C. Lloyd Morgan, and Pierre Teilhard de Chardin. Without doubt, the most important influence was Alfred North Whitehead, the originator of process theology.

Alfred North Whitehead

Whitehead (1861–1947), renowned for his mathematical/philosophical ability, wanted to find a set of philosophical concepts that was capable of explaining all beings, from God down to the smallest bacterium. Combining philosophical speculation with science, he created a construct he called the "actual occasion" or "actual entity," that is, the basic unit of all reality. Whitehead felt that all things could be explained as being the result of actual occasions, all related with different degrees of depth. An actual occasion is nothing more than a brief occurrence that is created by one's self and is influenced, in part, by other actual occasions.

Whitehead thought that every actual occasion or entity has two natures—one physical and the other mental. In terms of physicality, the actual entity experiences or "prehends" the corporal reality of other actual entities, whereas in terms of mental phenomena, it prehends objects through which actual entities possess intangible definition. These objects are usually defined as theoretical or conceptual possibilities of the universe, and the actual entities disconnect themselves from each other whether or not they recognize these possibilities. The term *prehend* refers to a touching or clutching of the material and/or theoretical data of actual entities. Prehending allows actual entities to be interconnected (not externally, however, as is the scenario in several other philosophical schools). In essence, this means that the entities are not inaccessible or autonomous beings, but are present in other actual entities as interconnected moments of an ongoing process. This quality of prehension or sensation is not a conscious or intellectual act except with higher forms of life but the dipolar formation and the prehensive role are present in some sense in every actual entity, regardless of its intricacies.

Whitehead felt that creativity was another universal concept and that each actual entity possessed a modicum of freedom that was articulated in one's "subjective aim." The self-creative process is a method for attaining one's subjective aims and includes the unification of its historical prehensions, accomplished through the addition of something new—which may be likened to the entity's exceptional gift to the world. Once the entity has realized its subjective aim, it attains "satisfaction" and then shuts down, no longer experiencing anything. It now becomes a focal point for the prehensions of any ensuing actual entities. The actual entity's life is brief, and each individual process that takes place in the world must be viewed as the development of organically related occasions or momentary experiences.

What traditional philosophers would call an everlasting substance, Whitehead called a succession or "route" of actual occasions with a common trait. Change is explained by the creative input of each occasion in the series, while endurance is clarified by common, everyday qualities that are inherited from antecedent occasions. How all things maintain stability is explained in this way, whether they are electrons, stars, plants, mammals, or human beings. Man is the center of all incidents involving remembrance, imagination, and discriminating intangible emotions. On the other hand, it is God who is the ultimate, actual entity; hence, he projects (in a perfect manner) each function of the supreme actual entity. Whitehead felt that metaphysical logic cannot be attained if one sees God as an exception to the rules; rather, God is the primary example from which all metaphysical principles are to be explained. This allows God to prehend absolutely by each entity found throughout the cosmos; likewise, he is prehended by everyone else, though only in a partial fashion. As the creator, he has power over everything and places boundaries regarding the use of imagination. He influences goals by making sure each individual has a perfect "initial aim." Whitehead felt that God did this with a "primordial nature," meaning that the Creator envisioned each unending thing and its relative worth in the "real" or "concrete" world.

Whitehead thought that without eternal objects, humanity would have no concrete possibilities, nor would there exist any values to be actualized, and yet only something that is "real" influences actual entities. This shows that God knows and comprehends each never-ending object; likewise, he has the wherewithal to function as the basic fount for universal order and values. For Whitehead, if there were no Creator, the cosmic process would be chaotic, not creative. God, in his infinite wisdom, enables the cosmos to become concrete by allowing specific principles to exist within certain divine parameters.

God, as bipolar, has a physical side, also called a "consequent nature," which may be defined as God experiencing the completed actuality for each individual circumstance. He brings the finished entities into heaven in order to exist with him as receivers of his perfect prehension—giving them "objective immortality" as a consequence of their achievements. (It should be noted that Whitehead stated that no actual entity has subjective immortality except God; humans live subjectively, due only to an ongoing chain of actual occasions.) In addition, the Creator gives the universe its information regarding any entities God prehended, so humanity will be knowledgeable and richer for its past.

God, through the process of prehension, is in continual contact with each subatomic particle found within our universe, within every nanosecond constituting the life of that being. This allows God to be immanent in the world process itself, while leading it on toward greater value and aesthetic intensity—however, it is not coercion, but gentle and loving persuasion that allows him to accomplish this. Although he transcends the world, God, as the actual entity, keeps the world consequently within himself, while suffering and growing along with it through the creativity that he and the world possess.

Charles Hartshorne

Although process theology, under Whitehead, had reached maturity in 1929 (when he published *Process and Reality*), few theologians cited him before the 1950s. During this period, theologians were preoccupied with neo-orthodoxy, a movement that rejected natural theology and compartmentalized theology and science. One notable exception was Charles Hartshorne, who developed Whitehead's thought and became its chief proponent during the 1960s and 1970s. Like Whitehead, Hartshorne looked at metaphysics as the study of general principles by which all particulars of experience are to be explained. Hartshorne was more rationalistic because, for him, metaphysics dealt with what was outwardly required, or with "a priori statements about existence," or true statements regarding any state of affairs regardless of the circumstances. He took up Whitehead's metaphysical system, defending it as the most lucid and feasible argument concerning philosophy. He agreed with Whitehead on the predominance of "becoming" (which is comprehensive of being, unlike that found in classical philosophy), as well as *panpsychism,* the grouping of sensation as a common feature of every entity.

Hartshorne agreed with the law of polarity, but his view regarding the dipolarity of God was slightly different from Whitehead's. He rejected Whitehead's beliefs about eternal objects and felt God's consequent nature was better termed "concrete nature," which translates into God living within an authentic existence, regardless of the condition, with all the wealth of accumulated values of the world up to that present state. God's intangible personality is composed of certain traits and characteristics that are everlastingly and essentially true of God, at all times. On the other hand, the traits regarding God's concrete nature are those specifics that he has gained by interacting with the cosmos in accordance with the circumstances. God in his tangible actuality is a "living person," in process; his existence is composed of an eternal retinue of holy occurrences or happenstances. This is different from Whitehead, who envisioned God as being a distinct, never-ending, actual entity.

The contradictions found in God's personality means he is absolutely essential (according to his intangible nature), but conditional according to his concrete nature. This does not mean, however, that he is independent in his intangible nature but dependent in his concrete nature; on the contrary, God is independent because nothing in the cosmos possesses the power to intimidate him, nor could anything induce him to act in a manner diametrically opposed to his loving-kindness. God is affected, however, by human responses to his will. Hartshorne did not think God should be seen wholly in terms of his goodness, nor in contrast to weakness of his creation.

Hartshorne thought that the single greatest mistake in classical theism was to think otherwise. For instance, denial of God's indispensable comprehension of the dependent world, or God's ageless act of constructing a world that is sequential, or the Creator's great and abiding love for humanity, which supposedly involves God in history—none make him relative to or dependent upon anyone or anything. Hartshorne contended that if chronological development and creativeness ultimately exist, then God, in some unknown manner, must have also been progressing. Likewise, he is reliant upon humanity's free will.

This set Hartshorne as an opponent to classical theology, and thus, he developed what has been called a neoclassical theism, which states that God can never be surpassed in either perfection or social relatedness. If God is perfect love, then he possesses a complete sympathetic comprehension of every creature and responds appropriately and lovingly in every situation in every event. In plain language, while the Creator is supremely boundless in his conceptual character, he is relative in his tangible nature. No one and/or no thing could exceed him in his supremacy regarding connectedness with every living being. On the other hand, the Creator can improve himself. He can and does progress, not becoming more moral or perfect, but growing in the joyousness and feeling of the world, in knowledge of actual events, and in the experience of the values created by the world. It should be noted that Hartshorne did not think God had the foreknowledge of future events; hence, while God's knowledge is complete regarding that which can be known, he nonetheless continues to grow with the process of the world.

God possesses a unique, transcendent personality, which means he is immeasurably more than the earth in its entirety (contra pantheism). Contraclassical theism states that God takes the universe solely within his being, in both his perfect comprehension and his love. This could be viewed as nothing more than his own, unique prehension, or God's understanding of the myriad innovative events taking place continually throughout the cosmos. This is a pantheistic image of God, making Hartshorne the chief protagonist for this argument in the 20th century. In Hartshorne's opinion, St. Anselm realized several, essential components regarding theistic beliefs, primarily "perfection" and its exclusivity among other notions. Anselm's argument lacked cogency, because it relied on a classical theistic view of perfection. The neoclassical view of perfection, Hartshorne felt, overcame the many objections modern philosophers had about the term—primarily that perfection cannot be consistently defined. In Hartshorne's opinion, perfection either exists or is required not to. This, in turn, leads to the conclusion that only the self-contradictory does not exist and that the Creator—if he is self-consistent—is in reality necessarily existent.

Teilhard de Chardin and After

Neo-orthodoxy waned after 1960, leading many theologians to study Whitehead and Hartshorne as philosophical sources for a modern-day expression of Christian faith. Beginning with the doctrine of God, theologians John Cobb, Schubert Ogden, Daniel D. Williams, and Norman Pittenger wanted to show that the process view of God is actually more in harmony with the biblical view of God (as dynamically related to human history) than is the time-honored Christian view of traditional theology. They felt that the monopolar conception of God as changeless, incontrovertible, impassible, and in every sense independent was a belief originating with the Greeks, not the Bible. Williams studied the Christian notion of love, arguing that Whitehead's philosophy aids theologians in clarifying God's boundless love in a manner completely divorced from the orthodox opinions of God.

Other writers of Christian theology using a process perspective are Bernard Meland, Ian Barbour, Peter Hamilton, Eugene Peters, Delwin Brown, William Beardslee, Walter Stokes, Ewert Cousins, Eulalio Baltazar, and Bernard Lee. Though process theology is encountered mainly within Protestantism, Roman Catholic thinkers now feel its influence as well (the last four theologians listed above are Catholic). Roman Catholic theologians are slowly accepting Whitehead. In addition, they ponder the writings of Teilhard de Chardin, whose ideas are traditionally split from Catholicism but share a philosophical kinship with the Whiteheadian tradition.

Pierre Teilhard de Chardin, the famous French priest-philosopher, viewed the universe as evolving toward a perfect state of being, or the end goal for humanity. His philosophy melded a scientific grasp of the reality of evolution as a force of nature within the universe (cosmogenesis) with metaphysics. In essence, Teilhard's beliefs regarding evolution centered on the idea that the earth is slowly becoming a collective brain due to a layer of human consciousness surrounding the globe. At some point in humanity's future, this stratum of consciousness will separate from the planet and will join with God and thus will become one with him. Teilhard called this the Omega point, as this uniting was, in his conception, our final goal as a species. His interpretations concerning humanity's future allowed process theology to be viewed as panentheistic; that is, while God is immanent, he is also transcendent.

Cary Stacy Smith and Li-Ching Hung

See also Alexander, Samuel; Becoming and Being; Bergson, Henri; Creationism; Design, Intelligent; Evolution, Organic; God and Time; God as Creator; Hartshorne, Charles; Teilhard de Chardin, Pierre; Teleology; Whitehead, Alfred North

Further Readings

Cobb, J. B. (2003). *Process perspective: Frequently asked questions about process theology.* Atlanta, GA: Chalice Press.

Cobb, J. B., & Griffin, D. R. (1977). *Process theology: An introductory exposition.* Louisville, KY: Westminster John Knox Press.

Ewert, H. (1971). *Process theology: Basic writings of the key thinkers.* Long Prairie, MN: Newman Press.

Kane, R., & Phillips, S. H. (1989). *Hartshorne, process philosophy and theology.* Albany: State University of New York Press.

McDaniel, J. B., & Bowman, D. (2006). *Handbook of process theology.* Atlanta, GA: Chalice Press.
Mellert, R. B. (1975). *What is process theology?* Mahwah, NJ: Paulist Press.
Mesle, C. R. (2006). *Process theology: A basic introduction.* Atlanta, GA: Christian Board of Publication.
Trethowan, I. (2002). *Process theology and the Christian tradition.* Boston, MA: Saint Bede's.

THUCYDIDES (C. 460–C. 399 BCE)

Thucydides was one of the great chroniclers of ancient history. Renowned for recording the history of the Peloponnesian War, Thucydides not only provided future generations knowledge of a war for which few other data exist, he also developed an influential methodology for observing and documenting historical events. Ironically, few records of Thucydides' life survive from which we might better know and understand the man himself.

Thucydides' great work was to chronicle the Peloponnesian War, the decades-long conflict between Athens and Sparta (and their respective allies), which began in 431 BCE. Like few previous historians, Thucydides went beyond compiling a cursory accounting of major events in his day. Throughout the conflicts of the time, Thucydides documented naval engagements, cavalry maneuvering, troop type and strength, and speeches of individuals commanding the war's course. Likewise, Thucydides documented the spread of plague throughout Athens and its devastating effect on both populations and society. All the while, Thucydides employed methods of data collection that included the verification of stories he heard secondhand, the investigation of contemporary texts, and the inscribing of speeches he witnessed. Additionally, Thucydides sought to view the onset of war from multiple perspectives, seeking an understanding of the causes of a conflict and people's reaction to it.

Although Thucydides, an Athenian, provided future generations with documentation of the Peloponnesian War, his own life remains a mystery. Thucydides is believed to have lived from approximately 460 to 399 BCE, dates based primarily on positions he held in the military rather than on actual documentation of his birth and death. At one time an Athenian general tasked with saving the colony of Amphipolis, Thucydides was exiled from Athens after failing to arrive in time to prevent the colony's capture. A final distinctive note regarding Thucydides' life is that he experienced firsthand the plague as it swept through Athens toward the beginning of the war, killing a significant number of Athenians in the process. Of the rest of his life, including the circumstances of his birth, his rise to the rank of general, and details of his exile, little more is known.

Neil Patrick O'Donnell

See also Alexander the Great; Herodotus; Hesiod; Homer; Peloponnesian War; Presocratic Age

Further Readings

Canfora, L. (2006). Biographical obscurities and problems of composition. In A. Rengakos & A. Tsakmakis (Eds.), *Brill's companion to Thucydides* (pp. 3–31). Boston: Leiden.
Rood, T. (2006). Objectivity and authority: Thucydides' historical method. In A. Rengakos & A. Tsakmakis (Eds.), *Brill's companion to Thucydides* (pp. 225–249). Boston: Leiden.
Thucydides. (1972). *History of the Peloponnesian War* (R. Warner, Trans.). New York: Penguin Books. (Original work c. 400 BCE)

TIDES

Tides are the cyclic rising and falling of the earth's seas and oceans caused by the concerted gravitational pull of the sun, moon, and earth itself. On a geologic timescale, there has never been a more profound factor in the shaping of the world's coastlines than the everlasting ebb and flow of the tides. Even powerful tsunamis and hurricanes are no match for this primordial rhythmic cycle.

Classic tides tend to be semidiurnal, with two high and two low tides occurring each day. As the earth spins in its orbit, it creates a centrifugal force that is equal to the gravitational attraction of the moon, keeping the moon in place. As the moon rises in the night sky, the water will bulge toward its strong gravitational pull, forming a high tide. On the other side of the earth, the centrifugal motion of the earth is much stronger than the gravitational pull of the moon, creating another bulge away from the moon and another high tide. The low tides occur between these two periods, when the centrifugal force and the gravitational pull of the moon cancel each other. Areas at the poles often experience seasonal diurnal tides, with only one high tide and one low tide a day. This is due to a divergence of the two daily times when the moon shifts with the season to its maximum declination of 28º. Most areas experience a combination of semidiurnal and diurnal tides, which is referred to as mixed tides.

The sun also has a significant effect on the overall cyclical nature of these tides. During new and full moons, when the sun is in line with the moon, the combined gravitational pull of the sun and moon create higher than usual tide, known as a spring tide. Conversely, when the sun and moon are at right angles during the first and last quarter, their combined gravitational pulls offset each other, creating very low neap tides. Seasons also play a large role in tidal cycles. In the spring, the moon is closest to the earth, and its gravitational pull is even more profound on the tides, creating a perigean tide.

One common misuse of the word *tide* is in the term *tidal wave*. Tidal waves in a vernacular sense have no correlation with the gravitational pull of the moon and sun but rather are created by underwater earthquakes from the shifting of tectonic plates. These shifts cause shock waves of energy, creating enormous waves known as *tsunami* that race outward toward land. True tidal waves are actually called *bore waves;* in these, the tide produces a wave that travels upstream in a river that runs into the ocean.

The study of the tides has fascinated people since ancient times. Until science was able to explain the daily rise and fall of the tides, many cultures developed stories and myths to explain this daily phenomenon. The ancient Japanese believed that a giant fish lived in the ocean and would drink the water, only to spit it right back out later, causing the rise and fall of the tides. Many ancient cultures noticed the correlation between the moon and the tides. For example, Polynesians believed that the sea god Tangaroa married the moon goddess Hina, and that the two controlled the tides together. The ancient Scandinavians believed that the moon god Mani captured two children, Hjuki and Bil, who were filling a bucket of water from a well. He sent them to the moon, bringing the bucket with them, and it was believed that the emptying and filling of this bucket controlled the tides.

The study of the tides has many practical applications in daily life, including contributions to understanding of coastal states, barrier migration, sea-level changes, and morphological change in geology. Scientists use an instantaneous timescale to determine a real-time picture of the current state of coastal regions. This can be used to study sediment flow, bedform laminae, and intertidal ecology. Many boat captains use an instantaneous timescale to avoid running their ships aground on shallow rocks and reefs.

The event timescale is used to study the cyclic sequences of the tides, as well as extreme disturbances including earthquakes and hurricanes. This is often determined by averaging data from an instantaneous timescale. The event timescale can help to demonstrate how future events can impact morphological changes in the coastline, from the deposition of sediments over long time periods to the formation of completely new islands. The cumulative effect of the long-term mechanical force of the tides is often the driving force behind these overall morphological changes. However, extreme events like volcanic eruptions and major storms can drastically reshape the coastline in a very short time span. For example, a nor'easter off the mid-Atlantic coast of the United States that lasted from March 5th to March 8th, 1962—the notorious Ash Wednesday Storm—caused waves over 30 feet high to crash down on over 1,000 miles of coastline. The storm struck when the tide was at its seasonal highest, a spring perigean. This single event destroyed the landmark Steel Pier in Atlantic City, New Jersey, as well as the Ocean City Boardwalk in Maryland, causing over $500 million in damages along the eastern coastline as well as dramatic geological changes, including the destruction of many reefs and beaches.

A historical timescale is used to sum up several events, often spanning many generations. This is to give engineers an idea of the trends of the tides along a coastline that is to be manipulated for human use. For example, trends in sea level have been recorded since as early as 1682 with tidal-gauge records. These gauges can be analyzed to determine not only proper coastal use but also general environmental trends worldwide. However, because the historical timescale spans many generations, past generalizations of events are causing problems in creating an accurate picture on a historical timescale. Many engineers are turning to computer simulations of large-scale coastal behavior systems to get a more exact idea of coastal erosion and geomorphological changes on this scale.

The geological timescale covers a significantly longer time than the historical timescale, and it is used mostly to reconstruct the past through geological and paleoenvironmental evidence. This is much more difficult to determine, as much of geological history is limited to hypotheses and inferences due to limitations in science. Advances in dating techniques have made more accurate depictions of the past possible. Nevertheless, the consistent mechanical forces of the tides have swept much of the geological history of the coastline out to sea.

Christopher D. Czaplicki

See also Earth, Rotation of; Erosion; Geology; Glaciers; Ice Ages; Plate Tectonics; Stratigraphy

Further Readings

Dean, C. (1999). *Against the tide: The battle for America's beaches.* New York: Columbia University Press.

Wegener, A. (1966). *The origin of continents and oceans.* Toronto, ON, Canada; Dover.

Woodroffe, C. D. (2002). *Coasts: Form, process and evolution.* Cambridge, UK: Cambridge University Press.

Tillich, Paul (1886–1965)

Educated in German universities and having earned a Ph.D. from Breslau University (1911) and a licentiate in theology from Halle University (1912), Paul Tillich was ordained in the Evangelical Lutheran Church (1912) and served as a chaplain during World War I. Tillich taught theology at the University of Berlin (1919–1924), and this was followed by other teaching positions at the universities of Marburg, Dresden, Leipzig, and Frankfurt am Main (1929–1933). After he criticized the Nazi regime, the government barred him from teaching at any German university. Tillich's experiences during World War I and under the Nazi regime gave impetus to his awareness of the tragic nature of historical time. He emigrated to the United States at the invitation of the distinguished theologian Reinhold Niebuhr, and he taught on the faculty of Union Theological Seminary with Niebuhr until 1955, when Tillich moved to a position at Harvard University (1955–1962) before finishing his career at the University of Chicago (1962–1965).

Tillich's theology is governed by his method of correlation, which enables him to have an answering theology in which philosophy raises certain existential questions, and theology tries to provide the answers in the context of time. This method, which is also dialectic in the sense that every positive implies a negative, suggests that philosophical questions and theological answers are in mutual interdependence. In short, Tillich uses his method to analyze the human situation and its temporal nature; this analysis gives rise to certain questions, and the Christian message provides the answers to such questions. In response to the philosophical analysis of being and human finitude, the theological answer is, for instance, God, whereas the questions of existence and life are answered respectively by Christ and Spirit, demonstrating the central nature of the doctrine of the Trinity in Tillich's theology.

Tillich develops his thinking about time within the context of his philosophical ontology and especially the ontological categories that include time, space, causality, and substance. These ontological categories constitute the structure of experience itself and are thus present whenever something is experienced. Not only does the mind comprehend and form reality by philosophical categories, rational thinking is inexpressible without using some category. A category, such as time, is a way that finite beings participate in a mixture of being and nonbeing. Time possesses both positive and negative aspects, as do the other categories. Time is, for instance, creative, direct, and irreversible, and it symbolizes movement and life. From a negative perspective, time represents a moment from a past that is no more and a future that is not yet, whereas the present is a moving boundary line between past and future.

Becoming aware that time is moving one toward death, a person becomes anxious about the transitory nature of human existence. In response to such a threat, a person affirms the present and the threat of nonbeing through an innate, ontological courage that is based in God. Therefore, time is central to human finitude, and the anxiety associated with death reveals the ontological character of time. Moreover, human courage affirms temporality, whereas one would surrender to the annihilating character of time without courage.

Time moves ahead toward something new, unique, and novel, and the creative nature of time is evident with historical time, which appears as time running toward fulfillment, because it is united with the dimension of spirit. The fulfillment of historical time (*kairos*) is for Tillich the event of God's action in Jesus as the Christ, which is repetitively experienced. The fulfillment and aim of the end of history is answered, according to Tillich, by eternal life in the kingdom of God, which is the final meaning of history, because individuals are fulfilled in all areas of their lives.

Carl Olson

See also Christianity; Existentialism; God and Time; Ontology

Further Readings

Pauck, W. (1989). *Paul Tillich: His life and thought.* San Francisco: Harper & Row.

Tillich, P. (1951–1963). *Systematic theology.* Chicago: University of Chicago Press.

Tillich, P. (1952). *The courage to be.* New Haven, CT: Yale University Press.

Tillich, P. (1957). *Dynamics of faith.* New York: Harper & Row.

Time, Absolute

The concept of absolute time is a hypothetical model from the laws of classical physics postulated by Isaac Newton in the *Principia* in 1687. Although the Newtonian model of absolute time has since been opposed and rejected in light of more recent scholarship, it still provides a way to study science with reference to time and understand the phenomena of time within the scientific tradition.

According to this model, it is assumed that time runs at the same rate for all the observers in the universe, or in other words, the rate of time of each observer can be scaled to the absolute time by multiplying the rate by a constant. This concept of absolute time suggests absolute simultaneity by the coincidence of two or more events at different points in space for all observers in the universe. So, absolute time has been discussed in two senses of absoluteness. In first sense, absoluteness means independent of events, while in second sense, it means independent of observer or frame of reference.

Newton's theory was a dominant paradigm throughout the 18th and 19th centuries. Newton regarded time as something absolute, true, and mathematical, of itself and by its own nature, that flows uniformly without relation to anything external, and by another name it is called duration. He explained that the motion of a particle has to be described relative to an inertial frame in which the particle will move at a constant velocity in a straight line unless some external force is applied to it; time among different frames differs by a constant, and all times can be described relative to an absolute time.

This theory encountered strong opposition from many philosophers and some religious thinkers who considered time an illusion. Leibniz, a contemporary of Newton, criticized that Newton's concepts of time and space are identical by their definitions and also opposed him using religious reasoning: that if there were no way to distinguish one time from another, God was faced with an impossible choice to decide rationally on the moment of creation. Many critics do not accept this logic and considered it nonscientific; they would see time created at the instant of Creation.

The concept of absolute time became outdated in early 20th-century scientific dialogue, when electrical and magnetic phenomena were studied theoretically, and Albert Einstein challenged the existence of time and space as separate absolute concepts by introducing a model of spacetime in his special relativity theory. According to this theory, there may always be observers for whom simultaneity is always relative, while there is no such thing as absolute simultaneity and hence no existence of absolute time.

Muhammad Aurang Zeb Mughal

See also Einstein, Albert; Einstein and Newton; God, Sensorium of; Newton, Isaac; Space, Absolute; Space and Time; Spacetime, Curvature of; Spacetime Continuum

Further Readings

Disalle, R. (2002). Newton's philosophical analysis of space and time. In I. B. Cohen & G. E. Smith (Eds.), *The Cambridge companion to Newton* (pp. 33–56). Cambridge, UK: Cambridge University Press.

Earman, J. (1989). World enough and spacetime: Absolute and relational theories of motion. Cambridge: MIT Press.

Hawking, S. W., & Penrose, R. (1996). *The nature of space and time.* Princeton, NJ: Princeton University Press.

Time, Arrow of

Nothing in common experience would seem to be more assured than the one-way flow of time from past to future. Many everyday events seem to be irreversible. Air rushes out of a punctured tire, never back into the tire to reinflate it. Heat flows from higher-temperature bodies to those of lower temperature, never from lower to higher, cooling a room for free. Heat engines use up energy, never producing useful energy for free. People age and die, never rising from the dead and growing younger.

The empirical fact that many physical events occur in only one time direction is codified in physics as the *second law of thermodynamics,* which requires that the *entropy* of a system, a measure of disorder, must always increase or, at best, remain constant when that system is isolated from the rest its environment.

However, the second law does not represent an infallible universal principle. Consider a closed room full of people. The air in the room is composed of individual molecules that move around pretty much randomly. Suppose someone opens a window at just that instant when all the air molecules just happen, by chance, to be moving in the direction of the window. The air then rushes out of the room and everyone inside explodes and dies.

No known principle of the mechanics of particle motion forbids this tragic event from happening. Although possible, it is very unlikely. The probability that all the molecules are moving in the direction of the window when it is opened is minuscule, and therefore not likely to occur even once on earth during the planet's entire existence.

If we were watching a film showing all the air in a room escaping through a window, leaving behind a vacuum, we could reasonably surmise that the film is being run backward through the projector. But suppose we have a room with just three molecules, as illustrated in Figure 1. The chance that the molecules randomly fly out the window is not at all small. Watching a film showing this event, we cannot judge for sure that the film is playing in reverse.

So, in one case we can determine the direction of time. In the second case we have no basis for even assuming that there is a direction of time. Irreversibility seems to hold true when there are many particles, while it is absent when there are only a few.

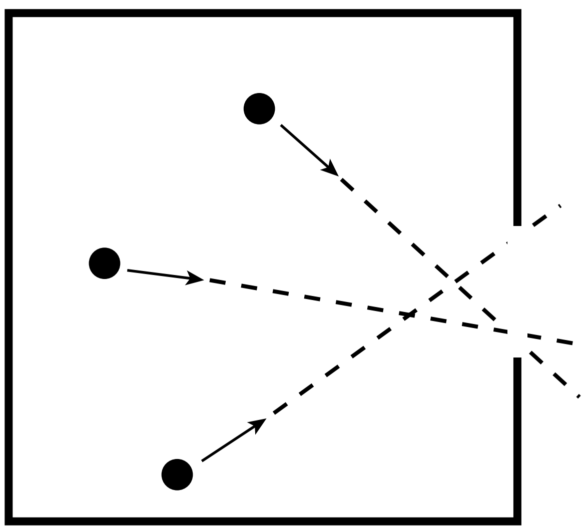


Figure 1 A chamber with three molecules

Notes: The probability of all three molecules escaping through an opening, leaving behind a vacuum, is not small. No direction of time can be defined with this observation.

Clearly, it cannot be a fundamental law of physics that processes involving *N* particles or fewer are reversible, while those with greater than *N* particles are irreversible. What is *N?* 100? 10,000? 3,486,756,493? For irreversibility to be fundamental, it would have to apply for any value of *N*. As far as we can tell, it does not.

The second law of thermodynamics is simply a convention that, as Ludwig Boltzmann showed in the late 19th century, defines the commonsense direction or *arrow of time*. It amounts to little more than a definition of the arrow of time as the direction of increasing entropy of the universe. Open systems, that is, systems that exchange energy with other systems or their environment, can gain or lose entropy. Organization is viewed as a lowering of the entropy of a system. It requires outside energy to do the ordering and a corresponding increase in entropy of the outside system that is providing that energy. So, as the sun provides energy for ordering processes on earth, the entropy of the universe as a whole gains the entropy that earth and the sun lose.

The arrow of time is thus a statistical asymmetry that is not built into the fundamental nature of the universe. The air in a room is not forbidden from emptying out when a window is opened, killing everyone inside. A broken glass can reassemble and a dead man can spring to life, if randomly moving molecules just happen to be moving in the right direction. However, these events are extremely unlikely, because our macroworld is composed of huge numbers of particles that move around more or less randomly.

Other Arrows of Time

The fundamental principles of physics do not distinguish between forward and backward time. Some rare processes exhibit a small (0.1%) asymmetry in the probabilities for both time directions, but these do not forbid events from happening in either time direction.

The expansion of the universe would seem to single out a particular time direction, thus defining what is called the *cosmological arrow of time*. But that direction is just the direction of increasing entropy of the universe, and so is identical to the thermodynamic arrow. Cosmological models can account for the low entropy at the beginning of the big bang, and an overall time symmetry is possible if one considers the time before the big bang as containing a mirror universe expanding in the time direction opposite to ours. While we cannot observe this universe, nothing in the known principles of physics or cosmology rules it out and, indeed, they seem to suggest the possibility.

A time asymmetry appears to occur with electromagnetic radiation, where sources are usually seen to emit radiation and not absorb it. This suggests a *radiation arrow of time*. However, the basic equations of electromagnetism, Maxwell's equations, are time symmetric and allow for radiation in both time directions. The observed directionality is the result of the boundary conditions that are set up in most problems, where the source and detector are specified by the way the experiment is conducted.

Finally, the measurement process involving so-called wave-function collapse in quantum mechanics has been suggested as a fundamental source of an arrow of time. However, it has been proven that quantum mechanics is perfectly time-symmetrical. Furthermore, quantum experiments seem to exhibit a backward causality that suggests that time is reversible at the quantum level. Many of the so-called paradoxes of quantum mechanics, such as particles appearing simultaneously at different points in space (*nonlocality*) can be understood with time reversibility without the need to invoke superluminal motion.

Victor J. Stenger

See also Cosmogony; Teleology; Time, Asymmetry of; Time, Linear; Time, Symmetry of; Universe, Origin of

Further Readings

Davies, P. (1996). *About time: Einstein's unfinished revolution.* New York: Simon & Schuster.

Price, H. (1996). *Time's arrow and Archimedes point: New directions for the physics of time.* Oxford, UK: Oxford University Press.

Stenger, V. J. (2000). *Timeless reality: Symmetry, simplicity, and multiple universes.* Amherst, NY: Prometheus.

Time, Asymmetry of

The directionality of time is a common, everyday experience. However, that direction, called the *arrow of time,* is simply a convention. Nothing in the principles of physics prevents processes from occurring in either time direction. In the human macroworld, however, many events have a much higher probability for occurring in one time direction than the reverse. That is, for all practical purposes, they are irreversible.

Air never flows back into a punctured tire to reinflate it. Heat never flows from lower temperature to higher temperature. People never grow younger. These events are never observed—yet they are not in principle impossible. The bodies of our normal experience are composed of a vast number of particles that move around randomly. The probability that particles of outside air just happen to move in the direction of a hole in a flat tire to inflate it is not zero; it's just so low that we are not likely to ever see it happen. A dead person could even come back to life spontaneously, but don't count on it.

An apparent asymmetry in time exists, but it is a statistical effect that is not present in the processes involving few particles, such as the processes observed in chemical, nuclear, and elementary particle reactions. These reactions all occur in either time direction. For example, hydrogen and oxygen can combine to form water, with some heat given off:

$$H_2 + O \rightarrow H_2O + \text{heat}$$

The reverse process also occurs when heat added to water produces hydrogen and oxygen:

$$H_2O + \text{heat} \rightarrow H_2 + O$$

While the rate for a reverse process will not always equal that of the original process because of various statistical factors, the basic probabilities are exactly equal. At least that is the case for all chemical and nuclear reactions and for most elementary particle reactions.

The operation that reverses the time direction of a process is referred to as *T* for *time reversal.* Two additional related operations are also defined. In one, designated *C* for *charge conjugation,* the particles in a reaction are all changed to their antiparticles. In the other, designated *P* for *parity,* the *handedness* of the process is changed—as if the process is viewed in a mirror. From very basic axioms in physics, it can be proved that all physical processes are *invariant* (unchanged) under the combined operation *CPT.* This is called the *CPT theorem.*

Indeed, all chemical and most nuclear and elementary particle reactions are invariant under the operations *C, P,* and *T* when each is performed separately. However, in 1956, C. S. Wu and her collaborators showed that parity invariance was violated in the beta-decay of radioactive cobalt-60. In general, the *weak force,* one of the four basic forces in the universe, violates parity invariance.

In 1964, Val Fitch and James Cronin discovered that the decays of neutral K-mesons were not invariant to the combined operation *CP.* Assuming that the *CPT* theorem is correct, this provided indirect evidence that time reversal invariance is also violated in these reactions.

Since then, direct evidence for *T*-violation has been found in the decays of neutral K-mesons. *CP*-violation has also been confirmed in the decay of B-mesons.

It is important to understand that the empirical fact of time asymmetry does not imply time irreversibility. The reactions violating *T*-invariance still happen in both time directions. However their basic probabilities are not exactly equal, differing by small amounts, typically 0.1%. Hence, it appears unlikely that this time asymmetry is the fundamental source of an arrow of time in the universe. Time reversal with equal probabilities can be maintained for all fundamental processes by making sure to also operate with *C* and *P,* that is, change all the particles in a reaction to their antiparticles and view the process in a mirror.

Invariance principles provide the foundation of much of physics, reflecting as they do fundamental symmetries of the universe. For example, applying a theorem proved by Emmy Noether in the early 20th century, it can be shown that any physical models that are invariant under translation and rotation of the spacetime coordinate system will contain as fundamental "laws of nature" conservation of energy, linear momentum, and angular momentum as well as Einstein's *special theory of relativity.* Einstein's *general theory of relativity* follows from similar considerations. Generalizing Noether's theorem to more abstract spaces, one finds that almost all of the rest of physics follows from a generalized principle called *gauge symmetry.*

The violation of any of these invariance principles shows that the corresponding symmetry is broken. Without broken symmetries, much of the complexity that is found in nature would not exist. For example, *CP* violation is believed to have played a role in the early universe to produce the large difference between matter and antimatter that now exists. Currently particles outnumber antiparticles by a billion to one. Cosmological models suggest that the universe was born in a state of complete chaos and thus in complete symmetry (*see also* Universe, Origin of). When the first particles appeared, there were equal numbers of particles and antiparticles. If this had remained the case, the universe today would be pure radiation, as all the protons would have been annihilated with antiprotons and electrons annihilated with positrons (antielectrons), with none left over to make atoms.

Original symmetries such as *CP* were spontaneously broken, making possible the complexity of stars, planets, and life. Complexity thus arises naturally out of simplicity, somewhat analogous to the way the spherical symmetry of a region of water vapor is broken as it freezes into a snowflake.

Victor J. Stenger

See also Time, Arrow of; Time, Symmetry of; Universe, Origin of

Further Readings

Ball, P. (1999). *The self-made tapestry: Pattern formation in nature.* New York: Oxford University Press.

Davies, P. (1996). *About time: Einstein's unfinished revolution.* New York: Simon & Schuster.

Lederman, L. M., & Hill, C. T. (2004). *Symmetry and the beautiful universe.* Amherst, NY: Prometheus.

Stenger, V. J. (2000). *Timeless reality: Symmetry, simplicity, and multiple universes.* Amherst, NY: Prometheus.

Stenger, V. J. (2006). *The comprehensible cosmos: Where do the laws of physics come from?* Amherst, NY: Prometheus.

Time, Cosmic

Cosmic time is a measure of time on a scale of billions of years, during which the universe is cooling and expanding from its initial hot, dense state, and stars and galaxies are evolving. The universe had its beginning about 14 billion years ago in the big bang. By contrast, the earliest signs of life on earth only date back to about 3.7 billion years ago, and cosmic time is vast in comparison with the scale of a human lifetime. An even shorter timescale marks the life of quantum particles, the smallest forms of matter and energy that wink in and out of existence so quickly that some cannot be detected directly.

Time itself did not exist until the birth of the universe in the big bang. Albert Einstein showed that it is the fourth dimension of spacetime (the other three being the conventional dimensions of space) and that any directional movement is also a movement through time. Throughout cosmic time, stars and galaxies evolve. This is evident in the birth, growth, and death of stars and in the formation and changes in galaxies. Change is a key factor in the slow-moving cycle of cosmic time, and a more narrow definition states that a single unit of cosmic time is the span of time through which the universe has changed fundamentally.

The fundamental change involves the shifting balance between matter and another, as yet poorly understood, form of energy. Recent observations indicate a change in the Hubble constant, a measure of the rate of expansion of the universe since just after the big bang. This evidence that the rate of expansion is accelerating was an unexpected finding, because calculations indicated that the amount of normal matter and energy present in the universe would lead to a gradual slowing down of expansion. However, scientists have discovered a previously unrecognized form of repulsive substance, a dark energy, that acts like negative gravity, pushing matter apart, and this may account for the acceleration. With the passage of time, matter will become more dilute, carried along, like raisins in a loaf of rising bread. Dark energy appears in minute amounts within this expanding space and, acting as a repulsive factor, will eventually overtake matter as the dominant factor in the universe. The fundamental change wherein dark energy overtakes matter is calculated to be about 10 billion years—a single unit of cosmic time.

Isabelle Flemming

See also Big Bang Theory; Bruno, Giordano; Cosmogony; Hawking, Stephen; Time, Emergence of; Time, End of; Time, Galactic; Time, Sidereal; Time, Universal; Time and Universes; Universe, Age of; Universe, Evolving

Further Readings

American Astronomical Society. (2004). *Ancient universe: How astronomers know the vast scale of cosmic time.* Retrieved August 10, 2008, from http://education.aas.org/publications/AncientUniverseWeb.pdf

Gribbin, J. R. (2000). *Birth of time: How astronomers measured the age of the universe.* Harrisonburg, VA: Donnelley.

Hawking, S. W. (1988). *Brief history of time: From the big bang to black holes.* New York: Bantam Books.

Jaffe, R. L. (2006). Times of our lives: Gravity, along with dark energy, plays a key role in the timing of our cosmic appearance and sets strict limits on the span of life anywhere in the universe. *Natural History, 26*(6), 115–119.

Time, Cyclical

Fundamental to human existence has been an attempt to understand, interpret, and influence the world in which we live. Various peoples have developed their own unique approaches to these issues in the form of systems of beliefs, values, and behaviors. It is within the context of these systems, collectively referred to as *culture,* that the interpretations of time have taken shape, which are thus rooted in raw human experiences and responses to life and to the natural world. On a daily level, the lives of most individuals seem to possess a one-directional aspect in that they consistently and ceaselessly move forward, from moment to moment and event to event, each day bringing new experiences, growth, and decay. Life does not appear to stop or move backward. A linear concept of time, then, reflects the common perception and experience of most people today and has been integral to various peoples' understanding throughout history. Logically speaking, whatever has a beginning will have an end: a line, a life, a universe, a history, and so forth. Because linear time typically posits a beginning, it implies that there will be an end as well.

In many traditional cultures and belief systems, the linear aspect of time is important, for it explains distinctions, growth, and change. At the same time, however, it is seen as simply a part of a greater dimension, a circular or cyclical one, that is far more encompassing and that can be seen in the daily rotation of the earth, the lunar cycle, the seasons of the year, the migrations of animals, and so forth. From early childhood and continuing throughout life, humans witness and live with the cycles of time both in nature and in human existence. In order to survive, early humans had to adapt themselves to these cycles and came to see themselves as a part of this natural process. The greatest amount of adaptation can be seen with the more rural peoples, for whom working with and depending on nature and its cycles are integral to daily life. As a consequence, the cyclical view of time has been a predominant view throughout history, especially in traditional cultures and belief systems. Cyclical time, or circular time, does not require either a beginning or an end. Thus, those who think of time cyclically need not conceptualize an ending of time, of humanity, or of existence. Instead, they tend to envision a reality that simply has always been and will always continue. This does not mean that creations do not occur, but that, generally speaking, they are also a part of a cycle, just as are all aspects of reality.

Ancient Cultures and Concepts

Although we cannot know for certain the various preliterate understandings of time and the human relationship to it, we have long had to pattern our lives in accordance with the cycles of the natural world. Hunters developed their methods and practices in conjunction with prevalent animals and migration cycles. Agriculturalists and food gatherers learned to function in conformity with seasons and weather cycles, which have also determined the types of shelters constructed and clothing worn. Because humans and nature share common space in the world, it is therefore natural that traditions and beliefs in many cultures reflect this fact. In the ancient beliefs of both India and China, for example, there developed a circular understanding of the relationship and even a dependency between humans, nature, and the spirit world.

Early Greek philosophers and poets, especially Hesiod and Pythagoras, conceived time cyclically. Pythagoras proposed that, at the end of the present universe, everything will return to its previous state and begin again exactly as it did before. In his *Works and Days,* Hesiod (8th century BCE) divides existence into five stages, starting with an age of wisdom and peace and gradually degrading to the final stage in which there is hatred, violence, and warfare. Ultimately, however, he posited a return and a new beginning. The ancient Hindu writings describe existence somewhat similarly, although in four stages. Both Mayan and Aztec cultures understood time in a great cycle, as can be understood in the latter's calendar.

Because ancient cultures have typically viewed humans within the broader natural order and cycle, they sought to live in some manner of harmony with and within it. Because the entire natural world has existed in a seemingly endless cycle, it is natural, then, that humans have not only lived in accordance with these cycles but have also seen their own existence as part of an endless cycle. In some of the earliest human burial sites to be uncovered, items such as foodstuffs, animals, and tools have been found. These point to a belief in an afterlife, a belief that humans will return to a material existence in some place and in some form where such items may well be useful and necessary. Thus, in many cultures, death has long been understood as a type of transitional sleep and transference state, from which one will awaken in a new place. Death precludes rebirth and a new life. In the myths of some religious cultures, even a god or deity will die, only to be reborn again, the death serving some important function. This does not mean that there has been a denial of the linear aspect of time. Instead, the linear progression of life has typically been viewed as ultimately leading to a return to a previous state. In some cases, this has been back to an original state, back to the beginning of time. To some, their "mythical past" is actually an ever-present reality. Tyson Yunkaporta, an Aboriginal writer and scholar from Australia, notes in relation to a popular Aboriginal creation myth: *The rainbow snake is still pushing up the mountains.*

Agrarian peoples have long lived in accordance with the natural cycles of the earth. In those cultures where technology has not changed life appreciably from generation to generation, the concept of time in the form of a cyclical constancy is easy to understand. Each generation is, in many ways, a reenactment of the previous one, albeit with new players. Values, traditions, beliefs, and practices remain the same; there is little reason to change. There is a security in this way of thinking and this approach to life. Within development of various advanced forms of technology, many farmers and others have been able, to a certain extent, to free themselves from those cycles, but not completely. Irrespective of technological advancements, the natural rhythms of the earth continue to exert great influence over the lives of humans and nature. As long as this is the case, the cyclical view of time will play an important role in the lives of many people.

Ramdas Lamb

See also Cosmology, Cyclic; Eternal Recurrence; Nietzsche, Friedrich; Spencer, Herbert; Universe, Contracting or Expanding; Universe, Evolving

Further Readings

Dowden, B. (2008). *Time.* Retrieved August 10, 2008, from http://www.iep.utm.edu/t/time.htm

Ridderbos, K. (Ed.). (2002). *Time.* New York: Cambridge University Press.

Time, Emergence of

"Time is inseparably connected with history. Everything that exists in time has its history. Time and history are almost synonymous: History is measured by time, and time flows together with historical processes." These are commonsense views, and there certainly is a grain of truth in them, but they also need to be revised in the light of contemporary physics. This entry reviews the findings of recent physical theory and research, discusses linear and cyclic models of time, and links the temporality of the world to change and the creative process.

History is doubtlessly rooted in the physical world, and the laws of physics that shape the physical world provide constraints for possible histories. The laws of classical physics seem to corroborate the aforementioned commonsense view regarding the connection between time and history. However, classical physics is valid only as a limiting case of some more fundamental theories, and the real roots of time and history should be looked for in these more fundamental strata of the world's structure.

In the theory of relativity, of which classical mechanics is a limiting case, it is not space and time taken separately that form a stage for physical processes, but their combination into a single geometric entity, called *spacetime*. Any particular decomposition of spacetime into space and time depends on the choice of a local reference frame; that is, on the state of motion of the observer connected with this reference frame. Only spacetime itself, and not space and time taken separately, has the invariant meaning—in other words, the meaning independent of the choice of a reference frame. Consequently, if history is measured by time, history is also dependent on the state of motion of a given observer. A typical example is provided by the process of a gravitational collapse. If it is viewed by an observer collapsing together with a dying massive star, its history will end up catastrophically in a finite time, but when it is viewed by an observer regarding the process "from outside," that is, from a safe distance, the history of the collapsing observer will last forever only asymptotically approaching the "nonreturn" surface. Human history is notoriously accused of lacking objectivity: No two accounts of the same event coincide. But the present case is much more dramatic: Physically, the history of a process is not constituted by this process alone, but rather by a relationship between this process and a particular reference frame.

As for cosmic history, the history of the universe, local time (time within a cosmologically small neighborhood of a given observer) is usually identified with the first coordinate of a local coordinate system. But, in general, there is no unique coordinate system that would cover all of spacetime, nor is there any guarantee that if we cover spacetime by many coordinate systems, all local times determined by them could be smoothly joined together to form a single cosmic time. This could be done only if certain conditions were satisfied. And what is extremely interesting—these conditions seem to be very exceptional in the collection of all possible universes.

Time and Causality

Is there any possibility to make the history of an observer or a particle more independent of the choice of a reference frame? There is such a possibility if we look at the concept of history from the geometric point of view. Geometrically, the history of an observer or a particle can be described by a curve in spacetime followed by a given observer or a particle. Curves, as geometric entities, are independent of the choice of a reference frame. In the theory of relativity such histories are classified into three classes. Curves traced by observers and by nonzero rest-mass particles are called *timelike* curves. Photons are distinguished from all other particles because as light particles they have a distinguished status in the theory of relativity—they move with the limiting velocity in nature, the velocity of light. Curves followed by photons (zero rest-mass particles) are called *light* curves or *null* curves. There are also the so-called spacelike curves that do not represent histories of any known physical objects. Such objects would move faster than light. Timelike and null curves together are called *causal curves,* because only along these curves can causal influences propagate.

Every point p in spacetime has a *normal neighborhood* in which timelike curves passing through p form the interior of a cone, the "surface" of which is formed by null curves passing through p. This cone is called the *light cone* of p. Two events can be causally connected (i.e., one of them can be the cause of another) only if one of them is situated on or within the light cone of the other. Spacelike curves, which transmit no causal influences, lie outside the light cone. Having all this in mind, one often speaks, like Stephen Hawking and George F. R. Ellis, of the *causal structure of spacetime.*

The causal structure of spacetime within the normal neighborhood is relatively simple (it is essentially the same as in the special theory of relativity), but things get complicated outside of it. For instance, spacetime can contain closed causal curves. In such a case the causality principle is endangered. In a world model in which this happens, the global history is replaced by the continuous recurrence. In 1949 Kurt Gödel discovered the first solution to Einstein's field equations with closed causal curves; now, many such solutions are known. The existence of these solutions testifies to the fact that the idea of "temporal loops" does not involve contradictions (at least within the conceptual framework of general relativity), but if we add some external factors to the causal structure of spacetime, serious problems can arise. For instance, if we put a killer into such a spacetime, he could be able to kill his father before his own birth! This seems silly, but if we replace the killer with suitable differential equations and the problem of initial conditions for them, difficulties can appear in matching suitable initial conditions with their corresponding solutions (the so-called Cauchy problem), and the paradox remains in its full force. Therefore, it seems reasonable to exclude such pathologies. We are doing so by imposing the *causality condition* on all "physically admissible" spacetimes. It forbids the existence of closed timelike curves in such a spacetime. But we must exclude also "almost-closed" causal curves that are on the verge of violating causality. Spacetime, in which this requirement is satisfied, is said to be *strongly causal.* (It satisfies the *strong causality condition.*)

Spacetime is a subtle mathematical structure, and its various substructures must cooperate accordingly. The *Lorentz metric structure* (or *Lorentz metric* for short) plays the crucial role in the spacetime architecture. It coordinates all other spacetime substructures by determining which curves are timelike, spacelike, and null. Another function of the Lorentz metric is that it makes meaningful space and time measurements, and there are space and time measurements that allow us to experimentally determine the Lorentz metric. But in every space and time measurement, unavoidable measurement errors are inherent (even if we do not take into account quantum effects). This implies that the Lorentz metric can be experimentally determined only with a finite accuracy. We can express this by saying that infinitely many "nearby" Lorentz metrics are compatible with given space and time measurements. Consequently, if we require that spacetime should be strongly causal, we must extend this postulate to all "nearby" metrics. Otherwise, within the "safety margin" (determined by the finite measurement accuracy) we could have causality violating spacetimes. Therefore, we must exclude the situation in which a slight perturbation of a Lorentz metric (on a strongly causal spacetime) produces closed timelike curves. As noted by Hawking and Ellis, spacetime that satisfies this condition is said to be *stably causal.*

It turns out that this causality property is strictly connected with the existence of a global time in a given spacetime. This means that every observer in this spacetime can be equipped with a clock measuring a smooth flow of time. Let us represent the history of such an observer by a timelike curve. A clock carried by this observer associates to every point of this curve a real number (an "hour" shown by this clock). In other words, a monotonically increasing function is determined along this curve. ("Monotonically increasing" means "increasing and never decreasing.") We see that from the mathematical point of view the global time idea is implemented by the existence of a smooth monotonically increasing function defined along every timelike curve representing the history of an observer. In 1968 Stephen Hawking proved the theorem stating that the global time (in the above sense) exists in spacetime if and only if this spacetime is stably causal.

We meet here a beautiful example of a subtle interaction of mathematical structures when they are incorporated into a physical theory. Three apparently very different things—the possibility of making space and time measurements (consequently the very possibility of doing physics), causal interactions (stable causality), and the existence of global time—turn out to be but some aspects of the same properties of the metric structure. The universe is a much more organized whole than standard textbooks of physics and astronomy allow us to suspect.

However, a relativistic world model satisfying the stable causality condition still does not resemble the Newtonian universe in which simultaneous events are well determined independent of how far from each other they are situated. In a stably causal relativistic universe, clocks carried by all observers need not be synchronized (they should only indicate a continuous time flow) and, in general, there is no way to determine simultaneity of distant events. To guarantee such a possibility we must impose a yet stronger condition on spacetime. This stronger condition is connected with deterministic properties of spacetime. A spacetime is deterministic if each event in it can be predicted from suitable initial data. These data must be given on an initial surface, called a *Cauchy surface.* In general, the geometric structure of spacetime does not admit the existence of such a surface (or it admits only a *partial* Cauchy surface, such that only the events situated in some region of spacetime can be predicted from the initial data on this surface). Spacetimes in which there exists a (global) Cauchy surface are said to be *globally hyperbolic.* Strong symmetry properties of globally hyperbolic spacetimes ensure that the concept of absolute simultaneity can be made meaningful in them. And only now we have our "familiar stranger" (from the title of J. T. Fraser's 1987 book), the cosmic time of our world.

The question arises: How restrictive are the above global time-admitting conditions? The answer is that they are very restrictive. In the collection of all possible relativistic world models (i.e., in the collection of all possible solutions to Einstein's field equations) the world models admitting the existence of a global time form the zero-measure subset. This means that if we had to choose a world model at random, the chances to pick up a model admitting a global time would be negligibly small. The same is true if we would like to pick up at random a world model with absolute simultaneity from among all world models that admit global time. All achievements of contemporary cosmology that so successfully reconstruct the history of our universe bear witness to the fact that the world we inhabit belongs to this selected family of universes that admit a global time. How to explain this fact remains so far an unanswered question.

Arrows of Time

In the preceding sections, we were able to establish conditions for the existence of the global time in a given world model. They are connected with causal properties of spacetime, and are—as we have seen—severely restrictive. We should notice that these conditions say nothing about the direction of the time flow (the arrow of time). Two such directions are possible, and neither of them is distinguished in any way within the geometric framework of general relativity. To determine the arrow of time we need an additional criterion. It is commonly believed that such a criterion is provided by the second law of thermodynamics: the law of the entropy increase. *Entropy* is a mathematical function that measures the degree of disorder—or, equivalently, the degree of energy dissipation—in a given physical system. The second law of thermodynamics asserts that the entropy of an isolated system (in which no reversible processes occur) always increases until it reaches its maximum value. The state with the maximum entropy is called the *equilibrium state.* The second law of thermodynamics, as applied to the universe as a whole, says that the entropy of the universe increases and goes to its maximum. It is this increase of entropy that determines the arrow of time.

There is no doubt that the present universe exhibits the thermodynamic arrow of time, but this fact poses several questions of a cosmological significance. The thermodynamic arrow of time implies that the present entropy of the universe is lower than its future entropy and higher than its entropy in the past. In fact, the very meanings of the terms *past* and *future* are defined by the entropy increase. According to theoretical physicist Paul Davies, we should also keep in mind that the law of entropy increase is a statistical law and should be understood in the probabilistic sense. This means that the increase of entropy is more probable than its decrease provided that a physical system under consideration consists of a sufficiently great number of individual entities (particles, molecules, and so on). When this condition is not satisfied, the thermodynamic arrow of time is not well determined or not determined at all.

The law of entropy increase, when extrapolated to the past, leads us to the *initial state* (near the big bang), when the entropy of the universe had to be extremely low. But the standard cosmological model tells us that "in the beginning" matter was evenly distributed throughout space and was at a uniform temperature. In the usual conditions (when only short-range forces are taken into account) such characteristics are typical for a system in the state of maximal entropy. However, in the cosmological environment, gravity (which is a long-range force) is acting, and conditions for the equilibrium state change radically. A large-scale self-gravitating system becomes more and more clumpy, and black holes will eventually be formed in it. Although the concept of gravitational entropy is not yet well elaborated, the thermodynamics of black holes (a subject rather well known) gives us a clear hint that in the cosmological setting the clumpiness of matter and the formation of black holes lead to a large entropy increase. Taking this into account, it is clear that the universe in its initial state could have a very low entropy in spite of a smooth distribution of matter. In this case, the contribution from the gravitational entropy would dominate over the contribution from the entropy of ordinary matter. According to Penrose, this is connected with the origin of the arrow of time on the cosmic scale. However, we should keep in mind that the relativistic statistic thermodynamics is so far not well elaborated and, in particular, there is no commonly accepted definition of gravitational entropy. And without these ingredients our understanding of the arrow of time remains partial and fuzzy.

Eternal Return

The discovery by Gödel of the solution of Einstein's equations with closed timelike curves has revived the old idea of a cyclic universe. In the context of general relativity, this idea can assume a stronger version or a weaker version. The stronger version is suggested by Gödel's solution. In this version, the history of the universe forms a closed "time loop"—the same event occurring somewhere in the universe has already occurred infinitely many times, and it will be occurring in the future infinitely many times. As we have seen above, such an idea—philosophically attractive as it might be (at least for some philosophers)—faces rather serious difficulties related to the problem of causality, and it is nowadays not popular among philosophizing cosmologists. But from time to time it attracts attention of some of them. For instance, in 1998 J. Richard Gott and Li-Xin Li speculated that in the very early universe there could exist a region with closed timelike curves. This would eliminate the troublesome concept of the beginning of the universe. However, to make this idea physically more plausible, these authors had to assume that the region of spacetime with closed timelike curves is separated from us by *causal horizons*. Otherwise, causal pathologies could infect our present physics.

According to the weaker version of the eternal return idea, the history of the universe is open (i.e., the same events are never repeated), but it consists of an infinite sequence of oscillations: each contraction phase is followed by an expansion phase that in turn initiates another contraction phase, and so on to infinity. This scenario meets the very serious difficulty with the singularity separating every expanding phase from the preceding contracting phase. When one approaches the separating point, some physical quantities (such as matter density) tend to infinity, and the classical singularity theorems (proved by Stephen Hawking, Roger Penrose, and others in the 1960s) tell us that the singularities cannot be avoided without violating very realistic physical conditions. These conditions could eventually be violated by quantum gravity effects, but no commonly accepted quantum gravity theory is now existing.

The *eternal return* issue is clearly connected with the Poincaré recurrence theorem. Let us consider a classical system of material points acted upon by forces that depend only on positions of these points. Let us also assume that both the coordinates of the points and their velocities remain bounded. The Poincaré theorem asserts that the trajectories of these points will return, in fact infinitely many times, arbitrarily close to the positions already occupied by them. The theorem, when put into the cosmological setting, can be interpreted as saying that the history of a spatially finite universe will be "almost closed"; that is, the universe will come back arbitrarily close to the state already occupied by it, and this scenario will be repeated infinitely many times.

It was mathematician Ernst Zermelo who noticed that in the system satisfying conditions of the Poincaré theorem, the law of the entropy increase cannot be valid, because the increase of entropy leads the universe to the equilibrium and not to the states it previously occupied. Austrian physicist Ludwig Boltzmann responded to this difficulty by remarking that the objection does not stand if the law of the entropy increase is understood statistically. In such a case, a decrease of entropy is only less probable than its increase, but it is not excluded. Even if the universe reaches the equilibrium state, there is always a probability that it will deviate from it. Boltzmann speculated that the present universe can be fluctuating around its equilibrium state, and only its region of our astronomical vicinity finds itself in a fluctuation in which entropy actually increases.

The Poincaré recurrence theorem was formulated within the conceptual framework of classical mechanics, and it was Frank J. Tipler who proved its relativistic counterpart. Tipler's theorem asserts that if a cosmological model satisfies the following conditions: (1) It is spatially closed, (2) gravity in it is always attractive, (3) Laplacian determinism holds true in it, and (4) every curve in its spacetime, being the history of a particle or the history of a photon, at least once experiences tidal forces, then this cosmological model cannot be "time periodic"; that is, it cannot return to the state once occupied by it.

As we can see, neither the Poincaré theorem nor the Tipler theorem say anything about "open" world models, but for "closed" universes, the relativistic version of the theorem points in the opposite direction from the classical version.

Physical Clocks and Creative Processes

Independent of all discussions around the idea of eternal return, modern cosmology displays the universe in the state of a long evolutionary process: from the big bang and nucleogenesis to the formation of galaxies, clusters of galaxies, stars, and planets. Moreover, biological evolution, regarded as a fiber of cosmic evolution, is deeply rooted in all the above processes. There are strong reasons to believe that a long evolutionary history of the cosmos was indispensable to produce a living cell, not to mention an intelligent observer.

In our previous discussion we have indicated that, from the geometric point of view, a clock should be interpreted as a monotonically increasing function along a timelike curve in spacetime, but to have a truly evolutionary process, a physical clock is needed; that is, a physical device measuring real processes. Such a clock could be described as a subsystem of the world, itself a process, the changes of which could be compared with changes of its environment. Not in any conceivable world can such a subsystem exist. Without enough order, no sufficiently regular subprocesses are possible. This is why in the equilibrium state, admitting only chaotic motions, there could not exist a subsystem that could be identified as a physical clock. Our organisms are the sort of physical clocks that can exist only in far-from-equilibrium states. There is no doubt that truly creative processes had to be at work in our genesis and, as we know today, no creative processes can operate without the intervention of some chaotic phenomena. We are, therefore, creatures from the boundary region between order and chaos. The temporality of our existence is but an aspect of the temporal structure of the world.

Michael Heller

See also Big Bang Theory; Big Crunch Theory; Causality; Cosmogony; Entropy; Eternal Recurrence; Gödel, Kurt; Hawking, Stephen; Spacetime Continuum; Time, Arrow of; Time, End of

Further Readings

Davies, P. C. W. (1974). *The physics of time asymmetry.* London: Surrey University Press.

Fraser, J. T. (1987). *Time the familiar stranger.* Amherst: University of Massachusetts Press.

Hawking, S. W., & Ellis, G. F. R. (1973). *The large scale structure of spacetime.* Cambridge, UK: Cambridge University Press.

Heller, M. (2002). Time of the universe. In G. F. R. Ellis (Ed.), *The far-future universe: Eschatology from a cosmic perspective* (pp. 53–64). Philadelphia: Templeton Foundation Press.

Penrose, R. (1979). Singularities and time asymmetry. In S. W. Hawking & W. Israel (Eds.), *General relativity: An Einstein centenary survey* (pp. 581–638). Cambridge, UK: Cambridge University Press.

Time, End of

The concepts of the "end of time" or the "end of the world" can be viewed from both religious and scientific perspectives. The terms can encompass the extinction of the earth, the universe, humanity, and even the extinction of time itself. "End-time" is an example of a term associated more specifically with religious beliefs.

Religious Aspects

From the beginnings of civilization to the present, people of many cultures and religious backgrounds have accepted beliefs that offer some kind of reassurance about life after death. Such beliefs have been characterized by the association of specific cycles of time with the supernatural.

The term *eschatology* is associated with last things, specifically including the end of time. The earliest known example of an eschatological faith is Zoroastrianism, founded in the 6th century BCE by the Iranian prophet Zoroaster.

Mythical eschatology has generally offered a cyclic view of history in which order is created out of chaos at both the beginning and the end of time. Historical eschatology includes the concepts of messianism, apocalypticism, and millennialism. *Messianism* is characterized by the presence of a single person who will lead others to redemption. *Apocalypticism* anticipates a dramatic intervention by God, who will recognize the faithful majority. *Millennialism* is named for the concept of an ideal 1,000-year kingdom that would be formed before the world's end. In that kingdom, Christ and his saints will reign and the forces of evil will be destroyed.

An example of the persistence of an ancient belief into the present can be seen in the interest shown in an ancient Mayan calendar's identification of the year 2012 as the end of a world cycle. Some believers definitely anticipate it as an end time.

Scientific Aspects

History offers many examples of attempts to identify end times that did not materialize, but that fact is not likely to stop future speculation. Meanwhile, modern physicists have proposed a number of alternative theories about whether the universe is likely to have an end and how that might occur.

About 1920, Sir James Jeans proposed the "steady-state theory," where the universe has no beginning or end and continues to expand while maintaining a consistent average density. An important first step toward an alternate theory was Edwin Hubble's law, proposed in 1929. Hubble's law led to the concept of an expanding universe, which further led to the idea that the universe had a beginning and possibly an end. The end, or "big crunch," would occur when the universe stops expanding, its matter having enough density to cause it to collapse into itself.

Since the 1950s, several observations have supported the big bang theory of the origin of the universe. Physicist Stephen Hawking particularly points to explorations of the Cosmic Background Explorer satellite, COBE, in 1992, as providing support for the big bang. Hawking proposed that, though the universe is finite, it has no boundaries in imaginary time, which runs at right angles to ordinary time. The no-boundary theory does imply that the universe will eventually recollapse, but the collapse will take much longer than the 15 billion years that the universe will have taken to expand. He speculates further that the contracting phase will not take an opposite "arrow of time" from the expanding phase, and time will not go backward.

More recently, cosmologists Paul J. Steinhardt and Neil Turok have introduced the cyclic model of the universe as an alternative to the big bang theory. The model still includes a big bang and a big crunch. But since the universe in the model has no beginning and no end, these occurrences would represent transitions from contracting to expanding phases in endlessly repeating cycles. In the model, dark energy plays a role in regulating the way in which the cycles occur.

An alternative to the positive view of dark energy in the cyclic model has been proposed by a team led by physicist Robert R. Caldwell. The "big rip" theory speculates that dark energy, or another unknown force, might speed up the expansion of the universe to the point where all matter would essentially be ripped apart. Yet another theory, first proposed by the 19th-century Scottish physicist William Thomson, was "heat death"—a condition where energy would be evenly distributed uniformly throughout all matter, and the temperature of the universe would drop to nearly absolute zero.

Modern cosmologist Frank Tipler has moved in a less common direction, combining his scientific research with his religious beliefs to develop a theory that attempts to prove the existence of God and an afterlife by using the laws of physics. He refers to the end of time as the Omega point, a phrase used earlier by Catholic evolutionist Teilhard de Chardin. Tipler predicts that this point will occur about 100 billion years in the future. He distinguishes between proper time, by which the finite age of the universe is measured, and subjective time, which allows for infinite amounts of life and thought as well as the processing of information. He envisions a closed universe in which the gravitational energy from the collapse of the universe will increase faster than the universe's movement toward zero, allowing our descendants to have an unlimited knowledge of the system.

Instead of concentrating on speculations about the past, present, and future, British physicist Julian Barbour speculates that time itself does not really exist and is defined only by our perception of changes that occur. Others before him have made the case that time is an illusion invented to try to make sense of the universe. Following this logic, time would no longer exist if either life or the universe itself disappeared. Many have shared similar theories, recorded back as far as the writings of the Greek philosopher Parmenides (c. 515–c. 445 BCE).

Speculation about the future of the earth and the universe is of obvious interest to scientists, theologians, and philosophers, as well as to the average person. Whereas certain theories about the end of time have received more general acceptance than others, even the most advanced scientific and theological explanations will remain subjects of study and debate into the foreseeable future.

Betty A. Gard

See also Apocalypse; Big Bang Theory; Big Crunch Theory; End-Time, Beliefs in; Eschatology; Hawking, Stephen; Teilhard de Chardin, Pierre; Time, Emergence of; Zeno of Elea; Zoroaster

Further Readings

Davies, P. (1994). *The last three minutes: Conjectures about the ultimate fate of the universe.* New York: Basic Books.

Steinhardt, P. J., & Turok, N. (2007). *Endless universe: Beyond the big bang.* New York: Doubleday.

Thompson, D. (1997). *The end of time: Faith and fear in the shadow of the millennium.* Hanover, NH: University Press of New England.

Time, Galactic

Galactic time is the process of tracking time relative to the age of our galaxy. The center of the Milky Way galaxy is located in the terrestrial night sky in the constellation of Sagittarius, at a location with a strong radio source called Sagittarius-A. It is optically invisible due to the concentration of dust and debris that is gravitationally influenced by a suspected galactic black hole; however, it is found by utilizing radiotelescopes that receive radio frequencies that penetrate stellar obstructions.

A galactic year is one complete revolution of the sun around the galactic center. The sun takes approximately 240 to 250 million years to orbit the galaxy, and if the assumption of the age of the sun is assumed to be 4,500 million years, then the sun is approximately 18 galactic years old. Much of the information about the exterior of the Milky Way is difficult to discern given that observations are taken from within. This is the same effect that kept most of humanity puzzled over how objects in the solar system behaved before Nicolaus Copernicus revolutionized astronomy with the heliocentric solar system model in 1543. Now that technology and instrumentation are improving to more precise levels, it is easier to detect and determine the small-scale changes occurring in the "fixed" stellar background. The same technological improvement occurred in 1609 when Galileo was able to observe the night sky in more detail with the advent of the telescope.

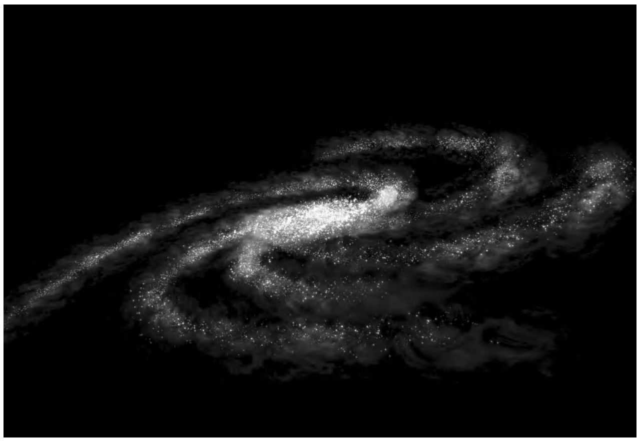
The Milky Way

Debates among astronomers regarding the rotational periods of galaxies create many questions. For example, we are able to surmise the rotational period of our own galaxy, but assumptions made in calculating other galactic rotation rates create unrealistic results. Edwin Hubble determined a range of age for the universe. When calculating the rotational period of Andromeda, the resulting value is greater than the Hubble range for the age of the universe. This discrepancy is based on assumptions made in calculating distances to galaxies, particularly in the mean distance of those stars known as Cepheid variables. Distances to Cepheids are estimates as well, and are used as "markers" to determine galactic separation because of their rotational periods. When the distance factor changes, all other related measurements change with it.

The local group of galaxies are assumed to be the same age as the universe, and, based on spectroscopy calculations, are mostly moving apart from one another at varying rates. There are also galaxies that are moving toward each other, such as ours and Andromeda, which are predicted to merge in another 6 billion years. Our sun is estimated to exist for only another 4.5 billion.

Stellar Evolution

To determine stellar evolution, astronomers use the Hertzsprung-Russell diagram (H-R diagram) developed by Ejnar Hertzsprung and Henry Norris Russell in 1910. The H-R diagram provides a way to age stars and reasonably predict their future behavior. The age scale relates the size, luminosity,



An artist's impression of our home galaxy—the Milky Way. Our solar system is one of billions in the galaxy, and the galaxy is one of billions in the universe.
Source: Photo courtesy of NASA.

and color of a star to calculate its relative age. Most stars spend their lives on an area known as the Main Sequence, evolving from high-temperature, high-luminosity stars to low-temperature, low-luminosity stars. The diagram also takes into account events that may occur to the star through its life cycle that change its classification from a Main Sequence star.

Our sun, for example, is in the average yellow range on the Main Sequence. Based on the H-R diagram, our sun is 4,500 million years old and at the midpoint of its existence. Eventually, it is expected to become a red giant, encompass part of the solar system including Mars, then recede to a white dwarf. However, the sun does not have enough mass to collapse upon itself and create a black hole.

Since its inception, other diagrams have been based upon the H-R diagram. The H-R diagram is also a tool useful in calculating distances to other galaxies and star clusters.

Timothy D. Collins

See also Big Bang Theory; Big Crunch Theory; Black Holes; Copernicus, Nicolaus; Cosmogony; Cosmology, Cyclic; Evolution, Cosmic; Galilei, Galileo; Light, Speed of; Space Travel; Stars, Evolution of; Time, Cosmic; Time, Sidereal; Time, Universal; Universe, Age of

Further Readings

Bosma, A. (1978). *The distribution and kinematics of neutral hydrogen in spiral galaxies of various morphological types.* Unpublished doctoral dissertation, Rijksuniversiteit, Groningen, Netherlands.

Hess, F. (2002). *Earth science.* New York: Glencoe McGraw-Hill.

Smolin, L. (1997). *The life of the cosmos.* New York: Oxford University Press.

Time, Historic

History (as opposed to prehistory) refers to a written record of the human past, so historic time is the period in which we have had such records. The line between prehistory and history is not distinct, and there has been much debate among historians and archaeologists about where the former ends and the latter begins.

The distinction between history and prehistory is fairly recent, with the word *prehistory* first being used in the 1860s. At this time, anthropology underwent a shift known as the "time revolution" or the "revolution in ethnological time." Prior to this revolution, the history of humankind was believed to extend back only a few thousand years, in keeping with beliefs about the timeframe of events in the Bible. The paradigm shift was spurred by the discovery of human tools near the remains of extinct species, and it also occurred around the same time that Darwin's *On the Origin of Species* (1859) was published. Humankind's existence was now lengthened by hundreds of thousands of years. It was during this time period that the field of anthropology emerged.

Because changes in the human way of life were gradual, no single date can be pinpointed as the start of history. The year 3500 BCE is often cited as the (approximate) date when recorded history began. This was contemporary with the beginnings of Sumerian society, located in Mesopotamia. The Sumerians developed cuneiform, one of the earliest known systems of writing. It began as a series of pictographs, in which different concepts and objects were represented by pictures, used chiefly for tallying and recording inventories of goods.

Another school of thought states that history began later, around 750 BCE, in Greece. It was during this period that writing began to involve analysis, instead of lists and simple records, as in prior times. For this reason, the period prior to these more detailed written records is sometimes referred to as "proto-history," a period between prehistory and history.

Herodotus, who lived in Greece in the 5th century BCE, is sometimes referred to as the "father of history." His account of the Greco-Persian war, known simply by the title *History,* is considered the first historical narrative of the ancient world. While other historical records had previously been written, his was the first to appear as a narrative whole. In addition to his narrative of the events of the war, Herodotus also described the political climate and social customs of the time, providing a rich source of information on Greece during the 5th and 6th centuries BCE.

While written records can provide information about a time period, historic sites, with their tangible artifacts, can provide even more information. Using both types of resources provides the most detailed information about a time period or culture. An example is the pyramids built in ancient Egypt, used as tombs and settings for funeral rituals. Inscribed on the walls of pyramids from the 5th and 6th dynasties (2465–2150 BCE) are *pyramid texts,* the oldest religious literature in Egypt. These hieroglyphic texts contain myths, spells, and incantations meant to protect the dead king or queen buried there. It is thanks to these writings that we understand the pyramids' purpose and Egyptian views of the afterlife. According to the pyramid texts, the tapered shape of the pyramids was meant to resemble a ramp or stairway for the soul to ascend to the afterlife.

These inscriptions were later augmented by *coffin texts* placed directly on the inside of the sarcophagi containing the bodies. These also contained spells and rituals, but they were used for all Egyptians, not just royalty. One of the coffin texts, later named *The Book of Two Ways,* gives a detailed picture of the journey to the afterlife, including maps and spells to help the deceased.

The Parthenon, a structure built in Athens, Greece, in the 5th century BCE, is another historical site whose history has been illuminated by the survival of written texts. Built as a temple for the goddess Athena, it was also used as a treasury building. Thanks to records describing its construction, we know that each column was built separately, under the direction of a different master mason. The records also state that a variety of methods were used to put the stones in place, including ropes and machinery.

Historical records have also enhanced our understanding of the Taj Mahal, built in India during the 17th century. The building acted as a tomb for Mumtaz Mahal, wife of Mughal emperor Shah Jahan. Official records from the emperor's court, as well as other Mughal historical records during that time period, describe the building of the tomb, its architectural features, and the cost of construction. A letter from the emperor's son also indicates that maintenance issues developed during the building's long construction. Without such records, our knowledge and understanding of this structure would be more limited.

Jaclyn McKewan

See also Anthropology; Archaeology; Egypt, Ancient; Presocratic Age; Rome, Ancient; Time, Arrow of; Time, Prehistoric

Further Readings

Bauer, S. W. (2007). *History of the ancient world: From the earliest accounts to the fall of Rome.* New York: Norton.

Houston, S. D. (2004). *The first writing: Script invention as history and process.* New York: Cambridge University Press.

Stavrianos, F. (1998). *Global history: From prehistory to the 21st century.* Upper Saddle River, NJ: Prentice Hall.

Time, Illusion of

Perceptual illusion has been defined as "a perception of a thing which misrepresents it, or gives it qualities not present in reality" and as "distortions or incongruities between percept and reality." Such definitions are often considered as aspects of the psychology of time, as there are states during which time perception does not faithfully represent what is regarded as objective time. This is especially the case for the dimension of event duration.

Time illusions associated with the duration of events reflect the nature of the cognitive processes underlying time perception. Because these processes are strongly context dependent and are affected by factors such as the duration measurement paradigm (prospective or retrospective), duration measurement method, and nontemporal information load required during a target interval whose duration is being estimated, situations will occur when, as a result of change in one or more of these factors, the duration of an event or a target interval will be perceived as different from that of another event or target interval although the clock time of these two instances may be identical. Hence, most time illusions that are related to duration are relative: That is, we can argue that the illusion appears only when two situations or two intervals are compared. For example: Present someone with two commands (e.g., "start" and "stop"), with a 10-second interval between them. Then ask him or her to judge the duration of the interval. Present another person with a similar task, but this time read a list of words during the interval and ask this person to memorize the list. Most likely the second person's duration judgment will be longer than that of the first person. The reason is that in the first case, the person was presented with an "empty" time interval, whereas in the second case the interval was "filled" with words to be remembered. The emerging illusion is called the "filled interval illusion," according to which "filled" time is estimated as longer than "empty" time. However, this direction of the illusion occurs only when durations are estimated retrospectively. The direction will be reversed if the duration is estimated prospectively; that is, when the person is told in advance and before the start of the target interval that he or she will be required to estimate its duration.

The filled time illusion—with its two aspects—occurs because retrospective and prospective time estimations rely on different courses of information processing. In the retrospective condition, duration judgment is based on information retrieval processes from memory, while in the prospective condition the perceived duration is a function of the quantity of attentional resources, which are directly apportioned to temporal information processing.

The difference in information processing between the retrospective and the prospective conditions causes another relative time illusion that results from the influence of the load required for nontemporal information processing during the target interval to be estimated. In the retrospective condition, when the required load is high, duration will be judged longer than when the required load is low. The prospective condition yields the mirror image of its retrospective counterpart.

Another time illusion is summed up by the saying: "A watched pot never boils." In an experiment bearing out this illusion, a person is asked to watch a transparent container full of water that is placed on a flame; the person is asked to wait until the water boils. The participant is told at the outset that she will have to estimate the time interval from the start of the experiment until she receives a certain instruction. In the second condition, the participant is asked to do the same, but this time, some transparent solution has been added to the water, which causes the fluid's boiling point to rise—as a result, the waiting time before boiling increases. When stopping the experiment under Condition 2 after a time interval that was exactly identical to the boiling time in Condition 1, and asking the participant to estimate the time interval, the estimation will be longer in Condition 2 than in Condition 1. The explanation for this is that when a person is asked to wait for water to boil and this does not happen at the expected point in time, increasingly more attentional resources will be invested in temporal information processing. Since this is a prospective condition in which the sense of duration is a function of the resources directly apportioned to temporal information processing, the sensation is extended under Condition 2. In principle, as long as a person is waiting for a certain event to occur (say, a friend's arrival) the sense of time will be extended relative to a situation in which he is not waiting.

Waiting in a line also constitutes a good illustration of the influence of a person's expectations concerning the end of a target interval on her sense of that interval's duration.

When an event comes to an end before its time, its duration will be experienced as shorter than that of an event with an identical objective duration whose end was perceived as taking longer than expected.

Our expectations regarding the end of an event are even more pronounced in the case of an unpleasant event, as, for instance, in the case of pain. When we put our hand in a container filled with water near the freezing point and are asked to estimate the duration of our holding our hand there, the estimation will be longer than in the case of holding our hand in a container with pleasantly lukewarm water for an identical interval. The reason for this difference is that our wish to end this aversive event increases the amount of attentional resources available to temporal information processing. Similarly, individuals were found to have an exaggerated estimation of the duration of earthquakes. The wish for an event to come to an end, depending on the event's degree of pleasantness, affects the sense of that event's duration. This is reflected in the saying: "Time flies when you are having fun."

Another time illusion is exclusive to the retrospective condition. If we ask a person to estimate retrospectively the duration of a reading of a list of words—say, a list of food-related words—the estimated duration will be longer as a function of the amount of unrelated words included—for example, names of countries. The unrelated words divide the list, and thus have a segmentation effect. This effect is apparently caused by the influence of information retrieval from the memory on which retrospective time estimation is based. Similarly, the larger the amount of contextual changes (e.g., change of light conditions in the room), the longer will be the perception of the event's duration in that room, compared with an identical event in a room whose lighting is not changed.

A well-known time illusion, which Gustav Fechner described as early as 1869, is the "time-order error," which is manifested in the influence of the temporal sequence of events' appearance on the estimation of their relative duration. Thus it can happen that an interval that occurred first will be perceived as longer than an interval of an identical duration that occurred second in time ("positive time order error"). The reverse, too, can happen, when the first interval is perceived as the shorter one ("negative time order error"). The direction of such order-related errors is determined by a number of factors, the most prominent of which is the objective duration of the intervals. The phenomenon has a number of explanations, as researchers have not reached agreement on one single valid one.

Another type of time illusion is connected with the complex interrelations between our perceptions of movement, time, and distance. One such illusion is called the Tau effect. For example: If we stimulate three points that create an equal-sided triangle on a person's forearm, and the objective time interval between stimulating the first and second point is longer than that between the second and the third, then the distance between the initial two points will be perceived as longer than that between the second and the third. The same phenomenon occurs for the visual and auditory senses (e.g., distance between light points or sound sources). The reverse effect—the perception of the time interval elapsing between the lighting up of two light points is influenced by the physical distance between them—is called the Kappa effect.

Similar illusions resulting from an intuitive perception of the connection between distance, time, and speed occur among children who are at a stage of cognitive development characterized by intuitive thinking. Thus, experiments conducted by Swiss psychologist Jean Piaget have borne out that if a kindergartner or first grader is shown two toy cars that are both made to start moving at the same point, but with one of them moving faster, and therefore completing, in a given time interval, a greater distance than the other, the child will estimate that the faster toy car has moved for a longer period of time than the slower toy car. This happens because a child at this developmental stage is unable to take the influence of speed into account and will judge duration as a function of distance only.

Dan Zakay

See also Amnesia; Dreams; Memory; Perception; Psychology and Time; Time, Imaginary

Further Readings

Block, R. A. (Ed.). (1990). *Cognitive models of psychological time.* Hillsdale, NJ: Lawrence Erlbaum.

Brown, S. W. (1997). Attentional resources in timing: Interference effects in concurrent temporal and nontemporal working memory tasks. *Perception & Psychopysics, 59*(7), 1118–1129.

Zakay, D., & Bentwich, J. (1997). The tricks and traps of perceptual illusions. In M. S. Myslobodsky (Ed.), *The mytomanias: The nature of deception and self-deception* (pp. 73–104). Hillsdale, NJ: Lawrence Erlbaum.

Time, Imaginary

Imaginary time is a concept most popularly known because of its use by physicist Stephen Hawking in his research on the origin of the universe and the relationship between time and space. The simplest definition of imaginary time is time measured by the use of imaginary numbers. The mathematical concept of imaginary numbers was developed in the 16th century in order to define the square root of a negative number. Just as imaginary numbers should be seen as positioned at right angles to ordinary real numbers, so imaginary time can be described as existing at right angles to real time.

It seems to be unclear when and where the precise use of the term *imaginary time* first came into being, though a number of sources have been identified in which the essence of imaginary time was described. An early example is a 1908 paper presented by German mathematician Hermann Minkowski, proposing the concept of time as a fourth dimension. Another is a 1927 book, *An Experiment With Time,* by J. W. Dunne, exploring the idea that the past, present, and future exist concurrently.

In modern mathematical and theoretical physics, imaginary time has been considered to be a necessary element in research involving various particle and field theories. It also has practical applications in such fields as engineering.

A fundamental aspect of Hawking's research has been an attempt to develop a quantum theory of gravity. General relativity does not work well on small distances and does not take the uncertainly principle of quantum mechanics into account. That principle states that the more accurately a position can be measured, the less accurately speed can be measured. The reverse is also true. As part of this research, Hawking has made use of imaginary time—a theoretical concept arising from quantum theory.

Hawking points out that imaginary time is well defined mathematically. And, though it sounds like a creation straight out of science fiction, he makes a case for it being just as real in its own way as is the real time within which we normally operate—perhaps more real in describing the actual axis of the universe.

Starting from the concept that the validity of any mathematical formula applied to our universe must describe it accurately, Hawking asserts that the use of imaginary time does produce results that we have already observed about the universe and that it is also supported by other observations, even though those may need further study and proof. This approach has been labeled top-down cosmology.

Hawking and physicist James B. Hartle have applied the concept of imaginary time in their research on the origin of the universe, including their efforts to develop a unified theory derived from Einstein's theory of relativity and from Richard Feynman's concept of multiple possible histories of the universe. In his sum-over-histories theory, Feynman considered time to be a dimension in space that could move both backward and forward, allowing for variant pasts and futures. Hawking later stated that the idea of multiple histories of the universe is now accepted as fact.

The big bang, now generally thought to have created the universe about 15 billion years ago, has been described as a singularity in ordinary time, or a point at which the spacetime curvature and the density of matter were infinite. But in imaginary time, it can be envisioned merely as a single point, such as the earth's north pole, with no beginning or end. Knowledge of the state of the universe in imaginary time can allow for the calculation of its state in real time, and, since the latter is dependent on the former, the universe can be described as a self-contained system.

In one model, the universe could be envisioned as a sphere with four dimensions, but with a slightly flattened south pole. Had the universe remained a perfect sphere in imaginary time, it would have continued to expand forever. Instead, there was an initial burst of expansion, followed by a decrease that allowed for the development of galaxies and life.

In another model, the universe would resemble a nutshell, or a membrane, with four dimensions. It would still be a sphere, but with some irregularities. The interior of the membrane might represent a fifth dimension where no time exists.

In real time, the occurrence of the big bang would have indicated that the laws of physics had broken down. But, since imaginary time does not necessitate that the universe have a beginning or an end or any boundaries, the laws of physics would still have been in operation. On a BBC radio broadcast, Hawking clarified that determining that the universe followed the laws of physics when it began would neither prove nor disprove that God exists—but it does indicate that there was nothing arbitrary about the process.

Hawking points out that the classical laws of physics work for large systems because the many changes that occur can be averaged for predictability. But when the big bang occurred, the universe was very small, making the uncertainly principle important at that early time. Hawking adds that changes in microwaves coming from space have allowed us to observe the probable small changes occurring in the history of the universe. In 1992, NASA's COBE (Cosmic Background Explorer satellite) detected such irregularities and provided evidence supporting the big bang theory.

Hawking and most other physicists make it clear that many of the concepts they have proposed are theories yet to be proven. As with any scientific effort, it is important that physicists build on the work of others. But it is also inevitable that they will not always be in agreement on the specifics. Yet Hawking and other physicists have expressed optimism that combined research efforts will produce a unified theory of the universe in the near future. When that occurs, Hawking anticipates that such a theory would be available to people in all walks of life, enabling enlightened discussion on the reason for the existence of the universe and its inhabitants.

Betty A. Gard

See also Big Bang Theory; Hawking, Stephen; Spacetime, Curvature of; Time, Nonexistence of; Time, Relativity of

Further Readings

Geftner, A. (2006, April 22). Mr. Hawking's Flexiverse. *New Scientist, 189,* 28–32.

Hawking, S. (1996). *A brief history of time.* New York: Bantam Books.

Hawking, S. (2001). *The universe in a nutshell.* New York: Bantam Books.

Time, Linear

Time is commonly conceived as being linear, in constant motion, moving from past through present to the future. The past is behind us and exists only as memory; we can live and experience only the present; we have to accept the inevitability of the future. This represents the way most people in the world today understand time and is predicated on the belief that all events happen in a linear sequence and that the direction is only one way: forward. This view has long predominated in Western thinking, and any alternate view is discounted as ill-informed and without substance. It is fundamental to nearly all Western worldviews, including those found in the contemporary physical and social sciences. It is integral to concepts as basic as growth, evolution, and cause and effect. The value of such a view is that it makes rational empirical sense, aids in organizing our lives and our societies, reflects our common understanding of everyday phenomena, and fits into our common approach to and conception of reality. Integral to this has been the belief that time exists independent of all other forces, and there is nothing that can be done to alter it.

In the latter half of the second millennium CE, several European thinkers sought to elaborate their own philosophy of time using existing Western models. These include Sir Isaac Newton, Immanuel Kant, and Martin Heidegger. Although they differ in their understandings and interpretations (Kant, e.g., denies an origin to the universe), they all essentially elaborate a linear concept. As a consequence, it is the European view that predominates in the West, and increasingly in the rest of the world as well. A competing model of time, the circular view, has also been important in the way humans have understood time. It has long been integral to indigenous cultures and Asian traditions and is addressed in a separate section.

Thinking in a linear fashion, we can reflect upon the past as well as make plans for the future. In actuality, however, it is this preparation for the future that tends to consume the bulk of most people's lives, whether it be in the form of work, study, exercise, or even eating and sleeping. The vast majority of human activities are undertaken, for the most part, to help make our futures better, rather than as ends in themselves. Concepts such as time wasting and time management, hourly wage, multitasking, deadlines, bank accounts, financial investments, and retirement planning all become important in one's thinking and functioning, and all are predicated on a linear understanding of time. While there are clear benefits to thinking of time in a strictly linear manner, many of our problems, especially in modern times, can also be traced to such an approach. The more one focuses on the passing of time, the more one thinks of the past with either longing or regret, and the more one also becomes concerned for the future and seeks to utilize more of one's present time in preparation for the future. If one is not able to adequately fulfill one's plans and hopes for the future, emotions such as stress, anxiety, and unfulfilled expectations are experienced. For many, then, the present is consumed by and becomes little more than planning for the future, which, in reality, never exists.

In addition, those who think about human existence with a strictly linear fashion tend to see humans as separate from nature, for the latter is viewed as functioning cyclically (rotation of seasons, migration of animals, etc.). This bifurcated view places humans apart from nature rather than a part of nature, and this separation allows humans to treat nature differently from the way that humans are treated. From this comes the view that while humans are believed to have souls, nothing in nature is seen to possess a soul. All of nature is viewed collectively as a process or as something for humans to use that has little or no independent value in itself.

However, not all Western understandings of time reflect the common linear understanding and independent nature of time. Christian mystics have posited a reality beyond these boundaries. William Blake's poem "Auguries of Innocence" expresses a similar vision. In the latter half of the 20th century, Albert Einstein and various theoretical physicists challenged traditional views of linear time and postulated a far more contextual approach in conjunction with space, human involvement, and other factors. The experiments of Alain Aspect and the theories of David Bohm and Karl Pribram have been fundamental in questioning long-held Western views of time and have led to many rethinking the supposed absolute nature and reality of linear time.

Ramdas Lamb

See also Bohm, David; Einstein, Albert; Heidegger, Martin; Kant, Immanuel; Newton, Isaac; Space and Time; Spacetime Continuum; Teleology; Time, Arrow of; Time, Cyclical

Further Readings

Heidegger, M. (1992). *The concept of time* (W. McNeill, Trans.). Oxford, UK: Blackwell.

Hinckfuss, I. (1975). *The existence of space and time*. Oxford, UK: Clarendon Press.

Time, Logics of

Logic can be understood as the study of principles of valid inference and demonstration. Inspired by a thorough analysis of arguments in natural language, formal logics investigate the structure of statements and arguments through the analysis of formal systems of inference. Formal inference systems represent symbolic models of reality or a certain application domain. Because of their very mathematical nature these models are predestined to draw safe conclusions about this reality in a quasimechanical manner. Logics of time (also temporal logics or tense logics) focus on the characterization of temporal phenomena of the domain being modeled. They constitute the subfield of philosophical logics where relationships like "earlier," "later," or "at the same time" are investigated.

The most prominent family of temporal logics traces back to Arthur Prior, one of the pioneers of temporal logics. Prior was convinced that the apparatus of formal logic could not only be used to characterize eternal and unchanging truths, but also would be suitable for a rigorous study of aspects of reality that change over time. In the middle of the last century he showed that certain canonical extensions of the well-known classical logics could be used for this purpose. As a consequence, there is now a system of temporal logics in the style of Prior's, giving interesting insights into the possible structures of time.

All temporal logics are extensions of classical propositional logics. We will therefore start our brief journey through the world of temporal logics with a short introduction to the calculus of propositional logics and will then sketch several simple but representative temporal extensions of this calculus.

Propositional Logics

A formal system of inference consists of three components: (1) a syntactically well-defined language adequate to formulate assertions about the application domain, (2) a set of distinguished assertions—so-called axioms—whose validity in the application domain is taken for granted, and (3) a set of inference rules used for the derivation of new valid propositions from existing ones.

The syntax of the language of a logical calculus is defined with respect to a symbol set specific to this calculus. In the case of propositional logic, this set contains three types of symbols: (1) connectives like $\neg$ ("not") or $\rightarrow$ ("if . . . then . . .") that can be used to form complex sentences from simpler ones, (2) punctuation symbols like that allow formulating nested sentences, and (3) an unlimited repertoire p, q, . . . of so-called propositional variables that represent the atomic parts of sentences.

Like mathematical variables, propositional variables can be assigned values. In the case of logic, possible values are "true" or "false": A certain propositional variable is set to "true" if one believes that the respective proposition holds in the application domain. Otherwise this proposition variable is set to "false."

Propositional variables are the basic (atomic) building blocks of the sentences of propositional logics. The following syntactical rules recursively describe how complex sentences, so-called well-formed formulas, can be systematically built using the available connectives:

1. Every propositional variable is a well-formed formula.
2. If ϕ is a well-formed formula, then so is $\neg\phi$ ("not ϕ").
3. If ϕ and ψ are well-formed formulas, then so is $\phi \rightarrow \psi$ ("if ϕ then ψ").

With the help of compound formulas, complex propositions can be expressed: Let us, for example, assume that the propositional variables p and q represent the elementary propositions "Abraxas is a raven" and "Abraxas can fly." The formula $(p \rightarrow q)$ then expresses the proposition "If Abraxas is a raven then Abraxas can fly," and the formula $\neg p$ represents the proposition "Abraxas is not a raven."

In order to improve the readability of complex logical formulas, propositional calculus offers additional logical connectives mirroring how humans form complex sentences from more primitive ones. Two of these connectives, the logical connectives $\vee$ ("or") and $\wedge$ ("and"), can be defined in propositional logics from the basic connectives $\neg$ and $\rightarrow$:

1. $(\phi \vee \psi)$ ("ϕ or ψ") as a shorthand for $(\neg\phi) \rightarrow \psi$, and
2. $(\phi \wedge \psi)$ ("ϕ and ψ") as an abbreviation for $\neg(\phi \rightarrow \neg\psi)$.

Hence, if the propositional variable r represents the statement "Abraxas is black," then the compound formula $(p \wedge r)$ can be used to say "Abraxas is a black raven" and the formula $(p \vee r)$ to express "Abraxas is either just a raven, just a black thing, or a black raven."

Once the interpretation of the propositional variables is fixed, the truth-values of arbitrary complex formulas made from these propositional variables can be determined. For this purpose, the truth-values of their subformulas have to be combined according to the meaning of the connectives gluing these subformulas together. If, for example, we assume that Abraxas is a regular raven, which therefore can fly, that is, p = *true* and q = *true*, then the meaning of the connective $\rightarrow$ forces the value of the formula $(p \rightarrow q)$ to "true"; but if we know that Abraxas had a fight with a cat that injured one of his wings and left him as a bird that no longer can fly, that is, p = *true* and q = *false*, then $(p \rightarrow q)$ will evaluate to "false."

A well-formed formula is called logically true (valid) if it evaluates to "true" for any possible combination of truth-value assignments to the propositional variables contained in it. Valid formulas form the basis of logical arguments because they are indisputable by definition. The formula $(p \vee \neg q)$, for example, evaluates to "true" whether the propositional variable p is interpreted as "The moon is made from green cheddar cheese," and therefore set to "false," or whether it is interpreted as "√2 is an irrational number," and therefore set to "true." The formula $(p \rightarrow q)$ on the other hand is not a valid one, because the meaning of $\rightarrow$ forces it to yield the value "false" if p is set to "true" and q is set to "false."

The classical propositional calculus is designed to characterize just those sentences that are valid. The key to this characterization is axiom schemata. Axiom schemata look like regular logical formulas but contain schema variables ϕ, ψ, . . . instead of propositional variables as basic building blocks. If each occurrence of a schema variable in an axiom schema is replaced by the same formula, an axiom results. Axiom schemata therefore serve as compact representations of big collections of axioms.

The logician Lukasievicz has shown that the following three axiom schemata suffice for a separation of the valid formulas of propositional logic from the nonvalid ones:

L1: $(\phi \rightarrow \psi) \rightarrow ((\psi \rightarrow \theta) \rightarrow (\phi \rightarrow \theta))$.

L2: $(\neg \phi \rightarrow \phi) \rightarrow \phi$.

L3: $\phi \rightarrow (\neg \phi \rightarrow \psi)$.

Schema L1 states that "if . . . then . . ." relationships are transitive. Schema L2 evinces that a proposition ϕ will hold if this proposition is a consequence of its negation $\phi \neg$ (*consequentia mirabilis*). In addition, schema L3 specifies that from a contradiction, as it is evident when both ϕ and $\neg\phi$ are given, anything (ψ) can be concluded (*ex falso quod libet*). Any instantiation of each of these schemata yields a formula that is valid in propositional logics. For example, one such instance is the axiom

$$(p \vee q) \rightarrow (\neg (p \vee q) \rightarrow \neg r)$$

which results from L3 by substituting ϕ with $(p \rightarrow q)$ and ψ with $\neg r$. This axiom evaluates to true whatever truth-values are assigned to the propositional variables p, q, and r.

From the logical axioms corresponding to L1–L3 and additional formulas, which the user of the calculus may have set as given for the application domain, new formulas—so-called theorems—can be derived by the following inference rule:

> If formulas ϕ and $(\phi \rightarrow \psi)$ have been derived in an earlier stage of the argument, then the formula ψ has the status of being derived as well.

This rule is called Modus Ponens. It is a safe inference rule: Any truth valuation of propositional variables that renders both ϕ and $(\phi \rightarrow \psi)$ true forces ψ to be true as well. Modus Ponens therefore allows reasoning with propositional formulas independently of their interpretation. It reduces reasoning to an act of symbol manipulation where new valid formulas are mechanically constructed from other valid formulas.

If, for example, the propositional variables $p1$ and q represent the statements "It is raining" and "The streets become wet," respectively, then one is justified to claim q as soon as both P and $(p \rightarrow q)$ ("If it is raining then the streets become wet") have been concluded. One can safely do so even if one does not have the slightest idea of what rain actually is and why streets in the real world are made wet by it.

Extending Propositional Logic to Temporal Logics

One way to introduce temporal specifications from natural language into formal logics amounts to extending formal logics by temporal modalities like "It was the case that" and "It will be the case that." Prior used the symbols p ("past") and F ("future") for this purpose. In order to simplify the expression of temporal statements he also introduced the following two derived modalities: H ("It always was the case that") for $\neg P \neg$ ("It was not the case that not") and G ("It will always be the case that") for $\neg F \neg$ ("It will not be the case that not"). The temporal modalities modify the proposition they are subjected to: The sentence $p\phi$ represents the temporal statement "ϕ was true in the past" and the sentence $F\phi$ the statement "ϕ will be true in the future."

Since temporal statements can be further modified by temporal modalities, complex temporal specifications expressed in natural language can be formulated in the language of temporal logic as well. If, for example, one wants to express that the event q, "It is raining," had happened in the past and before the event r, "The streets become wet," one can do so with the temporal formula $P(Pq \wedge r)$. Or, if one wants to assert that "It always rains (ever since, now, and forever)" then one can do so with the formula $(Hq \wedge q \wedge Gq)$.

According to Prior, the meaning of the temporal modalities has to be drawn from natural language. Natural language refers to the present with the help of *tempora verbi* and expressions like "yesterday" or "the day after tomorrow." Prior therefore states that even temporally unmodified sentences of temporal logic always have a relationship to the present. A temporally unmodified propositional formula ϕ in a temporal logic therefore always is supposed to mean, "ϕ holds right now." The point in time that represents the present and with respect to which a temporal formula is evaluated is also called the index of evaluation of this formula. Temporal operators like P or F shift the evaluation index to a point in the past or the future, respectively.

Depending on the specific conception of time one wants to formalize, the logical axiom schemata L1–L3 have to be augmented by a set of temporal axiom schemata that regulate how to draw temporal conclusions correctly. Any axiom setup of this kind implicitly defines a logic with its own temporal characteristics. All temporal logics by Prior set minimal temporal requirements by postulating the following three temporal axiom schemata:

T1: $H(\phi \to \psi) \to (H\,\phi \to H\,\psi)$ as well as $G(\phi \to \psi) \to (G\,\phi \to G\,\psi)$.

T2: $(PG\phi \to \phi)$ as well as $(FH\phi \to \phi)$.

T3: If ϕ is an axiom, then $H\phi$ and $G\phi$ are axioms as well.

Schema T1 describes how temporal and logical reasoning interact: If ϕ did always follow from ψ in the past $(H(\phi \to \psi))$, then, if ϕ was always true in the past, then ψ was also always true in the past $(H\,\phi \to H\,\psi)$; and, if it always will be the case that ψ follows from ϕ $(G(\phi \to \psi))$, then, if ϕ will always be the case, so will be ψ $(G\phi \to G\,\psi)$. T2 controls the interaction between the temporal operators: If at some time in the past, ϕ was clear to be always the case in the future $(PG\phi)$, then ϕ must also hold at present (ϕ); and if at some time in the future, it will be clear that ϕ was the case ever since $(FH\phi)$, then ϕ must hold now as well (ϕ). The precondition in T3, that ϕ is an axiom, is essential for schema T3 to produce only valid formulas.

According to Edward Lemmon, the temporal logic K_t (t for "time") resulting from the logical axioms L1–L3, the temporal axioms T1–T3, and the inference rule Modus Ponens is called minimal temporal logic. Minimal temporal logic, for example, allows the mechanical derivation of

$$F(\phi \wedge \psi) \to (F\phi \wedge F\psi).$$

This formula states that, if one knows that at some time in the future both ϕ and ψ hold $(F(\phi \wedge \psi)$, then there must be times in the future where ϕ and ψ hold $(F\phi \wedge F\psi)$. The converse statement $(F\phi \wedge F\psi) \to F(\phi \wedge \psi)$, in accordance with intuition, is not mechanically derivable in K_t: Just knowing that two events ϕ and ψ will take place at some time in the future $(F\phi \wedge F\psi)$ does not justify the claim that they will take place simultaneously at the same time in the future $(F(\phi \wedge \psi)$.

An interesting meta property of the minimal temporal logic K_t is directly visible in schema T1, T2, and T3: The mirror image of a formula ϕ is always derivable in K_t if ϕ itself is derivable in K_t.

If ϕ is a temporal formula, then its mirror image is the formula obtained by simultaneously replacing each occurrence of the modality F by P and vice versa. The formula $F(\phi \rightarrow P\psi)$, for example, is the mirror image of the formula $P(\phi \rightarrow F\psi)$, and $GP\phi$ is the mirror image of $HF\phi$ due to the definitions of the temporal modalities G and H. The mirror image of the mirror image of a formula ϕ, of course, is ϕ again.

Branching Structure of Time

The minimal temporal logic K_t already sets the necessary preconditions for mechanized temporal reasoning. However, it does not make any specific commitments with respect to possible structures of time. In order to formalize these structures, Nicholas Rescher and Alasdair Urquhart invented what they called branching (tense) structures.

A branching structure is a precedence relation < on events where $e_1 < e_2$ means that the event e_1 is temporally located before event e_2. Branching structures have to fulfill two conditions: transitivity and backward linearity. They are transitive if for any three events e_1,e_2, and e_3, $e_1 < e_3$ whenever I and $e_2 < e_3$. They are backward linear if for any two events e_1 and e_2 both preceding a third event e_3 (i.e., $e_1 < e_3$ and $e_2 < e_3$), the following holds: Either $e_1 < e_2$, or $e_2 < e_1$, or e_1 and e_2 occur at the same time.

In a branching tense structure, many different paths leading from an event into its futures may exist, but the past of this event, that is, the set of events preceding it, is always uniquely determined. Any path in a branching structure, that is, leading from earlier to later events and cannot be extended into the past or the future, describes a possible course of events (a temporal branch) allowed by the given branching structure. Temporal branches may be of infinite length. They may even contain temporal cycles: sequences of temporally ordered events where the last event coincides with the first. A branching tense structure that (1) does contain an earliest event e_0 (representing the origin of time), (2) does not exhibit branches with temporal cycles, (3) does not fall apart into completely separated temporal substructures, and (4) has the property that any event has a uniquely determined event immediately preceding it, can be imagined as a tree. All branches of this tree are labeled with events: The root of this tree is labeled with e_0 and the other branches with those events that immediately precede the events at the branches they directly lead to. Backward linearity ensures for treelike branching structures that there is exactly one uniquely determined path from any event back to the origin of time.

An event that has more than one immediate successor in a branching tense structure is called a branching event. An event e_2 is called determined with respect to another event e_1 of a branching structure, if this structure does not contain a branch that starts at e_1 but does not eventually lead to e_2. In this case, either e_2 has to lie in the past of e_1, or e_2 lies in the future of e_1 and the branch connecting e_1 and e_2 does not contain any branching event (e_1 included).

If e_3 is not determined with respect to e_1, then e_1 is said to lie in the open future of e_1. Depending on what happens at the branching nodes on the path connecting e_1 and e_1, e_3, may eventually occur or not. In a completely determined branching tense structure any event is determined with respect to any other event and the branching structure degenerates into a linear order of events where no event has an open future.

Branching Time Logics

Branching time logics assume that time has a branching tense structure with open futures. The simplest branching time logic Kb (b for "branching") results from augmenting minimal time logic Kt by the following two axiom schemata:

T4: $H(\phi \rightarrow HH\phi)$ as well as $(G\phi \rightarrow GG\phi)$.

T5: $(P\phi \wedge P\psi) \rightarrow (P(\phi \wedge \psi) \wedge \psi) \vee P(\phi \wedge P\psi) \vee P(P \vee \psi)$.

Axiom schema T4 characterizes time as exhibiting a transitive branching structure: If ϕ was always true in the past ($H\phi$), then it was always true in the past that ϕ had been always true in the past ($HH\phi$); and (according to the corresponding mirror image schema): If ϕ will always hold in the future ($G\phi$), then at any future time, we can be sure that ϕ will hold in the future ($GG\phi$).

Axiom schema T5 commits time with respect to its past as a backward linear structure: If ϕ and ψ were true at two (maybe different) times t and t' in the past ($P\phi \wedge P\psi$), then either $t = t'$ and therefore $P(\phi \wedge \psi)$, or t' precedes t forcing $P(\phi \wedge P\psi)$, or t precedes t' entailing $P(P\,\phi \wedge P\psi)$.

As in the minimal temporal logic K_t, only the Modus Ponens rule is needed for deriving theorems like, for example,

$$(H\phi \wedge \phi \wedge G\phi) \rightarrow GH\phi$$

from the axioms specified by L1–L3 and T1–T5. This formula states: What was always true ($H\phi$), is true now (ϕ), and will be true forever ($G\phi$), has the property that at any future time it will be true that it was always true in the past ($GH\phi$).

Branching time logic K_b, in accordance with intuition, gives time a treelike forward branching structure leaving open alternative futures while excluding an ambiguous past.

Linear Time Logics

Linear time logics make even stronger commitments on the structure of time. The simplest linear time logic K_l (l for "linear") augments the branching time axiom schemata T1–T5 by axiom schema

T6: $(PF\phi) \rightarrow (P\phi \vee \phi \vee F\phi)$.

This schema requires that any proposition ϕ, for which at some time in the past it was true that ϕ would be true at some later time ($PF\phi$), either must have been true in the past ($P\phi$), hold at present (ϕ), or will be true at some time in the future ($F\phi$).

K_l forces a linear structure upon time and therefore uniquely determines both its past and its future. With $\phi = \neg\, q$, T6, for example, excludes a temporal structure, which declares a proposition q true at some time in the past while leaving a chance that its status today is false ($\neg\, q$) and not true (q) until today and beyond. Such a temporal structure would make ($PF \neg\, q$) true without making at least one of ($P \neg\, q$), $\neg\, q$, or ($F \neg\, q$) true at the same time and therefore contradicts the temporal postulate T6.

Linear time logic K_t, for example, allows the derivation of proposition ($\phi \rightarrow HF\phi$): Of anything true at present (ϕ) it always was clear that it would hold at some time in the future ($HF\phi$).

There exist, of course, many more ways to specify the structure of time consistently and in even finer detail than the simple temporal logics we have sketched so far. It is, for example, possible to force a dense structure on linear time via the axiom schema

T7: $(F\phi \rightarrow FF\phi)$ as well as $(P\phi \rightarrow PP\phi)$.

If an application demands this axiom schema to hold, then it assumes that between any two points in time there is at least one more point in time where an event can happen. Another axiomatic extension of linear logic ensures the opposite by underlying time as a discrete structure. Using appropriate axiom schemata, time can also be given a start or an end: Adding

T8a: $G\phi \vee FG\phi$

to Kl forces time sooner or later to come to an end, and adding

T8b: $H\phi \vee PH\phi$

results in time not extending infinitely into the past. If, on the other hand, one wants to make sure that time does not have an end, one can do so by postulating the axiom schema

T9a: $F\,(\neg\,\phi) \vee F\phi$,

while a commitment on

T9b: $P(\neg\,\phi) \vee P\phi$

expresses the assumption that time has no beginning. T8a and T9a as well as T8b and T9b, of course, are axiom schemata that are pairwise incompatible with each other—an attempt to add them simultaneously to K_l would result in an inconsistent and therefore useless logical theory from which anything could be concluded.

Spacetime Logics

Branching structures are not restricted to purely temporal relationships between events. A complex interaction of temporal and spatial aspects, for example, occurs in Nuel Belnap's theory of branching spacetimes. This theory generalizes

Rescher and Urquhart's theory of branching time by allowing histories (complete courses of events) to be not just linearly ordered sets, but spacetimes with a relativistic causal ordering: The interior of the forward light cone in Minkowski space contains the possible futures of a spacetime point—those locations that can still be reached from and affected by it by sending a signal at a speed slower than light. The theory of spacetime also addresses questions of causality because in spacetime structures the ordering relation "e_1 precedes e_2" can be understood as "e_1 could cause e_2."

Until recent work by Thomas Müller it was not evident that a tense-logical language can adequately work in the context of special relativity: Special relativity rigorously defines which events are simultaneous for any observer and any given point on his world line. Depending on the respective frames of reference used by observers, and their relative movement, they may or may not agree upon the presentness of an event. A simple tense logic like K_b therefore cannot consistently model relativistic affairs. What is needed instead is a generalization of simple tense logic of the type that Müller calls a "logic of points of view," that is, a logic where (1) the index of evaluation includes an inertial frame of reference and (2) there are (modal) operators available to shift that index. In the simplest case such a logic would provide a propositional modal language, where the propositions refer to what is true or false at "moments" that are given by spacetime points in the sense of Belnap and not just time points as in nonrelativistic logics of time.

Applications of Temporal Logic

Not any arbitrary axiomatic commitment to the structure of time is intuitively plausible or even useful for practical applications or philosophical considerations. In order to be appropriate for the application of logical methods, potential application domains should profit not only from being describable in its relevant spatiotemporal aspects. The corresponding descriptions should also allow for drawing valuable conclusions about the respective domains.

Typical application domains for temporal logics therefore are fields like the philosophy of language, the field of linguistics (especially the subfield of computational linguistics, which studies computer models of language), the field of computer science (especially the subfields studying the specification and verification of dynamic technical systems), the field of artificial intelligence (especially the subfield studying automated planning of actions that intelligent agents perform in order to achieve certain goals), or the field of systems biology (especially the subfield studying the dynamics of biomodels). All these fields, like philosophical logic in general, utilize formal tools and methods of symbolic logic in order to approach questions of foundational relevance for their theoretical and practical advancement.

Clemens Beckstein

See also Time, Measurements of; Time, Relativity of; Time, Teaching; Time, Units of

Further Readings

Belnap, N. (1992). Branching space-time. *Synthese, 92,* 385–434.

Copeland, J. (Ed.). (1996). *Logic and reality: Essays on the legacy of Arthur Prior.* Oxford, UK: Oxford University Press.

Emerson, E. A. (1990). Temporal and modal logic. In J. van Leeuwen (Ed.), *Handbook of theoretical computer science* (chap. 16). Cambridge: MIT Press.

Gabbay, D. M., & Guenthner, F. (Eds.). (2002). *Handbook of philosophical logic* (2nd ed., Vol. 7). Dordrecht, The Netherlands: Kluwer Academic.

Goldblatt, R. (1992). *Logics of time and computation: Lecture notes No. 7* (2nd ed.). Stanford, CA: Center for the Study of Language and Information.

McArthur, R. P. (1976). *Tense logic.* Boston: D. Reidel.

Müller, T. (2004). *Arthur Priors Zeitlogik.* Paderborn, Germany: Mentis.

Prior, A. (1967). *Past, present and future.* Oxford, UK: Oxford University Press.

Rescher, N., & Urquhart, A. (1971). *Temporal logic* (Library of Exact Philosophy 3). New York: Springer-Verlag.

van Benthem, J. (1983). *The logic of time.* Dordrecht, The Netherlands: Reidel.

Time, Measurements of

Time is commonly defined as a measured or measurable period during which an action, process, or condition exists or continues. Throughout history, time has been measured by various cultures in standard natural units of days and years, and in hours, minutes, and seconds or their equivalents. Weeks and months were culturally selected for civic preference.

Time is measured in discernible units, all related to solar and lunar motion across the terrestrial sky. From an observational perspective, it is easy to understand the reasoning behind the geocentric model holding influence over culture for so many centuries. The most basic measurement of time is the length of the day, or the time it takes for the sun to complete an apparent circle in the sky beginning at the local meridian. The true motion is the earth rotating on its axis; however, time measurements were developed from a geocentric perspective.

Origin of the Day

The length of day was assigned the closest number of periods that fit between solar meridian transits. Mathematicians and archaeologists credit the origins of the time divisions back to the Sumerians, who employed a base-12 counting system. Various theories state that, excluding thumbs, there are 24 segments on the remaining eight human fingers, which Sumerians are believed to have used as a basis for counting. At night, time was measured by the appearance of given stars crossing a certain sky point to mark the time passage. For tracking time during the day, the sundial was invented.

The Babylonians improved this division by segmenting the day into 12 hours (each twice the modern length). Furthermore, the hour was subdivided into 60 units (another base-12 factor), and then divided again by 60 to define the smallest unit. Using factors of 12 kept things simple, and archaeologists know that Babylonians utilized a base-60 (sexagesimal) counting system. The sexagesimal concept has been retained for many centuries because it is simple and reliable. It is no surprise, then, that measurements of geometrical shapes are also in a sexagesimal (extended base-12) system of 360°.

Origins of the Hour, Minute, and Second

When the ancient Greeks required a standard for measuring time, they asked the philosopher Hipparchus to devise a system for planning events. As a result, Hipparchus applied the concept of divisions based on an equinoctial system (equal day and night). This occurred at the equinoxes, and was called *Hora,* the Greek word from which we derive "hour." Hipparchus, however, considered only the daylight hours when making these divisions. Ptolemy later defined geometrical divisions of the circle into 60 (*minuta*) and in turn divided *minuta* again by 60 (*secunda minuta*). To this day, clocks are still circular with 60 divisions. Eventually, the geometric system was copied to the measuring of time, and the minute and the second were applied.

The Calendar

Calendars were developed to track the passage of days. The first calendars date back to the time of Mesopotamia, but the Greeks are credited with being the first to attempt to use a standard form of measurement based on the motion of the moon around the earth. The Romans created a separate solar calendar, which became the basis for our modern calendar. Several revisions were made, including adding months to synchronize the lunar and solar cycles, rearranging month lengths, and rearranging monthly delineation. Over time, political issues throughout the empire resulted in an unreliable calendar, and Julius Caesar reorganized the calendar into a standard measurement. The Julian calendar was adopted circa 46 BCE. The lengths of the months in the 12-month Julian calendar remained centered on the lunar cycle, and alternated 30- and 31-day lengths. The only exception was February, which contained only 29 days in order to maintain calendar reliability. Originally, January and February occurred at the end of the calendar year, but eventually the Julian adaptation moved them to the start of the year instead. The result was a misalignment of the names of months with their position in the year: For example, the 7th month, prefixed *septem,* Latin for "seven," became the 9th month.

The Week

Grouping days into a week was done mostly as a matter of civil convenience. Many civilizations have had varying numbers of days in the week, usually based around civic events. The Babylonians began the practice of the 7-day week due to their belief that the number 7 was sacred. In addition, other religions give importance to the number 7, particularly Judaism and Christianity. The most apparent characteristic of choosing a 7-day week, however, is the equivalency of the lunar phase points and the lunar cycle. The names assigned to the days of the week were those of the Roman gods related to the seven known nonstar objects (see Table 1).

The Month

The month was based on the lunar cycle. The lunar synodic cycle, or the time it takes the moon to complete a meridian cycle, is 29.5 days. As a result, most calendars reflect this in an average 30-day cycle. Each cycle consists of a full set of lunar phases measured between each new moon phase. Additional days are appended to certain months in order to round out the earth's orbital period and reach to the return of the summer solstice, or the point at which the sun is highest in the sky. The names of the months are also taken from cultural gods of interest, as well as some notable historical figures (see Table 2).

The Year

The measurement of the time between the summer solstices marks one complete orbit of the earth around the sun and became known as the year. The year is the basis for most historical measurement, including how humans measure age. The concept of the year and the four seasons has been constant for more than 4,000 years. Regardless of whether a culture employed a solar or a lunar calendar, most had a concept of marking the earth's revolution around the sun (although for most of this time people believed it to be the sun's motion around the earth).

Time Zones

When dividing the earth's angular sum of 360° by 24, the result is 15°. For each hour, then, there is 15° of the earth's sphere that can see the sun in a relatively common position. It is common practice now to use these lines of longitude on a globe, where each line of longitude represents one official time zone. Therefore, there is a 1-hour lag in solar position at the time zone extremes, so sunrise and sunset times will vary within a given zone. For example, sunrise and sunset between Boston and Detroit (both in the Eastern Time Zone) differ by nearly one hour; sunrise in Madison, Wisconsin, at the eastern edge of the Central Time Zone is similar to the Boston sunrise, but time tables in Pierre, South Dakota, on the western edge of that time zone, are similar to time tables in Detroit.

Celestial Time

Astronomically, time is measured from one standard location in order to keep stars at a constant sky position. This system, called the equatorial coordinate system, measures locations in right

Table 1 Origins of weekday names

Day	*Original Meaning*	*Culture*	*Roman Deity*	*Other Deity*	*Celestial Object*
Saturday	Saturn's Day	Roman	Saturn	N/A	Saturn
Sunday	Sun's Day	Old English	N/A	N/A	Sun
Monday	Moon's Day	Old English	N/A	N/A	Moon
Tuesday	Tyr's Day	Nordic	Mars	Tyr	Jupiter
Wednesday	Wodan's Day	Nordic	Mercury	Wodan	Mercury
Thursday	Thor's Day	Nordic	Jupiter	Thor	Jupiter
Friday	Freya's Day	Nordic	Venus	Freya/Frigg	Venus

Table 2 Names of the Julian and Gregorian months

Month	*Culture*	*Deity*	*Deity Function*
January	Roman	Janus	Beginnings/Endings
February	Etruscan	Februus	Keeper of the Underworld
March	Roman	Mars	God of War
April	Roman	N/A	Named for the word *aperire*; to open or bloom
May	Roman	Maiesta	Goddess of Honor
June	Roman	Juno	Queen of the Gods
July	Roman	N/A	Julius Caesar
August	Roman	N/A	Augustus Caesar
September	Roman	N/A	Latin; Septem, or seven
October	Roman	N/A	Latin; Octo, or eight
November	Roman	N/A	Latin; Novem, or nine
December	Roman	N/A	Latin; Decem, or ten

ascension and declination, allowing astronomers to pinpoint exact celestial locations for observational accuracy. The right ascension divides the 360° of the sky into 15° segments synonymous with the earth's longitudinal system; each line of right ascension marks 1 hour of clock time. Declination is the height above or below the celestial equator. This type of coordinate system allows astronomical time to be constant for every star. Due to sidereal variation, the coordinates on the equatorial system will shift progressively from night to night.

Timothy D. Collins

See also Attosecond and Nanosecond; Clocks, Atomic; Clocks, Mechanical; Earth, Rotation of; Egypt, Ancient; Hourglass; Janus; Pendulums; Planck Time; Presocratic Age; Rome, Ancient; Stonehenge; Sundials; Timepieces; Time Zones; Watches

Further Readings

Aaboe, A. (1974, May 2). Scientific astronomy in antiquity. In The place of astronomy in the ancient world [Special issue]. *Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences,* 276(1257), 21–42.

Audoin, C. (2001). *The measurement of time.* New York: Cambridge University Press.

Neugebauer, O. (1969). *The exact sciences in antiquity* (2nd ed.). New York: Harper & Row.

Newton, R. G. (2004). *Galileo's pendulum.* Cambridge, MA: Harvard University Press.

Raju, C. K. (1994). *Time.* Boston: Kluwer Academic.

Time, Nonexistence of

Time's movement is apparent to us in the rising and setting sun, the seasons, birth, growth, and death. Throughout history these changes have been seen as a flow from the past into the future. That flow exists alongside another aspect of time—the present. The present is where I am writing this article and though it is obvious time moves from the present into the future, philosophers have often debated that fact and some even claim that time does not exist.

Before deciding about the existence or nonexistence of time, a definition is needed, which is where the problems begin. Time is defined as a duration; possessing past, present, and future; every moment that has been or will be; the entire period of existence of the known universe; a system of measuring duration; a precise instant; and a measured interval, to name just a few. With so many different definitions it is difficult even to discuss the subject.

Physical time, however, is the subject of this entry. As to its definition, there may be no better authority than Albert Einstein, who succinctly stated that time is *what the clock measures.* This time is represented by the *t* variable found in physical formulas that we use to put satellites into orbit, calculate the speeds of falling bodies, measure the motions of planets, and many other things.

Physical time as we know it didn't always exist. Long ago there were no clocks and no formulas that possessed a *t.* Time was not measured in seconds or minutes or hours. It was defined by sunrise, sunset, mid-morning, noon, afternoon, and early evening.

Time: A Standard Motion

This relaxed view of time began to change when ships began sailing on the open seas. For sailors, transportable mechanical instruments—clocks—that matched exactly the spin of the earth became a matter of life and death. Knowing an exact time, combined with sky charts, allowed navigators to calculate a ship's distance from ports and shoals. Clocks started out as imprecise timekeepers, which led in turn to imprecise charts, incorrect locations of shoals, and shipwrecks. Of course clocks didn't improve instantaneously. It was an evolutionary process with a huge selective pressure for perfection.

The gut of a mechanical clock is called its movement. That movement is a miniature earth whose hours, minutes, and seconds, respectively, represent smaller portions of that spin.

Time is not usually thought of as distance, but a second, or 1/86,400 of a mean solar day, represents about 30 meters of the spin of the earth. As clocks became more precise, they were in the race to be the official standard of measurement. Each swing of a pendulum has a period of motion determined by its length. The definition of the meter was once the length of a pendulum having a half-period of one second. The earth's motion, the clock's motion, and distance were all elements of time.

But since the period of a pendulum is determined by the force of gravity, and gravity varies slightly over the surface of the earth, this produced clock error. So motion was removed from the definition of the meter and replaced by: one 1/10,000,000 of the length of the earth's meridian that passes from the pole to the equator through Paris. Just when a distance seemed secure as a standard for the meter stick, it was deposed again by time and the movement of a clock. Today that clock does not track the earth's spin but is defined as "the time interval equal to 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom." That movement also defines the meter: the length of the path traveled by light in vacuum during a time interval of 1/299,792,458 of a second.

This brings us closer to understanding the nature of physical time. It is a uniform and unvarying motion that we use to measure other motions, and distances. When your boss says, "Come to a meeting at eleven or get fired," what he is saying is that his motion and your motion should cross paths simultaneously with a certain position on the clock face, whose hands are a standard motion. People are examples of nearly random motion since they regularly stop, start, and change their speeds and directions. A standard reference motion such as a clock helps us gauge our activities so that we can arrive at places on time.

If no regular motions existed—for example, if the earth didn't spin and the sun were always at high noon—the question "What time is it?" would have no meaning. The time would be the same time it always was, high noon. So the answer to the question, "How fast does time flow?" is *time moves exactly as the earth spins.*

In a broader view, time represents a class of motion, call it a subset of motion. Which is to say that as far as can be determined, physical time is a useful uniform motion.

Time Dilation and Biological Clocks

Until the beginning of the 20th century, scientists had the sense that time was a steady, unchanging flow. The invariant flow of time came to an end in 1905, when Albert Einstein formulated the special theory of relativity. He showed that motion affected how clocks kept time. A fast-moving clock, really fast moving, keeps slower time. This has since been shown to be true with atomic clocks. That helped end the notion that a clock in one part of the world would keep precisely the same time as a clock elsewhere. Studies of high-speed subatomic particles show that their rate of decay slows down in relation to their speed of travel, according to the predictions of special relativity. Known as time dilation, this slowing of clocks established that time can flow at different rates in moving frames of reference.

The effect of time dilation has been expressed in the "twins story." Imagine one twin becomes a space traveler while the other stays on earth. The traveler takes a one-year journey into space at nearly the speed of light and discovers on returning home that his twin has aged 50 years. Time for the traveler had slowed down.

Relativity predicts that this slowing is even more dramatic the closer one travels to the speed of light. At light speed, all clocks come to a dead stop. A traveler with a relativistically stopped clock would not experience time, or anything at all. For him, travel across the universe would be instantaneous; indeed, infinite time would pass by instantaneously. Of course, earthbound clocks would measure the duration of a trip across the universe in the billions of years.

What is the meaning of Now in radically different speeding frames of reference? At the speed of light, the Now of a stopped clock is a frozen instant of time that contains the whole time span of the universe. Clearly, if living observers could travel close to that speed they would have deep differences of opinion about the flow of time and the meaning of the present. For this reason, philosophers tell us the Now has no meaning in our universe.

Bio-Relativistic Speed Limit

However, philosophical speculations about the existence of the Now seldom take into account biological laws. It is widely assumed in writings about relativistic travel that life can exist at high speeds. Yet to date no one (to my knowledge) has examined how the laws of relativity will affect biological clocks.

For a century it has been hypothetically assumed that a biological clock moving at high speeds will slow down similarly to a mechanical clock. The operative word is hypothetical. In physics, observers are not real live actors in experiments. They are ghosts looking at what takes place. Somewhere, storytelling by physicists dropped the "hypothetical" and replaced it with real live observers. Live observers, however, are multicellular organisms whose cells are packages of chemical soups. The clocks within each cell are not gears, they are baths of molecules, ions, and atoms that are in constant motion. Called "Brownian motion," this is high-speed random molecular motion to and fro, up and down, that assists in biochemical reactions.

Biological clocks, therefore, can be reduced to particles in motion that must follow exactly the same rules examined by physicists in particle accelerators. Those studies confirm that molecules that approach the speed of light will require geometrically larger amounts of energy for each incremental increase in speed. How would this affect the rapidly ricocheting molecules within the cells of a speeding observer? Unlike at slow speeds, near the speed of light Brownian motion in the direction of travel would be restricted and shortened. This is because the forward direction of motion requires substantially more energy than any other direction. This effect becomes pronounced near the speed of light, where it would take energy approaching infinity to accelerate a molecule faster in the direction of travel.

What would happen inside the cell? Imagine being a tiny observer who could throw a ball in the direction of motion toward a cell wall. As you started to throw, your arm would feel a strange force. This would be caused by the increased energy needed to accelerate your arm in the direction of motion. If the ship was moving fast enough, you would barely be able to move your arm in the forward direction. And when you let the ball fly, it would move very slowly. Even more perplexing, if you threw the ball in the opposite direction, your arm wouldn't feel that force. The ball would fly quickly toward the cell wall. But when the ball rebounded off the wall it would immediately slow.

This asymmetric movement of particles would lead directly to strange activities within the cell. Each molecule, especially those freer to move, would move more distance toward the cell wall opposite the direction of travel. Over time the more mobile molecules would accumulate in that region. The same thing would be happening to all the motions of particles within the cell. Molecules in the electron transport chain would end up in the wrong locations. Electrons would not be transported. Cellular systems would be disrupted.

Since life itself depends upon the isotropy of Brownian motion, it seems no theoretical possibility exists that we can move at high relativistic speeds. Relativity, contrary to what has been written, establishes that high-speed motion will extinguish life. Why the relativistic effects of Brownian motion have remained unexplored until now is because biologists seldom or never study physics, and physicists seem desperately to want to travel to the stars someday.

As yet we do not know what that biorelativistic speed limit is. Can cellular systems tolerate a 0.1%, 1.0%, or a 10% increase in relativistic mass? We don't know. Even small changes in the energy needed to accelerate particles faster could accumulate into a statistical and fatal disruption of biological engines. It seems likely that a 1.0% increase in relativistic mass, which corresponds to travel at 14% the speed of light, may be a maximum upper speed limit for life, though the speed limit is most probably at an even slower speed.

A quirky discovery about where we live supports the existence of a biorelativistic speed limit. Radio telescopes have found background radiation that appears left over from the event marking the origin of the universe, known as the big bang. This radiation can be used as a benchmark of speed and shows that our planet is moving through space at about 380 kilometers per second, a little faster than one-thousandth the speed of light, or about 800,000 miles per hour. This is really fast by vehicular standards but very slow by cosmological standards.

We are moving so slowly that it poses a pivotal philosophical question. We could claim we are unique, but when arguing about humanity's relationship to the universe it is widely agreed that the proper argument is to assume we are not unique. From a statistical point of view it makes sense that it is more likely we are average than a rare example of life. Similarly, it is more likely that the conditions of our evolution represent the standard conditions for the evolution of life elsewhere. It follows then that life elsewhere is likely to exist at the slow end of the speed spectrum too. And, like us, it probably can't travel at relativistic speeds either.

Why would life be concentrated at the slow end of the speed spectrum? One possibility is that the statistics of evolution requires low not high relativistic speeds. An object moving at near the speed of light experiences the birth and death of the universe in an instant. At such speeds the moving object has a stopped clock where no or little physical change is taking place. In contrast, evolutionary change requires the high clock speed characteristic of slow-moving matter.

The origin of intelligent life is built upon a long chain of chance chemical interactions beginning with the big bang that took place around 15 billion years ago. The first stage of life formation was the making of heavy atoms such as carbon in the nuclear furnaces of stars. How long this took is uncertain, but it would likely have been billions of years. Next this material was ejected back into space as a result of supernova explosions. This material then became part of new star formation. The solar system appeared about 5 billion years ago. Biological laws of evolution require that a planet possess proper conditions, and a vast number of chemicals and molecules that can interact. Evolution may even depend upon the regular cycle of night and day. So after about 12 billion years of chance chemical and nuclear reactions, and then 3–1/2 billion years more of chance biological evolution, we finally appeared. All of this took a high clock speed.

Observation of the background radiation shows that biological clocks are running at about the highest clock speed possible. It is hard to know if we are at the leading edge of the evolution of intelligent life, but we certainly are not at the tail end. Taking the above into account, our speed through the universe does not seem unique; it is the speed at which life would be expected to evolve.

This has theoretical implications. Physicists tells us that "time is relative," but the laws of evolution, the biorelativistic speed limit, and star formation suggest that slow speeds are good for the evolution of life. Time becomes significantly relative only at high speeds where intelligent life probably has not yet had time to evolve and may never evolve. That being the case, intelligent life in the universe is likely to share a similar time frame, which would mean that for life, *time is not relative.*

Frozen Motion

The arrival of the general theory of relativity raised new problems concerning the nature of time. Almost anyone could understand Newtonian physics, but few understood the full implications of Einstein's general theory, as it is called. His gravitational field equations were a mathematical laboratory for experimenting with the nature of time and space.

Enter Kurt Gödel, who had gained fame for his solution to a vexing problem concerning the logical foundation of mathematics known as the incompleteness theorem. Both Gödel and Einstein had escaped Nazi Europe to live near Princeton University in the state of New Jersey. There they became good friends.

Gödel surprised Einstein with calculations concerning time based on the formulas of general relativity. He played with the variables to create a universe where the distribution and motion of matter caused the axis of time to bend around and connect with itself to form a time loop or circle. This result is known as a closed timelike curve (ctlc). If one were caught in this time loop, every year forward would represent a year closer to the past. This is strange, because in our universe time moves only from the present to the future. The past is gone completely.

Interpreting the nature of the universe from gravitational field equations is tricky. Those equations do not include important laws such as the second law of thermodynamics, which shows that the direction of time is toward the future, not the past.

Assuming Gödel's universe behaved like ours quickly leads to paradoxes and inexplicable physics. In Gödel's universe, all matter must ultimately return exactly to an earlier physical and temporal state. On a trip into that universe you would find that light behaved strangely. After leaving the sun it would someday converge back onto the sun and unite with the same electron from which it came. Think of it as a wind-up toy. When the toy quits moving in Gödel's universe, the hand of a mysterious force must reach down and push the toy backward to rewind it so that it can run down again. The Gödel universe was a cyclic winding and unwinding of the universe. There the fusion of hydrogen to make helium within the sun would have to reverse each time the toy ran down. The heat and light that left billions of years ago would have to be sucked back from intergalactic space. That also means that all the molecules in existence, all the photons, subatomic particles, and the solar wind would ultimately reverse directions and return to their place in the sun.

But such physical activity is contrary to known laws. For example, hydrogen fusion, a reaction in the solar furnace, is caused by gravitational forces that squeeze atoms together so that the reaction can take place. To reverse that action would require the reversal of gravity. The result, of course, would not be a return to a prior condition. Gravity is not a time-symmetric force like other forces of nature. Its reversal would not return matter to prior positions. Reversal would result in a phenomenal explosion as matter repelled itself violently throughout the universe. So bringing the sun back to its original condition cannot be achieved by reversal of the laws of physics.

Gödel sidestepped these grave physical problems by designing a simplified universe that was an unchanging cloud of homogeneous dust that rotated rigidly through spacetime. In his universe there are no stars to produce light, and all matter moves in the same relative positions. Gödel's universe can be viewed as a huge plane upon which balls are resting. The whole thing is spinning like the earth, but nothing is moving. If one sat a video camera on that plane and watched for an eternity, no motion, not even the spinning, would be detected. Basically it was a static universe where an unchanging eternity was the principal feature of time. It was a cosmological spacetime clock that ticked but did not keep time. Gödel reasoned that if a future time became a past time, then neither past nor future really existed. The logical paradox is obvious. The flow of time had lost its meaning. In his universe, time no longer existed. Given that the properties of time in his universe were based upon general relativity, he concluded that time had the same properties here, too, so time must not exist for us either.

A major difference exists between our universe and the Gödel universe. Gödel assumed a living being could travel in a speeding rocket to the future and arrive at the past. But if that were possible, an examination of Gödel's mathematics should reveal a point when a person's body would begin reversing its biological growth and aging patterns. No such mathematical turning point exists. The math would also show when a trip into the future would cause a person to shrink in size and mysteriously return into the womb. It should also show how a cremated person's dispersed ashes could be collected and reconstituted, like a can of condensed milk, by adding water or some miraculous substance. The absence of a mathematical reversal point, where matter begins to reconstitute itself into a prior state, is a glaring deficiency that points theoretically to something other than common interpretations.

Growth and development are fundamental biological laws that are as absolute as the constancy of the speed of light. The laws of physics were not designed to govern issues about life, and Einstein's formulas wisely make no statements about life. In our universe biological laws govern the growth and development of life and those laws are clear. Adults don't grow younger and trees don't reverse their growth to become seeds.

A hint to a resolution of the time travel problem was given by Gödel himself. Closed timelike curves (ctlcs) that appear in some solutions of the formulas of the general theory might be a direct result of peculiar (*frozen*) motion of matter. Though this was not his preferred explanation, Gödelian-like ctlcs appear in formulas where there are high gravitational fields associated with rapidly spinning matter, such as near black holes, wormholes, spinning-solid-cylindrical universes, and superstrings. In all of these, matter has become compressed and perhaps frozen in time. Examining the conditions of matter in all those locations is beyond the scope of this article, but another example, a spinning-solid-infinitely-long-cylinder of matter that has ctlcs helps to confirm a causal link between spinning, frozen matter, and time warps.

The idea that the motion of matter is related to time has ancient philosophical origins. The flow of time and relative motion have been viewed as the same. For example, if all motion stopped, in our homes, on the streets, and in the world around us, we would intuitively see this as stopped time. Time starts again when motion begins again. This is also captured by special relativity. At the speed of light, clocks come to a stop. From that speeding vantage point, motion has stopped too. There the flow of time and existence itself comes to an end. The reason time did not exist in the Gödel universe was because relative motion didn't exist. It was a frozen universe.

Incomplete and Inconsistent

The view that other life in the universe may not experience the same Now that we do is based in part upon the fact that observers moving in relation to one another will have different clock speeds. But there is another Now, known as the present, that is not connected to clock speeds. This is a "universal Now" that is under philosophical attack. We know the Nows experienced by observers having greatly different clock speeds are not identical, but we know too that they both exist in the present. This is confirmed by cosmic rays with very slow clock speeds that collide with relatively stationary atoms that have high clock speeds.

The debate about the nature of time is in part a struggle over competing definitions of its flow and of the Now. At the turn of the 19th century, light had conflicting definitions. It was first considered a particle, then a wave, and finally Einstein won a Nobel Prize for describing light as both a particle and a wave. His quantum of energy, or photon, helped kick off quantum mechanics. Given that light has multiple properties, and that philosophers over the centuries have frequently seen time as an eternal present, or as motion, then this suggests that time may exist at least as a duality: an eternal present or Now, where the flow of time depends on matter in motion. Rather than competing descriptions, these are complementary explanations of time—just as a wave and a particle are complementary descriptions of light.

Gödel's incompleteness theorem is a life raft for those who may not agree with the metaphysics of time commonly derived from the laws of physics. This theorem states that mathematical systems ultimately are inconsistent and/or incomplete. Physical laws are mathematical systems that are known to be incomplete. Most notably, quantum mechanics, the description of the microcosm, has yet to be unified with Einstein's theory of gravitation.

A disturbing feature of many of the laws of physics is that they lack an arrow for the flow of time from the present to the future. This is interpreted as implying that such an arrow does not exist, yet no observation of nature is more solidly established than that time flows from the present to the future. Therefore the absence of an arrow of time is another instance where the laws of physics are incomplete.

Further, if ctlcs indicate matter can go back in time, this requires a duplication of mass, which violates the law of the conservation of mass and energy. That law was basic to the gravitational equations that produce ctlcs, so either the general theory of relativity is being misinterpreted or the theory is inconsistent. The former is the most likely.

The incompleteness theorem allows us to look hard at metaphysical statements like "time doesn't exist" or "the Now doesn't exist" or "time forms a block where past and future exist." Because the mathematics upon which those statements are based is incomplete and/or inconsistent, some consider such metaphysics to be suspect. The readings below include a selection of views on these and related topics.

Donald R. Perry

See also Duration; Einstein, Albert; Gödel, Kurt; Light, Speed of; Now, Eternal; Pendulums; Quantum Mechanics; Time, Arrow of; Time, Illusion of; Time, Imaginary; Time, Relativity of; Time and Universes; Time Machine; Time Travel; Time Warps; Twins Paradox

Further Readings

Davies, P. (1995). *About time: Einstein's unfinished revolution.* New York: Viking.

Hawking, S. (1988). *A brief history of time.* New York: Bantam.

Nahin, P. J. (2001). *Time machines: Time travel in physics, metaphysics, and science fiction.* Woodbury, NY: American Institute of Physics Press.

Thorne, K. S. (1994). *Black holes and time warps: Einstein's outrageous legacy.* New York: Norton.

Yourgrau, P. (2006). *A world without time: The forgotten legacy of Gödel and Einstein.* New York: Basic Books.

Time, Objective Flux of

The concept of an objective flux of time, time that flows equally in all places, has existed for thousands of years. Humans have thought about time—its beginning, its end, and its characteristics in between—since before the advent of written history. Every culture had a creation myth, which inevitably included the idea of time itself. The incipient science that emerged in ancient Greece looked at time more objectively, searching for its nature. Aristotle, in the 4th century BCE, dissected the everyday term *time* into a mere number used for measurement. Although the number *of* something (in Aristotle's argument, movement) may be changed by adding or taking away an amount of the thing being measured, the number *itself* could not be changed. A concept like speed does not apply to a number, so time must flow continuously everywhere. Two centuries earlier, the Greek metaphysicist Heraclitus outlined his explanation of time's movement. His famous concept of flux, the constant change that everything in the world experiences at each moment, was in a way that of time itself. Time and change were inextricable, although not explicitly the same. Furthermore, since every event changes, time must be one of the main characteristics of all events. So Heraclitus defined time and events by each other, making each necessary for the other's existence. This agreed with his theory of the inherent unity of all objects. However, Heraclitus did not at any point deviate from the common idea that time passes at the same rate for all observers.

Time as a universal constant maintained its place in common belief with very few dissenting voices until modern times. In the 18th century, though, a renewal of interest in philosophy and discoveries in natural science gave birth to new schools of thought regarding the most basic ideas of all: time and matter. Bishop George Berkeley, in developing his philosophical theories, utterly rejected matter and time as real phenomena. The minds of humans and the ultimate mind of God were the only things he believed truly existed, and all other items that are usually considered concrete Berkeley reasoned to be thoughts in discrete people's minds. This included time, which became the procession of these thoughts through the mental landscape.

Another philosopher of the era, Immanuel Kant, also attempted to elucidate the elusive flow of time. He also labeled it a construct of the intellect, what humans use to order experiences into a useful form. It was one of the first substantially subjective views of time, since logically if time was a pattern coming from an individual's mind, it could and probably would be different for each person. Still, neither Berkeley nor Kant managed to change the Newtonian outlook on time.

Isaac Newton stated unequivocally the objective and unchanging nature of time and space in his 17th-century masterpiece, the *Philosophiae Naturalis Principia Mathematica.* Time itself never changed, although Newton acknowledged that the common means of measuring time may be inaccurate. Especially, he connected the idea of the inexorable flow of time with the amount of time that things exist, claiming that nothing could change the duration of existence of an object. Technology was not sufficiently developed until the 20th century to prove Newton wrong.

Theory of Relativity

Albert Einstein's theory of relativity finally destroyed the concept of an objective flux of time. His work was spurred by one of the few problems known at the time that Newtonian physics could not solve. No matter how many experiments were carried out, no one could show that light's speed appeared greater when the earth was moving toward its source than when our planet was receding from it; in other words, light speed did not vary with relative motion as all other speeds did. Einstein solved the problem simply by taking the experimental evidence for the truth. If one considered the speed of light to be absolute, then space and time must be relative universal components, not speed. Einstein then investigated the other effects this relativity of our four everyday dimensions had on the universe.

The Unity of Space and Time

The unity of space and time can be derived from a simple, classic thought experiment. If one person arranges to meet another person for lunch in a building, four coordinates are used. The place chosen for the meeting must be described using three of the coordinates; two for the building's street intersection, and one for the floor the meeting room occupies. However, this is not enough information. The time of the meeting must also be specified. This need for this set of coordinates can be generalized to any event in the universe. All four coordinates are necessary to describe one point. Therefore, they and the objects they describe—namely space and time—are linked.

Hermann Minkowski took Einstein's original connection of space and time and developed it further, claiming that time and space were actually one thing, which he labeled *spacetime.* Points in space and events in spacetime are analogous, since each point in space also exists for some duration of time. Einstein used Minkowski's four-dimensional spacetime continuum for various later facets of relativity.

Objective Spacetime

If a room with no windows is floating in any given direction at a constant speed in empty space, there is no method to determine from inside the room whether or not the room is moving. This circumstance is a cornerstone of relativity; it's commonly known as an inertial reference frame. Within a reference frame, all the laws of physics apply and sets of measurements agree with each other. Moreover, due to the theory of relativity, every inertial reference frame has the right to consider itself stationary. The corollary of this claim is that everything else in the universe is in relative motion compared to the specified frame. When two frames are moving relative to each other, their measurements will differ. The size of the discrepancy depends upon the relative speeds of the two reference frames; the closer to the speed of light, the greater the discrepancy. When this mechanism applies to measurements of time, it is called *time dilation,* and when the mechanism affects measurements of distance, *length contraction* is the term. There is an absolute interval between two points in spacetime, however, and it can be deduced from the measurements taken in any inertial reference frame. This interval remains the same regardless of the reference frame measuring it. Therefore, spacetime is objective, although there is no absolute reference frame.

There is a single exception to the relativity rule: the speed of light. Regardless of any reference frame's velocity, light is always perceived as moving at the same speed. Relative movement at substantial percentages of the speed of light can lead to contradictions concerning simultaneity. For instance, two flashlights are shone on a person in the middle seat of a minivan going three quarters of light speed, one by someone in the front seat and one by someone in the back seat. Another passenger would say that both light beams hit the person simultaneously, provided the distances between the seats were equal. However, a person standing on the curb would claim, with equal validity, that the beam from the front seat hit the passenger first, since the minivan was moving toward the light and thus the light had less distance to cover. The two witnesses disagree on the simultaneity of the lights hitting the passenger. Such disagreements on simultaneity occur only for independent events, however. Dependent events, like the birth and death of a person, are always seen as occurring in the proper order.

The final result of Einstein's theory was the destruction of the concept of unchanging, rigid time. Time does not flow the same way for all observers; a universal objective flux of time is a fallacy. This is obvious in extreme situations still being researched, like the area near a black hole's surface. Gravity there warps spacetime so greatly that time stops at the event horizon, and disappears completely beyond it.

Supporting Experiments

Einstein's theory of the spacetime continuum has been tested multiple times since its conception over a century ago. All experiments, both mental and physical, have supported his original hypothesis.

In addition to the argument listed above concerning the use of four coordinates to identify a point in spacetime, several other thought experiments were instrumental in elucidating Einstein's more difficult ideas. The light-clock, made of one mirror fixed above another and a single photon bouncing between them, elegantly describes time dilation. If one light-clock, with a photon labeled A, is stationary on a table and another one, with a photon labeled B, moves along the table at a constant velocity, the moving light-clock slows down in comparison to the stationary one. This is because the photon cannot change its speed, but it must add a horizontal component to its motion (as seen from the reference frame of the stationary clock) to keep bouncing off the horizontally moving mirrors. Therefore, photon B must make one complete bounce in more time compared to photon A, since it has farther to travel.

Many scientific experiments have been carried out as well. Even earlier than Einstein's work, Albert Michelson conducted experiments in 1881, and again with Edward Morley in 1887, that showed that light always traveled at the same rate. The first experimental vindication after Einstein's controversial papers were published occurred in 1919, when astronomers showed that stars' light was bent by the mass of the sun by precisely the amount Einstein had predicted. More recently, researchers working with the elementary particles called muons have found that these subatomic particles go through time dilation in nature. When created in the laboratory and moving at earthbound speeds, these particles decay in several millionths of one second. In nature, when muons leave the sun traveling at nearly light speed, they live for at least 8 minutes. In 2007, a NASA probe conducted a space experiment to test the magnitude of spacetime warpage caused by the earth. The data supported Einstein's theory of relativity to within 1%.

Beginning and End of Time

Although the very concept of time having a beginning or an end requires a measurement of time outside of and encompassing this universe's time, it is still a highly researched topic by scientists and laymen alike. Stephen Hawking has created a mathematical trick to be able to visualize the beginning and end of time fairly simply without assuming an ultimate, beyond-universal measure of time. He labeled it imaginary time, and defined it conceptually as the dimension at right angles to time. This turns the beginning and end of time into ordinary points in spacetime, different from any others only because no time exists before the first point or after the last point. The current physical consensus is that time began at the big bang, as spacetime expanded along with all the matter constituting the modern universe. Time's end is a slightly more difficult matter, as it depends upon a measurement that has not yet been completed. The density ratio of matter throughout the universe determines whether the universe—spacetime itself—will expand forever or collapse back in on itself. If the universe expands indefinitely, time will never end; if the universe follows the big crunch scenario, time will end when the entire universe returns to a primordial singularity. Scientists are still calculating this crucial number, so the ultimate fate of the universe is still unknown.

Emily Sobel

See also Aristotle; Becoming and Being; Berkeley, George; Big Bang Theory; Big Crunch Theory; Einstein, Albert; Heraclitus; Kant, Immanuel; Light, Speed of; Newton, Isaac; Relativity, Special Theory of; Spacetime Continuum; Time, Emergence of; Time, End of; Time, Observations of; Time, Perspectives of; Time, Relativity of; Time, Subjective Flow of

Further Readings

Aristotle. (1941). Physica. In *The basic works of Aristotle* (R. McKeon, Ed.). New York: Random House.

Greene, B. (1999). *The elegant universe I.* New York: Norton.

Newton, I. (1999). *The Principia: Mathematical principles of natural philosophy* (I. B. Cohen & A. Whitman, Trans.). Berkeley: University of California Press. (Original work published 1726)

Thorne, K. S. (1994). *Black holes & time warps: Einstein's outrageous legacy.* New York: Norton.

Wudka, J. (2006). *Space-time, relativity, and cosmology.* Cambridge, UK: Cambridge University Press.

Time, Observations of

Time, as an object to be observed, is a human concept. In order for time to be observed, this concept needed to be converted to a measurable entity. These measurable, or observable, separations of time can be divided into various groupings.

Observations of time can first be categorized as either temporal or fixed. The temporal, or relative, observations of time constantly change in their lengths. Based, for example, on the apparent motions of the sun or moon, these temporal segments vary from day to day, and even from latitude to latitude in a single day. Whether it is local time, based on the hour of "high noon" when the sun is at the zenith, or the length of sunlight to be divided into equal components (traditionally 12), these would not recur at identical intervals from day to day or place to place (or both). While these observations were only relative, such as measured in the length and/or direction of a shadow on a sundial, they did provide reference points—useful in Jewish and Muslim societies, for example, in determining the daily prayer times in relation to the sun's position in the sky. Fixed observations, on the other hand, occurred regularly and at specific intervals—even if the intervals were not of equal size from day to day, they were equal in parts each day, such as the Catholic prayers being at specific hours of the day—whether they were temporal or fixed hours.

The cyclical nature of the universe was realized as a way to observe time was found useful by the nomadic societies who needed to know when to move their herds or the agrarian societies who needed to know when to plant seeds. It was noted the seasons changed regularly, and observable phenomena such as stars reappeared in the same spot in the sky on a regular basis—what we consider to be a solar year. This led to fixed separations of equal lengths of time that occur regularly, such as months and years.

Both temporal and fixed observations of time can be separated as well into two types of observations—naturally occurring and human made. Natural time is based on the regularly occurring events in nature, such as solar noon, or the reappearance of a star at a particular point in the sky, such as the Egyptians identified. Natural time observations can be based on the rotation of the earth on its axis—the 24-hour day, as we know it; or the revolution of the earth around the sun on its orbit—the solar year, as we know it. Even the recurrence of the full moon—the lunar month—is a naturally occurring event that indicates regular passage of time. These events occur naturally, and whether or not the passage of time between these events' recurrences is measured, they still recur regularly. It is only when humans decided to sort these times into observable components of equal lengths that the concept of a fixed-length passage of time, such as clock time (hour, minute, second, etc.), the 7-day week, or varying month lengths, for example, was instituted.

The Industrial Revolution created a greater need for a constant, consistent observation by which to measure time at work from day to day. This was still temporal in part, since it was based on latitude, with each location on the globe having its own starting and ending point of the day—varying even from town to town. In the 18th century and on into the 19th, many did not own clocks, and wristwatches had not been invented, so there was a reliance on factory whistles or bells to announce the start and end of the workday.

The growth of railways and the importance of accurate timetables, both to ensure against accidents and to enable passengers to schedule travel by rail, necessitated an even more standardized measurement of time. This did not occur all at once; it took the additional effects, in part, of instantaneous telegraphic communication requiring a need to know what was sent and received when and in what order, and, later, the First World War, to demonstrate a critical need for standardized time measurements and observations worldwide so that the starting and ending times of events could be shared across locations without confusion. Uniform observations would enable everyone to know of distant events, which would often affect local events as well.

The solar year is based on the observation of the earth's cyclical path around the sun, causing seasons and the changing ratio of sunlight to darkness at each sunrise. This is one type of year, the one that is truly cyclical. Before this type of year was regularly observed, the lunar calendar was in common use, based on the temporal cycles of the moon's revolution about the earth that created what became to be known as months; and the appearance of the moon, which changed regularly. Muslim calendars still follow the moon's cycles exactly, using a temporal, natural calendar for their year. A problem with this is that the time between the start of one year and the next is not aligned with the earth's revolution around the sun, causing a misalignment with the seasons and therefore resulting in a gradual shift in the months as time passes. The traditional Jewish calendar, for example, follows the lunar cycle but adds a leap month regularly to keep the observations of time close to equivalent between the solar year and lunar cycles. The Catholic calendar is the solar calendar, following the divisions that keep events occurring at the same point on the earth's orbit around the sun each year.

The increasing complexity of society created a need for more precise divisions of time and eventually resulted in the standardization of units to ease observations of time across great distances. Similarly, the need to share observations of larger periods of time—years, decades, centuries, millenniums—led to standardization. Rather than saying, for example, "five big snows after John's barn burned," which of course would be meaningless to outsiders, one could now observe the passage of time as 5 years.

Observations involving estimations of the age of artifacts from the remote past are now based on the rate of decay of radioactive isotopes. These measurements are especially useful in such disciplines as archaeology and geology that deal with prehistoric events that occurred thousands and even millions of years ago.

Sara Marcus

See also Psychology and Time; Time, Objective Flux of; Time, Perspectives of; Time, Relativity of; Time, Subjective Flow of; Time and Universes; Twins Paradox

Further Readings

Barnett, J. E. (1998). *Time's pendulum: The quest to capture time—From sundial to atomic clocks*. New York: Plenum.

Barnett, J. E. (1999). *Time's pendulum: From sundials to atomic clocks, the fascinating history of timekeeping and how our discoveries changed the world*. San Diego, CA: Harcourt Brace.

Korda, M. (2004). *Marking time: Collecting watches—and thinking about time*. New York: Barnes & Noble.

Maestro, B. (1999). *The story of clocks and calendars: Marking a millennium*. New York: Lothrop, Lee & Shepard.

Snedden, R. (1996). *Time*. New York: Chelsea House.

Tannenbaum, B., & M. Stillman. (1958). *Understanding time: The science of clocks and calendars*. New York: Whittlesey House.

Zeh, H. D. (1992). *The physical basis of the direction of time* (2nd ed.). Berlin: Springer-Verlag.

Time, Operational Definition of

All the quantities physicists call "observables" are operationally defined; that is, they are specified in terms of measurements performed by well-prescribed measuring procedures. Temperature is what we measure with a thermometer. Voltage is what we measure with a voltmeter. Following Einstein, time is operationally defined by what is measured on a clock. Whatever its construction, a clock will provide a series of ticks and a counter of those ticks.

Almost any series of repetitive events, such as your own heartbeats, can be used as a clock. However, defining time by your heartbeats would result in physics equations that would have to be written in such a way as to take into account your daily activity. The time it takes an object to fall from a given height would be less on a day that you sat around at the computer than on a day when you ran a marathon. Obviously, for the sake of simplicity and the desire to describe reality in an objective way, we should use some more universal measure of time.

Throughout history, time has been measured by highly repeatable, nonsubjective events such as day and night, the phases of the moon, and other observations in the heavens. While astronomical calendars, divided into days and hours, suffice for the timing of familiar events, science has required a finer scale that does not have to be constantly recalibrated because of the irregularity of earth's movements. Galileo introduced the pendulum as a timing device for experiments, and even today mechanical clocks and watches rely on the pendulum to provide uniformity and accuracy. However, science has greatly improved the methods for standardizing time, and the mechanical clock has become obsolete except as an attractive piece of antique jewelry or furniture.

Today the standard of time is set by atomic clocks. The second is defined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine energy levels of the ground state of the cesium-133 atom at rest at absolute zero. Since observing such an atom is impossible, this requires a theoretical extrapolation to get the above value. The National Institute of Standards and Technology (NIST) and the United States Naval Observatory now provide a time source stable to 100 picoseconds (10^{-10} second) per day as a satellite signal. However, the primary time and frequency standard is now provided by averaging a set of *Cesium Fountain* atomic clocks at the NIST laboratory in Boulder, Colorado, which at this writing will not gain or lose a second in more than 60 million years.

All of the observables in physics are now calibrated against the time measured on the standard clock. In particular, the distance between two points in space was defined by international agreement in 1983 to be proportional to the time measured on a standard clock for light to travel between the two points in a vacuum. Specifically, the international standard unit of length, the meter, is the distance traveled by light in 1/299,792,458 of a second in a vacuum.

In developing his special theory of relativity in 1905, Einstein postulated that the speed of light in a vacuum is a constant—the same in all reference frames. Since then, special relativity has proved enormously successful in describing observations. As a result, Einstein's postulate is now built into the structure of physics by the very definition of distance.

The current definition of distance has a profound consequence that is rarely emphasized in the textbooks. Since 1983, distance in science is no longer treated as a quantity that is independent of time. In fact, distance is now officially defined in terms of time, that is, as a measurement fundamentally made not with a meter stick but with a clock: the time it takes light to travel between two points in a vacuum. Of course, in practice we still use meter sticks and other means to measure distance, but in principle these must be calibrated against an atomic clock.

So, as it now stands by international agreement, all physics measurements reduce to measurements made on clocks. The table below shows the fundamental units of various physical quantities shown as a power of a second, s^n.

time, distance	s^1
velocity, angular momentum, electric charge	s^0
acceleration, mass, energy, momentum, temperature	s^{-1}
force, electric and magnetic fields	s^{-2}
Newton's constant G	s^2
pressure, mass density, energy density	s^{-4}

Since the process of measuring time involves counting ticks, observables should be represented by rational numbers—integers or ratios of integers. The smallest time interval that can be measured is 5.4×10^{-44} seconds, the *Planck time*. In Planck units, any value of time is an integer.

Victor J. Stenger

See also Attosecond and Nanosecond; Clocks, Atomic; Clocks, Mechanical; Einstein, Albert; Light, Speed of; Pendulums; Planck Time; Time, Measurements of; Time, Relativity of; Time, Units of

Further Readings

Davies, P. (1996). *About time: Einstein's unfinished revolution.* New York: Simon & Schuster.

Stenger, V. J. (2006). *The comprehensible cosmos: Where do the laws of physics come from?* Amherst, NY: Prometheus.

Time, Origin Of

See Time, Emergence of

Time, Perspectives of

The 18th-century philosopher Immanuel Kant wrote that time has no real existence outside the human mind. It is of course true that time itself is not a tangible object and therefore can be considered an abstraction or a human construct. Humans have been organizing and making meaning out of time for millennia, with different cultures developing their own models, which have influenced their perspective of time. Although differing viewpoints on time can seem strange to outsiders, it is consensus within a given group that is important. As long as the people holding a given perspective agree on it, they can then measure the duration of events or synchronize activities.

An example of different cultural perspectives of time was demonstrated by a study at California State University, Fresno, where college students in California and in Brazil were asked about their concepts of "early" and "late." When asked how much time would pass before one would be considered late for an appointment, the Brazilian students' average was almost twice as long as that of the California students.

One way of looking at perspectives of time is by seeing time as relative or as absolute. *Absolute time* is measured quantitatively, using numbers and units. These units may be arbitrary (such as seconds, minutes, or weeks) or may be based on natural events (such as planetary motions). The units used will differ from culture to culture. The Mayans, for example, based days on the rotation of the earth. However, they used multiple calendars based on different numbers of days, and even one calendar based on the cycles of Venus.

Relative time is not measured with numbers. Instead, two or more events are compared, either in duration or in order of occurrence. The geologic timescale shows relative time. Using this system, scientists can describe the timing of an event (or the relationship of two events) in the earth's history according to a sequence of eras, eons, and smaller units. While the system divides time into more and more specific units, the units are not measured numerically. All of the eras (and all of the eons, etc.) are unequal in length, since the beginning or ending of a unit is usually determined by major geological events.

Time can also be seen as either circular or linear. Western culture tends to see time from a linear perspective, which is believed to have grown out of Judeo-Christian beliefs that the universe has a beginning (creation by God) and will have an ending. In the 17th century, Isaac Newton represented time mathematically with a line, and wrote that time "flows equably without relation to anything external." Although Newton is credited with introducing the idea of linear time to the Western world, ancient Hebrew writings also refer to this viewpoint. In this perspective, time consists of an orderly sequence of events, progressing continuously. The flow of time is constant, and we do not have control over its passage. (An example of this viewpoint would be the phrase, "Time marches on.") In this way, time can be understood as an arrow or a conveyor belt, always moving forward.

An example of a linear measurement of time is the Mesoamerican Long Count Calendar (also known as the Mayan Long Count Calendar). Dates are identified by the number of days that have elapsed since a particular starting point (calculated to be August 11, 3114 BCE, in the Gregorian calendar). A single day was known as a *K'in.* Additional units were used to describe periods of 20 days, 360 days, and even longer periods.

Many ancient Greek and Roman philosophers saw time as *circular,* a perception that is still found in Buddhism, Taoism, and neo-pagan religions. This perspective is based on observations of natural recurring phenomena, such as the rising and setting sun. In circular time, time is not "lost" to the past—events are just moved to another place in the cycle. Although new events continue to happen after older events, things always return to a previous state. An example would be reincarnation, in which a new life begins after one ends. In this case, the word *circular* does not mean that literally the exact same things happen over and over again.

Time can also be seen as monochronic or polychronic. In *monochronic* time, time is broken down into precise units, which allows events to be scheduled and organized. Tasks are performed individually within a fixed period. In this perspective, time is a finite resource that is not to be wasted, as embodied in the expression, "Time is money." Time is also sometimes treated as if it were a tangible object, as people often speak of saving or spending it. Punctuality is culturally important, and being late for an appointment is often taken as a sign of rudeness or a lack of respect. The monochronic viewpoint of time is also found in cultures that see time as linear, such as North American and northern European. To someone not used to this viewpoint, monochromic time may seem overly scheduled and rigid.

In *polychronic* time, time is seen as more fluid and not as rigid or precise as in Western cultures, allowing plans to be changed more easily. Schedules are not as important, and lateness is more acceptable. Many actions are performed at the same time, and completion of tasks is more important than preset schedules. Polychronic time is characteristically used in Latin American, Native American, and Middle Eastern cultures, as well as other cultures that view time as circular. A person accustomed to monochronic time may feel psychologically stressed when placed in a culture that follows polychronic time, as it may seem more chaotic and less organized.

Monochronic and polychronic time perspectives are not mutually exclusive. Specific environments within a culture (such as a home or a place of work) may operate in a more monochronic or polychronic way than the rest of society at large.

Jaclyn McKewan

See also Evolution, Organic; Geologic Timescale; Time, Absolute; Time, Cosmic; Time, Galactic; Time, Historic; Time, Observations of; Time, Planetary; Time, Prehistoric; Time, Sidereal; Time, Teaching; Time, Universal; Time and Universes

Further Readings

Aveni, A. (2002). *Empires of time: Calendars, clocks and cultures.* Boulder: University Press of Colorado.

Boslough, J. (1990). The enigma of time. *National Geographic, 177,* 109–132.

Hall, E. T. (1996). *The dance of life: The other dimensions of time.* Garden City, NY: Anchor Press/ Doubleday.

Time, Phenomenology of

Philosophers since the early Greeks have speculated on the nature of time, often with diverging views. Aristotle gave a clear and detailed definition of time, saying it represented a numerical measure of change between the past and the present. Plotinus later disagreed and saw time as more than counting and as related to eternity and the soul. Since then, philosophers such as Baruch de Spinoza, Immanuel Kant, and G. W. F. Hegel have proposed a variety of approaches to understanding the nature of time.

The phenomenological attempt to understand time began early in the 20th century when Edmund Husserl developed the major precepts of phenomenology. Husserl believed one should study specific phenomena—love, death, time, and the like—divorced from the traditional scientific method of gathering and analyzing data. Because phenomena are perceived by the senses, it is inevitable that there will be confusion and a dilution of the true description of each phenomenon because of ingrained presuppositions and attitudes. To understand a phenomenon fully, it must be reduced to its essence, removing any natural attitudes about it, relying instead on a subjective approach. In the case of time, this requires discarding any preexisting ideas concerning time as well as any scientific beliefs about the physicality of time. Any objective evidence of time at all has to be reduced to a relationship to consciousness, which in turn is defined by intentionality, a flow from the now to the new now. In a converse relationship, this also means that intentionality is basically time-consciousness, which originates with perception.

The first step on the way to understanding is to ask how a nonmaterial object such as time, viewed as a subjective phenomenon, can be made evident by a philosophical approach that opposes naturalism or objectivism, which our current technology and science embrace and have done so for more than 500 years.

Phenomenologists might respond that only by relying on a priori descriptions can one apprehend an explanation of the causes or purposes of elements. What then, is an a priori description of time? It is a concept of the living present, which implies another and more fundamental level of consciousness: the absolute flow of time-constituting consciousness, or the consciousness of immanent temporal objects. To study time from a phenomenological point of view is to attempt to understand time not in terms of physics or mathematics, but solely to describe it in nonempirical, philosophical terms.

A simple way to introduce the phenomenology of time is to think of time as a fountain—not the physical construct that creates the fountain, but the beingness of the fountain that exists only while it is running and throwing water up in an arc. The water changes, but the fountain remains as a fountain because the water, in its successive iterations, *retains* the form of the fountain. This idea of *retention* is integral to the phenomenological understanding of time consciousness. Retention, for Husserl, is a deeper concept than simply keeping something in memory. Rather, it implies intentionality; not simply an echo, but a consciousness of the past. In this sense, the common metaphor for time as a river leads to some confusion about how we perceive time. If the metaphor is extended, then the river begins with a glacier or melting snow, which proceeds from mountain to valley to the sea and then ends in a different entity—the ocean. Yet time, in a phenomenological sense, cannot be said to have a beginning or end. Time simply *is,* as the fountain *is.*

A phenomenological approach to understanding time implies that time is an essence that can be made evident, described, and "encountered." In other words, it should be possible, through this branch of philosophy, to apprehend the essence of time. In his lectures on the subject of time, Husserl distinguished among several types of time: objective, experiential within the inner self, and a deeper consciousness of inner time. He referred to the latter as the *deep living present,* which was the basis of the ego. Husserl also discussed the "now-point" as the source-point of individuality. Seen in these aspects, the ego, or self, has a temporal existence that can be understood.

Using an example from music as a temporal experience, consider a melody as it is played. A listener hears a note, then another note, and another, and so on, continuing to the end of the selection. At any one moment, the ear can hear only one note of the melody. How then can the fullness of the musical work be appreciated or understood? The mind puts all the notes together, but the experience of the musical work is not a totality of a temporally unitary action. If it were, we would hear a cacophonous mélange of incomprehensible sounds. Nor can the mind extend the apprehension of the notes over time—a note is played and then is gone.

Using a phenomenological approach, however, each individual note not only may be experienced in the present and recalled from the past, but there also may be retention of recent past notes, that is, a presence in the present of the past. In these terms there is a melding between the past and the present, reducing the distinct line between the two. Husserl referred to this as the living horizon of the now. Furthermore, there is a recessive parabolic effect to what is happening, in that as notes get farther into the past, the farther away they are, the less clear, although they can still be recalled. Instead of the objective view of time, which sees it as a sequential occurrence of individual events, time is viewed as wavelike phenomena where consciousness of time depends on a flow where events emerge and fade in intensity. Rather than a static, moment-by-moment view of discrete instants of time going by as visualized in everyday terms, the past and the present and even the future are simply part of the flow of experience corresponding to the clarity of their impressions.

Charles R. Anderson

See also Consciousness; Husserl, Edmund; Merleau-Ponty, Maurice; Time, Subjective Flow of

Further Readings

Husserl, E. (1991). *On the phenomenology of the consciousness of internal time* (J. B. Brough, Trans.). Boston: Kluwer Academic.

Kortooms, A. (2002). *Phenomenology of time: Edmund Husserl's analysis of time-consciousness.* Boston: Kluwer Academic.

TIME, PLANETARY

There are two ways to conceive of planetary time. The first is the length of each planetary axial rotation and corresponding revolution, each of which is measured in standard notation. This is practical for short-term measurements, yet quite involved when considering the age of the solar system. The second perspective of planetary time deals with describing the planet's time relative to the processes and events it has undergone throughout its evolution.

Short-Term Measurements

Planets orbit the sun due to the immense effect of gravity that the sun is placing on space. Each orbits at a different rate, directly proportional to its distance from the sun. A common misconception is that the smaller a planet is, the faster it rotates on its axis. However, the opposite is true. Jupiter takes nearly 12 Earth years to complete one orbit of the sun, but only 9.5 hours for the sun to rise and set. Timekeeping would be performed very differently from one planet to the next.

Long-Term Measurements

On a long-term scale, planetary time is vastly different from time measured in human terms. From the planetary perspective, centuries are the equivalent of nanoseconds in magnitude. On Earth, we measure planetary time by using the geologic timescale. The largest measurement is the super-eon. Super-eons divide the geologic timescale into eons. In turn, each division consists of eras, periods, and epochs. After epochs, millions of years become a realistic measurement. The divisions are denoted in terms of cataclysmic events, rather than as a specific continuum of time.

Since the planets in the solar system formed together, a similar scale measures the passage of time on each. Therefore, a similar scale of time is applied. Research continues on the moon, Venus, and Mars, and clues to their histories are developing rapidly. While each eon, era, period, and epoch may occur at different moments in time, all of these histories will use a similar scale of measurement to determine divisional boundaries. For instance, probes such as Magellan (Venus) in 1990, Clementine (Moon) in 1994, and the Mars Global Surveyor in 1997, have gatherer much data and contributed to increased knowledge of planetary geology. Mapping of surface features yields relative rock formation ages and past events. NASA plans to launch many more vessels to study aspects of all the major and minor planets in the solar system.

Study of events on the solid surfaces of the terrestrial planets provides an easy method of observation. The Jovian planets lack a solid core and contain no rocky surfaces. As a result, it is impossible to apply a timescale based on present surface features. Instead, researchers employ a climatologic or atmospheric timescale to measure the passage of events on the Jovian planets. For example, the deviations of Jupiterian radio emissions, changes in Saturnian density, variations in Uranian cloud concentrations, or differences in Neptunian atmospheric spectroscopy all measure the events that shape each Jovian planet's history.

Whereas all of the planets are the same age, each planet's timescale is its relative history broken down into smaller periods between major events. Although humans measure their own history in periods of years, planetary time is on much too large a scale to measure in years, although each event is unique to a planet's timescale; therefore the actual time between events is not a consistent block of time.

Timothy D. Collins

See also Dating Techniques; Earth, Age of; Earth, Revolution of; Earth, Rotation of; Evolution, Organic; Extinction and Evolution; Fossil Record; Geologic Timescale; Ice Ages; Planets; Time, Measurements of

Further Readings

Bridges, N. T., & McGill, G. E. (2002). *Geologic map of the Kaiwan Fluctus Quadrangle (V-44), Venus.* Flagstaff, AZ: United States Geological Survey.

Canup, R. M., & Agnor, C. B. (2000). Accretion of the terrestrial planets and the earth/moon systems. In *Origin of the earth and moon.* Tucson: University of Arizona Press in collaboration with Lunar and Planetary Institute, Houston.

Karttunen, H., Kroeger, P., Oja, H., Pouanen, M., & Donner, K. J. (2003). *Fundamental astronomy* (4th ed., English). Berlin: Springer.

McGill, G. E., Schultz, R. A., & Moore, J. M. (2000). Fault growth by segment linkage: An explanation for scatter in maximum displacement and trace length data from the Canyonlands Grabens of SE Utah: Discussion. *Journal of Structural Geology, 22,* 135–140.

Neugebauer, O. (1969). *The exact sciences in antiquity* (2nd ed.). New York: Harper & Row.

Time, Prehistoric

Prehistory is the time prior to written records. It includes not only human existence prior to written records, but also that of other forms of life. Since there are no written records, most of the information gathered about these earlier life forms is acquired through interpretation of fossils and artifacts left behind. These fossils may include human-made tools, whether stone or metal; animal bones; and coprolite, or fossilized excrement. Coprolite offers an insight into the dietary practices of animals and early humans. The study and interpretation of these fossils and artifacts is done by prehistoric archaeologists, and 99% of what is known today about human prehistory is through prehistoric archaeology. The earliest written records appeared around 5,000 years ago in Mesopotamia; 4,000 years ago in Greece; and 3,000 years ago in China. Prehistory ends differently for different cultures, since it is based on the advent of written records.

A number of methods are used in dating materials from prehistoric sites. Dendrochronology, or the study and use of tree rings as a method for dating events, is good for measuring changes in climate, beginnings of agrarian culture, and volcanic activity. Another way of dating fossils is through means of biostratigraphy: the study of fossil records and the surrounding strata in which they appear compared to those of other fossils. Although this method does not suggest a definite date, it does allow scientists to group fossils of the same time period together.

Carbon dating is also a commonly used method. All living things have carbon in them at the same ratio as the carbon in the atmosphere. Plants obtain carbon from the atmosphere through photosynthesis, whereas animals obtain carbon from the atmosphere by eating plants or animals that eat plants. Radiocarbon will cease to be created when an animal dies, at which point carbon-14 will begin breaking down at a constant rate. By measuring the amount of carbon-14 remaining in a corpse against the amount of carbon-12 in it, scientists can give an approximate age of a corpse. Due to outside influences and possible discrepancies in dating techniques, scientists will synchronize their findings with tree rings when possible. This is very important because the margin of error for carbon-14 dating can be as great as 2,000 years.

Beginnings of the Earth

As currently understood, the universe began with the big bang roughly 18 billion years ago. Gases compressed and rotated to form our sun more than 4.8 billion years ago. The debris surrounding the sun started to collect and eventually formed the planets. Earth formed 200,000 million years later, starting as volcanically active molten rock and hardening as it cooled. The steam from the cooling of the lava created the oceans. The earliest forms of life appeared 3.4 billion years ago as blue-green algae, followed by eukaryotes 1.4 billion years later. The first 4 billion years of the earth's history is known as the Precambrian era. Due to plate tectonics and the subduction of older oceanic crust by younger oceanic crust, few Precambrian fossils remain. The last 540 million years are broken down further due in part to the abundance of fossils and the law of superposition, or the observed rule that rock layers follow a chronological sequence that can be observed clearly in current continental crusts.

Age of Invertebrates

The age of invertebrates occurred during the Cambrian and Ordovician periods on the geological timescale, spanning a million years. Multicellular life forms first appeared at the end of the Precambrian. These early life forms included soft-bodied creatures such as jellyfish and other coelenterates. As the earth continued to change, life forms also slowly began to evolve and adapt to these changes. An increase of life forms appeared during the 50 million years after the end of the Precambrian. Some creatures developed external skeletons as a form of protection, and marine life forms grew larger. Most of the modern phyla can be traced back to animals of this time.

Trilobites are an abundant life form of this period, and numerous fossils of these creatures are still in existence today. Other invertebrates, including corals and brachiopods, are abundant as well. The jawless fishes are known to be the first vertebrates to form during this time, nearly 500 million years ago.

Age of Fishes

Marine life expanded and various types of fishes roamed the waters. The first plants found on land begin to grow and multiply. Wingless insects made an appearance here and skitter on land. Jawed fishes arise and dominate the waters, while trilobites begin to decline in number. Toward the end of this period, some fish leave the water and walk on land, comfortable with either habitat. These were the early amphibians. After 90 million years of fishes evolving and dominating, came the rise of amphibians.

Age of Amphibians

Amphibians were abundant from 320 million to 260 million years ago. Large, coal-forming coastal swamps existed. The first reptiles appeared during this time. These early reptiles were small insect-eating creatures. Most amphibians at this time lived most of their life in the water, whereas these new reptiles spent their lives entirely on land.

Age of Reptiles

Two hundred fifty million years ago reptiles dominated the land, and would do so for the next 160 million years. Other reptiles appeared in the waters and in the skies. During these periods, mammals and birds first appear. Based on fossil records, the oldest known bird is *Archaeopteryx,* which appeared 150 million years ago. The dinosaurs died out rather suddenly, relative to the time spans of the geological timescale. Their extinction marks the end of the Cretaceous and the beginning of a new period, the Tertiary. Exactly why the dinosaurs died off is not known, but many scientists believe it was due to a meteor that hit the earth, kicking up lots of dust and debris, trapping sunlight and warming the earth's surface. A thin layer of debris can be found in bedrock strata separating the Cretaceous and Tertiary periods. This separation is known as the K-T boundary.

Age of Mammals

With the mass extinction of 70% of the earth's population, the mammals that survived grew in size and numbers to repopulate the earth. Primates first appeared during the beginning of the Tertiary period and soon evolved several characteristics still in existence today, such as grasping limbs, short snouts, and enlarged brains. Early hominids, or the first humanlike mammals, evolved away from the primate family and are believed to have spent much of their lives in trees.

It is only in the last 5 million years that humanlike creatures have roamed the planet. Our species, *Homo sapiens,* has existed for only the last 100,000 years, a small fraction of life's 600-million-year history of existence.

Hominids

Hominids first appeared in Africa 5 million years ago, south of the Sahara Desert. These early hominids may have used basic tools, such as sticks to poke at food sources. As hominids evolved, their jaws and teeth became smaller and their skulls rounded. The famous Lucy fossil is of this species of hominid. This species evolved into *Homo habilis,* the first hominids to be called humans. *Homo habilis* created specialized tools using harder rocks to create a sharpened edge on softer materials, such as other rocks and bones. These sharpened materials were later fitted with wooden handles, and early axes and knives were soon formed.

Homo erectus were the first hominids to use fire, improving their lifestyle. Fire offered warmth during cold nights, protected the hominids from wild animals, and also provided a means of cooking meat. The fire would become a focal point for hominid dwellings. *Homo erectus* migrated from Africa into Europe and Asia. *Homo neanderthalensis* appeared in Europe nearly 200,000 years ago and were accustomed to living in the colder northern lands. These are the first hominids known to bury their dead.

The first humans to venture to the Americas did so from Siberia via the frozen Bering Strait. From here, some groups settled in North America while other groups continued to migrate south and settle throughout South America. The two prominent cultures created by these nomads are known as the Clovis and the Folsom cultures. There is debate as to whether the Clovis people were the first Americans, or if there was another group on the continent prior to them. The majority of the sites cited as arguments for a pre-Clovis group are located in South America. The Clovis created an early arrowhead used as a projectile tip for hunting mammoths; some believe that the Clovis peoples hunted mammoths to extinction. The Folsom made the Clovis arrowhead as a smaller projectile tip for hunting smaller mammals.

The first humans to journey to Australia are thought to have done so by ocean voyage. The most logical route would have been from Southeast Asia and the Philippines to the New Guinea and Australia land masses. The journey to Australia would have required seafaring vessels, despite the lack of physical evidence confirming such an adventure. Fossil records indicate that early humans did exist in Australia; the questions that remain are when and how they first arrived. The Australian Aborigines are the descendants of these first Australians. Some of them, upon reaching Australia, settled on the Tasmanian peninsula, which, after the rise of ocean levels, became an island. As in the Americas, the first humans on the Australian continent led to the extinction of larger mammals and marsupials.

A hundred thousand years after *Homo neanderthalis* appeared, *Homo sapiens* migrated from Africa. Roughly 70,000 years later, the Neanderthals became extinct, leaving *Homo sapiens* as the only hominids left on earth. Not only were improved tool crafting skills evident, but fossils from this time reveal the artistic interests of these early humans. The oldest musical instrument, with the exception of primal percussion instruments, is a primordial flute that has been dated as 40,500 years old. Other artistic creations followed. Cave paintings were created 30 thousand years ago. These started as images of animals, such as mammoths, horses, and bison; much later abstract humans were added. The meaning of these cave paintings is unknown, but they are believed to be ceremonial in origin. The Lascaux caves in France and the Altamira cave in Spain are among the best-known sites featuring such paintings. After the discovery of Lascaux, several other cave paintings were discovered throughout Spain and France.

Figurines were another artistic creation of this time. Many of these were of animals, although some were human and others a hybrid. The most popular human figurines are the Paleolithic Venuses, or figurines of female entities. With the advent of ceremonial rituals of these hominids, such as cave paintings and human burials, it is strongly suggested that there was a religion of sorts. Since many of the burial sites from this period contain material belongings, it is inferred that these hominids believed that they lived on after death and could benefit from these possessions.

It has not been determined when language arose in prehistory, yet there had to have been some form of communication, verbal or physical, to organize groups for hunting animals and gathering fruits and seeds, to barter, and to share tool-making crafts.

Ancient Civilizations

Around 10,000 BCE, many hunter–gatherer groups began cultivating plants and domesticating animals, leading to settlements of villages and towns. The global transition from hunter–gatherer society and agrarian society took less than 10,000 years. This rapid transition is somewhat of an enigma. There have been a few theories proposed to explain this phenomenon, including that of a massive drought or a large world population boom; however, there is a lack of evidence to confirm either of these theories. Other theories include the competition for farm land and, in some areas such as the Americas, the extinction of larger animals as food supplies.

Early nomadic groups would settle in a valley-like region, near a water source. The valley would act as a natural pen for the extra live animals caught as a future food supply. These animals adapted to their new life, becoming domesticated. Domesticated dogs were used to help herd these animals, whether sheep, goats, or similar species. Seeds from plants gathered were also soon planted and harvested and there was no longer a need to roam. Soon settlements cropped up in similar geographical locations. Communities that were built around these settlements worked together to farm. Over the years, the settlements would grow in size to become villages and towns, and eventually cities, allowing many workers to leave farming to become tradesmen, building tools and making ceramics. The earliest wheel may well have been a potter's wheel for creating ceramic pottery. The creation of pottery becomes prevalent around the same time settlements were formed, since ceramics were heavy, susceptible to breaking, and not suitable for a nomadic lifestyle.

With the discovery of metals came advancement in tools and utilities. Some tools were designed for agricultural use. Sumer, one of the first early settlements, was in the lower Mesopotamian region, between the Euphrates and Tigris rivers. Around 5000 BCE, Mesopotamian farmers implemented irrigation systems to assist with watering their crops. Artifacts found today reveal a knowledge of metalwork and smelting of bronze as early as 3800 BCE. The population of Sumer boomed in 3300 BCE, with small towns evolving into larger cities. This increase in population could have been the result of merchants immigrating to the towns, workers in search of employment, or a combination of these and other possibilities. Because of this growth, there were a number of changes in the Sumerian culture, including city temples being the center of the town. Priests trained scribes to record ongoing town activities and historical events, the beginnings of written history. Other cultures followed with their own written records; for example, the Egyptians and their system of hieroglyphics.

Mat T. Wilson

See also Altamira Cave; Anthropology; Boucher de Perthes, Jacques; Chauvet Cave; Dating Techniques; Dinosaurs; Earth, Age of; Evidence of Human Evolution, Interpreting; Extinction and Evolution; Fossils, Interpretations of; Fossils and Artifacts; Geologica Timescale; Hominid-Pongid Split; Laetoli Footprints; Lascaux Cave; Olduvai Gorge

Further Readings

Cook, M. (2003). *A brief history of the human race.* New York: Norton.

Davis, J. C. (2004). *The human story: Our history, from the Stone Age to today.* New York: HarperCollins.

Lewis, R. (1999). *Human evolution: An illustrated introduction.* Malden, MA: Blackwell Science.

Time, Problems of

There have always been problems with time. Just its three forms and their mode of existence/nonexistence were sufficient to provide material for reflection for about 10 of the most significant philosophers (and philosophizing natural scientists) in history. These thinkers filled hundreds of pages with their ideas on this topic, yet they have almost always, in various forms, repeated one and the same thesis: Time is being that does not exist or it constantly escapes us. Yes, time has the status of being, time is, and our everyday experience or our imprisonment in the flow of time, from which we are not able to escape, proves this. Could we actually deny the existence of something that restricts and determines us so considerably? No, time *is not,* of course. The very definition of its three forms—past, present, and future—is based on the fact that *what we talk about is not.* We cannot explain *it* and yet, we understand *that.* The very expressions used here—"is," "was," "history," "previous"—in some way express the individual modes of time, which we understand but do not know how. Somewhere within these limits all the reflections on the way we perceive and experience time are situated from Aristotle to Jean-Paul Sartre or Maurice Merleau-Ponty.

Being and Becoming

The very problem of time thus becomes an excellent example of how useful it is to abandon the reflections based on the category of being. It is in its essence conceived as being able to resist time and form its opposite in order to guarantee the certainty of knowing in a changeable world. The revision of such reflections by means of the notions of *becoming* and *events* gives us a chance to resolve some dualisms that result simply from metaphysical speculations on *being*. And, of course, this replacement is not only a question of a simple exchange of two words or notions. It is the indication of a different view of reality, the emphasis of its dynamic character and the restoration of its variability, which for centuries has been understood only as an accidental matter of the constantly searched-for substance.

Science, Experience, and the Traditional Oppositions

Physics presents a second and significantly different line of thought on time. The differences are apparently so vital that the first question to ask in relation to time might concern just this double-line character of our reflections on time. It should be pointed out that these two lines of thought represent traditional contradictory views of time: Is time a subjective or an objective matter? Is the time we perceive different from physical time? Are there two times, two different characteristics of our world, or two different views of a single characteristic? To answer these questions is yet more difficult because these two approaches were outlined at almost the very beginning of European thought. Aristotle introduces the obstacles he meets when trying to define time on the basis of movement (which later gives rise to the physical branch of reflections on time), and in an effort to grasp the moment in the sense of *now* (from which later reflections of a rather psychological—and even later of a phenomenological—character arise). In the case of Augustine of Hippo this division is already quite obvious. On the one hand, there are reflections on the creation of the world and the beginning of time; that is, the concept of cosmological time. On the other hand, there are mostly introspective analyses dealing with the question of the form of existence of the three modes of time—the past, the present, and the future—in relation to our perception of time. These two approaches diverge even more with the introduction of modern science, which, particularly in mechanics, transforms time into an abstract entity, and the flow of time itself is always reconstructed by means of differential equations on the basis of the initial conditions. Time becomes part of geometry in the form of the trajectory of moving bodies. The whole of history is thus concentrated in one abstract moment; the past and the future differ only by whether the mathematical sign is positive or negative. Time itself is a neutral background entity with no relationship to what is happening in the world.

Everyday human experience is confronted with all this, which tells us that we cannot exclude time from our considerations, plans, or ideas, that time is one of the decisive or limiting quantities that we have to take into account. The ceaseless awareness of different conceptions of time—physical, everyday, and philosophical—repeatedly raises the question of its essence, or more precisely raises it more or less urgently depending on the various events in human life and changes within society.

While a sense of time has never been absent from the human experience, it returns to physics very slowly and with difficulties, as a precaution, in several forms. The first is related to thermodynamics and *irreversible processes;* the second is conditioned by the limiting speed of signal transmission and causality; and the third is the expression of the whole universe, or *cosmological time*.

It certainly will not be redundant to explore more closely what the common understanding of time is in these areas. Thermodynamics is the study of processes whose main characteristic is a one-way flow of energy. These are also called irreversible processes, expressing the conviction that this one-way flow is a given and cannot be replaced with its opposite.

The final speed of the transmission of any of the signals and the principle of causality lead us to the conclusion that it is not possible to reverse processes so that the consequence precedes the cause, or—put differently—it is not possible to progress physically from the consequence to the cause against the direction shown by the arrow of the causal activity.

Cosmological time is in compliance with the recognized standard model of the universe connected to its expansion, which also seems to define unambiguously the direction against which it is not possible to go. It is probable that irreversible processes are typical not only of thermodynamics, but of all the given modes of expressing time, and we presume that it is important to emphasize this fact. Briefly, this emphasis would be as follows: *The real name of time is irreversibility.* Systems in which only impeccably reversible processes occur would in fact be timeless, that is, without memory, because we could not differentiate the separate and repeating states of the system and they would not have any one-way changing background (an increase in entropy, expansion, etc.).

In some areas of life we connect or even identify time with irreversibility quite intuitively and naturally; in others the connection is less evident but is gradually discovered.

Folk wisdom teaches us that we can never be wise before the event. We seldom understand this knowledge, proved by generations, as real information; more often it is just a sign concerning the irreversibility of our deeds. If we are interested in the theoretical basis for the futility of trying to be wise before the event, we will have to go through a considerable part of the history of physics and we will not be able to avoid a confrontation with existentialism in order to end up with physics again; this time, however, with its most modern, actually still developing, theories.

The conviction about the irrevocable and unchangeable character of our past deeds does not arise out of physics but out of experience (which has not been theoretically defined for a long time) of the one-way flow of events, which take us from the past and our birth to the future and the inevitable end. This experience is in sharp conflict with classical physics, which is based on formulas drawn from natural laws, which are perfectly symmetrical in relation to time. The invariable characterization of physical laws concerning time transformations is nevertheless (in classical science) also quite evident, and one could say it is self-evident. Would there be any sense in formulating laws that would apply differently on Mondays and on Sundays? Classical physics does not recognize a difference between the past and the future, and if it wants to calculate the state of the system, what it was like or what it will be like, it is sufficient to adjust the sign next to the quantity defining time.

Consequently, the description handed down through classical physics may be viewed as timeless. If it is possible to achieve through such simple adjustment a free manipulation of the past and the future, the term *irreversibility* disappears from our vocabulary and with it, in fact, the possibility to decide unambiguously what was first and what was next. And since for classical physics (intruded into the formulations of physical laws that are invariable concerning time transformations) there does not exist any "late"; the saying about being wise after the event thus loses its meaning and one easily can be wise before the event. Or, to put it more simply: It is not a problem for classical physics to change the values of the entry data and to discover the state of the system for a new input no matter whether the result is a state in the past or the future.

The evident discrepancy of such a description and common experience with irreversible events led to an alternative understanding of time that was found primarily in existentialism-oriented branches of philosophy. Here, irreversibility became one of the basic features of this concept of time, and the discrepancy between the physical and philosophical approaches seemed to be crucially important and unsolvable. Yet both sides offered arguments that could not be easily ignored. Physics has an array of successful explanations and even technical applications that are based on them; philosophy, on the other hand, emphasized the indisputable transitory nature of our being. It appeared that each concept dealt with something different, that there existed two different times, which also was reflected in the result of the discussion between Albert Einstein and Henri Bergson.

Despite the dissimilarities of all three approaches—the folk understanding of time as irreversibility; the philosophical approach to the existential experiences of finality, freedom, and responsibility of human beings; and finally the physical description of the world—they share one illusion, which is their opinion of the deterministic character of our world. "To be wise after the event" in the folk interpretation expresses nothing other than our regrets for the initial conditions we chose in the past and suggests that if we had chosen otherwise, we would arrive at clearly predictable consequences in the end. The futility of the hunt for these “woulds” (if I had . . . , I would now . . .) consists precisely in the fact that it is impossible to change a decision made in the past. But if it were possible, the folk saying would dissolve in the physical approach, for which the pursuit of “woulds,” that is, the counting of states of the system toward the past as well as toward the future, is the common experience. The existential approach also succumbs to the deterministic illusion, but the “would” present here is oriented rather to the future and in this sense the hunt for it is not futile. The existential philosopher asks how to decide now and here (i.e., what would/should I do?) to be able to bear the responsibility of the consequences, which are certain to appear in the future in the chain of causal relations. In a paradoxical way, determinism (i.e., in this interpretation of the certainty that it is possible to gain a good understanding of the consequences of one’s deeds—and to be responsible for them) on the one hand, and human freedom and responsibility on the other, are connected here. How could one be responsible for one’s deeds if it were in principle impossible to assess their consequences, because their appearance would be entirely accidental, without following any rules? Or, to put it in a different, perhaps more precise, way—the world must correspond to deterministic ideas so that responsibility is possible, and at the same time determinism must be violated so that freedom is possible.

The questions of irreversibility and determinism thus prove to be closely connected with the conception of time, and the development of physics since the end of the 19th century has shown such a connection more and more distinctly. Thermodynamics, quantum mechanics, and the theories of chaos represent in this development—one by one in the order given—the main theories that compel the changes in our understanding of time.

The laws of thermodynamics and the introduction of the notion of entropy are among the historically earliest forms of what is called the arrow of time—the physical process that embodies the irreversibility of time and, through that, the split with the existing concept related to classical mechanics. The idea of the irreversible growth of one physical quantity and the adoption of irreversibility into human thought constituted the first steps of physics toward the concept of time, which was somewhat closer to the existential or even just commonplace idea of the impossibility of going back in time and redeeming the mistakes of the past. The significance of such a step consisted, however, in the fact that the classical notion was seriously questioned rather than in the offer of the new conception. Because if we had remained at the fact that the essence of time was fully expressed only by entropy, the folk saying of “being wise after the event” would be a mere caution that most probably one can never be wise before the event. No matter how small the probability is, it is not an impossibility. It is the consequence of the fact that the growth of entropy is not a physical law of the same nature as Newton’s laws of mechanics, which are dynamic (i.e., their predictions are utterly unambiguous), but the result of a statistical count, therefore it belongs to laws of the statistical kind. Even time would then become just a statistical matter and it would be only probable that we will die once, that we cannot return to the past, but the opposite would not be physically impossible. The more people hunted for “woulds” and the longer they did so, the greater would be the hope that one of them would succeed. Thus there arise more complicated and complex conceptions and the search for irreversibility (which physics has accepted as its problem) is spreading to other areas of modern physics.

Quantum Mechanics and Time

Quantum mechanics in this respect brings one good and one bad piece of news. The bad news is that the conclusions of a number of experiments the result of which is the twofold possible interpretation of quantum processes allowing us to think of the movement of particles against the direction of time, of the violation of causality, and of the border behind which irreversibility is an unknown word again. Those who find these results unacceptable can reject the application of our conception of time in the microworld and ascribe to each level of the organization of material structures as well as to each system their own temporal characteristics. The better news (from the point of view of the supporter of folk wisdom) is brought by Hugh Everett’s concept of *many worlds,* which arises in the second half of the twentieth century as an alternative, or in a certain sense, broadening conception of the Copenhagen interpretation of the basic experiment of quantum mechanics. The principle of uncertainty, the principle of complementarities of some characteristics of the elementary particles and their probabilistic description lies in the foundations of what is called the Copenhagen interpretation of the experiment, during which the observer does (not) observe the transit of the particle through two holes, and alternatively discovers its particle and wave character. The Copenhagen interpretation discusses what is termed the collapse of the wave function, which occurs as a result of the observer's measurements. In other words—observers, through their observations, cause the quantum system to pass from one of the many probable states to one, the real one, which is also discovered by observations. The observations thus take part in the realization, and other possibilities from the probabilistic field are not fulfilled. Everett's conception of many worlds offers a different view. All the possibilities of the quantum system are not reduced by observations to one real state, but they are fulfilled in such a way that at the moment of choice the universe divides into various branches, where each of them is the continuation of one of the possibilities. The observers find themselves in one of these worlds, depending on the result of their observations. The universe thus splits in each quantum choice and there exist many more or less similar branches of its development. All possibilities are fulfilled. Even if it seems that in such a universe, where everything occurs, it would not be difficult to be wise before the event just because everything is real, things are by no means as simple as that. The folk saying ends in the impossibility of returning to the past and redeeming our previous decisions there. Even if we found the means for traveling through time and managed to get to the point of making a decision, even though we caught the "woulds" in this way, we would not achieve anything. The change of decision would not mean a change in reality, from which we got to the past. The only thing achieved would be that we would have set out on a different branch of development of the world; certainly without the possibility that the one we came from would cease to be real.

Chaos Theory

Significantly less fantastic, though not less strange and interesting grounds for our hunt for "woulds" are offered by theories of chaos. If we take into consideration these theories that have arisen since the 1960s, the hunt for "woulds" seems not only futile, but also dangerous even where we might, by some miracle, catch the "would." Let us leave aside for the time being irreversibility itself; what remains from the folk saying is the conviction (shared even by some theoretical conceptions) of the fully deterministic character of our world. If we wanted to change slightly the consequences of some of our deeds in such a world (supposing that we could return to the past in such a world), it would be sufficient to change slightly our initial conditions as well; if we wanted to achieve significantly different results, we would be able to change the power or the intensity of our decision. The difference in causes is directly proportional to the difference in consequences. The theories of chaos, of which the so-called butterfly effect is the most popular, show that it is not so in the macroscopic world controlled by dynamic laws. It shows that even in the case of much simpler systems, compared with the field of human decision making, it is often impossible to predict eventual consequences unambiguously, not because we do not know the initial conditions but for reasons concerning the principle itself, one of which is also the impossibility (not inability) of discovering the initial state of the system (appearing in the role of the cause) with arbitrary preciseness. In chaotic systems even a slight deviation in initial states can lead to very different results in final states. The field of human behavior definitely does not belong to simple systems, which means that it is even less possible to define with sufficient exactitude all the causes that contribute to the resulting state. For us it thus means that even if we found a way of being wise before the event, even if we coped with irreversibility, it would be very dangerous to perform only the slightest adjustments, because the consequences could not be unambiguously defined.

Irreversibility

Therefore we might merely complement the folk saying. It is never possible to be wise before the event, and even if we could be and were wise before the event, it would not change our reality, and if it could change it, we would never know what the change might be. Nothing essential has thus changed the folk saying, which is understood rather as a caution, at least in terms of its relation to the past. As far as the future is concerned (how to be wise enough now so that in the future I would . . .), it certainly still is a desirable activity, but it becomes the saying about looking before leaping. As far as the conception of time is concerned, much has changed. As has been shown, a meaningful discussion of time is possible only where we find irreversibility; that is, irreversible events and processes. A system with perfectly reversible processes is an eternal system, not a system of time; a fully reversible time is not time but eternity. And irreversible time is in fact a pleonasm: Time and irreversibility are the same. If time exists, it exists as the irreversibility of events. The replacement of time with irreversibility moreover provides us with the ability to understand much better, or even more vividly, some relativistic games with the temporal-spatial continuum, in which exchanges of the temporal and spatial coordinates occur—for example with the description of the fall of a material body into a black hole. If we understand space as part of a continuum where we can move freely in all directions, that is, we can return to places where we have been, and time as the part that allows movement in just one direction, thus preventing a return, then their exchange is evident precisely through (ir)reversibility. As soon as it is not possible to go back in space (and this is precisely the case of the body that falls into a black hole and has gone beyond what is called Schwarzschild's radius), this dimension has the same characteristics as the temporal one, which, on the contrary, can gain the character of reversibility and thus become the spatial one.

Nevertheless, the extreme area of black holes is not the world of folk wisdom. In our macroworld, where we clearly distinguish between temporal and spatial characteristics, it is still true that (as Michel Serres reminds us), as far as (ir)reversibility is concerned, we are the masters of space but the slaves of time.

The very name of time is irreversibility and irreversibility is embodied in concrete events. Time understood as flow is the result of the human effort to keep being in the world and have the chance to talk about events.

Three Basic Themes

The persistence of the discussion concerning time in 20th-century science thus has three basic themes: (1) Beginning of time, (2) Direction and irreversibility of time, and (3) Ontic basis of our considerations of time.

The question of origin, birth, and creation—simply the beginning of anything—has always been attractive thanks to its search for one of the basic secrets of nature: *Where does the new come from?* The question becomes more intensive when we realize its reverse aspect concerning annihilation and death: *Where does the old go?* The question seems difficult in the case of objects becoming and finishing; it is even more difficult in respect to the birth and death of human beings. Once we examine the origin of time itself, the question becomes cosmological. Despite the intensity of cosmological and other research, the most frequent answer is to wait for a better theory to appear.

We can state positively that it is proven without any doubt that the question cannot be answered if we consider time as an independent quantity, in both the physical and metaphysical senses. The next question might examine the conception of time as a real quantity.

The second sphere of problems completes this inquiry by adding an existential dimension. Is it really impossible to reverse the flow of time? What physical or other process determines the direction of the flow of time? If there are more processes, why does one of them become dominant? Is there a time flow whose physical basis could be discovered?

These formulations are, however, related to the third theme—the research of the ontic basis of our considerations on time. Is the differentiation between the past and the future anything but a psychological dimension of beings endowed with consciousness? If space is not a perpetual repetition of the same, which process, or whatever it is, decides about the course of history?

Direction of Time

One of the undeniable consequences of the fact that the considerations about time are deduced from such processes (origin–end) is the included conception of direction of time, its one-way flow and irreversibility. The picture of time flow seemed appropriate to describe the time dimension of phenomena and processes observed at the macroscopic level. The one-way flow and irreversibility of time was thus considered an obvious fact from the beginning, similar to a river flowing from its source to the estuary, or the sun moving from east to west. The thought of reverse direction of such processes meant transferring considerations into the sphere of miracles, myths, and fairy tales.

Psychological Arrow of Time

The psychological arrow of time explicitly expresses the state of the human mind. On the one hand, the mind is able to reconstruct out of apprehended pictures the succession of particular states of some events—in other words, to remember. On the other hand, the mind is capable of developing the succession and of continuing it by adding events that have not yet happened—that is, to anticipate. This arrow of time is thus constituted by the direction that stems from the remembered (the past) to the anticipated (the future). There is, however, nothing in the background of the psychological arrow but pure human experience without any deeper theoretical argumentation.

The first, so far the only arrow of time based on the pairs of concepts (past–future, memory–anticipation) is completed by an explanation more scientifically based, thanks to the development of the natural sciences and the disciplines mentioned above.

Thermodynamic Arrow of Time

In all closed systems, entropy is continuously increasing and its growth is irreversible, which would correspond with our conception of time flow. It is, however, problematic that the growth of entropy is a statistical phenomenon. That means that time and its flow are only questions of probability or our incapacity to register all data needed to evaluate the processes in progress.

Ilya Prigogine refuses to accept entropy as an obvious physicalization of time and draws attention to the larger context of the problem. Prigogine even talks about the rediscovery of time. Up to now, physics—the physics of Einstein and, for example, the physics and cosmology of Stephen Hawking—describes the world that is. That means the world of being that is considered static by physical laws, despite all changes observed by human eyes. Prigogine emphasizes that such physical theories are not able to describe the creation of the new. If we want to talk about evolution and emergence, we have to stop discussing the world of *being* and start to discover the world of *becoming*. The theory of being is no longer sufficient; we need a theory of becoming. Time in the universe that is becoming is not a simple scale or a physical quantity; according to Prigogine, it becomes a *constitutive element of the universe*. In the universe with history, even particular objects can exist only by becoming—they originate, develop, and perish—time is thus considered as the fundamental element of the universe, not as an a priori form or a number in equations, or even as our mistake in describing our world. Prigogine's attitude nevertheless conceals a certain danger: the hypostasis of time. The debate about the constitutive role of time necessarily evokes an idea of something, an independent entity gifted with creative capacity.

Wave Arrow of Time

By studying elementary interactions, some physicists show the indefiniteness of time and the problematic character of physical processes described by quantum mechanics. It turns out that the very process could be described by various means that would differentiate only according to their orientation in time. The electron–photon interaction can be illustrated by a diagram that corresponds with time orientation of other (even macroscopic) processes; the positron–photon interaction could be described by the same diagram, only with an opposite time orientation. In other words, the electron of the preceding interaction seems to move against the (generally accepted) orientation of time.

The possibility of several readings of the diagram thus means nothing less than a full symmetry of the mentioned processes in respect to the orientation of time.

Cosmological Arrow of Time

The universe has been evolving from a specific starting point (whose more specified determination is subject to intensive interest of cosmologists), via the emergence of recently observed structures to the future that is subject to many hypotheses and philosophical speculations. One of the basic features of the universe is its expansion; it is a physical process identified with the cosmological time and has the same orientation as the growth of entropy in the whole universe, at least in the contemporary phase of the evolution of the universe and according to the suppositions up to now.

It seems then that everything is perfectly related and shows the pertinence of our ideas on the direction of time. Up to now, we have considered only the processes that are finally interpreted on the macroscopic level; that is, on the level compared with ordinary human experience. But these waters, calm until now, seem to have been disturbed by the development of quantum mechanics.

It appears that the cosmological arrow is orientated from the singularity to the recent, richly structured universe that is still evolving. The adequacy of this consideration will be examined later. Nevertheless, another problem has emerged: How can we be sure that all past states of the universe are well measured by time units deduced from movements that emerged much later? To what extent could seconds be considered as a meaningful description of the state when there are no atoms whose oscillations could be defined (not to mention planets)? We might, perhaps, consider time units in which *seconds* would be replaced by *temperature degrees* of the universe, which would create a thermodynamic arrow.

The Problem Restated

At the expense of some simplification, it would be possible to formulate the problem in more precarious terms. The question of time is, to a certain extent, a problem created by human beings. The idea of time was deduced in early human history from relatively simple movements and started to live its own life—a life so independent and unique that it became difficult to find a physically real basis to serve as a criterion for decisions in more and more complicated situations that appeared during the evolution of human knowledge. The need for this criterion finally led to the fact that the anthropocentric character of the idea was fully demonstrated in the way human beings imposed on the universe (their description of it) their own image of the flow of time and based upon it the whole cosmological explanation of cosmogenesis.

If any effort to find the ontic basis of time leads to the difficulties mentioned above, let us accept the conclusion that we have looked for the basis of something that does not exist. Time does not exist. This does not mean that we should throw away our watches and timetables; time remains a fairly good tool for communication. We have to remember, however, that anywhere we talk about time, there is a hidden movement included. Time measurements are therefore nothing but a comparison of two or more movements, one of them considered the etalon. A question remains whether the comparison of movements in various orders (e.g., biological and physical) is always informative and whether it is even possible to conduct the comparison (e.g., the changes in the early states of the universe and the later movements).

If we accept this hypothesis, the evolution of the universe and its history will not be constrained. They are not determined by an ideal time axis, they are determined by events, their succession and sequence, causal relations and concrete processes.

Time does not exist, only events do. The number of years we count in our lives is not important; it is crucial what we experience during our becoming.

Josef Krob

See also Augustine of Hippo, Saint; Becoming and Being; Cosmogony; Einstein, Albert; Hawking, Stephen; Quantum Mechanics; Time, Arrow of; Time, Emergence of; Time, End of; Time, Measurements of; Time, Relativity of; Time and Universes

Further Readings

Augustine. (1992). *Confessions, a text and commentary by James J. O'Donnell.* Oxford, UK: Oxford University Press.

Gribbin, J. (1986). *In search of the big bang: Quantum physics and cosmology.* London: Heinemann.

Hawking, S. (1988). *A brief history of time.* New York: Bantam Books.

Prigogine, I. (1980). *From being to becoming.* San Francisco: Freeman.

Prigogine, I. (1983). *The rediscovery of time* (A discourse originally prepared for the Isthmus Institute, presented to the American Academy of Religion). Retrieved July 26, 2008, from http://www.mountainman.com.au/ilyatime.htm

Reichenbach, H. (1956). *The direction of time* (M. Reichenbach, Ed.). Berkeley: University of California Press.

TIME, REAL

There is no commonly agreed-upon definition of *real time*. Indeed, the definition of "real time" is dependent on its application and context. Some trace the origins of the term to the missile age in the early 1950s where it was used in the simulations of intercepts of ballistic missiles by analog computers. One can distinguish between the time of the simulation (where events of milliseconds, days, or years could be represented in minutes or hours) and the actual time or real-world "real time" of an event.

In fact, depending on the application, three different meanings can be ascribed to the term real time. As mentioned above, the first meaning is actual time as opposed to simulated or other non–real-world time. For example, a distinction can be made in a live theatrical production between the actual time that transpires during the production (the real time) and the elapsed time of the fictional event (illusory time). In 15 minutes of real or actual time, a period of years may have passed in the story portrayed on stage.

The second meaning of real time is that it occurs immediately, or without delay; that is, it happens almost instantaneously or at the same time. Technological advances, particularly the advent of the Internet and modern information and communication technologies (ICT), have made this type of real time achievable. For example, it was as early as 1988 that Internet relay chat (IRC), a forerunner of instant messaging, was developed by Finnish student Jarkko Oikarinen, enabling people to communicate via the Internet in "real time"; that is, appearing to communicate without any appreciable delay, almost synchronously.

Thus, with the coming of the Internet and other ICTs that allow users to access information from anywhere in the world seemingly instantly, real time as instantaneous access has become generally equated to "online"; for example, online gaming, online communication. The immediacy of the online environment can be contrasted to the batch processing of earlier computer systems where data were collected over time "in batches," and then submitted all at one time for processing. This resulted in a sizable delay between the collection of data or the query/event and the receipt of results or computer response.

Videoconferencing uses real-time systems that transmit video across networks, displaying it at the other end seemingly instantaneously. Court reporters now routinely use technology called computer-aided transcription (CAT) to make available words spoken in the courtroom as text on computer screens, with just a few seconds' delay; this is, in real time. Live satellite broadcasts allow viewers, for example, in the United States to see events in Iraq in real time. Improvised musical or other artistic works are created at the same time that these are being performed and so are real-time works. With the use of technology and skilled captioners it is now possible to convert the audio portion of a live program or event almost instantaneously into captioned text (real-time captioning).

The third meaning of real time is in its use in computer-controlled systems. Computers are now frequently incorporated or embedded into aircraft, cars, cell phones, home appliances, manufacturing assembly lines, traffic lights, video game consoles, and many other applications that control real-life processes. Computers must therefore be able to respond to the external environment or real-life conditions fast enough to satisfy some requirement (e.g., to deploy an airbag when a car accident occurs). Computers used in space flight must respond quickly to changing conditions to keep the rocket on its course. Robots in factories must respond within a certain time to keep the assembly line moving at optimum speed. To ensure that all operations in the assembly line run smoothly, the robots must respond neither too quickly nor too slowly. Thus, real time in these systems does not necessarily mean fast but rather as fast as required by the external conditions or particular system. So it is possible for a real-time system to be relatively slow, but it must be guaranteed to respond within a specified time. Therefore, the main characteristic of a real-time computer system is not that it is fast but that it has to meet explicit, strict deadlines. If it fails to meet the deadline, negative consequences result, with their severity depending on the particular system. For example, antilock brakes must respond to changing road conditions immediately in order to avoid serious damage to driver and vehicle. Real-time computer systems in which a catastrophic failure occurs if the "deadline" is missed are called hard real-time systems. In systems known as soft real-time systems, no major catastrophe occurs if the system is slightly delayed. There may just be degradation in service; for example, computer control of an audio and/or video signal that fails to meet its deadline simply results in poor or reduced quality audio or video.

In conclusion, the term real time is sometimes used in contrast to simulated or other non-real-world time or illusory time, as the *actual* time. In other contexts, real time is synonymous with fast, immediate, or instantaneous. At other times it is used to describe those systems for which response *must* be within a specified time. Thus for some applications real time means actual time; for others it means practically instantaneous; and for others real time can be in microseconds, minutes, hours, or even days, depending on external conditions or the function to be performed.

Real time may also be referred to as real-time or realtime.

Jennifer Papin-Ramcharan

See also Duration; Media and Time; Time, Illusion of; Time, Imaginary; Time, Measurements of; Time, Perspectives of; Time, Relativity of

Further Readings

Azvine, B., Cui, Z., & Nauck, D. D. (2005). Towards real-time business intelligence. *BT Technology Journal, 23*(3), 214–225.

Downey, G. (2006). Constructing "computer-compatible" stenographers: The transition to real-time transcription in courtroom reporting. *Technology and Culture, 47*(1), 1–26.

Hansson, H., Nolin, M., & Nolte, T. (2006). Real-time in embedded systems. In R. Zurawski (Ed.), *Embedded systems handbook*. Boca Raton, FL: CRC Press Taylor & Francis.

Stankovic, J. (1988). Misconceptions about real-time computing: A serious problem for next generation systems. *IEEE Computer, 21*(10), 10–19.

Trebilcock, R. (2005). The changing face of real time. *Modern Materials Handling (Warehousing Management Edition), 60*(7), 24. Retrieved August 25, 2007, from http://www.mmh.com/article/CA623766.html

Time, Relativity of

That the nature of time corresponds to common human experience was an opinion expressed in the introductory passages of Newton's *Principia*. According to him, time is just as *absolute* as space. In more modern wording, the *spacetime continuum,* a four-dimensional set of point-like *events,* is "fixed" in a unique way by the sytsem of parallel straight lines, which are world lines of reference points at rest with respect to the absolute space, and, in this way, deremine what happened (or will happen) in the same place. Similarly, the spacetime continuum is "cut" in a unique way through the system of parallel three-dimensional planes orthogonal to he world lines of reference points, determining what happened (or will happen) *simultaneously.* In these planes (three-dimensional spaces in a given moment) Euclidean geometry is valid, with the laws most simply expressed in terms of Cartesian coordinates. Similarly, one time coordinate exists whose differences determine the time interval between separate simultaneities. This interval is common for all *ideal clocks* and objects, so that the interval of the *coordinate time* is also the interval of the *proper time* of an ideal clock. The laws of Newtonian mechanics also indicate how to construct instruments that measure time by their periods or motions.

Of course, belief in the absoluteness of space and time was based on experience, which absolutized temporally conditioned human knowledge. At first, absolute rest was considered as rest with respect to the earth's surface; after recognition of the planet's motion, absolute space could be related to the heaven of fixed stars, but later the mutual motion of these stars was also recognized. Thus the Newtonian concept of absolute space began to be rivaled by the (special) *relativity principle,* which insisted on the validity of Galileo's description of happenings inside cabins on a stationary and a moving ship. It seemed that although it is possible to determine experimentally an *inertial system of reference* where the law of inertia is valid, it is impossible to indicate a rectilinear and uniform motion with respect to such a system. Therefore, different frames of spacetime are equally valid and, consequently, absolute space does not exist.

The Newtonian concept was seemingly supported by optics, indicating that the speed of light is independent of direction only in the system connected with absolute space. After the inclusion of optics in Maxwell's electromagnetic theory, experiments were proposed with the goal of proving motion with respect to absolute space. The most famous was the Michelson–Morley experiment near the end of the 19th century. The negative results of these experiments would provide support for the principle of relativity and seemed to argue against the Maxwell theory. But according to Einstein in 1905, it is possible to combine the relativity principle with Maxwell's theory and so build a promising basis for the development of physics. It is only necessary to abandon—together with the concept of absolute space—the old concept of absolute time.

This old concept sprang from the feeling that *simultaneous* means "seen in the same time." The determination of finiteness of the speed of light undermined the background of this concept. A natural synchronization of distant clocks can be based on the exchange of light signals: If a light signal is emitted at time t_i from point A, reflected at point B, and received back at A in the time t_f, then the moment of the reflection in B corresponds with the synchronized time $t = (t_i + t_f)/2$. Of course, this definition of simultaneity depends on the system of reference, where clock A is at rest, and thus it is *relative*.

It is possible to understand the principal features of this new concept of space and time by watching a course of events in one-dimensional space (e.g., on a street with the movements of pedestrians, cars, and traffic lights). Let us denote t and x as the time and space coordinates with respect to the street, t' and x' these coordinates with respect to a car moving at velocity v. Then the speed c will retain its value in both directions, if the coordinates in both systems are connected by the *Lorentz transformation*

$$x' = \gamma\,(x - vt),\ t' = \gamma\,(t - \beta x/c) \qquad (1)$$

where $\beta = v/c$, $\gamma = 1/\sqrt{(1 - \beta^2)}$. According to the *special theory of relativity* (STR), the laws of physics are not changed by the Lorentz transformation. The Lorentz transformation gives a new presentation of the principle of relativity. It means that simultaneity is relative—the same t in different places does not mean the same t'! Putting the speed of light equal to infinity in (1), we obtain the *Galilei transformation* with absolute simultaneity.

Let us consider two events in the same places from the point of view of the car, that is, $x'_2 = x'_1$. The clock in the car will measure the interval of *proper time* $\Delta\tau = t'_2 - t'_1$ between them. As can be easily obtained from the Lorentz transformation, the time interval

$$\Delta t = t_2 - t_1 = \gamma\Delta\tau \qquad (2)$$

will be measured by clocks placed along the road and synchronized with respect to the rest of the clocks on the road. Thus the interval of proper time is the shortest of all the time intervals between events. We speak about the *dilation of time:* A clock moving with respect to some system of reference slows down with respect to this system. (Note that this delay is not immediately visible to a distant observer, because the finite speed of light also plays a role.)

The dilation of time was reliably confirmed above all by observation of the half-life of unstable elementary particles in cosmic space and in laboratories on earth. Let us stress its *relativity:* A specific clock of the system S´ delays with respect to the synchronized set of clocks of the system S, but this assertion also remains valid after the exchange of S and S´.

A deeper insight into the nature of simultaneity is offered by the four-dimensional formulation of the STR created by Henri Poincaré and Hermann Minkowski. According to this, the spacetime *interval* Δs between two events in spacetime exists independent of the choice of reference system, whose square is expressed in the *Minkowskian coordinates* as follows:

$$\Delta s^2 = c^2\,\Delta t^2 - (\Delta x^2 + \Delta y^2 + \Delta z^2). \qquad (3)$$

Confining ourselves to one-dimensional space (two-dimensional spacetime), we obtain the *Minkowski diagram* (see Figure 1) allowing one-dimensional motions to be represented graphically. Let us use *ct,* time multiplied by the speed of light, as the vertical coordinate, and x as the horizontal coordinate. The right-angled lines halving the quadrants depict events connected with the origin (the *now-here* event) by means of the light signal. These events form a *light cone* in four-dimensional spacetime. The spacetime interval, the light cone, and the speed of light are *absolute* according to relativity theory, whereas the space and time interval between events are *relative* with respect to the choice of the reference system. The upper half of the interior of the light cone (including the boundary) represents the events reachable in principle from the initial event by a velocity not exceeding the speed of light and thus causally influenceable. They form the *absolute future* of the initial event. Similarly, the events in the lower half of the interior of the light cone form the *absolute past* of the given event. The events outside of the light cone can always become simultaneous with the initial event with the proper choice of the system of reference. This fact does not create trouble, because the events outside the light cone are not causally connected with the initial event. Arthur Eddington proposed calling this set of events the *absolute elsewhere*.

Spacetime in the definite system of reference is therefore again fixed by parallel lines and cut by the three-dimensional surfaces orthogonal to them. But whereas this fixing and cutting results in a unique "net" according to Newton, every inertial system of reference defines its own net according to Einstein and Minkowski. (Remember that the Minkowski diagram in the Euclidean plane does not allow an illustration of orthogonality in the Minkowski sense, where the axes ct' and x' are orthogonal to each other, just as the axes ct and x are).

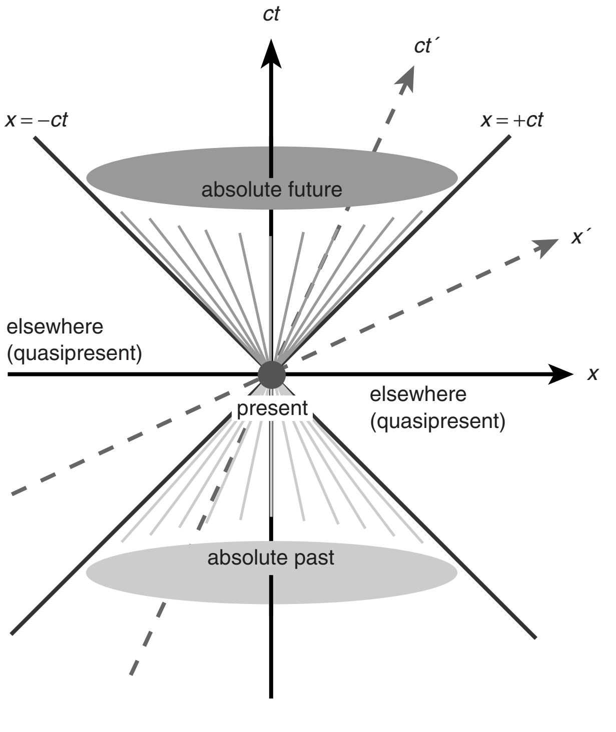


Figure 1 Minkowski diagram

The relativity of simultaneity in Einsteinian physics naturally aroused the interest of philosophers. In Newtonian theory, it was admissible to consider absolute simultaneity as something like a rising curtain at whose edge events are realized as they transit from a future "not yet" nonexistence into a past "already" nonexistence. The impossibility of clearly understanding such a curtain according to the special theory of relativity created doubts about the objectivity of time's *flow.* The natural reaction of a number of outstanding relativists (e.g., Einstein, Gödel) was to consider spacetime as "given" and the flow of time as an illusion of consciousness.

Einstein's general theory of relativity (GR) of 1915 meant a further advance. According to it, spacetime is curved by its matter content. The square of the infinitesimal interval has the general form

$$ds^2 = g_{ik}\,(x^j)\,dx^i dx^k \tag{4}$$

where x^i represents four spacetime coordinates and g_{ik} the components of the *metric field* dependent on them. It is possible to introduce a *locally geodesic system* in an arbitrary point (event). In this system, the interval takes the form of equation (1) with the diagonal matrix

$$g_{ik} = \mathrm{diag}\,(+1,-1,-1,-1) \tag{5}$$

but the first derivatives of the metric components with respect to spacetime coordinates vanish, which also means that gravity's forces in the given system disappear (weightless state).

In this way, STR and its concept of the relativity of time is locally valid. It is possible to retain the idea of fixing spacetime by the world lines of "reference points" and cutting it by the surfaces of "simultaneity." But the world lines are no longer parallel right lines, and surfaces are no longer parallel planes. In general, surfaces of equal amounts of time are not even orthogonal to the world lines of reference points, which means that coordinate "clocks" are not synchronized. It is possible (at least theoretically) to construct spacetimes without a globally defined reference system and without global time coordinates. (The latter is especially interesting in the case of spacetimes with "time loops" allowing the world lines to intersect each other and thus correspond with Gödel's universe, in which a return to the past is possible.)

Thus, GR deepened the difference between proper time and coordinate time. Whereas proper time is an absolute quantity independent of the choice of reference system, coordinate time is in general only an orienting tool for describing spacetime and loses real metrical and physical meaning.

On the other hand, there are realistic solutions for the Einstein gravitational equations that allow for the privileging of specific coordinates of time. In the gravitational field surrounding stationary bodies (e.g., the earth or the sun), it is suitable to choose the time coordinate in such a way that the gravitational field remains unchanged (i.e., the metrical coefficients are independent of time). This time has a different rate at different distances from the body, as can be demonstrated by the red shift of spectral lines in the case of sending the signal "upward." Similarly, in cosmology, the proper time of objects participating in the expansion of the universe is privileged, synchronized in such a way that its value corresponds with an equal level of evolution of the universe. Supposing the homogeneity and isotropy of the universe on large scale, cosmology thereby introduces time exhibiting some similarity with Newtonian absolute time.

The history of physics includes theories refuting the uniqueness of proper time. The Weyl unified theory from 1917 supposed that clocks moving along different paths do not retain their calibration after meeting, but Einstein showed that this contradicts the identity of atoms in the same quantum states. The theory of kinematic relativity, proposed in 1948 by Edward A. Milne, worked with two different measures of time, electromagnetic and mechanical, with the rate changed in the course of cosmological evolution. Similar ideas could be revitalized by the discovery of time variabilities of physical constants, but at present there exists no evidence for this.

Jan Novotný

See also Chronometry; Einstein, Albert; Experiments, Thought; Gödel, Kurt; Relativity, General Theory of; Newton, Isaac; Relativity, Special Theory of; Spacetime, Curvature of; Time Dilation and Length Contraction; Twins Paradox

Further Readings

Einstein, A. (1956). *The meaning of relativity.* Oxford, UK: Clarendon Press.

Galison, P. (2003). *Einstein's clocks and Poincaré's maps: Empires of time.* New York: Norton.

Hawking, S., & Penrose, R. (1996). *The nature of space and time.* Princeton, NJ: Princeton University Press.

Hey, T., & Walters, P. (1997). *Einstein's mirror.* Cambridge, UK: Cambridge University Press.

Newton-Smith, W. H. (1980). *The structure of time.* London: Routledge.

Raju, C. K. (1994). *Time: Towards a consistent theory.* Dordrecht, The Netherlands: Kluwer Academic.

Time, Reversal of

Our perceptions of the irreversibility of time seem obvious. We remember the past, we experience the present, and wonder about the future. Organisms are born, live, and die. Entropy, the gradual loss of energy by a body, increases. Nothing in our experience runs backward. There is even a popular phrase for this awareness—the arrow of time. Arthur Stanley Eddington, a physicist, popularized this phrase in the 1920s.

This belief in the forward motion of time is relatively new in our cultural history. Primitive peoples thought time was cyclic. They watched the recurring cycles of time in terms of the movement of the heavens and the seasons and drew a logical, if unstated, conclusion that the past and the future were constantly revolving and repeating. In Western culture, this was true until Judeo-Christian beliefs posited the concept of the irreversibility of time.

However, whether approached from the standpoint of Newtonian physics, Einstein's special theory of relativity, or the quantum mechanics formulated by Heisenberg and Schrödinger, there is a problem with our perception of the arrow of time. Equations from each of these fields work just as well whether time is running forward or backward. Another physicist, Eugene Paul Wigner (1902–1995), formulated the consequences of time reversal invariance for the solutions of the equations of quantum mechanics. Invariance, in mathematics, describes quantities that are unchangeable in mathematical operations. Wigner established the general notion of the time reversal transformation of quantum states. As it turns out, there is a resolution to this apparent paradox. Statements in quantum terms about the reversibility of time deal with equations relating to motion and not about actual motions that we experience empirically.

When physicists or mathematicians talk about time, they generally use the symbol T to represent the time variable. As such, T is an additive variable; that is, time intervals are physically measurable and can have associated algebraic signs (plus or minus). One can add two intervals together to make a longer one, or subtract intervals to create shorter time intervals. The neutrality of mathematical equations, particularly in physics, would imply that negative T can exist, and this possibility makes it easier to solve some equations as well as to deal with equations formulated in the mid-19th century describing the behavior of electromagnetic waves.

James Clerk Maxwell (1831–1879) was responsible, among other important discoveries, for developing equations that expanded from Michael Faraday's theories about electricity. Maxwell's research ended with four mathematical equations (known as Maxwell's equations) that described how electrical and magnetic fields performed. Maxwell's most important achievement was his extension and mathematical formulation of Michael Faraday's (1791–1867) theories of electricity and magnetic lines of force. In his research, conducted between 1864 and 1873, Maxwell showed that a few relatively simple mathematical equations could express the behavior of electric and magnetic fields and their interrelated nature; that is, an oscillating electric charge produces an electromagnetic field.

Maxwell's equations applied to radio waves imply that these waves travel at the speed of light, yet the equations are invariant regarding the past and future. In other words, the equations work equally well whether radio waves travel into the future or the past.

Two physicists, John Archibald Wheeler (1911–) and Richard Phillips Feynman (1918–1988), studying the mathematics and physics of electromagnetic waves in the 1940s and Maxwell's equations, advanced the idea that radio waves could be received both after and before transmission from the source. Waves that arrived after transmission are called retarded, and waves that arrive before transmission are advanced. Wheeler and Feynman hypothesized that advanced and retarded electromagnetic waves are produced in equal measure. Perhaps a radio transmitter sends out 50% of its power into the future and 50% into the past. Why then, do we not hear the advanced (past) radio broadcasts?

Wheeler and Feynman theorized that the advanced waves from a radio transmitter are absorbed by matter and disappear. However, the absorption itself produces secondary radiation in the form of new electrical charges, again with one half advanced and one half retarded. Eventually, the advanced waves return to their original source. Wheeler and Feynman were able to prove mathematically that the advanced secondary radiation could double the original transmission, which eventually would cancel the advanced wave of the original source through interference. This scenario could explain why we do not hear radio broadcasts from the 1920s.

The theory rests on an assumption that all of those radiated waves are eventually (no matter how long it takes) absorbed, as they reach farther and farther into the universe. If not, then at some point enough might return to the earth in the form of advanced (past) radiation. Perhaps this does happen, but our equipment is not sensitive enough to detect something like Franklin Delano Roosevelt's inauguration speech in 1932 where he said, "The only thing we have to fear is fear itself."

Several experiments have attempted to test whether or not any radio waves go into the past. Bruce Partridge tried beaming more or less continuous beams alternately between the universe and into a local absorber. His theory was that if any radio pulses were transmitted into the past as well as the future, then the waves that reached the past would have an effect on the power consumption of the transmitter. Even his most sensitive instruments did not find any such diminishment of power. An experiment by Paul L. Csonka suggested a different way to test this, but equipment sensitive enough to complete such a test was not available. In 1980, another physicist, Riley Newman, used a dipole-transmitting antenna fed with periodic microwave pulses of very short duration. A receiving dipole antenna 10 meters away searched for power above background noise level at fractions of time before transmission of each pulse. However, he concluded that if there were an incoming wave from the past, it would miss the detector antenna and arrive at a very different time. Therefore, none of these experiments established physical evidence of advanced waves.

As more particles such as antimatter and various subatomic particles such as the kaon are discovered and studied, there may at some point be a definitive way to determine whether, as there is with spatial asymmetry, time itself is asymmetric or symmetric.

Charles R. Anderson

See also Eternal Recurrence; Quantum Mechanics; Time, Arrow of; Time, Cyclical; Time, Linear; Time Machine; Time Travel; Twins Paradox;

Further Readings

Coveneny, P., & Highfield, R. (1990). *The arrow of time.* New York: Fawcett Columbine.

Davies, P. (1995). *About time: Einstein's unfinished revolution.* New York: Touchstone.

Hawking, S. (1988). *A brief history of time.* New York: Bantam Books.

Sachs, R. G. (1987). *The physics of time reversal.* Chicago: University of Chicago Press.

Time, Sacred

Sacred time is, in the strictest sense of the term *sacred,* time set apart. It is time that is separated from profane, everyday time, distinguished by its connection with the deeper, holy, extraordinary experience of life. Sometimes described as "the breaking forth of the eternal in time," the experience of sacred time has been conceived variously as a presence in which the past and future collapse into an "Eternal Now," or the complete conflation of past, present, and future into something that might be referred to as timelessness or the collapse of time. It includes notions of a sense of time "bending" or "stretching," particularly during private or public rituals; accompanying psychological or physical trauma; or resulting from deep encounters with an extraordinary event, object, or being. The experience of sacred time neither necessarily suspends nor eradicates "common" time. There are, however, instances where cultic beliefs regarding either a cosmic or individual end-time include an enlightenment that takes place outside of time, or where the ritual or spontaneous experience of the eternal includes an experience of the transcendence of time. An iconic experience of this transcendence of common time is represented, for example, where Buddhist iconography depicts the Buddha as sitting under a bo tree just before his enlightenment, then as having disappeared from under the bo tree upon his enlightenment, and finally as sitting under the bo tree again upon his decision to return to work toward the enlightenment of the world.

For the nonbeliever, the concept of sacred time is as a study in religious anthropology. For the believer, it is a study in piety. Whereas none are exempt from the biases of their own concepts of time to render a purely scientific assessment of sacred time, rigorous studies of sacred time do seek to avoid either religious or secular doctrinarism.

Whether grounded in philosophical or religious commitments, the main aspects of sacred time broadly include "cosmic sacred time" or the understanding of sacred time as it relates to the origins and ends of the universe, and "human sacred time" or the historical experience of human communities with their calendars of ritual time including feast, fast, and worship.

Cosmic Sacred Time

Basic to cosmic sacred time are the two ends of the cosmological spectrum: the cosmogon and the eschaton, the universe's beginning and its end. Cosmic sacred time presents sacred time on a cosmic scale calculated, so to speak, on the timepiece of the gods. Concepts of cosmic sacred time reflect what is arguably the primary directive of the religious enterprise: to explain the beginning of things and to speculate or give reassurances about the end of things. Various cultic systems provide sometimes vague, sometimes detailed speculation on the timeline that separates the cosmogon from the eschaton. For those cultic systems, this span reveals the ultimate sacred history.

Perhaps the greatest divide between broadly categorized concepts of sacred cosmic time lies between linear cosmic sacred time and cyclical cosmic sacred time. These two concepts are often referred to, in an imprecise way, as Western and Eastern concepts of time, respectively. But the more religious concepts anthropology and archaeology uncover, the less precise this geographic distinction seems. The history of Western, Greco-Roman-based philosophy is scattered with the ideas of an "eternal return." Many if not most European and American indigenous religions testify to the cyclicality of the world. And for their part, nominally cyclical concepts of time often appear to reflect cyclical experiences that are nevertheless experienced within a context of clearly linear time: cycles of birth, death, and rebirth—whether of a soul or of a universe—do not necessarily require or even imply the birth, death, and rebirth of exactly the same soul or the same universe.

The classical Mayans possessed perhaps the most well-known time-obsessed religious system. With a system of calculation that precisely calculated astronomical events spanning millions of years, the Mayan calendar appears to have calculated the beginning of time starting on the order of billions of years before the present. Some have proposed that the end of the Mayan calendar, though not, apparently, the end of time itself, can be calculated as coming late in either 2011 or 2012 CE. Although popular eschatological and apocalyptic speculation may well accompany the approach to this proposed end, scholars suggest that the classical Mayans themselves expected a "great change" rather than a proper universal eschaton. Not surprising for a belief system that placed such enormous emphasis on time, an end of time itself does not seem to have been part of the Mayan concept of cosmic sacred time.

The structure and timescale in the concepts of Hindu cosmic sacred time have been recognized as similar to those of modern scientific theories, speculating as they do on a potentially infinite succession of universes each with their beginning, middle, and end. Hindu concepts of cosmological time have included the establishment of each cosmogon in the flowering of a lotus from Brahma or in the Golden Womb. After a succession of phases called *yugas* that are perhaps billions of solar years long, a final and corrupt yuga would follow and, at its end, the closing of the universe that would be just as intimately connected to the divine as its opening. The big bang eventually is followed by the big crunch. According to most Hindu systems, the current universe is in its final yuga. Although the end of the current and final yuga is most commonly conceived as being millions of years after the present, imprecision has afforded sufficient interpretive room to allow for the occasional speculation on, and anticipation of an imminent eschaton.

Possibly due to their wealth of written scripture, Buddhist cosmologies are perhaps even more diverse than those of Hinduism, from which Buddhism inherited many of its cosmological and eschatological concepts. As for the end of time, Buddhist schools speculate that in a long succession of enlightened ones (or Buddhas), the coming Maitreya Buddha would be the final one. As with Hinduism, which declares the last age to be the most corrupt, Buddhist eschatology anticipates that the return of the final Maitreya Buddha would be preceded by great human corruption, the most telling aspect of which would be the complete forgetting of the Buddha's teaching. It was originally thought that the Buddha Shakyamuni had declared that his teachings would disappear close to 500 years after his death. But when that time came and went, this date was clarified by some of his followers as being not 500 but 5,000 years. Some time after these 5,000 years, the Maitreya Buddha would bring all beings to an enlightenment that would occasion a blissful human earthly experience or, alternatively, a Nirvanic collapse of time.

In Judaism and its inheritor Christian and Muslim systems, circumstances surrounding the birth of the universe are less clear than those connected to the creation of the world, which has been dated at a little more than 5,700 years before the present. Cosmological themes similar to other sacred systems already mentioned include formlessness and chaos preceding the activity of a creator God. Eschatological speculations within Judaism and among Judaism and its offspring, however, vary widely.

Late BCE and early CE Judaism was rife with messianic fervor during Greek and Roman dominance in the Eastern Mediterranean from at least the time of the Maccabee Revolt (165–67 BCE) and increasingly around the time of the fall of the second temple in Jerusalem (70 CE). Beliefs varied among different Jewish sects as to whether the arrival of a messiah would result in a divine reign in time or a collapse of time into a Platonic eternal present. In addition to better-known Jesus and

Dead Sea sects, there were various Jewish communities that gathered outside a Jerusalem laid ritually waste by occupation forces and their—from the perspective of these sects—apostate Jewish collaborators. One end-time scenario possibly produced by just such a sect is the Jewish Book of Daniel (mid-2nd century BCE) and its later imitators, including most famously the Christian Book of Revelation (mid- or late-1st century CE). In both of these texts, the essential message was articulate and succinct: The eschaton was near. Since the timeline of the Jewish canonical Book of Daniel came and went without the expected apocalypse, Messianic Judaism has made few claims of a sacred timeline for the eschaton, though speculation about possible messiahs continues.

In the sweep of Christian cosmic sacred time, various Christian sects have maintained the nearness of the eschaton ever since. There have been a variety of interpretations of cosmic time within both orthodox and heterodox Christianity that have included eschatological expectations around the year 500 CE, then before and after the turn of the 1st millennium CE, then around the turn of the 2nd millennium CE, and at various points in time in between.

Islam inherited both Messianic Jewish and Apocalyptic Christian expectations when the belief system accepted the books of Judaism and Christianity as divinely inspired, albeit not as authoritative as the direct words from the divine found in the Qu'ran. The Muslim eschatological concept focuses on the *Qiyamah* or Last Judgment. There are hadithic references to the expectation that this Last Judgment would be inaugurated by the return of the Prophet Jesus; but perhaps having learned from their Christian cousins, Muslims have tended to avoid any reference to the nearness or distance in time of the eventual eschaton.

Human Sacred Time

Human sacred time consists of time that is intentionally set aside for the purposes of at least acknowledging and anticipating, if not necessarily experiencing, "the breaking forth of the eternal in time." Observed throughout the world and throughout history, human sacred time results in calendars that regulate feasts, fasts, and ritual worship. Experiences that are considered to have been personal sacred moments (e.g., Saul of Tarsus's enlightening experience falling off his donkey), although certainly significant for the individual involved, are not times that have been intentionally set aside. As such, these are not included in this concept of human sacred time.

Ancient civic cultic life intentionally integrated political and sacred calendars or, perhaps more accurately, recognized no such distinction between the religious and the civic. Cultic practices of ancient Greek, Roman, and Asian civic cults grew up as virtually indistinguishable from their mythological cults, arguably rendering both civic and mythological cults "religious." More modern civic religious or quasi-religious cults such as Soviet, Nazi, or nationalistic cults, however, appear either to layer an intentionally and transparently fabricated mythology onto their civic cult or, alternatively, to adapt a preexisting mythological cult to meet their civic needs. As such, although modern civic cultic practices produce structures that function like human sacred time, they are at least nominally secular.

Sacred feasts celebrate the preferred god or saint or some divine or holy event. Feast time has often suspended distinctions, particularly social and economic distinctions. Kings might be lampooned or even come to bodily harm; servants might become "masters" for a time; or, in its diluted modern echo, secretaries might demean their superiors by cutting off their bosses' neckties. Such contrived and time-limited equality is reflected most clearly in the many cults where sacred feasts have been communal ritual meals. Whether this represents a theological position that the gods treat all humans equally or, on the contrary, reflects a reprieve from divinely established inequality, feast time provides an outlet for social pressure from below that might otherwise boil over—and do so under much less circumscribed circumstances.

Sacred fasts, which are at a minimum the sustained, nonnecessary suspension of solid nutrition, are closely connected to ritualized mortification or sacrifice. In the fast, the participants are usually encouraged to contemplate, just as in the feast they are usually encouraged to, celebrate. Somewhat more dramatically than in the feasts, the fasts often provide for, or contribute to a cultic path toward the sacred encounter. As such, fasting can encourage a personal, individual breaking forth of the eternal. More often, the fast serves to remind the participant of mortality, dependency on the cult's sacred source, or both.

Whereas feast and fast times are in a sense extraordinary, ritual sacred time is regular and includes scheduled worship. Scheduled worship sets aside a regular time to celebrate, contemplate, venerate the divine, or to abase oneself with perhaps less intensity and therefore perhaps somewhat diminished expectation than feast or fast time. Although ritual sacred time does not always necessarily include the breaking forth of the eternal in time, it does attempt to create an environment in which such a breaking forth is made possible in the worshipping moment. At minimum, ritual sets aside time for reflection on, and celebration of, an experience of the eternal in the past; or a time to focus on the hope in, and anticipation of the arrival or return of the eternal in the future. This experience of sacred time can result from the visitation of a god, gods, or deputy of the divine such as an angel or familiar of the god; the arrival of a divine person or avatar; simply "feeling the presence" of the divine or the eternal; or otherwise having the experience of transcending or existing out of time or physical space.

In addition to connecting a community to the important events in the lives of a cult's heroes and martyrs, human sacred time also connects a community to important astrological events. The most obvious of these are the events connected to the cycles of the earth and its sun. The solar year appears to be a nearly universal unit of time, the often invisible and unquestioned context in which sacred calendars are set. Seasonal events based on the earth's solar cycles have provided the context for the vast majority of sacred feasts and fasts. Closely associated with these seasons are the plant-focused events of gathering or farming cultures. Here, feasts and fasts reflect social or individual needs that coincide with the economic realities of seed time and harvest. Analogously, many hunting cultures integrate animal migration, mating patterns, and spawning seasons in their sacred calendars. The other main astronomical body that focuses human sacred time is of course the earth's moon. Lunar cycles have been closely attended to, even among cults that otherwise hold little or no particular reverence for the moon itself. Judaism and its descendant cults provide well-known examples of lunisolar calendars, human sacred time that follows the movements of both the sun and the moon. Other heavenly bodies that have influenced sacred calendars include, for example, Venus, Mars, and particular constellations of stars.

Conclusion

Both religious and secular sources have provided explanations for the apparently universal cultural experience of human sacred time. On the pious side, reasons for the intentional setting aside of time can include the necessity of sacred time to ensure the continuation of the individual's or the community's divine favor, or even the continuation of the universe itself. On the secular side, psychology, sociology, and anthropology describe sacred time as an essential tool for community coherence, or simply a means to make life more enjoyable or even bearable.

Persistent questions that continue about sacred time include debates about whether sacred time reflects an escape from life or a deeper experience of life; and whether the source of sacred time exists outside of or is somehow transcendent of time, or is best explained by natural human social or psychological needs. The basics, however, are well established. When fully understood, sacred time on both the human and the cosmological scale have been present in all cultures at all times, including the most secular of cultures and times. Observing and investigating the phenomena of sacred time provides important insights into particular cultures, revealing much about concepts of the sacred, the cosmos, the human, and time itself.

David V. McFarland

See also Bible and Time; End-Time, Beliefs in; Eternal Recurrence; Genesis, Book of; God and Time; Now, Eternal; Religions and Time; Revelation, Book of; Theology, Process

Further Readings

Eliade, M. (1959). *The myth of the eternal return.* Princeton, NJ: Princeton University Press.

Eliade, M. (1959). *The sacred and the profane: The nature of religion.* Orlando, FL: Harcourt.

Otto, R. (1924). *The idea of the holy: An inquiry into the non-rational factor in the idea of the divine and its relation to the rational.* London: Oxford University Press.
Pieper, J. (1965). *In tune with the world: A theory of festivity.* New York: Harcourt, Brace & World.
Sagan, C. (1980). *Cosmos.* New York: Random House.

Time, Sidereal

The precise definition of a sidereal day is the time it takes for the vernal equinox to return to the local meridian. The local meridian is simply an imaginary circle that connects the celestial north with the celestial south and passes through the zenith (the most overhead point) and nadir (the most underfoot point) relative to the observational location. The celestial sphere is an imaginary shell encompassing the earth on which all other objects are placed without taking into account stellar distances (see Figure 1). On the celestial sphere, the vernal equinox is the zero point for the equatorial coordinate system. The vernal and autumnal equinoxes are the points where the celestial equator intersects with the earth's orbital path. The length of a sidereal day is 23 hours, 56 minutes, 4.1 seconds. It is slightly shorter than the solar day, which causes stars to appear to rise and set earlier each night.

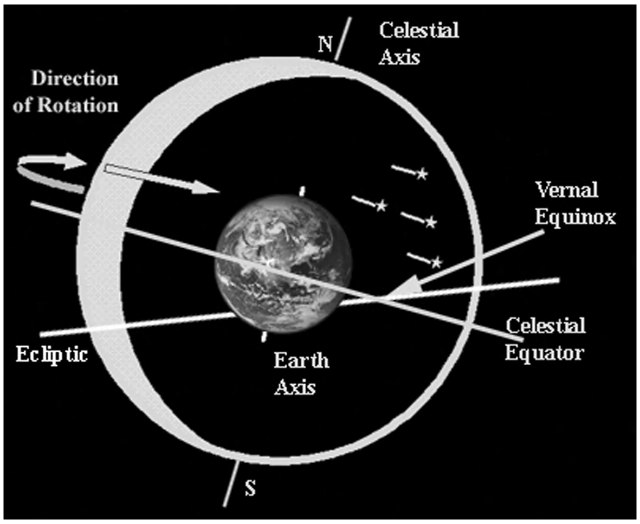


Figure 1 External view of the celestial sphere

Observational Effects

A less stringent method can be applied to any object on the celestial sphere, for example an arbitrary star such as Antares (Figure 2a). Any star appearing against the stellar background will need one complete sidereal day to return to its starting point (Figure 2b), as Antares has below. This includes not only stars near the earth's equator, but also stars and objects that appear at both polar regions and all points between. Since the sun is comparatively close to the earth, and the distant star is relatively "fixed" to the stellar background, the sun will take an additional 3 minutes, 56 seconds of the earth's rotational time to return to the local meridian than does the star. While the earth's axis is currently directed toward the region of Polaris, it is not fixed, and Polaris on a daily basis exhibits a small circular path that takes one sidereal day to complete. Stars near the poles tend to circle the polar regions visibly night to night, and are called circumpolar stars. These stars neither rise nor set because the earth's axis of rotation is directed toward those regions.

Precession of the Poles

The earth's northern polar axis will not always remain constantly aimed at Polaris, however (and the southern axis will change accordingly). The earth is acted upon by external gravitational forces such as the sun, moon, and other planets. This effect causes the earth to wobble and not spin vertically, but rather obliquely, like a gyroscope. This effect is called precession, and influences where the earth's axis will celestially point in a somewhat large area of space. The cycle, or Precession of the Poles, takes approximately 25,800 years to complete. In approximately 12,000 years from now, the star Vega will be the object of direction for the earth's northern axis. The South Star is currently Sigma Octans, and is quite faint. However, in 2,200 years, the star Gamma Chameleon will mark the southern pole with a bit more luminescence.

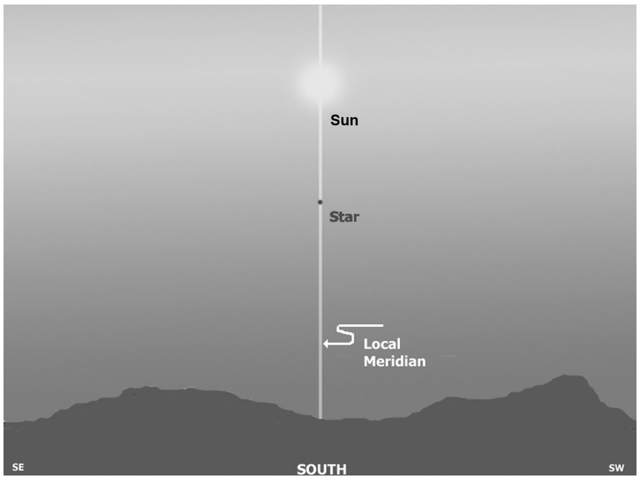


Figure 2a View of the sky at local noon on Day 1. Both the sun and the star are on the local meridian

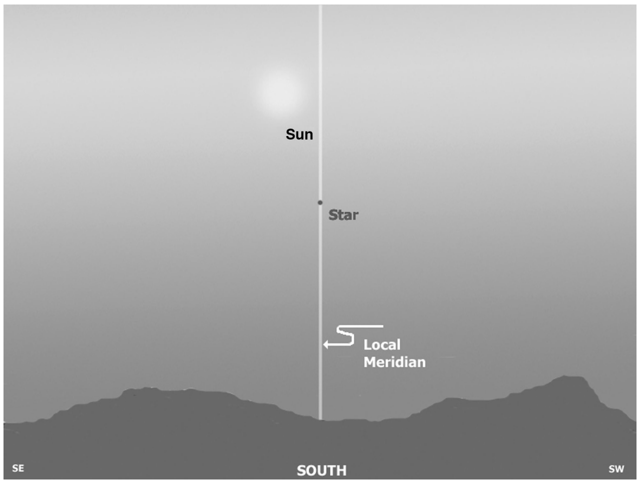


Figure 2b The star has returned to the local meridian before 24 hours has elapsed

Seasonal Variations

Throughout the year, the rotation of the earth and its orbit around the sun cause a seasonal shift in constellations. In addition, the axis of the earth is inclined at 23.5 degrees. This causes an additional change in the relative positioning of the objects on the celestial sphere. Following the vernal equinox, the sun and the stellar background objects seem to take a northerly change with respect to the ecliptic until the summer solstice, then a southerly decline past the autumnal equinox to the winter solstice. A northerly apparent shift resumes between the winter solstice and the vernal equinox, and the cycle repeats. On the vernal equinox, sidereal time and solar time are at their peak coincidence. Likewise, they are at 12 hours' difference on the autumnal equinox.

In the northern hemisphere, for example, the star Sirius makes a visible appearance in the summer dawn sky. After one sidereal day, Sirius returns to the exact same location; the sun, however, does not return for an additional 3 minutes and 56 seconds. After 6 months, this effect of the earth's revolution will lead to Sirius becoming visible almost 12 hours later.

Sidereal Variation

Measuring precise daily transits of the sun across the meridian uncovers discrepancies in the length of a sidereal day. These inconsistencies are due to the eccentricity of the earth's orbit as defined by Johannes Kepler. In addition, the sun's apparent annual motion varies along the ecliptic as it returns to the vernal equinox. These motions occur as the earth approaches the sun leading to its orbital perihelion, thus shortening the length of its sidereal day. As an object in orbit approaches the parent body, gravity accelerates the object and causes an apparent shortened time as the object has moved further and subsequently its parent object reaches the meridian faster. The reverse is true at orbital aphelion; the orbiting object is at its slowest, and therefore takes longer for the parent body to reach the local meridian, slightly lengthening the sidereal transit.

Sidereal Calendars

The ancient Egyptians employed a sidereal calendar in conjunction with a lunar calendar; it was the first to incorporate a fixed length of days to measure one year. The Julian calendar did not exist until the last century BCE (by some accounts, 46 BCE). The Egyptian new year occurred when Sirius was first visible in the morning sky, which in modern times corresponds to July 19. Akin to a lunar calendar, a sidereal calendar causes too much variation with respect to solar positioning.

Timothy D. Collins

See also Calendar, Egyptian; Earth, Rotation of; Equinoxes; Latitude; Longitude; Seasons, Change of; Time, Cosmic; Time, Emergence of; Time, End of; Time, Galactic; Time, Measurements of; Time, Universal

Further Readings

Audoin, C. (2001). *The measurement of time.* New York: Cambridge University Press.

McGrath, K. A., & Travers, B. (2007). Sidereal time. In *World of scientific discovery.* Detroit, MI: Thomson Gale.

Raju, C. K. (1994). *Time.* Boston: Kluwer Academic.

Time, Subjective Flow of

The subjective flow of time changes continuously. This variation is part of our everyday experience. When we are waiting, bored, or feeling blue, the subjective passage of time slows down. Time drags. When, however, we are involved in a fascinating discussion or absorbed in a skillful performance, we can become unaware of time and later feel that time has passed very quickly. As these examples show, attention and mood states play a fundamental role in the subjective passage of time. As explained below, our experience of the flow of time is based on our cognitive and emotional states.

In a phenomenological analysis of time experience, Edmund Husserl and Maurice Merleau-Ponty discern two complementary aspects of temporality: (1) the feeling of a present or "nowness" and (2) the flow of time. William James pointed out the paradox of this dual experience of time. We perceive the unity of the present. A fundamental temporal window of consciousness spanning a few seconds defines our sense of now. We simultaneously experience the passage of time, best described by a stream or flow. Events that have a certain duration constantly slip into the past. The flow constitutes itself into an event that might be anticipated, then actually experienced, and later remembered. This very phenomenon constitutes our experience of temporality.

The speed with which time flows can vary considerably. The allocation of attention to time or to events constitutes the first of two basic factors which influence whether the flow of time "speeds up" or "slows down." When we focus our attention on time, time slows down. When we are distracted from the passage of time, it speeds up. The upper portion of Figure 1 depicts this relationship graphically. The more we attend to the passage of time (left portion of the upper triangle), the slower the subjective passage of time and the longer the duration of experienced time. The more we pay attention to events around us (right portion of the upper triangle), the faster the subjective passage of time and the shorter the duration of experienced time. Thus, Figure 1 applies to the situation in which we attempt to achieve a sense of the flow of time, that is, we are "prospectively" (at present) attending to time (we are interested in how fast time goes by). When absorbed in entertaining activities, like watching a dramatic play or working on something exciting, we do not pay as much attention to time, and time "flies by." Attentional models of time perception have been formulated to account for these phenomena by assuming an internal "clock," similar to a stopwatch with a pacemaker and an accumulator, which emits and stores temporal units, respectively, and represents subjective time.

Emotional processes have an influence on whether attention is *directed to* or *distracted from* time. A subjective slowing of the flow of time is often experienced when we are bored, anxious, or depressed because when we are suffering from psychological distress, we have fewer meaningful thoughts and engage less in entertaining activities. Consequently, time becomes the focus of attention and is perceived as slowing down. Impulsive individuals often experience time as passing too slowly. As they easily become impatient in everyday waiting situations or when few distracting events are happening, these individuals pay more attention to time and subsequently experience an intensive deceleration of time. In contrast, when we are in good spirits, we usually are not focused on the passage of time. We may be absorbed in our activities and "forget" about time. When we finally get around to checking the time, it appears to have passed very quickly, and we are astonished.

A second factor also influences the subjective flow of time. This factor has yet not been accounted for here, but has often been reported in dangerous or life-threatening situations. In road accidents or encountered violence, attention is not directed to time, but focused solely on the sudden, unexpected situation. Nevertheless, people afterward report that time was slowed down, individual moments appeared prolonged, or everything even seemed to occur in slow motion. During a life-threatening event, a person experiences strong emotional

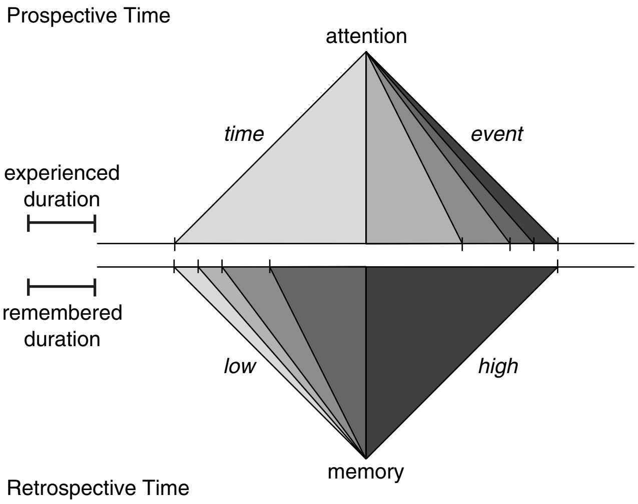


Figure 1 The paradoxical experience of the flow of time

Source: Illustration by Virginie van Wassenhove.

Notes: The upper triangle shows how paying more attention to time leads to a subjective slower passage of time and longer time intervals. In retrospect, however, the passage of time seems slower and time intervals appear to be longer when initially (prospectively) more attention was paid to a time period containing a lot of events that we stored in memory.

distress, needs to react as quickly as possible, and, for this reason, must direct all bodily resources to "fight or flight." Attention is focused on survival skills. Increased mental processing speed enabled by heightened arousal levels is fundamental to coping quickly with the threatening situation. If mental processing speeds up considerably, external events slow down in relation. As the world subjectively slows down, the person suddenly feels she or he has more time to choose adequate responses. In movies depicting battles, the scenes are often shown in slow motion to portray what a person in combat subjectively experiences.

Cognitive and emotional modulations in the flow of time have hitherto been discussed in the context of the present moment, that is, when an observer is presently experiencing a variation of seconds or minutes in the passage of time. However, the flow of time refers to past time intervals, and these time intervals can span years or decades of someone's life. Looking back, memory constructs the feeling of duration or the flow of time (too often leading to the surprised response of "how fast time passes"). Another time paradox unfolds: The time intervals that prospectively were perceived as passing so slowly (while we were directing more attention to time) are in retrospect perceived as if they had lasted a very short time only. Similarly, when we were not paying attention to the passage of time because we were involved in a lot of activities, the retrospective time interval seems to have lasted much longer. Figure 1 depicts this time paradox where an interval that lasted a long time prospectively (upper triangle), appears to have lasted a much shorter time in our memory (the segment with the same shade of gray in the lower triangle)—and vice versa. Time intervals prospectively last so long because nothing exciting is happening, but later on, after this time span has passed, nothing remarkable has been stored in memory. When, however, the flow of time was fast, a lot of interesting events happened, and these experiences, thoughts, and feelings were stored in memory. Memories form the building blocks for our conception of how fast time has passed or how long a duration has lasted in retrospect. Time intervals filled with exciting memories of changing events are regarded as having lasted longer. The flow of time is then retrospectively much slower compared to periods when, for example, during everyday routine, nothing extraordinary happened.

When looking back at periods of our life, we often feel that time passes too quickly. Inferring from the factors which influence the retrospective experience of time, it becomes quite clear that we can change the speed of the subjective flow of time. However, we can only modulate how fast time seems to pass. Time still goes by.

Marc Wittmann

See also Bergson, Henri; Cognition; Consciousness; Husserl, Edmund; Memory; Merleau-Ponty, Maurice; Psychology and Time; Time, Objective Flux of; Time, Perspectives of

Further Readings

Flaherty, M. (1999). *A watched pot: How we experience time.* New York: New York University Press.

Varela, F. (1999). Present-time consciousness. *Journal of Consciousness Studies, 6,* 111–140.

Wittmann, M., Vollmer, T., Schweiger, C., & Hiddemann, W. (2006). The relation between the experience of time and psychological distress in patients with hematological malignancies. *Palliative & Supportive Care, 4,* 357–363.

Time, Symmetry of

Although everyday experience leads us to believe that time "flows" in one direction, the equations of both classical and modern physics work equally well in either time direction. Since these equations accurately describe all observations of physical phenomena, from those made with the human eye to those made with the finest scientific instruments, the implication is that time can flow either way.

The *arrow of time* of human experience results from the fact that macroscopic objects contain many particles and these, to a great extent, move about randomly. The probability for a phenomenon happening in one time direction, such as air escaping from a punctured tire, is often much greater than the probability for the phenomenon happening in the opposite time direction, such as outside air reinflating a punctured tire. The reverse time event is not impossible, just highly unlikely. The arrow of time is defined as the direction of most probable occurrences.

At the level of chemical, nuclear, and elementary particle interactions, however, reactions occur in either time direction. Statistical differences between initial and final states can result in different reaction rates for the two directions, but at the basic interaction level the two directions are equally likely.

One exception occurs in certain elementary particle reactions that are mediated by the weak nuclear force. There a slight asymmetry of 1 part in a 1,000 exists. However, reactions can still proceed in either direction with only a slight difference in probabilities.

In 1949 Richard Feynman showed that an antiparticle, such as the anti-electron or *positron,* may be viewed as a particle going backward in time. This symmetry is built into the visual aids called *Feynman diagrams* used by physicists to calculate the rates of various reactions between elementary particles.

Despite the basic time symmetry of physics, most physicists continue to assume directed time in their models. This generally makes no difference, since a particle going backward in time is empirically indistinguishable from its antiparticle going forward in time, where "forward" is defined by everyday experience.

It has been known for decades, however, that quantum mechanics predicts certain phenomena that seem paradoxical. For example, electrons and other particles behave as if they can be in two or more places at the same time. Experiments have been performed that suggest "backward causality," where the changing of the parameters of a detector

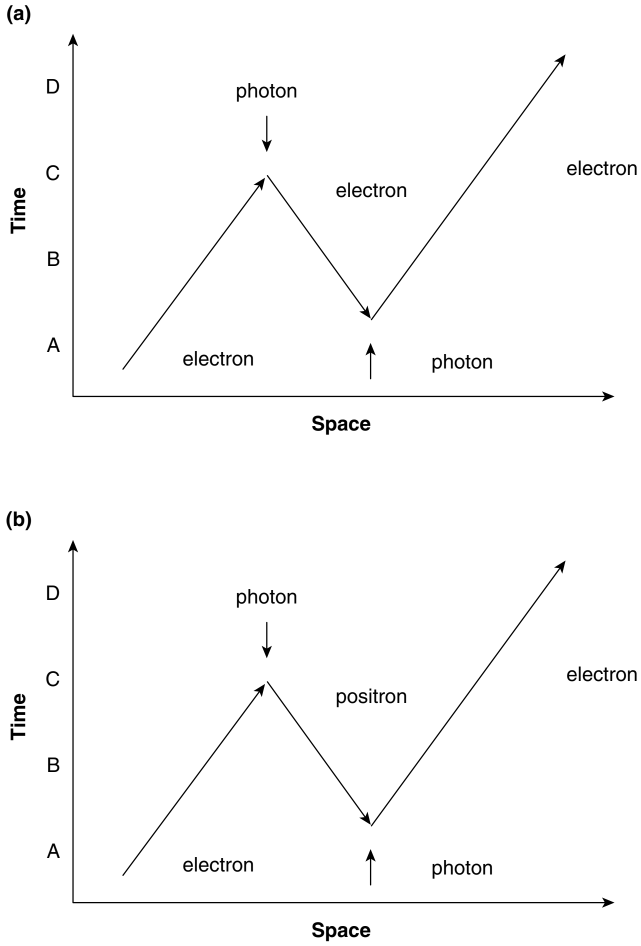


Figure 1 The "Feynman spacetime zigzag"

Source: Illustration courtesy Victor J. Stenger.

Notes: In (a), an electron goes forward in time, scatters off a photon, moves backward in time, scatters again, and goes forward. Note that the electron appears simultaneously in three different places at time B. In (b), the conventional time-directed view is shown in which an electron–positron pair is produced at time A, with the positron annihilating with the other electron at time C. The advantage of view (a) is parsimony, with no need to introduce antiparticles. It also offers an explanation for the indistinguishability of electrons.

after the particles to be detected are already in flight affects the behavior of those particles, even though they cannot be reached without sending a *superluminal* signal (signal traveling faster than the speed of light, violating Einstein's theory of special relativity). This is taken as evidence for *nonlocality* in quantum mechanics, in which two events separated in space are still connected despite the fact that no signal can pass between them without going faster than the speed of light.

Time-reversibility offers a possible explanation for these observations. For example, an electron can be seen to appear at two places at the same time when one uses the picture introduced by Feynman, as illustrated in Figure 1. An electron moving through space can be turned back in time by a collision with a photon. Normally this is viewed as simply the production of an electron–positron pair.

We can, however, view the positron as an electron going backward in time. If, in the "past," it is reversed again by a collision with a photon, it can proceed forward in time again, thus appearing in two places at once.

If we insist on a single time direction, an electron appearing two places at once implies superluminal motion (motion faster than the speed of light), which is forbidden by Einstein's theory of relativity. Indeed, in this case infinite speed is needed. While relativity does in principle allow for superluminal motion, it is restricted to particles called *tachyons* that must always travel faster than the speed of light. Particles, such as electrons, that normally travel at less than the speed of light cannot be accelerated beyond that speed. In any case, no tachyons have ever been observed.

In short, time reversibility is not forbidden and indeed is suggested by the basic principles of physics. Furthermore, time reversibility can help to explain the so-called paradoxes of quantum mechanics, what Einstein called "spooky action at a distance," without involving superluminal motion.

Still, one problem remains to be resolved: the *time travel* or *grandfather's paradox*. Simply stated, if you could go back in time, you would be able to kill your grandfather before he met your grandmother, in which case you would never have been born!

The answer to this paradox is rather subtle and has to do with the definition of the arrow of time. Time's arrow is determined by the direction in which the entropy of the universe increases. Entropy is a measure of disorder. Negative entropy is thus a measure of order or information. Thus time's arrow is the direction in which information decreases.

Now, if you were to go "backward" with respect to the conventional direction of time to kill your grandfather, you would be using information from the future that was not available in the past. This implies that the future has more information—*lower entropy*—than the past, a contradiction. That is, it would not be the future but the past by definition. If you traveled back without any information, as if you had amnesia and did not even know your own name, there would be no contradiction, but you would have no way of identifying your grandfather.

Victor J. Stenger

See also Eternal Recurrence; Time, Arrow of; Time, Asymmetry of; Time, Cyclical; Time, Linear; Time, Reversal of; Time Travel

Further Readings

Davies, P. (1996). *About time: Einstein's unfinished revolution.* New York: Simon & Schuster.

Feynman, R. (1985). *QED: The strange theory of light and matter.* Princeton, NJ: Princeton University Press.

Lederman, L. M., & Hill, C. T. (2004). *Symmetry and the beautiful universe.* Amherst, NY: Prometheus.

Price, H. (1996). *Time's arrow and Archimedes point: New directions for the physics of time.* Oxford, UK: Oxford University Press.

Stenger, V. J. (2000). *Timeless reality: Symmetry, simplicity, and multiple universes.* Amherst, NY: Prometheus.

Time, Teaching

Because of the time-structured nature of modern society, learning about time is an important element in the socialization of children. Despite its importance, teaching about time is difficult, because it requires developing the most complex mathematical ideas and skills that a child will learn up to about age 12. Understanding time requires the perception that events take place in sequence and are proportionally spaced relative to each other; for example, that breakfast is in the morning, always before lunch, and that that interval is shorter than the lunch–dinner interval. This perception is difficult for young children to develop. Cultivating this perception, building time vocabulary, linking "time sense" to the socially constructed system for measuring time, and operating mathematically within that system must be done by creating physical and social experiences for children as their abilities to comprehend abstract ideas increase with age.

In addition to developing the personal ideas that a child must know to use time effectively, instruction must be linked to other social structures and mathematical thinking, as well as to science concepts defining *day* and *year.* Day and year are the elements of time defined by the reality of nature; all other concepts and units are socially constructed. Teaching time must also develop language and incorporate generalized reasoning and problem solving. A teacher creates activities appropriate to the learner's age, cognitive development, and background experience that challenge the child while creating success. To develop the ideas and skills concerning time, we engage the learner in social interactions to understand physical experiences in order to create active learning that builds deep understanding. Over several years, teaching time must refine the child's understanding of time and develop the language to use it in communication.

Time is difficult to teach meaningfully to children in that the basic ideas are all *constructs,* that is, concepts that have no physical referents. Any concept is a mental construction of the rule that makes all members of a class alike but different from nonmembers. A concept such as *mammal* can best be developed by having children encounter different mammals and through discussion drawing their attention to what makes these examples alike. The concept is further refined by showing how the examples differ from nonexamples, for instance, how mammals differ from reptiles or fish. Alternately, a *construct* is an idea that is built up from other ideas, such as *fairness.* Fairness means free from bias, dishonesty, and injustice, that is, not possessing qualities expressed in other ideas belonging to different constructs. Time constructs explain events in the physical world, but a child cannot hold time, smell it, or feel it. It is an idea that is created by a mental awareness of the pattern of day and year, which are characteristics of the world in which we live.

The basic paradigm for teaching abstract ideas, with the complexity identified above, is to develop the foundational ideas intellectually and build mental relationships among them. The physical component of instruction is to involve the learners in a physical/sensory event and draw their attention to the germane aspects of the experience. The social component requires the use of oral and written language to refine the concepts. Preparation for this social component means developing language, including vague terms such as *soon, later, in a little while, evening,* or *twilight,* as well as precise terms like *noon, night, tomorrow,* or *10 o'clock.* The social component of naming, discussing, and comparing experiences with others gives the learner practice in mentally relating, organizing, and reorganizing the concepts being learned.

Learner-Appropriate Activities

Learning about time begins informally, as is true of other number-related concepts. Still very concrete in their thinking, preschool children begin to use numbers 1 through 10 and usually up to 20. Time vocabulary is developing related to experiences, for example, "*Time* to play!" "*Tomorrow* is your birthday." "We will do that *later.*" "How many *years* old are you?" At this age, it is easier to think about the future than the past, which may get confused with the present; all of *today* is equated to *the present.*

Young children's time sense can be developed by drawing their attention to the passage of time. *Time sense* is the ability to gauge the passage of time mentally and is needed both to grasp time units and to estimate. Funnels with sand can be used in a useful game of seeing which funnel allows the sand to come through *faster.* Preschool children can learn to compare two events that start together and recognize that the one that finishes first is "faster."

By kindergarten, children will know numbers up to about 70 and have a better grasp of what numbers represent. They should have experience with regrouping: the idea that one of one thing may be converted into several of something else, such as 1 dozen eggs is the same as 12 individual eggs. Instruction should develop a sense of *seconds* at this age, as the concept of second is easier to grasp than minute or hour; the child can hold a second's worth of experience in memory and think about it. Rhythmic counting accompanied by clapping helps develop this sense of a second. One child may count rhythmically while another child performs a task, so that the last number named represents the *duration,* just as the last number named when counting a set represents the value of the set. Events can now be compared even if they do not begin together: the one that requires the highest number of counts is "longer." The sense of seconds can also be refined by helping children find five things that take one second, five things that take 10 seconds, and so forth. These benchmarks allow a child to compare personal references to events encountered in other contexts. Telling time to the hour is more important than telling time to the minute, however, because hours are the key time markers of the day—we awake at 8:00, lunch is at 12:00, and we go home from school at 2:00.

By this age, home and school experiences have begun to develop concepts involving *measurement* of time. Measurement serves as an interface between physical experience and mental ideas that adds precision to communication and aids problem solving. Measurement compares a property of the environment against a standard, assigning a number to the property. To use any measurement system fluently in problem solving or social situations, one must have the previously described *personal references* for the socially agreed-upon units. The user must know how the standardized units compare to understood benchmarks and also be able to use the units to estimate values. Refining the previously mentioned *time sense* needed to understand the time measurement system is difficult for children, since the experience of passing time is affected by perception. To tell time, the student must understand personal event markers (lunch is at 12:00) and have a feel for the passage of time. Yet children, being concrete thinkers, think that the week before a birthday *seems* longer because it *is* longer than other weeks. An hour in the doctor's waiting room is longer than the hour of playtime in the afternoon.

Understanding the time-measurement system allows discourse with others incorporating time concepts, and this social interaction furthers the understanding of time. Activities and conversations draw children's attention to the concepts of age, years, and *birthday,* as well as the names of the days, months, and holidays. These discussions refine the child's understanding of *day* and *night* as defined by the presence or absence of light, and related terms including *yesterday, today, tomorrow, morning, noon, afternoon,* and *evening.* Continued attention to noticing "time" to wake up, eat meals, watch favorite television shows, and go to bed strengthens the child's sense of time.

Continued development of the sense of time passing can be enhanced by the presence of chiming clocks in the classroom (although after a period of acclimation, the teacher will have to draw students' attention to the chiming as they will stop noticing it). At this age, children can hold a longer experience in their memories and begin to grasp larger blocks of time. These children should make lists of five activities that take a quarter hour, a half hour, and up to an hour.

A major tool in developing time concepts and mathematical thinking in the primary years is the use of calendar activities every day. Children come to learn that today's date is signified by a name and number, and that a "month" is made up of days. Questions based on calendar activities can help children learn to count, add, and subtract while improving their sense of time passing. At this age children can name the days of the week and know such vocabulary as *weekday* and *weekend.* They should be able to name the months, classify them by season, and connect them to holidays and other events.

It is appropriate at this age to provide instruction on telling time to the hour. However, to do so effectively means accounting for the abstruseness of the digital clock versus the complexity of the analog clock. The digital clock is easier to use to learn to state the name of the present time, so much so that it is possible to name the time without relating this answer to its meaning. For example, it is easy for a 6-year-old child to use a digital clock to state that the present time is 5:56, but he may not understand at all that 5:56 is closer to 6:00 than to 5:00. The digital clock becomes a tool for the child to complete a defined task superficially without having the underlying conceptual understanding.

The digital clock does not convey the passage of time as well as an analog clock. In teaching time at this age is still trying to refine time sense, watching the second hand sweep around an analog clock dial is more sensory than watching a digital clock advance once a minute. Even if the digital clock has a second display, the child has to relate the numeral changes intellectually to the sweep of time. The analog clock also visually displays the idea that the time cycle restarts at 12:00, and it has other advantages.

Nevertheless, the analog clock also has its drawbacks. A typical "regular" clock is three timepieces in one housing. The face usually has a numbered set of indicators for hours (12) and may or may not have an unnumbered 60-part number line for minutes and seconds (60). The minutes/seconds are determined by determining a number of groups of five using the hour-indicating numbers (a mathematical process of skip counting that can be used as preparation for multiplication) and adding remaining units, for example, the minute hand is two marks past the 4, therefore 20 + 2 or 22 minutes. This is a complicated, multistep mathematical process at this age. After learning to use a fully articulated analog clock face, children can learn to interpolate on a clock face that has fewer, or possibly no, hour- or minute-indicating marks.

For starting to learn to tell time to the hour, a good instructional tool is a one-handed analog clock. Instruction should lead to conversations such as, "When the big hand is here (e.g., 8:00) at night, what might we be doing?" (Going to bed). Commercially available teaching clocks can be obtained for such activities. Another appropriate activity is to have a child roll a die, add that number of hours to 12:00 (Midnight), name the new time, and state something that might happen at that time (5:00 a.m.—I am sleeping.). Then a partner rolls the die, does the same thing, and the children continue taking turns.

By second grade, the learner has a more well-developed sense of time and a better grasp of the meaning of numbers (up to about 200). The goal at this age is to refine time-telling to the half hour, quarter hour, and nearest 5 minutes. With an analog clock, if the children have a sense of the meaning of the hour hand, then they may be shown a clock with the hour hand positioned and asked to predict where the minute hand would be; first practicing with hours and half hours and progressing to quarter hours. The clock face also becomes a tool for relating to other mathematics; for example, as a model for unit on fractions. The digital clock can be used more easily to link time benchmarks to the child's daily schedule, for instance, We go to lunch at 11:20, We check the outside temperature every day at 9:10.

In the upper elementary grades (3–5), the *Standards* of the National Council for Teachers of Mathematics call for students to be able to "select and apply appropriate standard units and tools to measure" time. By the third grade, instruction further refines time-telling with analog clocks to the minute. Now children can practice going back and forth between the two time systems, as they can use both systems with equal precision. Given a digital time, children are asked to draw what the analog face would look like or to write the digital time based on a picture of an analog face. The analog clock scale may also be "unwound" to a line and related to a 0–60 number line for other mathematics instruction. The clock scale can also be used as a model for negative numbers, as in "five minutes to lunch," or countdowns to events. Third grade is generally when fraction concepts are used more, and the 60-part analog clock face easily represents halves, fourths, thirds, fifths, sixths, and tenths.

In Grade 4 and above, more complex skills are introduced. Converting weeks into days and vice versa gives practice with a 7:1 conversion process, while day/hour is 1:24, hour/minute and minute/second are 1:60. Converting months to weeks and/or days requires conditional thinking, as months come in 28-, 29-, 30-, and 31-day varieties. Time lines, variants of number lines, can help visually scale historical events relative to each other.

Calculating elapsed time is good practice in a multistep mathematical task for which multiple algorithms (including those invented by the children) can be used to arrive at the answer. Computing elapsed clock time is usually introduced in Grade 4 and refined over a couple of grades. The three skills in elapsed clock time include: determine the duration given the start time and end time, find the end time given the start time and duration, or find the start time given the end time and duration. This instruction starts with finding durations in hours and half hours not crossing noon or midnight, and is eventually refined to finding durations in hours and minutes for events passing a.m./p.m.

By age 14 or so, students are much less limited by concrete thinking. An appropriate skill at this level is to estimate time requirements from a map or scale drawing. Given a map, the student should be able to determine how long it would take to get from one point to another. While a concrete-thinking child could not relate to the representation of a street on a paper map, the older and more abstract-thinking student can. This skill can also serve as a basis for simple, formal algebraic thinking, such as the development of the symbolic representation $D = rt$.

At this age, students can effectively discuss other social constructs such as time zones, the International Dateline, various calendar systems, and daylight saving time. Lessons in science will demonstrate the impact on physics and astronomy of the increased precision with measuring time through history. Internet resources provide intriguing options for various calendars and clocks, based on decimal or base-2 number systems, which can be incorporated into mathematics. Historically, some of the oldest human artifacts indicate records of time reckoning processes that imply our ancestors' first rudimentary observations of nature. This can lead into social studies discussions of prehistoric cultures' efforts at making calendars and keeping time.

Dennis E. Showers

See also Clocks, Mechanical; Education and Time; Perception; Psychology and Time; Time, Measurements of; Time, Units of

Further Readings

Maccarone, G., & Hartelius, M. (1997). *Monster math school time*. New York: Scholastic.

Martinez, J. G. R., & Martinez, N. C. (2007). Number systems and time. In *Teaching mathematics in elementary and middle school: Developing mathematical thinking*. Upper Saddle River, NJ: Pearson.

Sperry Smith, S. (2009). The language of time. In *Early childhood mathematics*. Boston: Pearson.

Sperry Smith, S. (2009). Time. In *Early childhood mathematics*. Boston: Pearson.

Stenmark, J. K., Thompson, V., & Cosey, R. (1986). *Family math*. Berkeley, CA: Lawrence Hall of Science.

Van de Walle, J. (2007). Measuring time. In *Elementary and middle school mathematics: Teaching developmentally* (6th ed.). Boston: Pearson.

Time, Units of

The units of time that we find in all cultures are the obvious ones based on observable natural cycles, particularly the global or astronomical events that seem to occur with regularity. The day is the interval between appearances of the sun in the sky at dawn; the month is the time for the moon to repeat one of its cycles; and the year is marked by when the cycles of the seasons repeat.

The 7-day week arose in Babylonian astronomy, the days representing the sun, the moon, and the five visible planets, which were regarded as deities.

The hour was used in a number of ancient civilizations, defined as 1/12 the time from sunrise to sunset, that is, 24 hours in a day. This probably reflected the widespread use of the base-12 or duodecimal number system in ancient times.

The definitions of the minute as 1/60 of an hour and the second as 1/60 of a minute probably arose from the Babylonian use of a base-60 counting system. There were 86,400 seconds in the 24-hour day.

Many cultures used the moon as the clock by which they scheduled various important rituals. It remains today the basis of the Jewish and Islamic calendars. However, the cycles of the moon are not closely linked to the seasons, with the result that these rituals drift though the seasons as the years go by.

As civilized life became more complex, these measures were refined. The Egyptians needed an accurate way to predict the rise of the Nile and found that counting the moon's cycles was inadequate. Around 4200 BCE they discovered that the "Dog Star" (now called Sirius) in Canis Major rose near the sun about every 365 days, around the time of the annual Nile flood. This led to the 365-day year, which is still in use.

However, the time between seasons is not quite 365 days and even the 365-day year drifts through the seasons. In order to better synchronize Roman festivals, in 46 BCE Julius Caesar introduced the Julian calendar, which included a leap day every 4 years. That is, the year was redefined as 365.25 days. This was corrected further by 11 minutes per year in 1582 with the Gregorian calendar. The Gregorian year is defined as 365.2425 days. The Julian year is still used in astronomy to specify the number of days for a long time interval. Astronomers, however, more commonly use the *sidereal year,* the time it takes the earth to complete one revolution in its orbit, as a fixed frame of reference.

As science developed, so did our units of time. The second was originally defined as 1/86,400 of a mean solar day. In 1956 this was changed by international agreement to 1/31,556,925.9747 of the tropical year for 1900 January 0 at 12 hours ephemeris time. (Since this is an obsolete definition, we need not bother explaining the meanings of *tropical year, January 0,* and *ephemeris time*.)

Defining time in terms of astronomical observations, no matter how precise the measurements, eventually proved inadequate. A clock was needed that could, in principle, sit by itself in a laboratory and not have to be constantly recalibrated against Earth's irregular motion around the sun.

In 1967, again by international agreement, the second was redefined as the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine energy levels of the ground state of the cesium-133 atom. In 1997 this was further refined to specify that the second so-defined referred to a cesium atom at rest at absolute zero. Since observing such an atom is impossible, this requires a theoretical extrapolation to get the above value.

With the second defined as the primary unit of time, the minute remains 60 seconds, the hour remains 60 minutes, the day remains 24 hours, and the year is still taken to be 365 days, as in ancient Babylonia. Our calendars still need to be corrected occasionally to keep them in harmony with the seasons because of the lack of complete synchronization in the motions of astronomical bodies.

Time is inextricably connected with space. Once we have a measure of time, we next need a measure of space or distance. The international standard unit of distance is the *meter.* In 1793 the meter was introduced as 1/10,000,000 of the distance from the pole to the equator. In 1889 the standard meter became the length of a certain platinum–iridium bar stored under carefully controlled conditions in Paris. In 1906 the meter was redefined as 1,000,000/0.64384696 wavelengths in air of the red line of the cadmium spectrum. In 1960 it became 1,650,763.73 wavelengths in a vacuum of the electromagnetic radiation that results from the transition between two specific energy levels (2p10 and 5d5) of the krypton-86 atom.

In 1905, Albert Einstein introduced his *special theory of relativity,* profoundly revising our notions of space and time. The primary postulate of relativity is that the speed of light in a vacuum, a quantity conventionally referred to as *c,* is a constant that does not depend on the motion of the source of light or its observer. Thousands of scientific observations in the century since have confirmed the validity of Einstein's postulate.

In 1983, by international agreement, Einstein's postulate was incorporated into the definition of the meter, which was then defined to be the distance traveled by light in a vacuum during 1/299,792,458 of a second.

This latest definition of the meter, which is still in effect, has a profound consequence that is not widely recognized. Since 1983, distance is no longer treated as a quantity that is independent of time. In fact, as we see from the above definition of the meter, distance is now officially defined in terms of time. Distance is the time it takes light to travel between two points in a vacuum. Of course, in practice we still use meter sticks and other means to measure distance, but in principle these must be calibrated against an atomic clock. The primary time and frequency standard is provided by averaging a set of *Cesium Fountain* atomic clocks at the NIST laboratory in Boulder, Colorado, which at this writing will not gain or lose a second in more than 60 million years.

A further implication of the definition of the second and the meter is that the quantity c is simply an arbitrary conversion factor. If you measure time in seconds and distance in meters, then c is *by definition* 299,792,458 meters per second. If you measure time in years and distance in light-years, $c = 1$, since the light-year is defined as the distance traveled by light in one year. The photon, the particle of light, is believed to be massless and indeed is measured to be so with enormous precision. This implies that photons and thus light travel at the speed c in a vacuum. When light travels through a medium, however, its speed is given by $v = c/n$, where n is the index of refraction of the medium.

Since no perfect vacuum exists in the universe, light can generally be found moving at a speed other than *c*, although the difference is very small in outer space.

Finally, let us list some of the commonly used units of time smaller than the second.

one millisecond = 10^{-3} second

one microsecond = 10^{-6} second

one nanosecond = 10^{-9} second

one picosecond = 10^{-12} second

one femtosecond = 10^{-15} second

Victor J. Stenger

See also, Attosecond and Nanosecond; Duration; Einstein, Albert; Plack Time; Time, Measurements of; Time, Operational Definition of; Time, Relativity of; Time, Teaching

Further Readings

Davies, P. (1996). *About time: Einstein's unfinished revolution.* New York: Simon & Schuster.

Stenger, V. J. (2006). *The comprehensible cosmos: Where do the laws of physics come from?* Amherst, NY: Prometheus.

Time, Universal

Universal time is the international time standard common to every geographical area in the world. Coordinated Universal Time (UTC) is the number of hours, minutes, and seconds that have elapsed since midnight at the prime meridian. This time is kept on 24-hour clocks and is carefully monitored by international organizations, coordinated by the International Bureau of Weights and Measures in France. Coordinated Universal Time is transmitted by radio signals so people around the world can set their clocks to the exact time, adjusting for their individual time zones.

There are actually several different Universal times, which have varying degrees of control by astronomical forces. These are UT0, UT1, UT2, and UTC. Currently the UTC commonly used by the world is calculated by more than 260 cesium atomic clocks on the earth and 24 above the earth in satellites. Because the earth's orbit around the sun and rotation on its axis is not consistent, adjustments need to be made so that UTC remains close to the actual solar day.

Universal time replaced Greenwich mean time (GMT) in 1928 when the International Astronomical Union defined it as the mean solar time on the Greenwich meridian (zero degrees longitude), with the day beginning at midnight and each day composed of 86,400 seconds. Not all countries made this change in time standard at the same time. As late as 1997, the United Kingdom was unable to change its legal time standard in Parliament away from GMT, although they use UTC.

History

Universal time is the result of a developing history of the human need for timekeeping accuracy. Before the 19th century, local areas adjusted their clocks at noon when the official sundial showed the sun had reached its highest position for that day. In 1878, the needs of railway travel across long distances without accidents led to a system of standardized time zones. In 1880, Great Britain decided to have the same time throughout the country, GMT, which started a new day when the sun was at the highest point above the Royal Greenwich Observatory. In 1884, an international convention was held in Washington, D.C., where it was agreed that Greenwich, England, would be the home of world time, known as GMT or Zulu time and the world would be divided into 24 time zones.

The 20th century began with astronomers in charge of timekeeping and ended with physicists in charge and astronomers in supporting roles. In 1912, the French Bureau des Longitudes conference called for an international organization to oversee world timekeeping, and the following year the Bureau International de l'Heure was set up. In 1920 this group was incorporated into the International Astronomical Union (IAU). Through years of astronomical observation, variations led to the conclusion that some days are longer and some days are shorter due to a variety of factors such as latitude location, earthquakes, continental plate movements, and severe storms. GMT became the mean solar time on the prime meridian at the equator, thus an average of statistical data. In 1928, the IAU replaced GMT with the new designation Universal time.

The year 1955 marked several important events in the development of Coordinated Universal Time. The astronomers and the United States Naval Observatory under the leadership of William Markowitz had been working to define time more precisely through detailed charts of observations of the rotation of the stars through the earth's sky. This became ephemeris time (ET), a timescale based on the movement of bodies in the solar system. In 1955, the General Assembly of the International Astronomical Union, meeting in Dublin, adopted ephemeris time as the international standard. In an attempt to come to terms with the fluctuations of the earth's rotation, they decided there would be three different forms of Universal time. UT0 is measured directly by observation of star transits derived from sidereal time. UT1 is UT0, but corrected for polar wobble and so is a measure of the earth's orientation in space; it is the same everywhere on the earth and was to be used for navigation. UT2 was UT1, but corrected for seasonal variation in rotation speed and tidal friction. These versions of Universal time have specific astronomical uses.

Physicists at the National Physical Laboratory, the United Kingdom's standards laboratory, under the leadership of Louis Essen, had been developing the first successful atomic clock based on the predictable vibrations of the cesium atom. In June 1955 this clock was able to run at a steadier rate than the earth's rotation and to describe the second more accurately. Markowitz and Essen began a project to determine the length of the ephemeris time second in terms of the cesium frequency.

January 1, 1960, marked the beginning of UTC's adoption adjusting seconds each year in order to remain close to the mean solar seconds and the system of radio time signals broadcasting this time. In 1967, a second became officially defined as the time taken for 9,192,631,770 vibrations of the cesium-133 atom inside an atomic clock.

A compromise timescale was devised and on January 1, 1972, UTC became the basis for legal timekeeping in all countries. Civil timekeeping around the world is based on UTC emanating from one of the 49 national timing centers.

Standards Maintained

The International Bureau of Weights and Measures (BIPM) in France is responsible for international standards of measurement, and its time section administers the formula for UTC. Their officials send out two timescales: International Atomic Time (TAI) and UTC. They monitor the accuracy of the more than 260 atomic time clocks around the world that are used for this purpose. In 1972, these two time standards were combined for use with international radio time signals.

GPS, the U.S. Defense Department's Global Positioning System satellites, broadcasts time signals from its own internal atomic clock. These signals are compared with the atomic clocks used to determine UTC. The BIPM coordinates all this timing data as well as adjustments that need to be made for rotational variations. Whenever changes in the length of a solar day threaten UTC to be more than 0.9 seconds from UT1 (which includes the earth's wobble), a leap second may be introduced to bring it back in line. By the year 2000, 22 of these leap seconds had been added due to the slight slowing of the earth's rotation. Radio-controlled clocks adjust themselves automatically from satellite radio signals.

The official source of time used in the United States is the Time Service Department of the U.S. Naval Observatory. Three radio stations of the National Institute of Standards and Technology provide around-the-clock broadcasts that can also be accessed by telephone. Ham radio operators around the world all use the same time, UTC, without the time zone adjustments, so they are always on the same time no matter where in the world they are on the air.

As mobile phone networks, satellites, and computers rely on the coordination of the same accurate time, the latest generation of atomic clocks with laser-cooled atoms and newer technologies will be used to refine that accuracy. The inconvenience and unpredictability of the leap seconds used to match UTC to actual earth rotation of UT1 will need to be worked out as computer systems currently need to be reset to account for these leap seconds. The GPS atomic clock is becoming more dominant as navigation more often uses satellite signals rather than stars. The quick travel and communication of an increasingly complex world demand precision timekeeping of Coordinated Universal Time in order to synchronize human actions.

Ann Louise Chenhall

See also Clocks, Atomic; Prime Meridian; Space and Time; Time, Absolute; Time, Cosmic; Time, Emergence of; Time, End of; Time, Galactic; Time, Measurements of; Time, Sidereal; Time and Universes; Time Zones; Universes, Baby

Further Readings

Audoin, C., & Guinot, B. (2001). *The measurement of time: Time, frequency, and the atomic clock*. Cambridge, UK: Cambridge University Press.

Barnett, J. E. (1998). *Time's pendulum, the quest to capture time—From sundials to atomic clocks*. New York: Plenum.

Jones, T. (2000). *Splitting the second: The story of atomic time*. Bristol, UK: Institute of Physics Publishing.

Landes, D. S. (1983). *Revolution in time: Clocks and the making of the modern world*. Cambridge, MA: Belknap Press of Harvard University Press.

Time and Computers

The digital computer is the most important invention in the area of information technology since Johann Gutenberg began, around 1450, to use movable type in the art of printing. A computer can be programmed to process, as specified by its user, any information that is translatable into series of 0s and 1s (bits). Even the first fully operative program-controlled digital computers of the 1940s could perform numerical calculations much faster than a human being. Since then, they have succeeded in enormously speeding up all activities that are dependent on real-time information processing (like stock trading) or the efficient handling of huge databases (such as biological research). This is, however, just the most obvious relationship between time and computers. Considering the computer as a highly complex artifact that should be described at different levels of organization, it shows many more connections with time.

The famous computer scientist and pioneer of artificial intelligence, Allen Newell, described a general hierarchical organization of digital computers whose levels become, on the one hand, more and more abstract and, on the other hand, more and more specialized. At the basic level, any computer consists of electronic devices (like transistors). To explain their structure and behavior, knowledge of quantum physics is needed. This implies that on this level the microphysical understanding of time is most relevant.

The next level of computer organization is reached when electronic devices are put together. The behavior of the resultant electrical circuits depends on the current that flows through them. To predict its change over time, the theory of electromagnetism must be applied to circuits of electronic devices (Ohm's and Kirchhoff's laws). It is, in respect to time, even more interesting to look at electrical circuits from a particular functional point of view. This brings us to the third level of computer organization: the level of logic circuits—that is, of electrical circuits whose behavior over time fulfills a function that can be described in terms of logic-based information processing (or Boolean algebra). For example, the logic circuit called OR-gate calculates an output that is the logical sum of two input bits. If the input consists of a single 0 at the most, the output is 1; otherwise it is 0. By abstracting from the physical substrate of the OR-gate and describing its behavior in terms of information processing, irreversibility emerges—a quality that is of utmost importance to our ordinary experience of time. Irreversibility arises from loss of information, which occurs, for example, by calculating the logical sum of two bits. If the logical sum of two bits is equal to 1, the two input bits could have been two 1s, or one 0 and one 1. Knowing just the output makes it impossible to reconstruct the input exactly, so without storing the input the calculation of the logical sum cannot be reversed.

On the next organizational level of computers, integrated circuits are incredibly complex networks of logic circuits. Their designers must know how many bits these networks can process in parallel in a unit of time. Yet most computer users are not interested in hardware engineering. The computer-literate ones begin to work at the fifth level, on which programs written in a wide variety of artificial languages transform data structures. It is a very important question how the time a program maximally needs to perform its task depends on the minimal amount of information that is required to describe this task.

At the top of Newell's general hierarchy of computer organization is the knowledge level on which the behavior of computers (and of computer-controlled artifacts like robots) is described in terms of rationality. Computers are thus considered artificial rational systems that try to realize goals they want to attain, have knowledge about actions as a means of attaining these goals, and choose actions that most probably realize the preferred goals in the best possible way. The subfield of computer science that tries to construct such rational agents, artificial intelligence, has to deal with many fundamental problems concerning time. Rational agents, natural and artificial, have only limited resources at their disposal to solve problems. Their speed of information processing, for example, is finite. They must also make decisions under time pressure since the environments with which they interact are constantly changing. So rational agents must update knowledge of their environment efficiently and make predictions about how a change in some part of the environment will affect all other parts. If, for example, a woman changes her shoes, she does not usually change the color of her hair to go with them. This seems to be a trivial fact, but if there were no general rules by which rational agents reason about changes over time, the computer must be told myriads of such facts explicitly.

Newell's hierarchical picture of computer organization shows that, from the different perspectives of physicists, engineers, information theorists, and programmers of computers, time does indeed play a very important role in the construction and use of computers. This confirms the highly complex nature of these artifacts as physical systems that process information. Going beyond Newell's hierarchy, networks of computers (or groups of robots) that communicate with each other involve a functional equivalent of intersubjectively shared time as an important factor in social cooperation and conflict.

Stefan Artmann

See also Cognition; Information; Time, Units of

Further Readings

Shoham, Y. (1988). *Reasoning about change: Time and causation from the standpoint of artificial intelligence.* Cambridge: MIT Press.

Siewiorek, D. P., Bell, C. G., & Newell, A. (1982). *Computer structures: Principles and examples.* New York: McGraw-Hill.

Time and Universes

Our perception of physical existence is measured on four dimensions. The first three are spatial: length, width, and depth, to give a location of an event or object in the universe. The fourth and most complex is time, which gives that event or object a classification of "when." *Our* measurement of time is based on the earth's planetary motions; one revolution on its axis being one day, and one revolution around the sun being one year. This type of measurement offers insight into time's being understood as cyclical, but this could merely be an interpretation based on what was most evident when observations were first being made.

Historically, different civilizations have had differing viewpoints regarding the structure of time flow as either cyclical or linear. The notion of cyclical time has been given primacy by many civilizations including the Hindu, Greek, Babylonian, Chinese, Aztec, Mayan, and Norse. The cyclical flow of time is sometimes symbolized by the *Uroboros,* the snake wrapped in a circle bringing its tail to its mouth. Another manifestation is the circular-shaped calendar, of which the Chinese version is among the most widely recognized. Current cyclical measurements of time include not only how we still use the earth's motions for recognition of the passing of days and years, but also how we divide these measurements into smaller portions. We repetitively use the same names for labeling the 12 months of the year, and use the same number of hours in a day, minutes in an hour, and seconds in a minute.

Although measurements of seconds, minutes, and hours are used in cyclical time measurement, they can also be recognized in linear time measurement. For example, if timing how fast athletes can run the 40-yard dash, their time would be recorded with a linear measurement in seconds. However, the athletes' time could also be broken down into milliseconds, offering either a linear measurement of many milliseconds, or for every thousand milliseconds a cyclical recognition could be made as the equivalent to one second. Among the first to promote the concept of time being linear as opposed to cyclical was Saint Augustine of Hippo (354–430 CE). When he became deeply religious in his 30s, he noted that major events occurred only once in the Bible. The Bible also offers a definitive beginning of existence, with God's creation of the world and everything within it and surrounding it. However, the recurrence of the four seasons passing each year also offers insight as to why cyclical time would have been a natural first perception of time's structure in earlier civilizations.

The modern world uses a combination of cyclical and linear time measurement. This includes the cyclical recurrence of the earth year and the breakdown of its parts (months, days, etc.), and the linear measurements used to keep track of the passing years. Yet if time is actually linear and there is no actual beginning, then following with the second law of thermodynamics (which states that as working systems move forward in time, they move increasingly into a state of entropy), why hasn't the universe completely "run down" on itself? One explanation, discussed later, is the cyclical universe theory.

Two factors that affect time in our universe are gravity and speed. In places where gravitational pull is stronger, time is slower, and vice versa. On a microscale, this effect has been recorded on special, precise clocks on airplanes (which travel at about one millionth the speed of light). The conclusion drawn from these observations predicts that you theoretically could extend your life by about one millisecond (or travel one millisecond into the future) by spending your life flying on a plane around the world from west to east. Speed can also affect time. Mathematically, as an object accelerates, approaching the speed of light, time slows down.

Time Travel

Some cosmologists have proposed so-called wormholes as offering, theoretically, a mode of time travel. It has been conjectured that when a wormhole forms, part of a given plane in the universe is bent in half, with the wormhole acting as the bridge between the two ends. Or, put differently, imagine an empty hard-shell taco with an hourglass-shaped tube—the wormhole—connecting the sides. This theoretically offers a route that is a fraction of the distance than if you were to travel, for example, the 54 trillion miles from earth to the star Sirius.

This theoretical route is so far the closest science has come to an explanation for possible time travel. Unfortunately, no technologies yet exist that would be capable of surviving such a trip, so where or when one would go, and whether one would go forward or backward through time remains unknown. The only other way to theoretically traverse the time continuum is to create a tear in the fourth dimension. To do this would require controlling more than exorbitant amounts of energy, which today we have no way of generating or containing. But for discussion's sake, let's say that we do have the capabilities to travel at will throughout the fourth dimension, and particularly to travel backward. Could we then alter the world by affecting events in the past? This question opens another door: Would you be affecting the events of *your* timeline, or would you be traveling back and changing the events of an alternative spacetime, thus not affecting *your* spacetime at all? For this to be the case, multiple time continuums would have to exist, which would immediately raise the question of whether the traveler to different times would be in turn traversing simultaneously existent but separate universes? And if this is true, since there are literally infinite positions in time in between, for example, this instant and one year ago, would this imply that there are actually *infinite* universes? Clearly our ability to capitalize some day on the possibilities of time travel will require a far greater understanding of time than humanity can be said to possess at present, as illustrated by certain paradoxes and conundrums.

First, we have what is called the *Grandfather paradox*. It poses the question of what exactly would happen if you traveled backward through time and killed your grandmother before your mother was born. Obviously your mother would no longer come into existence, thus negating the event of your eventual birth. So if you were never to be born as a consequence of this murder, then how would it be possible for you to travel back in time to kill your grandmother? Perhaps, at the point of death of your grandmother, you could instantly be "blinked" back to the point in time before you traveled backward on the fourth dimension. A second depiction of using time travel to alter past spacetime is in the popular 1985 movie *Back to the Future,* in which Marty, the protagonist, travels back 30 years and accidentally hinders the courtship of his parents. As events play out in the movie to the point where his parents would no longer fall in love, Marty pulls out a picture of himself and his older siblings in which they start disappearing from the picture, and eventually his hand starts to dissolve into nonexistence until his father makes a move and kisses his mother, at which point Marty's hand and his siblings in the picture reappear. This example also offers a paradox that, if his parents never fell in love to give birth to him, then he never would have been in existence in the first place to travel back in time to interfere with their courtship from the beginning.

Black Holes

Time is recognized as a dimension but without the equivalent parameters of length, width, and depth used to measure physical dimensions. The fourth dimension has only two known dimensions within itself, forward and backward. Perhaps other undiscovered dimensions within time might lead to a greater understanding of controlling its distortions. According to scientists, time in the universe may be compared to an elastic sheet. Any object with mass warps the first four dimensions around it. Although it is not recommended to look directly into the sun, sometimes this effect can be seen in the sun's rays when looking over the silhouette of a rounded edge of an object with the sun immediately behind it. To a very small extent, you can see the light rays bending around the object. The shape of a black hole in spacetime would look similar to the distortion made by placing a heavy ball on a stretched sheet of rubber; it would create a circular sinking effect. This distortion effect is discussed in Albert Einstein's theory of general relativity. It also suggests that spacetime is further distorted when objects are spinning, which would be portrayed by a spinning object twisting the sheet of elastic. This effect, first predicted in 1918, is called "frame dragging," and can be observed by the earth's mass affecting spacetime, with the orbiting satellites lagging by approximately 6 feet each year.

Cyclical Universe Theory

This idea of the universe changing before entropy has fully set in originates in the question of the existence of time and space prior to our current universe. Some theoretical physicists are investigating the cyclical universe theory: while time itself never actually loops—everyone knows that we can never live the same minute over again—what this theory proposes is that before the big bang, there could have been an infinite number of big bangs. Over an infinite amount of time, universes could have begun with a big bang, grown and lived out their life span, and collapsed in on themselves to a point where all the matter and energy converged so densely that it eventually issued forth in the next big bang when all the energy is released (of unthinkably monumental size). This cyclical universe theory puts us humans in the *current* era, not the only era of the universe. This theory ties in well with what cosmologists are saying about a black hole that could eventually grow so large as to engulf the entire universe.

A black hole is a region in space where matter becomes greatly condensed, to the point where the gravitational pull is so strong that no type of energy, not even light, can escape its draw. This force is present within a radiant distance on a flat plane surrounding the hole, called the *event horizon.* Over time, as a black hole pulls in more matter and energy, it grows not only in size but in force. This essentially creates small portions of the universe where time slows down immensely. Cosmologists have theorized that, upon a single black hole growing large enough, it will not only engulf other black holes, but eventually the entire universe. At that point, time in this universe as a whole will come to a near halt due to the overwhelming gravitational pull emitted by the gargantuan black hole. Following this chain of events, time in the universe will go from a near standstill to returning to normal "speed" upon the discharge of enormous amounts of energy in a massive release, which we would call the next big bang.

From this, we might conclude that there is no definitive beginning or end to time.

To date, however, modern physics has proven that in all physical actions and reactions there is no creation or destruction of matter or energy, but only transfers of both. This would suggest that since it is all the same energy and matter that is being condensed into the final massive black hole that swallows the current universe, that upon the next big bang it would create a somewhat identical universe with all the same properties, matter, and energy. However, theoretical physicists are not completely sure about this. There is a mysterious variable force deep in space that scientists are calling Lambda that seems to produce a force that helps the universe expand, much as dark matter does. Its properties are little understood, but what is known about it so far indicates that accepting its existence also admits the potential for the laws of physics and time, which dictate our immediate surroundings, are either null or different in other parts of the universe. This understanding gives way in turn to the scientific speculation that under the cyclical universe theory, new energy and matter are created about every trillion years, the amount of time estimated by Paul Steinhardt of Princeton University and Neil Turok of Cambridge University to be the probable duration of each universe cycle. However, there are still ways that the cyclical universe theory could be disproved.

Ekpyrotic Universe Model

We know of our own universe and the four dimensions we experience within it. But are there perhaps other dimensions, or even other universes currently existing? A very new and unproven theory introduced in 2001 gives insight into these possibilities. This ekpyrotic universe model contradicts the beginning of the big bang model of the universe. The distinction between the two is that the ekpyrotic model states that instead of there being an initial big bang coming from infinitely condensed matter and energy, the universe was instead originally very vacuous and contracted until our first three directional dimensions (stretched like an elastic sheet, a membrane, or "brane" for short) collided with another three-dimensional brane. This caused the two to combine and produce something similar to the big bang effect, creating the universe we now live in and also causing the universe to then start expanding with much more matter and energy within it. The venue for this collision was the fourth dimension (time) that the two branes were moving along. This adds yet another possibility for the creation of the big bang.

Paul Steinhardt also explains that the basis for the ekpyrotic universe model comes from what is called the superstring theory, which requires 10 different dimensions for most formulations. The additional 6 dimensions are suggested as being twisted up into a microscopic ball called the Calabi-Yau Manifold; this is too small to be experienced in our everyday life, which is why our initial perception of the universe is of only four dimensions. Further, the theory places our four-dimensional universe on a five-dimensional spacetime that derives from what is called the *heterotic M-theory.* The theory constrains the physical movement of particles to within only our first three-dimensional boundaries, but on either side of the extra (fifth) dimension. The reality we perceive around us is one side of it. It is proposed that gravitational energy would be the only way for matter or light to traverse to the other side of the fifth dimension. But where, exactly, is the other side of this fifth dimension? The theories creators explain that it is on the other side of what we see as the "edge" of the universe, suggesting that there is no actual boundary to our universe, just an expanding membrane in our portion of it, with physics different from our own. The heterotic M-theory does not include other universes, just alternate dimensions within our own.

Whether or not there was an actual beginning of time, the more pertinent question that remains is whether or not there will be a definitive end to time. There are some theories of how the universe will end billions or even trillions of years from now, giving rise to the question whether or not time will also be destroyed with them. But if time is neither a physical object nor energy, can it really be destroyed? If the universe were to collapse in on itself or shred apart according to the big rip theory, then would the universe simply become a vacuous space of endurance of nothing? Although some say that time would cease to subsist, since there is no actual way to create the physical existence of time, it would seem impossible to actually destroy it.

Other universes and other aspects of time beyond our imagination may always remain unknown.

Patrick J. Wojcieson

See also Augustine of Hippo, Saint; Big Bang Theory; Black Holes; Cosmogony; Cosmology, Cyclic; Cosmology, Inflationary; Eternal Recurrence; God as Creator; Histories, Alternative; Multiverses; of Time, Cyclical; Time, Emergence of; Time, End of; Time, Measurement of; Time, Units of; Time Travel; Universe, Baby; Wormholes

Further Readings

Gott, J. R. (2001). *Time travel in Einstein's universe.* New York: Houghton Mifflin.

Kaku, M. (2005). *Parallel worlds: A journey through creation, higher dimensions, and the future of the cosmos.* New York: Anchor Books.

Rees, M. (1997). *Before the beginning: Our universe and others.* New York: Basic Books/Perseus Books.

Steinhardt, P. J., & Turok, N. (2007). *Endless universe: Beyond the big bang.* New York: Random House.

Vilenkin, A. (2006). *Many worlds in one: The search for other universes.* New York: Hill and Wang.

Time Capsules

In the simplest terms, a time capsule is a receptacle containing objects chosen as representative of the current age and preserved for future discovery. Contents of time capsules should ideally provide a genuine sense of the time period represented. For that reason, written messages and items reflecting popular culture are often included. A well-conceived time capsule can effectively bridge the gap between the present and the future.

A distinction has been made between a "real" time capsule and other experiences that provide insight into earlier cultures. Specific examples include sunken ships, archaeological sites, libraries, and archives. Forerunners of modern time capsules can be found in artifacts discovered in building foundations in ancient Egypt and Mesopotamia and in cornerstone dedications such as the one that took place at the York Cathedral in 1361. By the late 19th century, it was common in the United States for organizations and businesses to include time capsules in local and national ceremonies.

Many time capsules have a target date for opening, making it important to use materials that will last, to find a secure place for storage, and to record the capsule's location. Just one of many examples of lost capsules is the George Washington Cornerstone, laid in 1793 by Washington at the dedication of the U.S. Capitol. A centennial time capsule was introduced during the 1876 U.S. International Centennial Philadelphia Exhibition. It was opened by President Gerald Ford in the 1976 Bicentennial year. Now called the Centennial Safe, it is available for public viewing through a glass door in the Capitol Building.

The term *time capsule* was not introduced until the 1939 New York World's Fair. Constructed of copper, chromium, and silver, it was intended to last until 6936. Its contents include fabrics, metals, plastics, art objects, microfilm describing contemporary events, and common items such as fountain pens. Even more ambitious are millennial time capsules. An example is the 2,000-cubic-foot Crypt of Civilization, conceived by Oglethorpe University's president, Thornwell Jacobs. Its contents were sealed in an exhibition room on May 28, 1940, with plans for opening on May 28, 8113. It includes thousands of items, ranging from newsreels to a Donald Duck doll.

Use of time capsules has become common enough to be applied in the classroom, encouraging children to reflect on their own lives and note changes that occur over time.

One example of applying time capsules in outer space is the golden recording placed by NASA on *Voyager 1* and *Voyager 2*. Its contents could conceivably portray the diversity of earthly life and culture to extraterrestrials. There are many possibilities for creating time capsules in cyberspace. An example was seen when MIT's Sloan School of Management encrypted digital samples to represent the online world in the year 1999.

Time capsules illustrate a belief in the importance of the present and optimism about the future. When a capsule is opened by a future generation, it could be described as having achieved a kind of time travel.

Betty A. Gard

See also Futurology; Museums; Time Machine

Further Readings

Jarvis, W. E. (2003). *Time capsules: A cultural history.* Jefferson, NC: McFarland.

Reingold, L. A. (1999). Capsule history. *American Heritage, 50*(7), 1–6.

Time Dilation and Length Contraction

Until the beginning of the 20th century time was thought to have a constant unvarying flow. A minute in North America was the same as a minute in Africa and anywhere else in the universe. But Einstein's theory of relativity changed that notion. He had discovered a bizarre aspect of the universe that is still not fully understood. A second of time here is much different than a second of time on a fast-moving object. Clocks on fast-moving objects actually slow down as compared to clocks on stationary objects. This is known as time dilation.

Understanding time dilation takes us back to the Michelson and Morley experiments of 1887. At that time it was thought light waves behaved like cars on a freeway (to use a more contemporary analogy). If one used a radar gun to measure the speed of an approaching car one might find that it was traveling 50 miles per hour. But if you are driving toward the car at 50 miles per hour the measurement would be different. The measured speed would be 100 miles per hour, the sum of your motion and the motion of the approaching car. Likewise, following the car at the same speed would produce a measurement of zero miles per hour. It is obvious that placement of the radar gun will produce different measurement of the car's speed. And it is equally obvious that light should behave in the same way. That is what made the Michelson and Morley experiments so revolutionary. The speed of light remained constant regardless of the speed of the measuring equipment.

Einstein delved deeply into this apparent contradiction and established the speed of light as a universal constant. To formalize this idea he used mathematics developed by Hendrik Lorentz, who had made the following observation: The speed of light in a moving frame of reference would remain constant if lengths contract in the direction of motion. For example, from the point of view of a stationary observer, a spaceship traveling at 86.6% the speed of light would measure one half its length. This idea was developed from the field of electrodynamics, which showed that the distribution of charged particles put into high-speed motion would similarly contract.

Along with length contraction, Einstein discovered that time was not equal between moving frames of reference. With each increment of speed, moving clocks slow down in relation to stationary clocks. This aspect of time has been firmly established by experiment. Though the time intervals are extremely small at our speeds, atomic clocks have become so accurate that time dilation has been measured. The observed slowing of clocks with speed conforms to the predictions of special relativity.

However, length contraction and the slowing of the clocks is what the stationary observer sees. Within moving vehicles, time and lengths appear to remain the same as they always were. Changes in length and time can only be inferred from knowledge about one's speed with respect to light. Further, it is a premise of special relativity that the view from within a moving vehicle is equivalent to all other views.

In a way, the calculations and impressions that emerge from the constancy of the speed of light and special relativity are an outlandish intellectual funhouse that annihilates our intuitive views of how the universe should and must behave.

For example, imagine you are in a spaceship traveling at 86.6% the speed of light. (You calculate this from the Doppler shift of the cosmic background radiation.) You decide to measure the speed of light entering the front of the ship and the back of the ship, doubting that light has a constant speed. It stands to reason that light coming in the back will take more time to reach the measuring point because the measuring device is moving away from the light source. Once again, that is not what happens. Light speed remains constant.

Now you measure the speed of light coming in the front. Light traveling in that direction will have less distance to travel since the measuring device is moving toward it. So, intuitively, the speed of light in that direction should measure at about twice the speed of the light. Of course this is a foolish experiment because we already know the outcome. Relativity tells us the measured speed of light coming in the front will be the same as light coming in the back, which was 300,000 kilometers/second.

However, this experiment may not be so foolish after all. Alterations of space and time with respect to the forward and backward directions within a speeding rocket have seldom been examined.

So how could light coming in the front have the same speed as light coming in the back? The Lorentz transformations tell us that light coming in the back is traveling over a shorter distance and that the clock has slowed way down. For a ship traveling at 86.6% the speed of light, the clock has slowed to half its duration compared to a stationary clock. This makes sense because for light to catch up with the measuring device it must travel over both a shorter distance and a longer time interval if the speed of light is to remain constant.

But these requirements are exactly opposite those for measuring the speed of light coming in the front. In that direction light must travel over a longer distance and/or a shorter time interval for the speed of light to remain constant. So you conclude the clock rate must have increased but you quickly realize this is not possible since you know exactly how fast the ship is traveling and that the clock must be ticking at half the rate of a stationary clock. Clock rate in any given speed frame is a constant determined exactly by the Lorentz transformations.

You would also know that the forward direction cannot contract because a shorter distance of travel combined with a slow clock would produce a speed measurement that would exceed the universal constant speed of light. Therefore you know that the light coming in the front of the ship must be traveling over a much longer distance, at least twice as long as the back. Of course you would not see that the distance is longer than the back. Nevertheless, the measurement of the speed of light leaves but one conclusion: The ship has become longer. As the velocity of the ship gets closer to the speed of light, your clock would slow down to practically a dead stop. Because of your knowledge about special relativity you know that for the speed of light to remain constant in both directions, the back of the ship must be shrinking dramatically and the front of the ship must be lengthening dramatically.

Relativity has not discussed a length expansion, but the thought experiment presented above suggests it must take place. Admittedly the writer is not an Einstein; nevertheless, the thought experiment conforms to the axioms of relativity and offers what may be the first relativistic explanation for why no experiment has shown that a physical length contraction takes place. It also suggests that no physical experiment will demonstrate the existence of a length contraction because simultaneous with that contraction is a length expansion that exactly cancels the effect.

Imagine now that you are inside the ship and flying at an infinitesimally small speed less than that of light. From your measurements you conclude the length of the front of the ship must be reaching toward infinity while the back of the ship must be contracting to nothing. This simultaneous stretching and compression of lengths takes human intuition beyond the warped reflections in fun-house mirrors and indicates that the relativistic world may be even more bizarre than generally thought.

Donald R. Perry

See also Einstein, Albert; Light, Speed of; Relativity, General Theory of; Relativity, Special Theory of; Space and Time; Time, Measurements of; Time, Relativity of

Further Readings

Lawden, D. F. (2003). *Introduction to tensor calculus, relativity and cosmology.* London: Dover.

Lightman, A. (2005). *The discoveries: Great breakthroughs in 20th-century science, including the original papers.* New York: Pantheon.

Penrose, R. (2005). *The road to reality: A complete guide to the laws of the universe.* New York: Knopf.

Timelines

A timeline is a visual sequence of related events arranged in chronological order and displayed on a vertical or horizontal line. Graphing events on a line in the order of occurrence shows the relationship between the events. Timelines might also include dates, visual illustrations, and written commentary. History is the subject most often addressed by a timeline, but timelines might also be used as a scheduling tool to estimate the time needed for the completion of a project or task.

The emergence of modern publishing technologies enables the use of visual enhancements to display on a line graph the same information that might first have been recorded in an ancient or medieval chronicle. In contemporary culture, the use of the Internet and self-publishing software enables the creation of online and digital timelines that go well beyond the traditional historical subject matter covering a broad range of topics that can include all aspects of modern life such as science, religion, culture, and politics.

Closely related to the science of chronology, timelines are used to show a sequence of events that occur in orderly succession from the past to the present and possibly into the future. Two broad categories of information appear in chronologies and on timelines. Relative events that are temporal address the organic evolution of the earth and human experiences. Absolute events, such as the origin of the universe and cosmic history, can also be represented on a timeline or in a chronology. Although the words *timeline* and *chronology* are often used interchangeably, the visual component of a timeline sets it apart from a chronology. Both timelines and chronologies locate historical events in time but, perhaps because of the visual component, timelines lend themselves more readily to popular use and expression than chronologies. Chronologies, making almost exclusive use of written text to list events with the accompanying dates, often become the basis for writing scholarly history.

Chronologies have existed since ancient times in the form of king lists that predate written history. Two of the best-known king lists are from Egypt and Samaria. Other well-known chronicles come from medieval England. These ancient and medieval chronicles have been incorporated into modern accounts of ancient and medieval history. For purposes of understanding and teaching history, timelines are a recent development. The construction and assembly of historical information on a timeline, although useful for communication and learning, is not typically thought of as scientific research.

The concept of placing events on a line graph to show their order of occurrence is based on a worldview that is closer to Newton's than to Einstein's. That might explain why timelines are more often used in the discipline of history than in physics. Although the concept of time is derived from the study of physics, the visual representation of time on a linear continuum is more closely related to the efforts made by historians to assemble chronologies that place events in the order of their occurrence with no attempt to measure the duration of events. Physics concerns itself with duration, the measure of time between two repeating events. Establishing the most accurate time measurement requires the use of Einstein's relativity theory. Timelines assume, as Newton did, that there is a single universal time order to events and that all events have a unique chronological order. Physics as a discipline refers to timescales rather than to timelines when presenting the succession of epochs from the past. In everyday life it is still possible and useful to assume a Newtonian view of the world, making timelines an important tool for communication and teaching.

Elaine M. Reeves

See also Bede the Venerable, Saint; Chronology; Chronometry; Diaries; Evolution, Organic; Stratigraphy; Time Capsules; Timetables

Further Readings

Cooke, J. (1981). *History's timeline: A 40,000-year chronology of world civilization.* London: Grisewood and Dempsey.

Daniel, C. (1987). *Chronicle of the 20th century.* Mount Kisco, NY: Chronicle Publications.

Giles, J. A. (1971). *The venerable Bede's ecclesiastical history of England. Also the Anglo-Saxon chronicle.* New York: AMS Press.

Scarre, C. (1993). *Smithsonian timelines of the ancient world* (Smithsonian Institution). New York: D. Kindersley.

Time Machine

The vision of being able to travel through time much like traveling through space became popular in science fiction in the late 19th century. Since then, many different ways of time travel have been envisioned, such as by the means of drugs, mind power, dreams, hypnosis, godlike superpowers, cryogenic freezing, or time machines. The modern notion of devices for traveling through time was introduced by the writer H. G. Wells. In his 1895 novel *The Time Machine* he described a motionless machine that allows its operator to go forward and backward to any point in time. Time traveling is described as a continuous movement that is experienced by the time traveler as an accelerated passing of time. Wells's vision of a time machine has since become a model in science fiction. Yet, the descriptions of time travel using time machines vary. For instance, in the film trilogy *Back to the Future* by Robert Zemeckis, a modified car serves as a time machine that enables movement through time in jumps whereby the time traveler experiences a sudden and abrupt shift from one point in time to another.

Not only in science fiction but in physics as well, the theme of time machines became an intriguing and seriously debated issue in the late 20th century. According to current technological possibilities, the construction of a time machine is not possible, yet its theoretical possibility has been avidly discussed over the past decades. It is widely accepted that, according to Albert Einstein's special theory of relativity, time travel to the future is in principle possible. This is explained by the phenomenon of time dilation that occurs at speeds close to the speed of light. A vehicle capable of moving this fast would serve as a time machine to the future. Furthermore, according to special theory of relativity, traveling faster than the speed of light would result in a reversal of causality; that is, events that happen in the future would have effects on the past. However, Einstein's theory also states that it would take an infinite amount of energy for an object to accelerate to a speed faster than light and thus rules out the possibility of time travel to the past. The question of whether a machine could be built that nevertheless enables time travel into the past is a contentious issue in today's physics. With reference to Einstein's general theory of relativity, proponents of time travel brought forth various possibilities of how a time machine to the past could work in theory. Skeptics claim, however, that the laws of physics prohibit time travel into the past.

General relativity gives another explanation for travel into the future. The theory predicts that gravity slows down time. This phenomenon has been put into practice in creating the Global Positioning System (GPS). Moreover, general relativity explains travel into the past. Kurt Gödel was the first to propose a solution to Einstein's field equations that implies this possibility. He showed that spacetime can form a loop; this became known as a closed timelike curve (ctlc). By traveling along such a ctlc one can proceed to an earlier point in spacetime, namely where the two ends of the timelike curve meet. Even though it is conceivable that ctlcs appear naturally in the universe, it is disputed whether a spacetime structure that would serve as such a pathway to the past could be created artificially by a time machine. Yet, one of the restrictions of time travel utilizing ctlcs is that one cannot travel to all points in time. Thus, it is impossible to reach a time before the closed curve was established.

The first hypothetical model of a time machine was suggested by Frank J. Tipler in 1974. With reference to a solution of Einstein's field equations found by Willem Jacob van Stockum in 1936, Tipler showed that the construction of a large rotating cylinder would produce a ctlc and therefore create a time machine. A spaceship flying on a spiral path around a so-called Tipler cylinder could travel backward and forward in time. However, it has been shown that this is not a realizable model for a time machine because the cylinder would have to be infinite in length in order to create a ctlc. A more viable model for a time machine was proposed in 1988 by Kip S. Thorne, Michael Morris, and Ulvi Yurtsever that makes use of a two-way traversable wormhole, which is a topological feature of spacetime that establishes a shortcut through spacetime. Although no evidence of existing wormholes so far has been found, its theoretical possibility according to general relativity lead Thorne and his coauthors to the thesis that a future generation capable of creating and maintaining a traversable wormhole could transform it into a time machine. For that, a time shift between the two ends of the wormhole has to be induced, caused either by special relativistic time dilation or general relativistic time dilation. The two ends of the wormhole then exist in different times and hence one could travel forth and back in time by passing through it. Manifold objections have been raised against the possibility of creating a time machine by establishing ctlcs by physicists as well as philosophers. Most notably, Stephen Hawking formulated in 1990 a chronology protection conjecture, stating that the laws of physics prohibit the actual existence of ctlcs and hence dismissed the idea of time travel to the past altogether.

Marcus Burkhardt

See also Novels, Time in; Space Travel; Time, Relativity of; Time, Reversal of; Time Dilation and Length Contraction; Time Travel; Time Warps; Wells, H. G.

Further Readings

Hawking, S. W. (1992). Chronology protection conjecture. *Physical Review, 46,* 603–611.

Morris, M. S., Thorne, K. S., & Yurtsever, U. (1988). Wormholes, time machines, and the weak energy condition. *Physical Review Letters, 61,* 1446–1449.

Nahin, P. J. (1998). *Time machines: Time travel in physics, metaphysics, and science fiction.* New York: Springer.

Tipler, F. J. (1974). Rotating cylinders and the possibility of global causality violation. *Physical Review, 9,* 2203–2206.

Time Management

The concept of time management applies in several different domains. In the sense of the scheduling of goods transport capacities, time management, with the goal of minimizing transportation costs, plays an important role for transportation companies. Time management in the coordination of timetables is highly important for railway companies because railway systems are often characterized by high-traffic density and heterogeneous traffic that is sensitive to disturbances.

The concept of time management also applies to the careful scheduling of manufacturing processes. This is especially important for companies that use a just-in-time approach to reduce inventories. Here the necessary parts for the following production step are produced and delivered right before they are needed; a mistake in scheduling can be quite expensive.

The concept of time management can be used in other areas, for example, to describe the organization of work time on the social level. Usually, however, the term is applied in the context of the individual use of time. A steadily growing number of books, articles, and seminars deal with this form of time management, and many companies spend huge amounts of money to improve time management by their employees.

Definition

An analysis of the concept of time management requires a closer examination of the separate concepts of management and of time. The word *manage* stems from the Italian word *maneggiare* (meaning to handle), which in turn originates from the Latin word *manus,* which again signifies "hand." Time management is most often used to describe the professional leading or supervising of a defined unit such as an organization or a business operation.

By knowing which options are available for achieving a specific goal, management can be better able to meet its objectives through planning, organization, and coordination of necessary resources, leading coworkers, and controlling results. In other words, management can be defined as the planning, organizing, directing, and controlling of everything necessary to achieve an intended goal.

But is the analogy to other kinds of management correct? There are different things that can be managed in the given sense: staff, money, natural resources, and many more. The question is whether time can be managed like natural resources. As the hundreds of entries in this encyclopedia testify, "time" is of philosophical interest as well as the subject of scientific investigation; furthermore, there is no simple definition of time. What can be said is that we experience the world in a way that allows us to differentiate between space and time.

Whereas process philosophers agree that the flow of time is a fact, philosophers of the manifold think that our experience of the flow of time is an illusion. Even though this question cannot be solved, it is a fact that time serves as an important reference quantity when thinking and communicating about different experiences during our lifetimes. In addition, a shared conception of time—whether time is real or constructed—allows us to coordinate our actions.

Yet at the same time it is important to note that we cannot save time in the sense of saving money or resources. We cannot store it and use it when needed. As individuals we cannot change the course of time.

Because we are not able to control time, we cannot manage it in the usual sense and the definition given above seems to make no sense. We have just the option of acting in a certain way with respect to the flow of time. In that sense, time management can be only the conscious planning, organizing, and controlling of one's own activities with respect to the flow of time.

History of Time Management

Historical Foundation

In premodern times, the understanding of time was strongly influenced by natural cycles and by religious beliefs and practices. Social interactions were organized based on the cycles that can be observed in nature, such as the phases of the moon.

Mainly as a consequence of the development of new instruments for the measurement of time, and in the course of the Industrial Revolution with its growing need for the coordination of economic activities, another understanding of time developed. With the evolution of large and automated factories, the usage rate of expensive machines became a crucial factor for business success, and the willingness to work on these machines at a specific time was an important factor for employment. In addition, the development of artificial light resulted in the extension of working time.

Even though there have also been attempts to set aside certain times as work-free—for example, in many countries Sunday as just a day of rest—more and more businesses also work then; for example, railroad companies, theaters, and restaurants.

As a tool and a symbol of this new understanding of time, clocks became common in every home in the second half of the 19th century. The standardization of time and the abandoning of "local times" orientated to the specific conditions of a particular place were other steps toward the easier use of time within the production process.

In an increasingly industrialized world it became more and more important to know the time and to be on time. To find time-saving work patterns was crucial for business success, and the corresponding scientific management approach of Frederick W. Taylor played an important role in maximizing profits. The mentality of finding the fastest way to finish a given task transferred to work that was done at home. As the 20th century progressed, more and more people began to wear wristwatches, and it became still easier to tell time and to organize life on the basis of the clock.

Origins of Modern Time Management

As a pioneer of modern time management, in the sense of planning and controlling one's own activities with the help of professional methods, Peter Drucker is among the most influential contemporary management authors. In his management book *The Effective Executive,* published in 1967, he allocates an important role to time management as one of the five talents that he identifies as essential for executives. As a basis for good time management, Drucker recommends the manager discover where his time actually goes and cut back on unproductive demands. In addition, he stresses the role of setting priorities. At the end of the book, Drucker discusses the art of making effective decisions. These topics are still important in modern time management.

Popularization and Development

In the following years a number of writers carried the subject forward. In the English-speaking countries, authors like Alec R. Mackenzie and Steven R. Covey gathered new ideas for the professional planning and controlling of one's own activities. In German-speaking countries, writers such as Lothar Seiwert published new books and articles.

At the same time, the subject grew in popularity. Covey sold more than 15 million copies of his book *The 7 Habits of Highly Effective People,* from the first publication in 1990 until now. In 1996, *Time* magazine named him one of the 25 most influential Americans. Seiwert sold more than 2 million copies of his books in 20 different languages and trained more than 100,000 people in time management.

Many organizations in the industrialized countries invested a lot of money to train their employees in the efficient use of time. In the year 2000 in Germany alone there were more than 30,000 people in the time management business, and more than 200 different books on the subject have been on the market with a revenue of about 5 billion euros.

In their publications, the new proponents of time management declared different aspects as being important for the sensible use of time. Two publications symbolize milestones in the development of contemporary time management and are discussed below.

In his 1972 book *The Time Trap: Managing Your Way Out,* Mackenzie gives a comprehensive idea of time management and discusses many methods to help managers to save time and be more efficient. The two factors that he sees as most important for the efficient use of time are: the management of oneself and the management of the work environment.

For the first task he recommends a "realistic self-appraisal," the use of a "time log," and the setting of realistic deadlines. For overcoming procrastination he refers to Norman Vincent Peale and recommends training oneself in the habits of making decisions on the first suitable occasion and of doing one thing at a time. Mackenzie also illustrates the importance of planning in the work process. The setting of priorities is explained with the help of the Pareto principle. In this context, Mackenzie stresses the importance of saying "no" to many of the projects offered as a key to effective time management. Some of his other suggestions include training in speed reading and avoiding the excessive use of memos. Along with stressing that delegation is an important organizing tool, Mackenzie also emphasizes the importance of being cautious in the use of the time of one's subordinates.

For the second task—the management of the working environment—Mackenzie develops different methods for preventing interruptions, such as the effective placement of one's secretary or executive assistant. Other aspects covered are the arrangement of the office, the establishment of a filing system, and the use of dictating equipment.

Nearly two decades later, in 1990, Covey published his influential book *The 7 Habits of Highly Effective People*. In contrast to Mackenzie, Covey concentrates on certain habits that he holds important for being effective. His key idea is that executives have to take care of their own habits before they can be good leaders and that their habits determine their effectiveness in the first place.

The first habit Covey recommends is learning to make a conscious choice of response to given circumstances ("Be Proactive"). A second important habit is having a clear idea of what one wants to achieve ("Begin With the End in Mind"). The third habit he recommends is to set one's priorities and act accordingly ("Put First Things First"). The fourth habit he stresses is the habit of thinking and acting cooperatively ("Win-Win"). As a fifth habit, Covey points out that an effective person needs to try to understand the standpoint of other people ("Seek First to Understand, Then to Be Understood"). Habit 6 grows out of the last two and is called "Synergize." According to Covey, the success of this habit is based on the two preceding ones. It rests on the idea that the creative atmosphere engendered by these habits allows far better results when people work together to solve a problem than when they work solo. As the final important habit for effectiveness, Covey recommends constantly preserving and improving one's own capacities ("Sharpen the Saw").

The development in time management was not limited to North America. An author especially important for the advancement of time management in Europe is Lothar Seiwert. In his 1984 book *Mehr Zeit für das Wesentliche* (*More Time for the Essentials*), Seiwert describes certain factors and techniques that he holds important for business success. These are the analysis of one's own strengths and weaknesses, having a clear plan for one's career, optimizing one's communication, and, finally, good time management.

In his book *The 1 × 1 of Time Management* (1989), Seiwert deals with factors that waste time (e.g., certain types of meetings); the use and methods of goal setting, and the use and tools of planning (e.g., follow-up charts); the advantage and the methods of prioritizing (e.g., ABC analysis); the optimal utilization of the output curve and of breaks; how to create productive hours; the value and rules of delegation; the optimization of the beginning and the end of the day; and the importance of self-discipline.

Until the middle of the 1990s the target group of time management literature and seminars was mainly executives. The authors in this period applied it mostly to work life. As shown in the examples, time management was understood primarily as a set of tools or habits to help executives to achieve business success in a shorter amount of time.

Time Management Today

In recent decades, time management advanced further. Time management today is not applied just to work, but to all of an individual's life. The target group of the corresponding literature and seminars broadened. Regular employees were included along with executives. Seiwert's publications show this change. In his book *Life Leadership* (2001), Seiwert distinguishes four areas of life (family and friends; work and achievement; body and health; meaning and culture). According to Seiwert, all of them need to be integrated into the new form of time management.

A closer look at the recent publications of major authors in the area of time management shows another change that went beyond adding new ideas. It was a change in perspective. Examples of this important transformation are demonstrated by American author Steven R. Covey and European author Lothar Seiwert.

In his book *More Time for the Essentials,* Seiwert focused on the persistent planning of time and the maximization of success in the field of business. Well-being was not considered or was just a small aspect. A decade later, in his 1998 book *When You're in a Hurry, Go Slowly,* Seiwert focused mainly on quality of life. Not acceleration but deceleration seems to him the key to this goal. He stresses the importance of a balance between work and free time. In his book *Don't Hurry, Be Happy* (2003) he goes a step farther. The book can be interpreted as an ode to idleness. Time management becomes a tool for maximizing well-being.

Stephen R. Covey's books show a similar development. As we have seen, his focus in *The 7 Habits of Highly Effective People* was on taking responsibility for being effective. In *First Things First* (1995) Covey stresses the importance of having a clear idea of what is important and what is not. In this book his focus is not on effectiveness but on well-being and life satisfaction. He asks, "How many people on their deathbed wish they'd spent more time at the office?"

In his 2004 publication, *The 8th Habit: From Effectiveness to Greatness,*" Covey extends this idea. In Covey's view, a new dimension is needed to deal with the challenges of the new knowledge-worker age. For Covey this dimension consists mainly of "finding of one's one sense/task of life." Finding it gives greater meaning to everything one does and makes a person more effective at the same time.

The Science of Time Management

As pointed out, time management is the subject of many publications and seminars. On the other hand, it must be said that the scientific basis of time management is small. Nevertheless, some studies investigate the subject, and Gary S. Becker's "A Theory of the Allocation of Time" (1965) builds an early theoretical framework for understanding the allocation of time in the modern world.

Several kinds of empirical studies on the subject of time management have been conducted: The first and most common type investigates the work and time management behavior of employees—especially in the field of management. One of the first studies, conducted in 1951, explored the working behavior of Swedish managers. The data show long work hours and little uninterrupted time for executives. Other studies examine a number of hypotheses; for example, based on behavioral decision theory and exploring the idea that people discount the consequences of their time management decisions. This assumption has been supported by research.

A second type of study explores the need for time management in specific areas, for instance in the field of health care. These studies explore and compare the need for time management competencies and the existing knowledge of time management, usually with the help of questionnaires. A third kind of study investigates the current use of different time management methods and the arrangement of time management training in specific contexts, such as in companies. A fourth type tries to discover important aspects of successful time management in the work environment.

A fifth type of empirical study tries to prove or disprove the efficiency of time management methods. These studies show different results.

A last type of empirical study tries to illuminate the relationship between the use of time management methods and certain human characteristics. A 1991 study examined the relationship between college grades and student use of time management methods. Time management was shown to be a better predictor than Scholastic Aptitude Test scores. Studies have also investigated relationships between time management, control, work–family conflict, and stress. Research on the interrelationship of academic stress, anxiety, time management, and leisure satisfaction has led investigators to conclude that adding time management to measures for anxiety reduction and leisure activities could be an effective strategy in reducing academic stress for college students.

Time Management in the 21st Century

Is professional time management useful in the 21st century? Five of the most common criticisms of time management are summarized here.

First, critics claim that some time management approaches pay little attention to human nature and that planning time in the ways proposed is neither possible nor useful. A closely related criticism is that the concept of time management perceives people as resources.

A second major criticism of time management is that it has the wrong goal—to encourage doing many things rather than focusing on one task—and that it therefore creates the problems it tries to solve. This critique is related to the claim that time management is for people who fear missing something. This leads back mainly to either the troubled relationship our society has with death, the attempt to escape from oneself, or the longing for a state of timelessness.

A third critique is that the concepts of time management are focused on the wrong thing. In this view, the new challenges caused by a dramatic change in work life cannot be mastered by individuals through the use of individual time management. What is needed is a change in the structuring of time on a societal level. Time management is accused of underestimating this need and of overcharging the individual.

A fourth criticism is that time management conceals a normative life concept. Even though it seems to be neutral, it actually defines certain goals of life, like business success, and it propagates a particular way of life.

A fifth line of criticism argues that time management doesn't keep its promise: "Who controls his time, has time." Karlheinz Geissler, one of the mayor critics of time management, gives four main reasons for this claim: First, that we cannot possess time; time does not vanish, we do. In his view, time management ignores or at least underestimates the use of the useless. Second, he argues that since we cannot posses or control time, attempting to do so results in controlling oneself. Time management training is nothing but a course in self-control. People become precision instruments, policemen of themselves. His third reason that time management doesn't keep its promise is that permanent time planning wastes time. Geissler's final reason points out that when using time management, planned spare time isn't free time—it has the touch of business.

What can be said in response to these points about time management? The critique that time management pays little attention to human nature makes an important point by saying that the planning of time should be limited by natural needs and cycles. The new concepts of time management take these points into consideration and the criticism is no longer valid. These new approaches try to incorporate research results about biorhythm, sleep, and recreation.

The second critique, that time management has the wrong goal—doing several things instead of focusing on one task—and that it creates the problems it tries to solve seems to be no longer a serious criticism. Recent books by Covey and Seiwert showed that doing many things is no longer the focus of time management. Yet it should also be said that some people do use time management for this purpose. The reasons may vary: from a disturbing relationship with death to an escape from oneself. But it is an incorrect use of time management that creates such problems, not time management itself.

The third criticism is that the concepts of time management are focused on the wrong things. The observation that many problems cannot be solved merely on the individual level is true, but it seems wrong to make this a criticism of individual time management. Although attempting to change the management of time on a societal the (e.g., through legislation) can be useful for the individual, it means interfering with the freedom to choose. In contrast to time management on a societal level, individual time management is a useful tool for dealing with the challenges of the 21st century without losing the freedom to choose (e.g., the freedom to decide when to work).

The fourth critique is that time management carries a hidden agenda in terms of promoting a normative life concept. To some extent this is normal since authors and speakers nearly always convey part of their own convictions along with their subject. But especially with the new developments in time management, these tendencies need to be looked at more carefully. Time management specialists should not automatically assume the stature of gurus who have answers to all of life's questions. But this is also true of a lot of advisory literature. When time management advice and methods are handled with care, they can offer useful tools for one's own life.

The important implication of the fifth criticism of time management, that it doesn't keep its promise of controlling time, is that time management does not claim to offer the total control of time. Time cannot be possessed. At the same time, life is not consistent and there will always be changes. Nevertheless, it seems useful to have a clear idea of one's own priorities and tasks. Without some kind of time management it would be even more difficult to act in a changing world.

Normal life offers new tasks every day. This can be buying food or clothing, but especially earning the money to purchase what we need and want. In the workplace there are even more responsibilities—be it participation in meetings or the preparation of reports. All of these tasks are directly or indirectly linked to human needs. We need to purchase food to satisfy our hunger; we want to be successful in the job to win acceptance or love.

While dealing with our tasks we must also respect the plans of others. This is especially true in the workplace. In that sense we need a basic planning of our tasks and our time to be able to fulfill them and to satisfy our needs.

Today certain reasons seem to make it even more necessary to plan and control our own activities and the use of our time. The first is the acceleration of life. A number of indicators show this development. In industry, product cycles are becoming shorter; even old movies are remade nearly twice as fast as the original film was produced. Tasks have to be done more quickly than before and speed is now an important factor for personal success.

A second reason is the tight social network that we are part of. We live in a highly interdependent working environment. To fulfill our responsibilities, we need preliminary work from others and we do preliminary work for others. The private lives of most people are highly interdependent as well.

A third reason for a growing need for personal time management is an ongoing time deregulation. The given time structure of our society vanishes. For the sake of jobs in a globalized world, more and more flexibility is demanded. Shift work has became normal and store hours extended. As a consequence, opportunities for activities with friends and family have decreased and coordination has become more difficult.

A fourth reason is a strong need for freedom of choice. Living in a democratic market economy means having many options. Many different political decisions can be voted on, countless activities can be done, and numerous products can be purchased. As a consequence, many options compete for the available amount of time.

A fifth reason for the growing importance of time management is that many people have started their own small businesses, and an increasing number of people are working from home (telecommuting). This development means workers are forced to be their own managers and to plan and control their own activities.

In addition, various empirical studies show negative side effects from a poor use of time. A majority of employees say that they have the impression that they need more time and that their health is impaired by time pressure.

According to the empirical evidence, it is still too early to know whether the effectiveness of different time management methods is proved or disproved. Overall, the studies seem to show that at least some forms of time management can be quite valuable. More research is needed, especially in regard to the efficiency of the different time management methods. Considering the number of negative consequences of the poor use of time, for example, the burnout syndrome, these studies seem to be worthwhile.

Reyk Albrecht

See also Clocks, Mechanical; Economics; Industrial Revolution; Perception; Time, Perspectives of; Time Poverty; Timetables; Watches

Further Readings

Adams, G. A., & Jex, S. M. (1999, January). Relationships between time management, control, work–family conflict, and strain. *Journal of Occupational Health Psychology, 4*(1), 72–77.

Becker, G. S. (1965). A theory of the allocation of time. *Economic Journal, 75*(299), 493–517.

Covey, S. R. (1990). *The seven habits of highly effective people: Restoring the character ethic*. New York: Fireside.

Covey, S. R. (2004). *The 8th habit: From effectiveness to greatness*. New York: The Free Press.

Drucker, P. F. (1967). *The effective executive*. New York: Harper & Row.

Green, P., & Skinner, D. (2005, June). Does time management training work? An evaluation. *International Journal of Training and Development, 9*(2), 124–139.

Kisa, A., & Ersoy, K. (2005, Winter). The need for time management training is universal: Evidence from Turkey. *Hospital Topics, 83*(1), 13–19.

Macan, T. H. (1994, June). Time management: Test of a process model. *Journal of Applied Psychology, 79*(3), 381–391.

Macan, T. H. (1996). Time-management training: Effects on time behaviors, attitudes, and job performance. *Journal of Psychology, 130*.

Mackenzie, A. R. (1972). *The time trap: Managing your way out*. New York: Amacom.

Orpen, C. (1994, July). The effect of time-management training on employee attitudes and behavior: A field experiment. *Journal of Psychology, 128*(4), 393–396.

Seiwert, L. J. (2001). *Life-leadership*. Frankfurt am Main & New York: Campus.

Seiwert, L. J. (2003). *Don't hurry, be happy*. Munich: Gräfe and Unzer.

Slaven, G., & Totterdell, P. (1993). Time management training: Does it transfer to the workplace? *Journal of Managerial Psychology,* Number 8, 20–28.

Tyler, K. (2003, November). Beat the clock. *HRMagazine, 48*(11), 103–105.

Timepieces

The term *timepiece* can refer to any device used for measuring time, including watches, clocks, and earlier devices such as the hourglass and the sundial. An amazing variety of timepieces have been produced throughout the ages, reflecting the ever-increasing importance of time and its measurement to humans in many different cultures.

Timepieces have long been recognized for their practical application. They have also been prized for their historical and artistic value, as can be noted by the preservation of antique timepieces in museums and their appeal as collectables. Early clocks—mostly affordable only by the wealthy—were often constructed of valuable materials and sometimes had unusual features such as animation.

But the concept of time, as well as the need to measure it, was likely not recognized by prehistoric humans. They relied on natural changes that they could observe—daylight and dark and seasonal changes—adjusting to them to ensure their survival. In that sense the celestial clock can be described as the initial natural timekeeper.

The first commonly used artificial timepiece was the sundial, which enabled the measurement of time by the sun's movements. Its use began as early as 3500 BCE, with the invention of the gnomon, angled so that a shadow would be cast on a base marked with the hours.

An increased emphasis on accurate time measurement can be traced to the Renaissance period, and that emphasis appears to be tied very closely to the social, business, and scientific advancements seen during that time. The earliest known clocks were turret clocks in towers, striking only the hour. An example can still be seen in Britain's Salisbury Cathedral clock. In the 15th century, clocks driven by springs were developed, enabling more portability. The mid-17th century marked the first use of the pendulum, the concept of which has been attributed to Galileo Galilei.

In 1840, the spring and pendulum were still in use when the first battery electric clock was invented. A completely battery-driven clock was developed in 1906, and domestic use became common. The first use of the quartz crystal in 1929 allowed for even greater accuracy, and it is still used in most clocks and watches today.

Eventually it was commonly agreed that there needed to be some standardization of time so that it could be accurately measured over all the parts of the globe. The system of Greenwich mean time, dividing the world into 24 time zones, was agreed upon as an international standard in 1884. Coordinated Universal Time (UTC) has been used for scientific purpose since 1972. The most accurate clocks in existence today are the atomic clocks used by the United States Naval Observatory.

For most of mankind's existence, time has been the main measurement that people make on a regular basis. The ability to keep track of time accurately in today's fast-paced world with its increasingly international connections has become even more important. As new timepieces continue to be invented, human beings will continue to acquire them. At the same time, it's not surprising that historical timepieces generate considerable interest.

Betty A. Gard

See also Astrolabes; Hourglass; Observatories; Planetariums; Sundials; Time, Measurements of; Watches

Further Readings

Barnett, J. E. (1998). *Time's pendulum: The quest to capture time from sundials to atomic clocks.* New York: Plenum.

Christianson, D. (2002). *Timepieces: Masters of chronometry.* Buffalo, NY: Firefly Books.

Time Poverty

In recent decades, scholars from a range of disciplines including economics, sociology, psychology, and leisure studies have been exploring the question of how Americans spend their time. How much time do we devote to paid labor, over the course of a year and over the course of a life? How much time do we have for leisure? How much time do we spend with our children, or in our families? How much time do people devote to community service? And how have the amounts of time devoted to these activities changed over time? Of late, activist organizations and movements have sprung up to combat what many define as a crisis of *time poverty* in America—that is, not having enough time to do all the things one wants to do. More specifically, many scholars define time poverty as a shortage of leisure time or as a shortage of time "to care"—for personal health and spirituality, families, community, and the environment.

This entry provides an overview of definitional and measurement issues related to social scientific studies of time, presents empirical data on uses of time across place and time, and explores consequences of time poverty, overwork, overscheduling, and time pressure on health, relationships, children, communities, and the environment. The conclusion contains an examination of old and new approaches to combat time poverty, including work by labor unions and activist organizations like the Simplicity Movement, the Slow Living Movement, and the "Take Back Your Time" Day organization.

Overview

Accompanying societal shifts in Western countries from industrial to service economies is a shift in how much time people spend in paid labor. In both Europe and the United States, scholars have drawn attention to rising hours in paid labor resulting in the social problem of time poverty, also referred to as time deprivation, time scarcity, time famine, the time crunch, and the time squeeze.

Although the issue is prominent in Europe, evidence suggests that American workers have long clocked more hours of paid labor than their European counterparts, and the gap is widening. Juliet Schor started a national conversation with her book, *The Overworked American,* in which she documents increasing work hours for Americans since the 1960s. More recently, she uses Current Population Survey (CPS) data to present a striking trend: Between 1973 and 2000, the average American worker added an additional 199 hours to his or her annual paid labor schedule (2003). This translates into 5 additional weeks of work per year if one assumes a 40-hour workweek. Not all scholars agree with Schor's measurement of work time. Some scholars argue that leisure time has increased for individuals. However, recent evidence suggests that when households are the unit of analysis, a rising time squeeze is evident. More households are headed by single parents, primarily women, and dual-earner couples; hence, overall time available for activities outside of work has grown more scarce.

Why are Americans working longer hours in recent decades? Juliet Schor's work points to demands of greedy work institutions and rising consumerism. Other scholars suggest only some Americans are overworked, primarily those employed in large firms, those with high levels of education, and those working on the highest rungs of the occupational ladder. Quantitative data analyses suggest a bifurcated workforce with overworked employees and underemployed workers. In the past two decades, the number of people working more than 50 hours per week increased, while the number working less than 30 hours also increased. In short, the economy and employers benefit if some workers have high demands and excessively long days, while other workers have jobs that fail to provide enough time on the job and money to meet workers' needs. The rise of part-time work is troublesome if employees are working part-time because of the lack of full-time jobs. Employers reap major advantages by having a high percentage of employees in part-time work, including having a larger reserve workforce, paying lower hourly wages, and providing fewer benefits. However, for some workers it takes two or more part-time positions, some not captured in official statistics, to make ends meet. For those workers, a full-time position with benefits may be more desirable but less attainable in the current economic landscape.

Beyond daily or weekly work hours, scholars have measured time spent at work over the course of a year. The United States is the only industrialized country without guaranteed vacation time. Hence, the Bureau of Labor Statistics reveals that Americans average 8.1 days of vacation after 1 year on the job, and 10.2 days after 3 years. Approximately 26% of American workers take no vacations at all. Workers in several European nations, in contrast, are guaranteed 4–5 weeks of paid vacation each year (and sometimes more with collective agreements).

What does time poverty look like if we compare women and men, lower-class workers and upper-class workers, or racial/ethnic minorities and whites? In her now classic work, *The Second Shift,* Arlie Hochschild calculated that if paid labor and unpaid labor in the home were combined, women worked an extra month of 24-hour days per year when compared with men. More recent evidence suggests that the gender gap in leisure persists. In part because of continuing inequities in the gendered division of labor in the home, men have far more hours of "free time" than do women. In addition, gender differences exist in the experience of free time. Women's leisure time or "free time" is often contaminated by household chores and interrupted by children's needs.

Given their location in the secondary labor market and informal economy, poor and minority Americans are least likely to have protections against overwork, and least likely to have paid leave options. The "contingent" workforce, composed of part-time and temporary workers, includes 30% of all U.S. workers and consists primarily of women and people of color. In addition, those at the lower end of the socioeconomic hierarchy are less likely to have flexible or elastic time on the job. For example, executives can have secretaries reschedule appointments so they can attend a child's soccer game. Those secretaries, or factory workers punching a time clock, are less able to rearrange work time for children's activities, doctor's appointments, or parent–teacher conferences.

Beyond Work Hours: Perception and Experience of Time

While data on changes over time in relative hours devoted to work, family, and leisure are compelling, of equal interest is the perception of overwork, which also leads to the experience of time poverty or time famine. Recent studies show one in three workers is chronically overworked, but a higher percentage, more than 54%, feel overwhelmed by how much work they must complete. The perception of being overwhelmed is a critical new area of study. Beyond analyses of time poverty is scholarship on how we experience time in a fast-paced, global, 24/7 economy full of electronic gadgets, commercial products, and more "stuff" in general. One skill workers must possess to survive in this environment is multitasking, which also contributes to feeling overworked and overwhelmed. Many people perceive a decreased sense of time, even if actual time spent in an activity, for example, leisure, is unchanged. The question of how to measure quality time is an important one for time scholars in the future.

New concepts that capture quality of time are evolving. Some suggest we are experiencing more "dead" time or time spent in an activity not inherently fulfilling or satisfying or pleasurable. In particular, the Internet and proliferation of electronic gadgets and media are viewed as compromising the amount of "live" time we have. *Time estrangement* refers to the absence of meaningful activity. Work along these lines concerns itself not with how much time we spend at various activities, but rather with how often we are engaged in activities that allow us to be fully and deeply engaged in life. *Time thievery* refers to unpaid hidden work, like commuting, phone solicitations, tax preparations, conflicts with insurance companies, and arguing with children over homework. These are often viewed as unnecessary activities that erode our experience of quality time.

Consequences

Consequences of time poverty are far-reaching, influencing productivity, personal health, personal relationships, children's well-being, and the strength of neighborhoods and community organizations. Ironically, the more hours people clock at work over the course of the year, the less productive they are likely to be. In an interesting experiment at SAS, a private computer software company in an industry notorious for long work hours, employers began limiting weekly work hours. Starting with CEOs and eventually incorporating all employees, they reduced hours to 40 per week, then 35. The company switchboard was turned off at 5:00 p.m. and the gates locked at 6:00 p.m. In consequence, there were fewer programming errors, programmers were more alert, and millions of dollars were saved because of low employee turnover. Other examples exist, both historical and contemporary, of shorter workweeks leading to increased productivity.

In general, overwork contributes to a range of health problems for Americans, including obesity induced by lack of time for exercise and proper diet, high stress levels, and sleep deprivation. Evidence suggests that annual vacations reduce the risk of heart attacks in men and cut women's risk of death from heart disease in half. In particular, a sense of "time urgency" or time pressure leads to burnout, stress, and a range of mental health problems including anxiety and depression. Given this situation, perhaps it is not surprising that economist David Korten refers to our high-consumption, fast-paced economy as a "suicide" economy. The World Health Organization reports that by 2020, clinical depression is expected to outrank cancer and follow only heart disease as the second greatest cause of death and disability worldwide. Since those experiencing overwork are far more likely to exhibit symptoms of depression than other employees, solving the problem of overwork is necessary for improving the health of employees.

Arlie Hochschild's work on the second shift documented relationship problems experienced by couples who must conform to a job culture in which time for relationships and families are secondary. In particular, much evidence exists to highlight how stresses related to time poverty can have negative influences on children's health and wellbeing. Beyond the impact caused by the time famine for parents is the separate issue of time famine for children. In the last three decades, children have lost about 12 hours per week of "free time." Play as an activity has declined 25% overall among children, and 50% for unstructured outdoor activities. A trend in overscheduling, especially for middle-class and upper-class children, has reshaped the landscape of childhood. Of particular concern is the loss of sleep experienced by children, and especially teens, in the past three decades. Consequences of a speeded-up, heavily structured environment include stress, anxiety, and sleep deprivation.

For the past two decades, social critics have decried the decline in civic engagement. In his book *Bowling Alone,* Robert Putnam presents evidence of a trend toward less involvement in community and civic causes such as the PTA or NAACP. Whether the hard numbers exist to back up Putnam's assertion is unclear. What is clear, however, is the extent to which, at a local level, community organizations are competing with workplaces, families, and electronic media (e.g., television, the Internet, video games) for a share of increasingly scarce time needed to keep their organizations afloat.

Finally, time poverty has repercussions for the environment. Busy Americans have less time to recycle, less time to shop in local markets, and are more likely to consume fast food, buy processed foods, use disposable "convenience" items, and engage in online ordering. All of these practices have major environmental consequences and contribute to higher rates of pollution, full landfills, contaminated water, and perhaps even global warming. In short, those who spend fewer hours at work report behaving in more ecologically sustainable ways. In addition, certain forms of convenient transportation, like automobiles, have replaced public transportation, bike riding, and walking in a time-poor society. Environmental consequences include air, noise, and water pollution, along with solid waste from abandoned cars.

Solutions

Proposed solutions for time poverty exist at both micro and macro levels, from individual-level coping strategies to community activism to changes in public policy and the economy. At an individual level, a self-help industry has emerged to help people become more "efficient" with their time and to manage competing demands better. Grassroots organizations have sprung up worldwide to support advocates of slow living. The Slow Food Movement began in Italy, and now claims 80,000 members worldwide. Other organizations connected to a "slow" movement champion slow travel, slow schools, and slow cities. The United States is ground zero for the Simple Living Network and the Voluntary Simplicity Movement. While these initiatives can raise awareness of time poverty and provide support for alternative ways of living, larger structural-level solutions are also proposed to solve time poverty.

Currently, the push to rein in time on the job seems to come from activist citizens more than labor organizations. However, a look back in time proves illustrative for understanding what is possible. Peoples in industrial nations, led by the United States, long viewed one accomplishment of capitalism and industrialization as more money and more time. In effect, higher wages and fewer hours on the job were viewed as a mark of progress and a worthy goal. Aristotle wrote, "We work in order to have leisure," and throughout the 19th century, his vision was prominent in certain circles. In 1926, the American Federation of Labor made a commitment to shortening hours of labor—first to an 8-hour, 5-day week; next to a 6-hour, 4-day week. In 1930, W. K. Kellogg implemented a 6-hour day, allowing workers more time with family and in the community. Leisure infrastructures began to form, and public facilities (e.g., parks, community centers) flourished. In part because of the Great Depression, legislation was introduced into the U.S. Congress to set the workweek at 30 hours, with "penalties" for overtime.

This bill, the Black-Connery Bill, was passed in the Senate in 1933 but failed in the House. Fast-forward 75 years. Today, the push for shorter workweeks and improved quality of time is limited to smaller segments of labor and comes largely from people and organizations outside of labor and government. In terms of labor, the AFL-CIO has been at the forefront of pushing for family-friendly legislation. High rates of burnout in certain professions, like nursing, have influenced unions to fight unchecked escalating work hours in the health care industry, especially mandatory overtime for nurses. The service industry is not exempt from problems of overwork, especially with the rise of a 24/7 economy in which service providers are expected to work around the clock. In 2000, 37,000 telecommunications workers went on strike to protest required overtime. Certainly, the passage of the Family and Medical Leave Act in 1993 was a step in the right direction. But with only 12 weeks of unpaid leave guaranteed for new parents or a health crisis, the U.S. policy falls dead last in terms of provisions when compared with other industrialized (and some nonindustrialized) nations. All other industrialized countries provide some form of paid leave, and generally for longer periods of time. Of course, Sweden's policy is the crème de la crème, and provides a stark contrast to the inadequacy of U.S. policy. Swedish parents are entitled to 18 months of paid leave (with at least 3 months mandatory time for Dads, although couples can split it any way they like), and shorter workweeks until children are 8 years old. Even tiny Estonia manages to provide 18 months of paid leave, while Bulgaria provides 2 years of paid leave and an additional year of unpaid leave.

For the most part, the business sector has resisted efforts to rein in work hours or provide more leave time for workers. Hence, major changes at the level of political economy might ultimately prove most valuable. Former Harvard and Stanford Business School professor David Korten argues that Americans have forgotten the purpose of an economy. In his view, the purpose of an economy is to help us live fully and well. Time poverty results from a corporate global economy centered on a global financial system. In this system, government policies that speculators and businesses view as unfriendly to their interests, such as living wages, environmental protections, and reduced work hours, are resisted. In his view, combating time poverty and its debilitating consequences requires a shift in ideology, from economic decisions based purely on financial values to those based on life values. This involves changing the rules of the marketplace to honor full cost pricing and eliminate market-distorting subsidies that promote financial gain but are bad for worker health, relationships, child well-being, communities, and the environment.

While a shift in ideology and change in labor market practices may seem impossible to accomplish, the tide is turning as activist organizations press for change. John de Graaf reports on a new agenda for free time called It's About Time. Several organizations, including Take Back Your Time, Work to Live, and Mothers Ought to Have Equal Rights, have formed a coalition to push for public policies that provide time to care. In addition to paid parental leave and sick leave for workers, the coalition lobbies for more paid vacation, including an election day holiday, limits to compulsory overtime, better part-time work options with prorated benefits, and living wages. De Graaf recalls the great strike of 1912 by the women textile workers of Lawrence, Massachusetts. The overworked, underpaid women carried signs that read "We Want Bread, and Roses Too." More Americans are actively resisting time poverty. They want bread, the symbol for enough money to live, but also roses and the time to enjoy them.

Susan W. Hinze

See also Economics; Futurology; Marx, Karl; Psychology and Time; Time, Perspectives of; Time Management

Further Readings

de Graaf, J. (Ed.). (2003). *Take back your time: Fighting overwork and time poverty in America.* San Francisco: Berrett-Koehler.

Epstein, C. F., & Kalleberg, A. L. (Eds.). (2004). *Fighting for time: Shifting boundaries of work and social life.* New York: Russell Sage.

Hunnicutt, B. K. (1988). *Work without end: Abandoning shorter hours for the right to work.* Philadelphia: Temple University Press.

Jacobs, J. A., & Gerson, K. (2004). *The time divide: Work, family and gender inequality.* Cambridge, MA: Harvard University Press.

Robinson, J. P., & Godbey, G. (1997). *Time for life: The surprising ways Americans use their time.* University Park: Pennsylvania State University Press.

Schor, J. B. (1992). *The overworked American: The unexpected decline of leisure.* New York: Basic Books.

Time-Release Medications

Time-release (also *timed-release*) medications are designed to increase the duration of the drug's action. "Time-release" is commonly understood to mean medication that delivers constant amounts of the drug that it contains over an extended period of time, or that releases its ingredients gradually to produce a sustained effect; for example, a capsule in which the casing dissolves in sections, releasing dosages at predetermined intervals. In other words, time-release medications are formulations that control the rate and period of drug delivery. Although there are many drug delivery devices or drug forms that deliver medication over an extended period of time (e.g., skin implants, patches), the term *time-release* is generally used to describe orally administered medication. The most direct effect of time-release medication is that instead of having to take several doses per day to get the therapeutic effect, one can take a time-release medication once a day, every 3 days, or even once every few months. Being able to take a pill once a day instead of four times or more, for example, can certainly improve a patient's compliance with a drug regimen. That is, it's often easier to remember to take fewer doses of medication. Examples of such medications include time-release pills that reduce the number of doses required for pain relievers and antidepressants.

Rationale for Time-Release Medication

Some drugs are inherently long lasting and require only once-a-day oral dosing to maintain adequate drug blood levels and the desired therapeutic effect. Many other medications, however, are not inherently long lasting and require multiple daily dosing to achieve the desired therapeutic results. Multiple daily doses are inconvenient for the patient and can result in missed doses, made-up doses, and noncompliance with the medication's regimen.

Almost all medications marketed today are initially in what is called "immediate-release" or "rapid-release" preparations. These are medications that disintegrate and dissolve in 5 or 10 minutes. Immediate-release medications produce a relatively rapid and high concentration of the drug in the body (a burst), followed by an exponential decline in levels of the drug in the blood, a peak and valley (trough) effect. So when conventional immediate-release medications are taken on schedule, using more than one daily, they cause sequential drug blood-level peaks and troughs associated with the taking of each dose. When the doses are not taken on schedule, the resulting peaks and troughs produce less than optimal drug therapy. For example, if doses are administered too frequently, minimum toxic concentrations of the medication may be reached. If, on the other hand, doses are missed, periods of subtherapeutic drug blood levels (those below the minimum effective concentration) may result, with no benefit.

On the other hand, a typical time-release medication provides an immediate release of the drug that promptly provides the desired therapeutic effect followed by gradual release of additional amounts of the drug to maintain this effect over a predetermined period of time. Many of these medications are formulated in such a way that the active material is coated with some relatively insoluble material or film. So when we take them, the upper coating or film releases very slowly in the body with the slow release of active material over a period of time. Thus, the advantages of time-release medications include less fluctuation in drug blood levels, less frequent dosing, enhanced convenience and compliance, reduction of adverse side effects, and reduction in overall health care costs. The potential disadvantages include the possible toxicity or nonbiocompatibility of the materials used to enable the time-release properties of the medication, undesirable by-products of degradation of those materials, lack of control of dosage once ingested (once ingested, time-release medications deliver treatment continuously, rather than providing relief of symptoms and protection from adverse events solely when necessary), dangers of high drug-delivery levels, and toxicity resulting from any loss of integrity of the release characteristics of the medication.

Terminology

Over the years many terms and abbreviations have been used to refer to medications designed to release their drugs in the body at a predetermined, rate, duration, and/or location to achieve and maintain optimal therapeutic drug blood levels. These include: controlled-release (CR), continuous-release (CR), delayed action, delayed-release, extended-release (ER, XR, XL), prolonged-release, prolonged-action, slow-release (SR), and sustained-release (SR). It is common for these terms to be used interchangeably, sometimes resulting in confusion about their exact meaning and whether there are differences among them. There are indeed technical differences. For example, "extended-release" refers to medication that allows at least a twofold reduction in dosing frequency as compared with conventional drugs; "delayed-release" medications are those that release the therapeutic drug at a time other than promptly after administration.

The United States Pharmacopeia (USP) recognizes the use of the term "modified-release" to embody the terms in common use today (controlled-release, extended-release, time-release, etc.) and defines modified-release medication as any medication or other dosage form having drug-release features based on time and/or location that are designed to accomplish therapeutic convenience objectives not offered by conventional or immediate-release dosage forms.

History

Development of time-release technologies began many years ago. In fact, in 1952, SmithKline and French introduced the first time-release medication, Dexedrine (dextroamphetamine sulfate) Spansule (a time-release capsule prepared so that an initial dose is released promptly and the remaining medication is released gradually over a prolonged period). Since then, several modified-release products based on different technologies and processing techniques have been developed that can be administered via different routes, namely, oral, transdermal (absorbed through the skin), ocular, parenteral (injectable), vaginal, and so on. Different mechanisms of release have also been suggested and explored.

Some highlights of modified-release (time-release) oral solid medication developed in the pre-1970s are:

- The Spansule (coated/uncoated drug beads in a capsule) in 1945
- Lontab (tablets by Ciba) in 1950
- Duplex (film coated tablet between the core and external layer) in 1959
- Duretter (plastic matrix dosage form) in 1959
- Controlled-release systems (1970–present)

Many early pioneers worked on the development of early time-release medication. One such pioneer in the 1950s was Hans Lowey. He developed a so-called slow-release medication, which was a salt tablet for troops in the Korean War. The troops, who were taking salt to retain water, often became ill by taking large doses at one time. Lowey enclosed salt granules in cellulose pellets, and compressed them into tablets that dissolved over 10 to 12 hours. In 1953, Mr. Lowey used the same principle to enclose nitroglycerine, a drug used to treat angina attacks. By releasing small quantities of the drug into the bloodstream over a sustained period, instead of in one large dose, the new tablets made it possible to use nitroglycerine as a preventive treatment.

Another pioneer in the field of time-release or modified-release medications was Alejandro Zaffaroni, who coined the term *therapeutic system* to designate pharmaceuticals that delivered their drug at a specified rate in the human body for a specified period of time. He founded the firm called the ALZA Corporation, in 1968, where he developed various types of controlled-release drug delivery systems (e.g., Glucotrol, for non-insulin-dependent diabetes; Duragesic, for severe chronic pain; NicoDerm CQ, for smoking cessation).

In recent years, controlled drug-delivery formulations and the materials used in these have become much more sophisticated, with the ability to do more than simply extend the effective release period for a particular drug. For example, some controlled-release systems can respond to changes in the biological environment and release medication based on these changes. In addition, materials have been developed that could lead to targeted delivery systems, in which a particular medication can be directed to the specific cell, tissue, or site in the body where the drug it contains is most needed. For example, nanotechnology can be used to provide controlled release of drugs (e.g., to the eye to treat diseases such as glaucoma) by combining biodegradable nanoparticles with the drug. Work has been done on the development of an implanted microchip device and wireless technology to actively control the release of drugs in the body over a prolonged period of time.

Examples of Time-Release Medication

Most time-release medications are tablets and capsules designed to deliver drugs to the circulating blood over an extended time period. For example, aspirin extended-release tablets dissolve, after ingestion, at the following rate:

Time (hrs)	Amount Dissolved
1.0	15%–40%
2.0	25%–60%
4.0	25%–75%
8.0	not less than 70%

Some other examples of time-release (extended-release) medication are:

- Compazine (prochlorperazine paleate) Spansule capsules, which consist of coated pellets formulated to release the initial dose promptly with additional drug for prolonged release. This has been used to treat nausea and vomiting.
- Desoxyn (methamphetamine hydrochloride) Gradumet tablets, which consist of the drug impregnated in an inert, porous, plastic matrix. The drug leaches out as it passes slowly through the gastrointestinal tract. The expended matrix is secreted in stool. This has been used for treating Attention Deficit Disorder (ADD).
- Naprelan (naproxen sodium) Controlled-Release tablets; this is a rapidly disintegrating tablet system combining an immediate-release component (released within 30 minutes) and a sustained-release component of microparticles that are widely dispersed, allowing absorption of the active ingredient and maintaining blood levels of the drug over 24 hours. This has been used for the management of mild to moderate pain, fever, and inflammation.
- Toprol-XL (metoprolol succinate salt) tablets consisting of drug pellets coated with cellulose polymers compressed into tablets; used for high blood pressure, angina, and heart failure.
- Quinidex Extentabs (quinidine sulfate) tablets produce extended release of medication by using a hydrophilic matrix that swells and slowly erodes. This drug has been used as an antiarrhythmic.

Chronotherapy-Release Medication

Closely related to time-release medications are the relatively newly developed chronotherapy-release medications. Until recently, it was thought that it did not matter when medications were taken, as long as they were taken. As is well known now, the human body has an internal biological clock, and its biochemistry can vary according to the time of day, month, or year, as well as the phases of the sleep cycle. Studies are starting to show that medication can be more effective if it is taken following these rhythms. Indeed, heart attacks, asthma, and joint pain from rheumatoid arthritis are all more likely to strike in the early hours of the morning because of circadian rhythms (the daily internal timing system that affects the bodily functions). Pharmaceutical companies have started developing medication to work with our biological clocks. Such drugs are called chronotherapy-release medication. These vary the dose released according to the time of day (or night) when it is most needed. For example, a medication called InnoPran XL (propanolol hydrochloride) is designed to be taken at bedtime but starts working in the morning when the blood pressure is highest. Also, two chronotherapy-release medications that are taken to control high blood pressure (Covera-HS and Verelan-PM) delay release after they are taken at bedtime for 4 to 5 hours and then have an extended release for 18 hours.

Jennifer Papin-Ramcharan

See also Chemistry; Clocks, Biological; Diseases, Degenerative; DNA; Dying and Death; Gerontology; Heartbeat; Longevity; Medicine, History of; Senescence

Further Readings

Allen, L. V., Popovich, N. G., & Ansel, H. C. (2005). *Ansel's pharmaceutical dosage forms and drug delivery systems* (8th ed.). Philadelphia: Lippincott Williams & Wilkins.

Banker, G. S., & Rhodes, C. T. (2002). *Modern pharmaceutics*. New York: Marcel Dekker.

Kydonieus, A. (1992). *Treatise on controlled drug delivery: Fundamentals, optimization, applications*. New York: CRC Press.

Ranade, V. V., & Hollinger, M. A. (2003). *Drug delivery systems* (2nd Ed.). Boca Raton, FL: CRC Press.

Robinson, J. R., & Lee, V. H. L. (Eds.). (1987). *Controlled drug delivery: Fundamentals and applications*. New York: Marcel Dekker.

Timescales, Physical

The science of physics encompasses many orders of magnitude. This fact is witnessed impressively by the three most central entities of physical law—length, mass, and time. For example, the *length* or *size* of objects covered by experimental physics ranges approximately from 10^{-5} meter = 1 *Fermi,* the distance between two elementary particles in the atomic nuclei, to 3×10^{25} meters (m), the diameter of the universe. Flanked by these cornerstones one finds characteristic lengths such as the distance between two atoms in a solid (a few 10^{-10} m), the average distance between two air molecules at normal pressure and room temperature (1 µm = 10^{-6} m), and the thickness of a human hair, which is typically about 60 µm = 6×10^{-5} meter. In comparison, the diameter of the earth is about 13,000 kilometers (km), or 1.3×10^{7} m; the distance to the sun measures 150 million km (1.5×10^{11} m), and the distance to the next star, Proxima Centauri, is 4×10^{16} m.

The concept of *mass* comprehends an even wider scope: Between the mass of an electron (9×10^{-31} kg) and the estimated mass of the universe (10^{-42} kg), there is an incomprehensible gap of 72 orders of magnitude. For example, a protein molecule weighs about 10^{-21} kilograms (kg), and a bacterium amounts roughly to 5×10^{-16} kg. One cubic centimeter of air at normal pressure and room temperature weighs 1 milligram (10^{-6} kg). Of course, the laws of motion also apply to very heavy objects such as airplanes (100 tons = 10^{-5} kg), or for the revolution of the earth (6×10^{24} kg) around the sun (2×10^{30} kg).

The range of the third fundamental entity of physics, *time,* is the subject of this article. Similar to length and mass, the concept of time obeys many orders of magnitude, or *timescales,* varying from the rapid electron dynamics in the atom (10^{-18} s) to the slow dynamics of cosmology (10^{-17} s). The 35 orders of magnitude in between—a factor of one hundred million billion billion billions!—host the full variety of microscopic and macroscopic phenomena.

The diversity of physical timescales is like that of physics itself. It cannot be the aim of this entry to describe every possible temporal dependency of physical interactions, as this would imply reducing the whole of physics to a few pages. Instead, it presents an overview of a selected number of characteristic timescales in the form of a viewgraph (Figure 1), where each time is representative of certain classes of physical events (e.g., the cosmological scale or the mechanical scale). Following the time arrow in Figure 1 from the very slow to the very fast, every timescale is specified by important examples governed by physical law. This entry will furthermore explain how our perception of time is related to the perception of other physical entities, which allows us, for example, the use of the spatial coordinates of the clock's hands as a measure for time. Particular attention will be paid to the occurrence of periodic events in nature, which are the basis of any type of time measurement. It will turn out that our human definition and classification of time is in fact the natural result of our limited senses, determined by the physical conditions we are encountering on earth.

Time Mapping and Periodicity

Time measurements are at the heart of physical experiment. In order to characterize the temporal evolution of a physical state, it is necessary to know the time during which the observed change occurs. Humans, however, do not possess a specific organ for the measurement of time flow—time cannot be measured directly. If we want to know how much time has passed, it is necessary to refer to other entities that are quantitatively more accessible to us, such as the position of an object. When we move, for instance, we cross a certain distance within a certain interval of time. This relation is captured by the physical definition of velocity and its unit: meter per seconds, or kilometers per hour. At a constant velocity, the crossed distance is directly proportional to the passed time, which implies that the physical entity *length* can be used as a measure for the entity *time*. In fact, whenever we observe moving objects, say, a train passing us with a constant velocity, or a cup falling off the table, or the hands of our watch moving with respect to the marks and numbers on its face, we compare the change of the spatial coordinates with the flow of time. This mapping also works in the opposite direction; for example, we conveniently denote distance in terms of traveling time when we say, "Montreal is about 5 hours away from Toronto."

In our daily experience, the flow of time is linear, meaning that it passes constantly and independently of our recognition. It shall be but mentioned here that neither the linearity of time flow, nor the linear relation between time and velocity holds for very fast objects—a rather counterintuitive result owed to the theory of relativity. The speed of light can in principle not be exceeded by any object, and in fact for objects moving with a velocity close to the speed of light, time passes more slowly. Also, if a velocity is not constant but changes with time, the observation of time flow via spatial measurements becomes more complicated, if not impossible. The relation between space, time, and velocity is then arbitrated by the mathematical operation of integration, and the velocity as the quotient of "distance per time" applies to average velocities only. Nonetheless, it is clear that the physical timescales are closely related to a discussion of motions and velocities, which will play an important role later in the discussion.

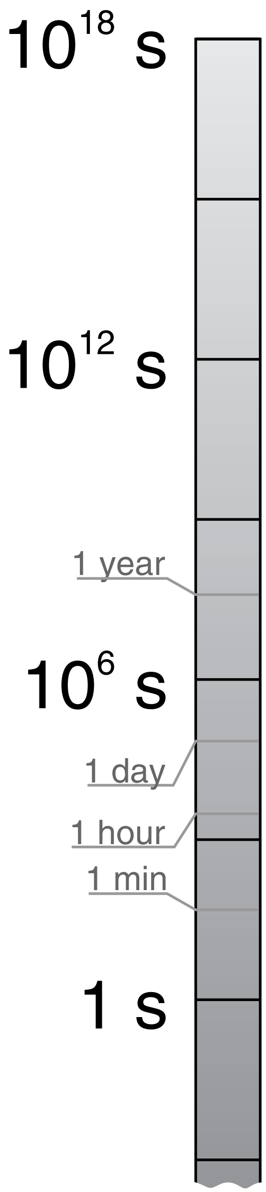
Although our normal temporal experience is linear, time is often measured against periodic events or motions, such as the oscillation of a pendulum or the rotation of the hands of a clock, the vibration of a resonantly excited quartz crystal, or the frequency of an electromagnetic wave emitted from an atom. The analysis of physical timescales is thus also strongly correlated to the discussion of frequencies, the unit of frequency being *1 Hertz* (1Hz) = 1/s (one oscillation per second). The favorability of periodicity for the measurement of time is owed to two facts. First, many events in nature do in fact occur in a regular, repetitive manner—from the very small (e.g., the oscillation of an electron around the atomic nucleus) to the very large (e.g., the revolution of celestial bodies). Two very important cycles both for biological evolution on earth as well as human history are the rotation period of the earth and the duration of the earth's revolution around the sun. The corresponding time intervals, one day and one year, have been synchronized against each other by, for example, the Julian calendar and more complex concepts like *sidereal time* and *universal time*.

Secondly, periodic events in nature represent the most stable known time measurement standards, and thus represent a reliable source for the definition of temporal units. For example, in the atomic clock, the energy difference between two atomic states of the cesium atom (the hyperfine states $F = 4$ and $F = 3$ at $m_F = 0$) corresponds to a certain frequency that is converted to the clock rate of a reference clock with the help of a microwave resonator. The relative standard deviation of this clock rate is better than 10^{-13}, which results in an inaccuracy of 1 second in 300,000 years. In fact, time can be measured with much higher accuracy than masses and lengths. For this reason, the unit "meter" was redefined in 1983 using the constant speed of light as "the distance that light travels within the time interval of 1/299,792,458 seconds."

The "Conditio Humanae" of Temporal Perception

The discussion of physical orders of magnitude at the beginning of this entry evidences a very anthropocentric perspective: It is striking that the units for measurement of the three entities match human proportions closely: One meter is about half the size of a man and comparable to the length of one step; multiples of one kilogram are appropriate measures of how much we can carry and how much we weigh; and one second resembles for example our heartbeat, our walking frequency, and the time it takes for us to walk one meter. This is not too surprising, for the discovery and measurement of the world started with immediate human perception. Conversely, human dimensions and senses are the result of billions of years of biological evolution and are almost perfectly suited to the physical conditions we are encountering on earth. For example, the visual sense is adjusted to the motions of mechanical objects in our vicinity—that is, close to the earth's surface—which in turn is determined by the gravitational acceleration of $g = 9.81$ m/s^2. The somewhat odd unit m/s^2 is better understood as m/s per second, which means that a body initially at rest will have a velocity of roughly 10 m/s = 36 km/h after one second of free fall—an easily conceivable and observable speed. Thereby, our visual sense processes information at the rate of roughly 20 times per second, which—for a velocity of 10 m/s—corresponds to an update of the object's position every half meter. This perfect accommodation of the visual sense to conditions on earth becomes even clearer if one compares the above values to other stellar objects. On the sun's surface, the acceleration is 274 m/s^2 = 1 km/h per second, which would be impossible to follow by eye for even 1 second. On the other hand, acceleration on the moon happens at 1.6 m/s^2, which would prevent the detection of motion from a greater distance.

Strictly speaking, however, the visual sense is not limited to this tiny temporal window of observing kinematics. Visual information is inseparably bound



astronomical scale

Age of the universe (13.7 billion years)
Age of the sun (4.6 billion years)
Age of the earth (4.5 billion years)
Earliest life on earth (3.5 billion years)

Earliest mammals (200 million years)

Earliest great apes (33 million years)

Homo sapiens (130,000 years)

The slowest physically relevant timescale is that of astronomical events, starting with the formation of the universe about 13.7 billion years ago. Although this vast age seems incomprehensible in comparison to a human lifetime, we do have a direct means of access to it: telescopes. Since light travels at the finite speed of 299,792 km/h, the light from a distant star takes a certain time before it reaches us. The information obtained through a telescope is thus that of the star at an earlier age, and the more remote an object is, the further we look into the past. Light from the sun takes about 8 minutes to reach the earth. The light from closest star beyond our sun, Proxima Centauri, has travelled already 4.2 years when we observe it, and the next galaxy, Andromeda nebula, is about 2.7 million light-years away. Probably the oldest object observed so far is a very faint and distant galaxy behind the massive galaxy cluster Abell 2218, with an approximate age of 13.4 billion years — just a few hundred million years younger than our universe.

solar scale

Revolution period of Neptune (165 years)
Tectonic motion (~1 cm/year)

Revolution period of the Earth

Revolution period of Mercury (87 days)

Rotation period of the Earth

macrobiological scale

Oldest living tree,
a bristlecone pine (4,800 years)

Lifetime of a human (80 years)

Lifetime of an erythrocyte (100 days)

microbiological scale

Aerobe ATP synthesis within citric acid cycle (< 90 min)
Cation exchange in the cell (min - hours)

Round trip time of blood in human body (1 min)

pH-equilibrium in cells (~ 1s)
Rotation and emission period of a pulsar (1 ms - 10 s)

AC frequency (50/60 Hz)
Speed of nerval impulse (10 - 100 m/s)
Water exchange in cells (~0.01 s)

mechanical scale

Electron transport in conductor (0.1 m/s)

Photographic exposure time
(1/1,000s of a second - 10s of seconds)
Speed of car (130 km/h)

Tennis Ball, Baseball (200 km/h)
Hurricanes (300 km/h)
Car engine (5,000 rot/min)

half life times of radio isotopes

Tellurium (^{128}Te) - 7 x 10^{24} years
Bismuth(^{209}Bi) - 2 x 10^{19} years
Thorium (^{232}Th) - 14 x 10^{9} years
Uranium (^{238}U) - 4.5 x 10^{9} years
Uranium (^{235}U) - 704 x 10^{6} years

A physical phenomenon that occurs on every timescale is radioactivity, i.e. the decay of atomic cores under the emission of radiation. One can distinguish between α (helium cores), β- (electrons or positrons) and γ-radiation (photons). Radioactivity is a statistical process, which means that it cannot be predicted when exactly an individual core will decay. However, for a large number of particles one can determine a certain time after which half of the particles will have decayed — the half life time ($\tau_{1/2}$).

Plutonium (^{239}Pu) - 24,110 years
Radium (^{226}Ra) - 1,602 years

Cesium (^{137}Cs) - 30,2 years

Sulfur (^{35}S) - 87.5 days

Radon (^{222}Rn) - 3.8 days

PET isotopes for cancer diagnostics:
Fluorine (^{18}F) - 109.3 min
Carbon (^{11}C) - 20.3 min
Nitrogen (^{13}N) - 10.0 min
Oxygen (^{15}O) - 2.1 min

Lifetime of a free neutron (15 min)

Thorium (^{223}Th) - 0.6 s

Polonium (^{215}Po) - 1.7 ms

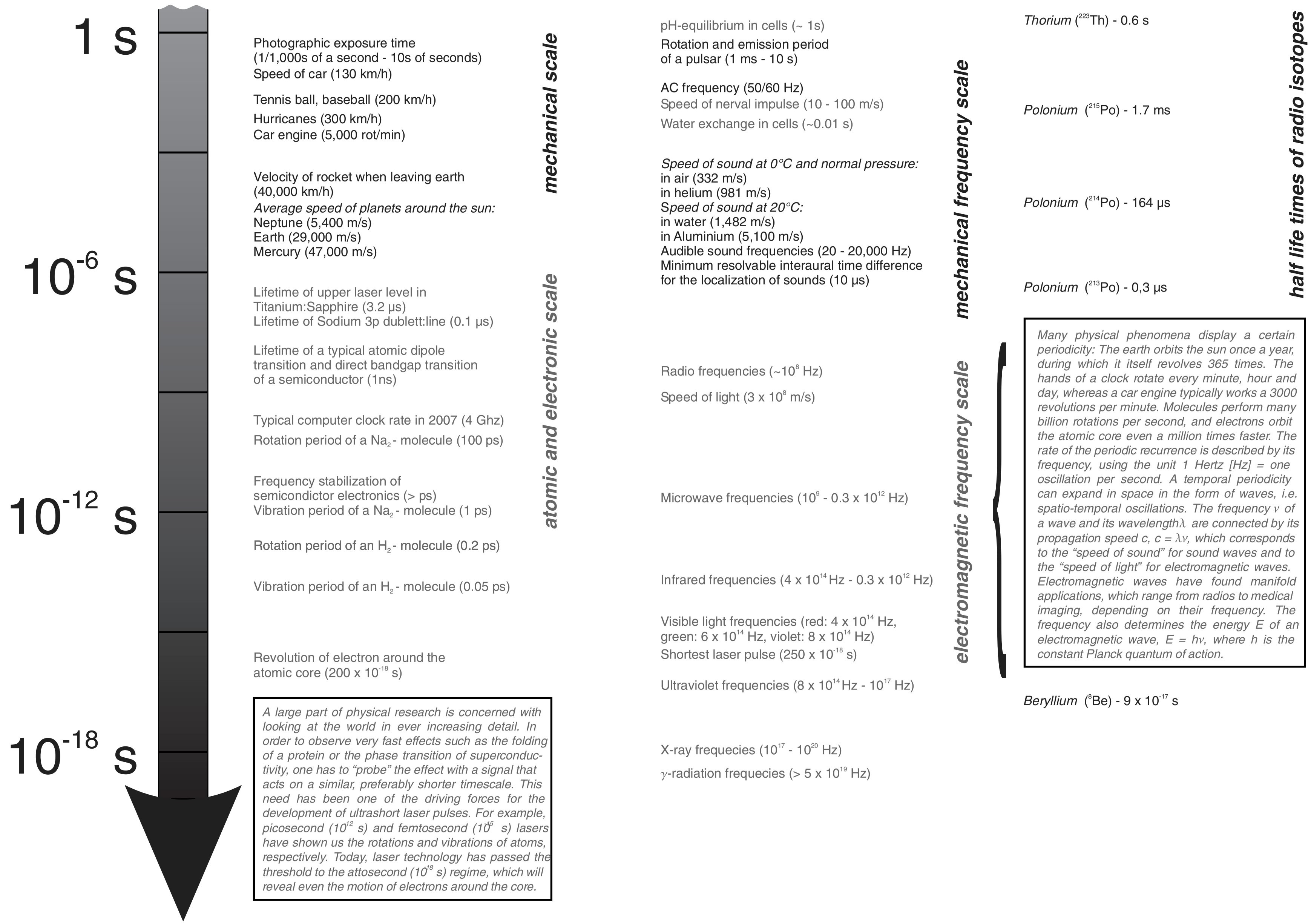


Figure 1 Selected timescales

Source: Illustration courtesy of Sebastian Pfotenhauer.

Notes: This viewgraph represents an overview of selected characteristic timescales of physics, each of which is representative for certain classes of physical events. The time arrow is given in logarithmic units, that is, each tick denotes a factor of 1,000 in duration.

to a second, much shorter timescale: the frequency of optical waves. Light propagates through space as an *electromagnetic wave,* a wave where an electric and a magnetic field reproduce each other with a certain frequency (predicted by Maxwell in 1865, experimentally confirmed by Hertz in 1880). From the full spectrum of electromagnetic waves, only waves with frequencies of $\nu = 3.3 \ldots 7.7 \times 10^{14}$Hz are visible to the human eye, which corresponds to the "optical" wavelengths between 780 nm (red light) and 390 nm (violet light; note also that this part of the visual sense is optimized to our surroundings, that is, to the spectral emission maximum of the sun at 500 nm). Although we are not able to resolve such rapid oscillations directly, we nonetheless use the information encoded in the frequency—the color—and in the incidence position of the wave to form our visual impression. For that, we make use of the fact that every frequency ν corresponds to an energy $E(\nu)$ determined by the famous equation $E = h\nu$, where h is Planck's quantum of action. That is, we measure the frequency of a wave by measuring its energy! This energy is absorbed by certain types of dye molecules (e.g., rhodopsin) in the uvula and rods of the retina, where it triggers within picoseconds a certain photochemical reaction (stereoisomeration) to change the configuration of the molecule. This alteration affects other proteins that control the ion transport of the cell, that is, the cell potential, and through that the intercellular signal transmission. A signal is thus passed on onto deeper-sited ganglion cells, the axons of which form the optical nerve and connect the eye to the brain.

The human body is also sensitive to other types of electromagnetic radiation. For example, the storage and transfer of heat in a solid can be physically described as the excitation of lattice vibrations, or *phonons.* Such atomic vibrations act at 10^{13} Hz and can be aroused by infrared and microwave radiation. The corresponding heat is measured by our body with the help of specific thermosensory receptors in our skin, which "fire" at a specific rate of a few Hertz according to the surrounding temperature.

Finally, humans are also capable of detecting nonelectromagnetic waves such as mechanical *sound waves.* Sound waves propagate from their source to our ear through an acoustic medium such as air or water. This medium performs periodic density modulations and hence pressure oscillations, which are translated by our eardrum into mechanical oscillations of the ossicle and consequently transmitted to the inner ear and converted into nerve impulses. Our acoustic sense covers timescales from tenths to tenths of thousands of seconds, that is, 10s to 10,000s of Hz. It is evident that human perception is indeed a very complex compound system of different detection mechanisms acting on very different timescales, which makes it thoroughly ambiguous to speak of one "humanlike perception."

Relevance of Different Timescales in Physical Description: Time Hierarchies of Complex Systems

For the mathematical treatment of complex physical systems, the existence of different timescales is of crucial importance, because entities varying slowly with respect to the ones of interest can often be considered quasi-constant—they are *separable,* which reduces the complexity of the problem significantly.

In many cases, the different processes form a whole temporal hierarchy. For example, an erythrocyte cell has a lifetime of about 100 days. During its aging process, it changes several properties, including certain average ion concentrations in the cell plasma. However, the ion concentration can also vary on a shorter timescale according to momentary needs of the cell. Part of the short-term ion exchange is mediated by active ion pumps like the sodium-potassium pump (Na^+/K^+-ATPase), which can create ion gradients on a minute to hour scale, during which the overall lifetime variations are negligible. The formation of a pH-equilibrium within the cell happens on account of the much quicker H^+ (proton) transport on a second scale, so that in turn the sodium–potassium distribution appears quasi-static. Finally, proton and ion fluctuations have an effect on the concentration gradients and the electrochemical potential between the cell interior and exterior, which is compensated by the osmotic pressure difference created by water fluxes. Since water can permeate the cell membranes freely, this compensation happens within hundredths of a second.

Viewed from the opposite direction, the existence of a time hierarchy implies that all subsystems follow the slower higher-level changes instantaneously. For example, to any variation in the ion concentration, the osmotic pressure adjusts instantaneously, so that—on an ion timescale—the cell is always in a steady state, which has led to the coining of the term *quasi-stationary state.*

The foregoing biophysical example simplifies matters to a certain degree, but nonetheless gives the right feeling for the separability of timescales in a complex system. Other typical examples include the different response times of electrons and heavy ions in electric fields as known from (for example) plasma physics, the Slowly Varying Envelope Approximation used to separate the rapidly oscillating electromagnetic waves from, say, the comparably long overall Gaussian shape of a laser pulse, or the thermodynamic net production of entropy while increasing the local degree of complexity.

Concluding Remarks

It is fascinating that the conceptual basis of physics holds for so many orders of magnitude, and that in most regimes physics is successful in predicting events ahead of time. Although generally presupposed, this coherence is neither trivial nor a necessity—it is the result of a centuries-long attempt to unify distinct physical theories and phenomena, whereby faster and slower regimes of motion were conquered successively. During this process, the concept of time had to be refined many times, leading sometimes to the border of comprehension. For example, the theory of the great and the massive, Einstein's general relativity, has taught us that time is neither absolute nor linear, but only one dimension of an inseparable four-dimensional spacetime, which is furthermore curved due to the existence of masses.

The search for a conclusive concept of time is not yet finished. Contemporary physics still struggles with inherited inconsistencies, for example regarding the use of time in quantum mechanics. Quantum mechanics, the theory of the very small, does not treat time as a regular physical observable, but has granted it an "exceptional status" (*Ausnahmestellung*), as Erwin Schrödinger once put it. Strangely, it is the only variable that is assumed not to be influenced by measurement, contrary to all other variables. This conceptual difference continues to pose difficulties for the positioning of quantum mechanics with respect to other physical theories. It is thus to be expected that any unified theory must provide a new, unified physical definition of time.

Sebastian Pfotenhauer

See also Attosecond and Nanosecond; Clocks, Atomic; Clocks, Mechanical; Cosmogony; Earth, Age of; Light, Speed of; Quantum Mechanics; Sun, Age of; Time, Cosmic; Time, Galactic; Time, Linear; Time, Measurements of; Time, Perspectives of; Time, Relativity of; Time, Sidereal; Time, Units of; Time and Universes; Timelines; Timetables; Universe, Age of

Further Readings

Demtröder, W. (2000). *Experimental physics* (2nd ed.). Berlin: Springer.

Glaser, R. (1996). *Biophysics.* Jena: Gustav Fischer Verlag.

Hawking, S. (1996). *The illustrated brief history of time.* New York: Bantam.

Hentschel, M., Kienberger, R., Spielmann, C., Reider, G., Milosevic, N., Brabec, T., Corkum, P., Heinzmann, U., Drescher, M., & Krausz, F. (2001). Attosecond metrology. *Nature, 414,* 509–513.

TIMETABLES

An essential tool of modern life, the timetable is thought to be an inheritance from medieval monastic communities. Usually created in tabular format, these documents help us organize and plan what is to occur and at what time. Without them, parents would not know when to send their children to school, passengers would not know when to catch their buses, and planes and trains would risk colliding. It could be said that the timetable provided the essential foundation for the globalization of travel, communications, and economics.

Timetables require a standardized unit of time together with a standard system of references to time. In order to have meaning, statements such as "your flight leaves in one hour" or "two weeks ago I borrowed a book" must be universally understood and accepted. Societal acceptance of what time is, its divisions, as well as a common understanding of what constitutes the past, present, and future, are the basis of a shared civilization. Conventions such as time zones and the international date line clearly play an important role in forming this shared social understanding. The international date line separates two consecutive calendar days. By international agreement, the eastern hemisphere, located to the left of the line, is always one day ahead of the western hemisphere. Requiring travelers who cross the date line to change their watches upon arrival brings them "into synch" with others at their destination. Convenience and the politics of local government interests have relocated the line several times, as happened in 1995 when Kiribati, an island in the Pacific Ocean, moved a large segment of the international date line so that the entire nation would be on the same time zone.

Standard time refers to the division of the earth into 24 time zones, each corresponding to 1 hour of time, and set to the same local time within each particular zone. When travel was limited to short distances, time zones were not needed. However, with the development of great railway systems, standardization of time became an issue debated and discussed by businessmen, politicians, engineers, and vacationers. The development of the 24-hour clock was the work of the Canadian Pacific Railway. Prior to the establishment of standard time zones, railroads picked their own standard of time. An 1870s issue of the *Traveler's Official Guide* illustrates the problems with this method: 12:02 Baltimore time was 12:12 in New York, 12:24 in Boston, and 11:52 in Buffalo. Municipal variations in departure and arrival timetables caused considerable frustration and confusion for travelers. Safety was an overriding issue, as different time references increased the risk of trains meeting head-on. Through the work of Sir Sandford Fleming, a Canadian railway engineer, Standard Railway Time was established in 1883 following a 19-nation meeting. To Fleming, the lack of standardization impeded industrialization and the modernization of society. The earlier efforts of Charles Dowd, an educator from Madison, Connecticut, and William Allen, an official of the American Railroad Association, contributed to this significant event.

Timetables establish rhythms—the observance of holidays, the start of the school year, occupation-based work schedules—around which our lives, our everyday comings and goings, are formed. Today, sophisticated computations are applied to urban bus networks, rail and air travel, classroom and exam scheduling, and shift work and just-in-time delivery systems. Scheduling timetables must be efficient, robust, and flexible enough to adjust to external influences, such as the grounding of a plane or the cancellation of midterm exams due to inclement weather. Heuristic algorithms are frequently applied in order to maximize the use of limited resources, and to coordinate and synchronize numerous and varied parameters. (A heuristic is a rule used to find a feasible solution that is close to the optimal solution.)

Timetables are published as books, booklets, posters, back-lit displays, on the Internet, and via text messaging. Early rail timetables were haphazard in format, cluttered as they were with advertisements, footnotes, and tiny type, and they were not always specific about whether times were morning or afternoon. Travelers now enjoy access to rail, bus, ship, and air travel timetables from any device with Internet access, and can receive up-to-the-minute status reports on arrivals and departures.

Jocelyn Phillips

See also Time, Measurements of; Time, Units of; Timelines; Time Zones

Further Readings

Schwantes, C. A. (1975). The joy of timetables. *Journal of Popular Culture, 9,* 604–617.

Turner, M. W. (2002). Periodical time in the nineteenth century. *Media History, 8,* 183–196.

Time Travel

Long before time travel was embraced by science, the subject captured the imaginations of shamans, mystics, and science fiction writers. In his novel *The Time Machine,* H. G. Wells depicted a world where the past, present, and future coexist all at the same time. The distant future was a terrifying realm where murky, subterranean beings cannibalized the people who lived above ground. And returning to the past was as simple as making a

U-turn on the highway of time. For centuries, perhaps thousands of years, time travel to both the past and the future has been a persistent dream.

In 1905 Albert Einstein brought time travel into scientific discussion with his special theory of relativity. In a "thought experiment," Einstein demonstrated that a clock moving through space will tick more and more slowly the faster it travels, until it stops completely at the speed of light. (A clock could never actually attain the speed of light, however, because its mass would become infinite at that speed.) Ever since Einstein, it has been assumed that because the tick of a mechanical or atomic clock slowed with increasing speed, a way to travel into the future had been discovered. This widely accepted theory of time travel is explained by the so-called twins story.

Imagine that spaceships in the future are capable of traveling near the speed of light. A twin decides to journey to another solar system 15 light years distant while his brother stays home. Because the traveling twin is moving at high speed, his clock slows and from his perspective the trip lasts just 1 year. However, the clock of the twin who stays home ticks off 30 years while his brother is away. When the traveling twin arrives back home, he finds that his brother has aged 30 years.

Most theoretical explanations of time travel assume that a highly advanced civilization could overcome the insurmountable technological problems of designing spacecraft that could fly at near the velocity of light, where time dilation is most pronounced. Science fiction accounts, therefore, have time travelers hurtling through space at nearly the speed of light; in some cases their journeys last billions of earth years.

But do we live in a universe where such travel is actually possible? Are the clocks in living cells like mechanical clocks, and will they slow down at high speeds?

Travel to the Future

The interactions of life processes are complex and interdependent. Quantum mechanics describes how chemicals form bonds, and these reactions are the basis of the electron transport chain of metabolic machinery, which is the basis of biological clocks. An often-heard interpretation of special relativity is that relativistic speed will slow down each cellular part, exactly proportionally, so that delicately balanced chemical reactions of oxygen transfer, electron transport, protein synthesis, and diffusion of chemicals across cell membranes will precisely intermesh. But is this an accurate understanding of relativity?

Cellular processes are not like the gears of a clock. They depend upon a bath of chemicals in a constant and rapid motion called Brownian motion. This motion takes place in all directions over very short distances where the molecules behave like mass in a particle accelerator. This has unexpected effects for the molecules moving in the direction of travel. Approaching the speed of light, much more energy is needed to accelerate them faster. Inside the cell this means that the molecules bouncing forward travel at a slower speed and shorter distances than those bouncing in the other directions. And this effect is greater for the faster molecules than for the slower ones. At high relativistic speeds this anisotropy concerning acceleration would cause molecules to move more easily in any direction but the direction of travel. This disrupts the normal pattern of Brownian motion as well as the distribution and concentration of ions within the cell. Particularly mobile molecules would tend to accumulate on cellular partitions away from the direction of motion, thereby disrupting all cellular processes. Any disruption of the pattern of Brownian motion would cause cell death.

The technology does not exist to accelerate life to high speeds, and given the sensitivity of cell processes negative effects would begin to be felt at around 14% of the speed of light. This corresponds to a relativistic mass increase of about 1%. A speed limit, slower than one would expect, is indicated by the laws of special relativity.

The existence of a low bio-relativistic speed limit has far-reaching theoretical consequences. To return to the traveling twin, let us arbitrarily place the speed limit at 30% of the speed of light. The round trip to a solar system 15 light-years distant would take about 30 years. The space traveler who began his trip at the age of 20 would be 48.5 when he returned, whereas his homebound sibling would be 50 years old. The age difference is hardly worth mentioning. All travel into the future requires much faster speeds, which would likely lead to cell death.

When Einstein proposed his theory of special relativity, little was known about our speed through the universe. Now we know, as a result of the discovery of the cosmological background radiation (the radiation left over from the big bang), that we are moving through space at around 380 kilometers per second. In comparison to the speed of light, which is about 300,000 kilometers per second, our speed is practically a dead stop. This seems odd, since other galaxies are traveling at very high speeds. One must then wonder if our extremely slow speed is a requirement for the evolution of life.

When trying to make sense of life in the universe, theorists are wary of claiming humans are unique. So the accepted philosophical argument assumes that life on Earth is not unique. This implies that the conditions of our evolution are shared by life in the universe; otherwise we would be a rare exception. It follows then that other intelligent life also probably evolved on slow-moving planetary systems. A bio-relativistic speed limit would likely exist for them as well.

The existence of a bio-relativistic speed limit greatly restricts the radius of possible space exploration. Assuming that our life span remains at around 70 years, the maximum radius an individual could travel away from Earth, without sophisticated methods of suspended animation, may be about 25 light-years. At this time, only travel within our solar system appears possible, although no attractive destination exists.

Putting the speed limit aside, there are other reasons time travel is primarily a subject of science fiction.

Travel to the Past

General relativity, Einstein's subsequent theory, opened a door to travel into the opposite direction—the past. The mathematical grid-work of gravitational fields in general relativity theory maps the movement of matter. The formulas have predicted some of the most exotic phenomena in the universe, such as black holes, as well as the bending of light by gravitation.

Kurt Gödel, a friend of Einstein's known for his incompleteness theorem, used Einstein's formulas to pave a soul-preserving path into the past. Gödel's universe is perhaps an ideal laboratory for understanding time and the motion of matter. That universe was a carefully designed mathematical description of a spinning cloud of dust. The dust of astrophysics, however, is not ordinary dust. The universe is so vast and galaxies so numerous that an entire galaxy is treated as a single dust grain. His solutions showed that spinning, galactic specks could produce a closed, timelike curve (ctlc), where the axis of time bends back on itself. Presence of ctlcs is widely believed to indicate the possibility of travel into the past. At least Gödel thought so, and he claimed a powerful spaceship flying at relativistic speeds could carry a traveler into the future, to arrive at the past. Ctlcs appear in other solutions of the general theory; however, few theorists seem to have understood the implications for life that might get caught in these warped regions of spacetime.

When we hear that travel to the future can lead to the past we naturally wonder what would transpire during such a journey. If we could find Earth in Gödel's universe it would not be the planet we know. The return to the past of our Earth would not be a process of reversal, where all the molecules and atoms would stop their forward motion and begin moving in the reverse direction. That would be contrary to the laws of physics that made Gödel's universe tick.

For a while on Gödel's Earth, perhaps mountains would grow and erode, but then something strange would happen at a future date. Inexplicably, each particle, atom, light wave, fractured atomic nucleus, exploded cosmic ray, everything would have to follow a new set of physical laws that would cause Gödel's Earth to reconstitute itself—returning to exactly the same conditions, positions, temperatures, masses, energies, and velocities as an earlier time. Migration to an earlier energy state is contrary to the laws of physics.

This, of course, would require new physics, since such patterns are contrary to the second law of thermodynamics. This law states that everything tends toward increasing randomness and entropy, which is the opposite of what was taking place in Gödel's universe.

Some theorists object, stating that the second law of thermodynamics is statistical and does not preclude unusual chance events. For example, the law does not prohibit an ice cube that has just melted from forming again into an ice cube, which would produce an apparent reversal in time. It states only that that event is unlikely to take place. However, the mathematical chance of rewinding the whole universe is infinitesimally small.

These same theorists claim that if one chance exists in an infinite number of possibilities, then given enough time that event becomes probable. It must be noted that this exact argument for what is possible is applicable to crying statues, staffs that turn into serpents, parting oceans, water changing to wine, and the inside of a whale being a safe location for human travel. Such speculations are beyond the realm of science.

On Gödel's Earth, time moved toward the future and arrived at the past. There winds had to blow in exactly the same manner and the sun could never run out of fuel. Galaxies and stars didn't collide and black holes were not gobbling up matter. The birth and death of stars, even life itself, played no role.

Although we can't draw the multidimensional spacetime Gödel contrived, a simple model represents how his universe was designed. Think of matter in the Gödel universe as moving like cogs on a wheel, and think of the wheel itself as spacetime. Gödel's universe moved into the future a cog at a time, moment by moment, until matter eventually arrived back at an initial cog position. Each dust particle had a simplistic, mechanistic movement. Gödel's universe was a spacetime cosmological clock that expressed the basic mechanistic properties of the formulas of the general theory of relativity. The clock ticked, the hands went around, but no one was there to notice that the new times were identical to the old times. In Gödel's universe the past was the future and the future the past. All times were the same time. Time itself had ceased to exist. Gödel's world does not exist, but it offers a tantalizing mathematical hint that travel into the past might be possible.

Wormholes

Wormholes, known as Einstein–Rosen bridges, are another mathematical construction of the general theory that offer the theoretical possibility for travel into the past. Think of spacetime as a two-dimensional piece of paper folded over but with its sides not touching. These bridges connect the flat portions of the folded sheet, representing a rapid shortcut between two distant regions of the universe. Under normal cosmological conditions, wormholes, if they could exist, would slam shut before a spaceship could pass through. Many books and articles and Internet pages espouse modified wormholes that can stay open as a possible means of time travel. A great deal of thought has gone into the physics necessary to build a wormhole-based time machine. They are plagued by many theoretical problems besides the fact that they require relativistic speeds, which would kill life. Setting that aside, major theoretical obstacles exist for making and operating a "time machine," not least of which is that the fundamental physics of time is uncertain.

To travel back in time using a wormhole time machine means that one would be able to shake hands with oneself. Inexplicably, theorists are mute about that astounding event but are almost universally worried about a paradox: What happens when someone goes back in time and kills oneself? Obviously, if you killed yourself you would not exist, so you couldn't then go back in time to kill yourself.

The physically interesting problem, however, is that shaking one's own hand defies at least one law of physics: the conservation of matter and energy. Few ask this simple question: Where would the matter, nervous system, and memory come from to manufacture a duplicate self? Theorists, many of them physicists, offer no physical explanation for when, where, and how the clone is produced. We are only told duplication magically happens and then we are distracted in the next breath when it is claimed that the duplication of matter does not defy the laws of physics. A little-advertised consequence of travel to the past is that once such a mysterious process were started, it would continue operating into infinity in the past. The present would appear to become flooded with an infinite wave of clones that would cause the universe to collapse into a massive black hole.

The belief in time travel rests completely upon one's definition of time. Most discussions see time as a type of spatial dimension, but this is not a physical fact. The time used by science, general relativity, special relativity, and Newtonian physics is not a spatial dimension, it is a measurement of motion. Time helps us measure the positions of matter as thay move through the universe. The clock ticks differently from place to place and is a full-blown mathematical dimension, but no past travel destination exists within that dimension. The known universe of time is the ephemeral ticks themselves, and nothing more.

Thus, the idea that time travel is possible rests upon an incomplete understanding of relativistic law. Our cells are not simplistic mechanical clocks. They are rapidly moving particles that have altered trajectories at high relativistic speeds. At such speeds these clocks do not just slow down, they die. Accordingly, despite the closed timelike curves that pop up in various solutions of the formulas of general relativity, the prospect of traveling to the past to meet one's younger self remains the stuff of dreams.

Donald R. Perry

See also Einstein, Albert; Gödel, Kurt; Space Travel; Time, Relativity of; Time, Reversal of; Time Machine; Time Warps; Twins Paradox; Wells, H. G.; Wormholes

Further Readings

Gott, J. R. (2002). *Time travel in Einstein's universe: The physical possibilities of travel through time.* New York: Houghton Mifflin.

Nahin, P. J. (2001). *Time machines: Time travel in physics, metaphysics, and science fiction.* Woodbury, NY: American Institute of Physics Press.

Thorne, K. S. (1994). *Black holes and time warps: Einstein's outrageous legacy.* New York: Norton.

Yourgrau, P. (1999). *Gödel meets Einstein: Time travel in the Gödel universe.* Chicago: Open Court.

Yourgrau, P. (2006). *A world without time: The forgotten legacy of Gödel and Einstein.* New York: Basic Books.

Time Warps

Time warps have been a favorite topic in science fiction literature from H. G. Wells's *The Time Machine* (1895) to the present-day *StarTrek* series. According to these stories humans can jump throughout history to change or observe events in the past or future, and spaceships can travel quicker than the speed of light in order to travel to other galaxies, but what exactly is the scientific basis behind this phenomenon?

A time warp is defined as the slowing down or speeding up of time. This is a relatively recent concept in the history of science. In 1905 Einstein showed that space and time were relative rather than absolute, and in 1912 he showed that space and time were related ("spacetime" as it came to be known), stating that it was actually curved instead of a straight line as had previously been thought. Since the 17th century, Newtonian physics had stated that space and time were absolutes. Einstein concluded that space and time are warped by matter and energy and thereby elastic and relative. His *special theory of relativity* states that time is elastic and as a result can be stretched and shrunk.

What are the methods by which time can be warped? Speed is one tool. In order to test this theory, physicists Joe Hafele and Richard Keating put highly accurate atomic clocks into airplanes and flew them around the world in 1971. They compared the readings of these clocks with identical clocks they had left in the laboratory. The result was that time ran more slowly in the airplanes. The airborne clocks were 59 nanoseconds slower relative to the clocks that were kept in the laboratory.

This is a small difference; to get a really dramatic effect one must move very fast. Speed will distort time based on how fast an object is moving. The closer you get to the speed of light (300,000 kilometers per second) as you travel, the bigger the time warp gets. The time warp becomes infinite when the speed of light is reached.

Speed is only one method of warping time. Another method is gravity. The earth's gravitational pull causes clocks to lose one microsecond every 300 years. Because of the lack of gravity in space, it would make sense that time would run faster in space. It is not that noticeable, though; one would gain just a couple of milliseconds by spending 6 months aboard the International Space Station. Stephen Hawking, one of the modern leading experts on the relationship between space and time, has suggested that spacetime is nearly flat on Earth, so the curvature resulting from gravity makes very little difference in our everyday life, making us oblivious to the time warp phenomenon.

Contemporary physicists are researching recent developments such as string theory, which may provide greater insight into time and space and the relationship between the two.

Carol Ellen Kowalik

See also Black Holes; Spacetime, Curvature of; Space Travel; Time Machine; Time Travel; Wormholes

Further readings

Kaku, M. (1995). *Hyperspace: A scientific odyssey through parallel universes, time warps, and the tenth dimension.* Oxford, UK: Oxford University Press.

Thorne, K. S. (1994). *Black holes and time warps: Einstein's outrageous legacy.* New York: Norton.

Time Zones

A time zone is one of 24 mostly equal divisions of the earth, created in an effort to standardize time worldwide. For the most part, a time zone is equal to 15 degrees of longitude and operates at exactly 1 hour plus or minus its eastern and western neighboring zones. In any time zone, the zone immediately to its east is 1 hour ahead, and to its west, 1 hour behind.

It was 1879 when Sir Sandford Fleming proposed the use of time zones, which were officially adopted in 1884 at a conference held in Washington, D.C. Prior to the use of time zones, localities kept their own central, or civil time. Usually, towns would set their clocks to noon once the sun reached its high point. The method was not exact and even neighboring cities and towns saw great variation in time within their own boundaries. Some towns had residents who would travel the town every week with watches in hand for people to set their own watches, in order to try to keep a uniform time within the town.

This system worked as well as it needed to and had strong ties to the days when sundials were used to tell time. The sun reaches different points across different places of the earth, so local times were very different, but with relatively sedentary communities, there was no need to keep standardized times. Although travel between towns was not uncommon, there was little inconvenience in resetting one's clock based on the locale.

With the onset of faster modes of transportation, those needs changed. Railroads were being built and used extensively, and the increase of travel and people being transported across greater distances in shorter times posed a great problem to scheduling and timekeeping. Fleming, a Canadian engineer and surveyor, played a major role in the development of the rail system throughout Canada and the United States. He quickly realized that the need for more accurate scheduling demanded a standardized time.

Fleming used simple mathematics to determine the size of each time zone: with the world comprising 360 degrees, and a day consisting of 24 hours, each zone should equal 15 degrees of longitude—1/24 of the world's circumference. He presented his plan at numerous conferences until a version was adopted at the International Meridian Conference of 1884. Despite Fleming's assertions that time zones allowed for use of local time, the conference rejected the use of time zones. It was, however, agreed that the use of the meridian of Greenwich as the prime meridian made sense, as the majority of maps and charts at this time had already been using it as such.

The United States and Canada adopted the use of their time zones on November 18, 1883, also known as "The Day of Two Noons." Within 30 years, Coordinated Universal Time (abbreviated UTC) and time zones were being used by all major countries. There have been some changes to each zone's size based on local and political considerations, allowing countries and states to remain within a given zone. For example, China, which should span five zones, uses just one, and in the United States, most states are within its own zone, despite geographical boundaries.

Amy L. Strauss

See also Clocks, Atomic; Earth, Rotation of; Harrison, John; Latitude; Longitude; Prime Meridian; Sundials; Time, Measurements of; Time, Universal; Timelines; Timetables; Watches

Further Readings

Blaise, C. (2000). *Time lord: Sir Sandford Fleming and the creation of standard time.* New York: Pantheon.

Central Intelligence Agency. (2006). *Standard time zones of the world.* Washington, DC: Author.
Morgan, J., & Muir, G. (Eds.). (2004). *Time zones: recent film and video.* London: Tate.

Toffler, Alvin (1928–)

Alvin Toffler, American author and futurologist, is noted for his contributions to the analysis of social change and the human condition. Taking a psychological and sociological approach to the impact of technology, Toffler presents a unique perspective on the dynamics of the human condition as society rapidly progresses from industrialism to a quasi-Marxist state. Although not concerned directly with time as such, he does concentrate on the rate of change that is relative to previous periods of history and the effects that are seen today. Toffler is known for his major works *Future Shock* (1970), *The Third Wave* (1980), and *Powershift* (1990).

Toffler depicts the dynamics of human life and the development and restructuring of societies. As humankind expanded its intellectual horizon and implemented newly developed technologies, the rate of change increased dramatically within a social framework. Increases in population (dispersion), extent or degree of individualism, social relationships, and economic development and restructuring (e.g., the decline of industrialism and technocracy) are critical points in the attempt to create a new society. In times of shifting power, corporate downsizing, and multitasking, individual longevity and identity are depicted as being psychologically transferred and expressed in social relationships; for example, modular relationships and maladaptive actions and reactions. From clearly defined economic (employment) and social (family) structures to the development of a continual transient state found at all levels, humankind is depicted as grappling with and attempting to adapt to this new environment. When vast changes within a short time created stress and distortion beyond the adaptive capabilities of our species, Toffler acknowledged the phenomena with his term *future shock*. Essentially, it is almost a *Twilight Zone* scenario: surreal perceptions of dynamic change with real consequences.

The affluence and materialistic nature of modern society is well documented. This fact regarding modern society, along with Toffler's conception of future shock, can push humankind's physiological and psychological resources to the limits. In response to this condition, Toffler identified maladaptive psychological conditions seen in the attempt to adjust. This adjustment entails forms of denial, specialization, obsessive reversion, and super-simplification. Although Toffler does not offer direct solutions for this predicament, he does hold that education and educational environments may have a critical and essential place in directing the future of society. Education, for Toffler, must be dynamic and ever-changing to meet the expectations found in the evolution of modern society. Education must keep pace and mimic in structure the concepts and rates of change seen within society. This open-ended process of changing the mind-sets of youth, via individual focus, can be seen as a unique adaptation to prepare for the future.

Toffler's account of social problems, along with the theoretical underpinnings, exposes the serious problems that are seen within modern societies. Rapid technological advancements, changing complexion of family structures, changes in business strategies and structures, and political and social upheaval all denote the rapid changes experienced in society. Future shock, similar to Marx's concept of alienation, depicts the experience of disconnection that individuals experience directly from the mode of production, for example, as seen in both *Future Shock* and *Powershift,* and its perceived reflection of the individual's identity and self-worth. In the attempt to offset the implications of radical change, no single individual can correctly predict or solidify the future of humankind. The rate of change, similar to the behaviors of individuals, is beyond the control of a preplanned structured society. In the endeavor to construct the future, to adapt at the very least, humankind must guard itself from pseudoscience, hidden political agendas, and the rising tide of fundamentalism. Change, as seen in both biological and cultural evolution, is an integral and constituted part of our species and its related humanity. Toffler's works expose the difficulty experienced during periods of rapid change and the effects it has on society. How successfully our species will adapt to the future remains to be seen.

David Alexander Lukaszek

See also Bradbury, Ray; Evolution, Cultural; Evolution, Social; Futurology; Time Management; Verne, Jules; Wells, H. G.

Further Readings

Toffler, A. (1970). *Future shock*. New York: Random House.

Toffler, A. (1972). The strategy of social futurism. In A. Toffler (Ed.), *The futurists*. New York: Random House.

Toffler, A. (1974). Psychology of the future. In A. Toffler (Ed.), *Learning for tomorrow: The role of the future in education*. New York: Random House.

Toffler, A. (1990). *Powershift*. New York: Bantam Books.

Tolkien, J. R. R. (1892–1973)

J. R. R. (John Ronald Reuel) Tolkien was a storyteller in the truest sense, generating tales infused with contemporary concerns, classic themes, and ancient traditions. *The Lord of the Rings* trilogy, arguably his greatest work, certainly exemplified this reality. Yet, for all the grandeur of Tolkien's imagination and careful intertwining of reality, myth, and fiction, it is the complexity of Tolkien's view and utilization of time that truly make his work so masterful.

Pursuing the scholar's life, Tolkien ultimately became an eminent philologist whose academic career included appointments at Oxford, where he guided students and colleagues alike toward a better understanding of and appreciation for languages, both modern and ancient. Aside from his academic efforts, Tolkien was an imaginative writer whose fondness for mythology and Arthurian romances led to his translation of classic works such as "Sir Orfeo" and "Sir Gawain and the Green Knight," as well as creating original fiction, including his *Lord of the Rings* trilogy. It was within this latter work and associated writings that Tolkien thoroughly developed his concepts of time, particularly the concept of immortality.

Tolkien's elves, ever valiant, graceful, and dignified, anchored his perception of immortality and timelessness. Wherever elves dwelled, they lived eternally. While mortal weapons could slay them, Tolkien's elves remained impervious to the normal ravages of time, including aging and disease. Tolkien treated this conditioning as a blessing and a curse, with elves living endlessly but watching all else fade to memory. Yet, this duality did not diminish or limit Tolkien's conceived notion of time and eternal life.

In addition to the immortality of the elves, Tolkien viewed immortality from the perspective of themes that are timeless, ever cycling through the ethos of societies. Good versus evil and nature versus technology were two of the key themes that surfaced through Tolkien's writings. His works reflect the notion of such themes, continually resurfacing as time passes, making such conflicting viewpoints seem as immortal as the elves themselves. Time, consequently, becomes an echo of the very themes that play out in both Tolkien's Middle-earth and our own reality.

Immortality, as a temporal theme within Tolkien's writings on Middle-earth, was offset by the opposing premise of life being finite, time thereby having an end. Yet, the finality of an individual's life varied considerably among the creatures of Middle-earth. The wizards Gandalf and Saruman were far more ancient than they appeared to be. Notwithstanding the centuries they endured, they must have appeared relatively youthful. Likewise, the Ents, great trees that often walked about the forests of Fangorn, suffered through the encroachment of humanoids for ages, making Treebeard and his brethren early occupants of Middle-earth. Yet, for both the wizards and the Ents, time was not endless. Their time was not relegated to immortality. The Ents, in particular, seem caught in a state of decline as the Entwives were lost, making future procreation questionable; their time was consequently fading.

Humanity itself faced a variety of projected life spans in Tolkien's writings. While most humans lived less than a century, the descendants of Númenor lived for centuries, as did Aragorn, before succumbing to death. Regardless of ancestry, though, all humans were as mortal as the dwarves and hobbits that shared Middle-earth with them. No matter their ancestry, all humans would ultimately suffer defeat at the hands of time. Collectively, the mortal creatures of Tolkien's Middle-earth brought realism to this fantastic epic. While some, such as the bearers of the Ring of Power, could postpone aging, ultimately they too would surrender to time, effectively balancing those who would witness time's control of life.

The temporal nuances found throughout Tolkien's masterpiece, *The Lord of the Rings,* reflect the storyteller's deep understanding of tradition, myth, and history. These iconic and immortalized images—the immortality of the elves, the longevity of the heirs of Númenor, or even the endurance of Gandalf and his nemesis, Saruman—among others, continue to provide readers with a multifaceted understanding of time, while simultaneously granting J. R. R. Tolkien himself a bit of immortality.

Neil Patrick O'Donnell

See also Bradbury, Ray; Carroll, Lewis; Mythology; Novels, Time in; Verne, Jules; Wagner, Richard; Wells, H. G.; Woolf, Virginia

Further Readings

Anderson, D. A. (Ed.). (2003). *Tales before Tolkien: The roots of modern fantasy.* New York: Del Rey/Ballantine Books.

Bassham, G., & Bronson E. (Eds.). (2003). The Lord of the Rings *and philosophy: One book to rule them all.* Chicago: Open Court.

Tolkien, J. R. R. (1980). *Unfinished tales: The lost lore of Middle-earth* (C. Tolkien, Ed.). New York: Del Rey/Ballantine Books.

Tolkien, J. R. R. (1987). The Lost Road *and other writings: Language and legend before* The Lord of the Rings (C. Tolkien, Ed.). New York: Del Rey/Ballantine Books.

Tolkien, J. R. R. (1989). *The Hobbit or there and back again* (Rev. ed.). New York: Ballantine Books.

Tolstoy, Leo Nikolaevich (1828–1910)

Leo Nikolaevich Tolstoy was a Russian writer, essayist, spiritualist, and philosopher. Born to a noble family, he received a university education and served in the army during the Crimean War, which Russia launched against Turkey, England, and France. He traveled throughout Europe and later embarked on philanthropic missions to assist peasant children and serfs. *War and Peace* (1865–1869) and *Anna Karenina* (1875–1877) were the novels that established him as a world-renowned author. While *War and Peace* was a historical account that spanned 15 years, *Anna Karenina* focused on the personal struggles in an individual's life.

War and Peace is praised for its complex characters and is considered one of the greatest technical literary accomplishments in the history of Western novels. The story was set in a turbulent historic time when the French leader Napoleon Bonaparte launched the military campaigns of the Napoleonic Wars at the beginning of the 19th century. The lives of more than 500 characters are examined in the course of the novel; the book spans 15 years and the generational changes that naturally occur with the passing of such time. The novel tells of historical events, great romance, and family issues as it follows the turbulent events of the period and traces the changes as generations grow from children into adults.

Anna Karenina highlights the meaning and purpose in human existence, dealing with the common themes of love, marriage, family, and fidelity. It is the story of a woman who leaves her older, politically savvy husband, their young son, and a loveless marriage for an enticing, younger military officer. She strives to overcome her guilt and find love and peace in this relationship. She and the young officer have a child together. Still, her guilt overrides her potential for happiness and she ends her life by jumping in front of a moving train.

Tolstoy writes of universal problems and timeless issues such as childhood, youth, and death in *Three Deaths* (1859), love and marriage in *Family Happiness* (1859), and class relations in *Polikushka* (1859). Love, living naturally, and generational conflicts were themes in *Two Hussars* (1856) and *The Cossacks* (1852–1863). The timelessness of these literary themes and his approach created a body of literature whose appeal is universal.

Generations of readers and critics continue to read, study, and discuss Tolstoy's work. His output as a writer spans 45 volumes of fiction and an equal number of volumes containing essays, correspondence, and diaries, signifying an enormous cultural impact.

In addition to his stature as a literary figure, Tolstoy was a man of principle, regarded in his lifetime as a profoundly moral authority, particularly after he had released from bondage the serfs who by heredity and tradition had long been attached to his ancestral estate. Many thinkers were influenced by his viewpoints on religion and the duty of civil disobedience. But today his reputation rests primarily on the enduring body of literature he created.

Debra Lucas

See also Dostoevsky, Fyodor M.; Joyce, James; Mann, Thomas; Proust, Marcel; Woolf, Virginia

Further Readings

Tolstoy, L. (1995). Anna Karenina: *The Maude translation: Backgrounds and sources: Essays in criticism* (Norton Critical Edition; G. Gibian, Ed.). New York: Norton.

Tolstoy, L. (1996). War and Peace: *The Maude translation: Backgrounds and sources: Essays in criticism* (Norton Critical Edition; G. Gibian, Ed.). New York: Norton.

Troyat, H. (1967). *Tolstoy.* New York: Grove Press.

Totem Poles

From the Totempolar Region, the mountain-bordered coastline from southeast Alaska to coastal Washington, the indigenous Northwest Peoples—the Tlingit, Haida, Tsimshian, Kwakwaka'wakw, Bella Coola, Salish, and others—carved their legacies in columned sculptures of cedar. The iconographic symbols of their sophisticated abstract art, later to be known as "form line," were visual documentations, a primal form of "written" language for communicating significant cultural and historical events. It is factual that songs, dances, oratory, painted and woven clothing, house fronts, ceremonial utensils, canoes, and other *at.óow* (Tlingit clan identity) were also records of history to these West Coastal Tribes. Nevertheless, it is the totems standing majestically, bearing witness through the ages that these coastal people have for the most part identified with; and those of other cultures have recognized as symbols of the Northwest culture.

The Northwest Peoples' intricate hierarchical civilizations were divided into clans and caste systems, and were contingent on the knowledge of tribal and family lineage as the foundation of their status, and on the right of proclamation of certain crests to be displayed artistically in songs, dances, and narrative accounts. Witnesses were required to authenticate the claims; wealth would be accumulated to pay these witnesses in the ceremony known as a potlatch, the vehicle employed to establish this worldview. It is surmised that house posts and memorial poles were predecessors of the totem poles, for the first explorers noted external totems in small numbers. The availability of metal tools in abundance revolutionized totem art, as the wealth from the fur trade with Europeans established the means for the various clan chiefs to commission totems for their potlatches, thereby launching an artistic renaissance in totem art.

Totem poles have been categorized as follows:

- Some totem poles *celebrate clan history.* Legends belonging to a clan could tell how the clan came to be. Some totem legends deal with the seasons, such as "Fog Woman," who is a symbolic representation of the fog that arrives in the summer with the salmon run, signifying the beginning of the Tlingit New Year. Also within the Potlatch oratory the locations of where the clan had settled are given. The symbols on the totems then remind the witnesses of the chronological order of history concerning the clan.

- Some totems served as *memorials to the deceased.* Chiefs and other high-caste clan members had the means to accumulate the wealth required to honor their deceased with a memorial pole; this in itself was a record in time of the numbers of high-caste members honored within a tribe, as well as a testament to the clan's wealth. Illustrated upon the poles are the clan's *at.óow* (crests); through the years a clan might add a crest, perhaps through marriage. Older poles would therefore lack that crest, and the newer pole would thereby bear witness to the advent of the acquired crest; or in the case of shamans, the representation of spirit helpers, for example, the owl memorial totem at Saxman, Alaska.

• Some totem poles serve to *commemorate historic deeds or events.* When an extraordinary event occurred, such as the advent of the Europeans, which is represented on a Kasaan totem with a man in European garb standing on the water from whence he arrived, a totem would be commissioned with the crest of the chief who was active during the event and with symbols of the event or deed, thereby giving a date for this occurrence.

• Some totem poles convey *ridicule, shame, or revenge.* The ridicule pole concerns an unpaid debt due a person or clan. A totem is a costly item, so the debt due the clan would likely be a huge amount in order to warrant the pole's commission. The magnificently sculpted Three-Frog Pole in Wrangell, Alaska, is such a totem; there is a shroud of mystery over the payment, so when a replica was commissioned by the Civilian Conservation Corps (CCC) for Wrangell Park, there was outrage in the Native community that this debt was being resurrected. The shaming pole is usually interchangeable with the ridicule pole since the commissioning clan intends to shame the debtor into remuneration; except in cases where shame is the primary objective, such as the lewd pole once placed in front of the longhouse that used prostitution as the means to support their potlatches; this occurred during early colonization. Finally, the balancing in righting a wrong was complex in these societies; for instance, should one of low caste slay a high-caste person of another clan, the person blamed for the murder would not be required to die, but one of his high-caste kinsmen had to balance the loss. A former grave post at Kake, Alaska, illustrated a European man on top, a Native man second down, with pertinent crest and other symbols below them. This totem is a testimonial representation of a requisite due for the slaying of their clansman; the fact that a totem was commissioned may presume that a European of the clansman's caste is required for the "eye for an eye" judgment. Whether a ridicule, shaming, or revenge totem, a public record was required to give substance to the case and to remain for all time, or until the situation was settled.

In the 20th century a growing concern arose over the limited time left to gather tribal knowledge from dwindling numbers of elders, and to save the tribal languages that were dying. The efforts in this fight against time resulted in today's Northwest Natives experiencing a resurgence of their cultural identity and arts. Today, restorations of older totems are being administered, such as at the Klawock Totem Park in Alaska; also the Repatriation Act of 1990 initiated more totems being returned to the Native Peoples and replicas being carved; for instance, the Burke Museum's return of two "Kats the Bear Hunter" house posts

Exxon Ridicule Pole and carver Mike Webber. This modern-style ridicule pole was commissioned by the Eyak Tribal Council for the multibillion dollars owed by Exxon Mobil for the 1994 court judgment (overturned in 2008) to the oil spill victims of 1989.

Source: Photo by Ross Mullins. Used with permission: http://www.alaskacarving.com to the Tongass Tribe, for which master carver Nathan Jackson and son Stephen each carved a replacement pole to be displayed at the Burke. In addition, new totems are also being carved, such as the commemorative poles of Liberty and Freedom at Washington, D.C., by Salish carver Jewell "Praying Wolf" James for the victims of the attacks of September 11, 2001. And, in 2007, at Cordova, Alaska, Alutiiq/Tlingit carver Mike Webber sculpted a shaming pole for the 1989 *Exxon Valdez* oil spill and the damages that resulted.

The art of totem pole carving, which once neared extinction because of missionary fervor during the colonization of the Northwest Territory by Europeans and Americans, has returned. Totem poles continue to function as symbols of Native cultures and records of time.

Pamela Rae Huteson

See also Anthropology; Calendars, Tribal; Chronology; Creation, Myths of; Mythology; Navajo; Pueblo

Further Readings

Bolanz, M., & Williams, G. C. (2003). *Tlingit art: Totem poles & art of the Alaskan Indians.* Surrey, BC, Canada: Hancock House.

Garfield, V. E., & Forrest, L. A. (1984). *The wolf and the raven.* Seattle: University of Washington Press.

Huteson, P. R. (2002). *Legends in wood: Stories of the totems.* Tigard, OR: Greatland Classic Sales.

Malin, E. (1986). *Totem poles of the Pacific northwest coast.* Portland, OR: Timber Press.

Transhumanism

Transhumanism is a philosophical movement that affirms the technological enhancement of the human species and the coming about of transhumans and posthumans. Like the Christian religion or Marxism, it sets its hopes on the future. In contrast to the other movements, it is a dynamic worldview that does not expect a final perfect state. For transhumanists, human beings are a work in progress, a species to be overcome, and whose qualities need to be enhanced. In contrast to traditional evolution, one transhumanist goal is that human evolution will be directed and regulated by human beings so that their intellectual, psychological, and physiological capacities become improved. Some technologies that are relevant in that respect are bioetechnology, nanotechnology, information technology, and artificial intelligence.

Transhumanism sees itself as compatible with traditional liberalism; it is in accordance with one's own values or those of one's parents which capacities are supposed to be developed. Thus, transhumanists distance themselves from the eugenics movement. Yet in doing so they employ a restricted notion of "eugenics," one that refers to state regulated eugenics only. Other types of eugenics, like liberal eugenics and autonomous eugenics, on the other hand, are exactly what transhumanists are in favor of.

Past and Present

The first intellectual who employed the notion of transhumanism was the biologist, philosopher, and writer Sir Julian Sorell Huxley, who is the half-brother of the writer Aldous Huxley, author of the famous novel *Brave New World* (1932). However, the word *transhumanism* could already be found in a 19th-century English translation of the Paradiso section of Dante's *Divine Comedy,* and it consists of two Latin words: lat. *trans*—beyond, lat. *humanus*—human. The Iranian American futurist Fereidoun M. Esfandiary (1930–2000), who admitted to having "a deep nostalgia for the future," enabled the transhumanist movement to be connected with some well-developed philosophical ideas by means of his 1989 book, *Are You a Transhuman?* He published this book under his new name FM-2030, which refers to the year in which he believed that he would celebrate his 100th birthday. Meanwhile, the University of Oxford, in England, is one of the institutions in which some particularly influential transhumanists teach and discuss their worldviews. Particularly noteworthy is the philosopher Nick Bostrom (1973–), who cofounded (with David Pearce) the World Transhumanist Association in 1998. Since 2005, he has been director of the Oxford Future of Humanity Institute.

Transhumans and Posthumans

The concepts of transhuman and posthuman are particularly important for most thinkers in that movement. Yet there is no generally accepted understanding of what they mean. If we compare Esfandiary's and Bostrom's meaning of the concept *posthuman,* the vast number of meanings of that word that one can hold as a transhumanist becomes clear. Esfandiary distinguishes between the notion of the *transhuman* and that of the *posthuman.* Transhumans are transitory human beings who still belong to the human species but have technologically enhanced capacities, which is why they represent the evolutionary link to posthumans. Posthumans no longer belong to the human species. They are members of a new, enhanced species. The similarities between Esfandiary's concepts and some of Nietzsche's concepts are striking. Esfandiary's concept of transhumans resembles that of Nietzsche's higher humans, and Esfandiary's concept of posthumans seems to have a lot in common with Nietzsche's concept of the overhuman. Bostrom, on the other hand, holds that posthumans belong to the human species but have capacities that cannot be found in current human beings. He also holds that at the present time we might not even be able to imagine which qualities these might be.

Pro and Con

The transhumanist movement does not include philosophers only. Especially in the field of literature, quite a few adherents can be found, such as the French author Michel Houellebecq (*Les particules élémentaires,* 1998). A number of public intellectuals, however, are highly critical of the transhumanist movement. The political scientist Francis Fukuyama is a vehement critic who fears that this movement could undermine the basis of liberal democracies, something he points out in detail in his bestselling book *Our Posthuman Future.* The philosopher Jürgen Habermas, in a 2001 book on liberal eugenics, made critical remarks concerning the transhumanism movement.

Stefan Lorenz Sorgner

See also Alighieri, Dante; DNA; Evolution, Organic; Futurology; Humanism; Nietzsche, Friedrich

Further Readings

FM-2030. (1989). *Are you a transhuman?: Monitoring and stimulating your personal rate of growth in a rapidly changing world.* New York: Warner Books.

Fukuyama, F. (2002). *Our posthuman future: Consequences of the biotechnology revolution.* New York: Picador.

Savulescu, J., & Bostrom, N. (2008). *Enhancement of human beings.* Oxford, UK: Oxford University Press.

TRANSPORTATION

Transportation is the act of transporting or conveying. Throughout history, transportation has developed into increasingly efficient means. The most basic yet most enduring form of human transportation is, of course, walking. Since the beginning of the species, humans have powered their own bodies, one foot in front of the other.

Even at the onset of what many feel to be a major advance in transportation—the wheel, around 3500 BCE—people still had to walk in order to use the wheel, which was set below pull carts. Even the early chariots were pulled by people. It was not until much later that humans were able to step off their own feet and onto a nonhuman powered, wheel-based device. This came in the way of the horse-drawn chariot around 2000 BCE.

Around the same time the wheel was being put to its first uses in carts and human-drawn chariots, the first boats were entering the water. These were used in river travel and again were powered by people through the use of oars, and later by the capture of wind power through the use of sails.

Only in the modern era was a major advance made in the development of boats, with the advent of the steam engine. This was an extremely slow process, as the first steam-powered paddle boat was demonstrated around 1783, with its first practical appearance 4 years later. The steam engine was adapted for use on land nearly 20 years later, with the invention of a primitive, not very practical steam-powered locomotive intended for use on roadways.

Meanwhile, some other variations of travel had emerged. Primitive oar-powered submarines were first used around 1620. Iron horseshoes had dramatically improved the ability of horses to pull carriages, carts, and buses by 1662. And hot-air balloons first took flight in 1783.

Except for wheelbarrows and simple carts, many of the primitive sources of transportation have been replaced. Again, walking remains the most primitive and to some extent the most popular mode of transport even in contemporary times. The wheel, ironically, came full circle more than 5,000 years after its invention. It was 1790 when the bicycle was invented. The first bicycles were powered simply by pedals that turned a larger wheel to create motion. Today there are many varieties, mostly chain-driven and many with multiple gear speeds.

By the end of the 18th century the steam engine had been perfected, and the first steam-powered passenger boat was introduced by Robert Fulton. A few years later, the first practical locomotive was designed, this time intended for use on rails.

The first rumblings of a gasoline-powered automobile were heard in the mid-1800s from Jean Lenoir. Karl Benz improved the idea and put the first practical automobile, equipped with a combustion engine, on the road in 1885.

Henry Ford would advance the science of automobiles, particularly their manufacture. He is well-known for the design of his Model T automobile, but in fact it was the assembly line from which the Model T was manufactured that made the automobile much cheaper to make and thus more affordable for individuals to own. The first Model T rolled off the line in 1908.

The turn of the 20th century was an exciting time for travel and transport, with Ford's mass production of cars and the Wright brothers taking flight in the first engine-powered airplane in 1903. The rest of that century witnessed explosive growth and development in transportation, with the birth of jet planes, helicopters, motorcycles, and rockets.

Not only has the passing of time seen greater advances in modes of transportation, the modes of transportation have themselves affected humanity's experience of time. In general, as time passed and new transportation vehicles were invented, less time was required for travel. Today, automobiles, commercial airplanes, trains, and ships have developed into some of the quickest modes of transportation. Automobiles themselves have seen great change over time, with the first automobiles traveling at speeds of only a few miles per hour. Now, privately owned automobiles (excluding customized racing models) have the capacity to travel at speeds greater then 100 miles per hour.

The average commuter train travels at speeds of about 25 miles per hour, and while personal automobiles may have the capacity to travel more quickly, the infrastructures differ greatly, allowing trains to travel their tracks virtually undisturbed, while autos must obey myriad traffic signals and stoppages.

Airplanes have developed into the fastest mode of transportation. A commercial airliner travels at an average speed of about 600 miles per hour, a far cry from the 42-mile-per-hour world record set by Orville Wright in the early 1900s.

The first rocket to be successfully launched was in Germany in 1942. Within 20 years, the first human to enter space aboard a rocket ship was the Soviet Union's Yuri Gargarin inside *Vostok 1* in 1961, when he made one orbit around the earth. Eight years later, the American astronaut Neil Armstrong was the first to walk on the moon. Space travel has been evolving ever since. Satellites, space stations, and exploration missions continue to be announced and developed. Missions studying Mars are underway, with plans for the further study of Venus and other planets. With the continued development of space travel and the ability to travel longer distances in shorter periods, the planets and beyond are not unreasonable targets for future exploration.

Amy L. Strauss

See also Industrial Revolution; Punctuality; Quantum Mechanics; Space Travel; Timetables; Time Travel; Time Zones; Wells, H. G.; Wormholes

Further Readings

Black, W. (2003). *Transportation.* New York: Guilford Press.

Clark, J. (2001). *Railroads in the Civil War: The impact of management on victory and defeat.* Baton Rouge: Louisiana State University Press.

Gergano, G. (Ed.). (1972). *Transportation through the ages.* New York: McGraw-Hill.
Piggott, S. (1992). *Wagon, chariot and carriage: Symbol and status in the history of transport.* New York: Thames and Hudson.
Rose, M. (2006). *The best transportation system in the world: Railroads, trucks, airlines, and American public policy in the twentieth century.* Columbus: Ohio State University Press.

TREES

The most common understanding of the term *tree* is that of its botanical meaning. Most botanists define trees as perennial woody plants with a single stem (trunk), normally greater than 13 to 16 feet (4 to 5 meters) in height. Trees are also important in dating objects and sites, and in commemorating both historical events and specific individuals.

Worldwide, the number of tree species is estimated to be more than 80,000. Yet, on average, 5% of tree species in any country are estimated to be threatened or endangered. Generally, a tree is differentiated from other living plants by its relatively large size and its structure (having a single stem or trunk). Some species of trees can be very large: giant sequoias, coast redwoods, Douglas firs, and some eucalyptus grow 300 feet tall or more and have trunks 30 feet across. Some species also have very long life spans. One of the bristlecone pines of the White Mountains of California in the United States, nicknamed Methuselah, is the world's oldest known living tree, with an age exceeding 4,700 years.

Particular trees are considered historic because of their age, size, or cultural significance. For example, the plane tree of Hippocrates on the Greek island of Kos is thought to be the largest tree in Europe. Hippocrates, the famous Greek physician who lived around 400 BCE and who originated the well-known Hippocratic Oath, is believed to have planted this tree. One of the most famous banyan trees, of the species known as the sacred fig or bo tree, is the Sri Maha Bodhi tree in Sri Lanka that is believed to have grown from a cutting from the tree under which the Buddha became enlightened in the 6th century BCE.

Because of the longevity of trees, it has been the practice to use them as markers to aid in the location of places. For example, a popular tourist attraction in Sherwood Forest in Nottinghamshire in the United Kingdom is a tree called the Major Oak. This is purported to be the tree where the legendary Robin Hood and his Merry Men met to hatch their plots. In the eastern United States, the locations of old graveyards can sometimes be determined by the cedars that were planted there.

Also, because of the longevity of many trees, it has been commonplace throughout history to plant trees as memorials (lasting tributes to people or events) or to commemorate significant events such as the birth of a child, the completion of a new house, the opening of a building, and the visit of a dignitary or other special person. As the tree grows, it is a reminder of the event or significant people or the passage of time since the occurrence of the event.

Tree Timepiece

A tree was probably the very first timepiece, indicating the passage of time during a day by its casting of a shifting shadow. Early humans would have noticed that, in the early morning, a tall tree had a long shadow pointing to the west. As the sun rose in the sky, they would have noticed that the tree's shadow became shorter. Then, in the afternoon, the shadow moved to the other side of the tree and pointed east. Gradually, the tree's shadow became longer as the sun set in the west. Thus, by looking at the changing shadow of a significant tree, early humans were able to count the passage of time, and it was probably this practice that led to the development of the first instrument for measuring time, the sundial.

As it grows, a tree incorporates some of nature's most accurate evidence of the past. Each year, a tree increases its girth or the size of its trunk. This growth is recorded as concentric rings in a cross-section of its trunk. These tree rings have been shown to record evidence of floods, droughts, attacks by pests, lightning strikes, fires, and even earthquakes, thus making trees some of nature's most accurate timekeepers. For example, Chinese pine trees (*Pinus tabulaeformis*) have been used to reconstruct total January–July precipitation in

Central China from 1775 to 1998! Indeed, a completely new scientific field, called dendrochronology, has arisen that involves the analysis and description of tree-ring data in order to date and interpret past events, such as climatic changes.

Trees have been important to humankind's continued existence. We are all familiar with the use of wood from trees as a common building material. Trees and other plants release the oxygen that we breathe; prevent soil erosion; provide food and shelter; and provide material for human use, such as paper, medicine, tools, weapons, and even toys. Trees also play an important role in many of the world's cultures and mythologies.

Tree Parts

The basic parts of a tree are the roots, trunk(s), branches, twigs, and leaves. The roots of a tree are generally embedded in the earth, providing support for the tree and absorbing water and nutrients from the soil. Not all trees have the same plant parts. For example, most palm trees are not branched, and the saguaro cactus (*Carnegia gigantea*) of North America has no functioning leaves. Yet, based on their general shape and size, these are both also generally regarded as trees.

Several different terms are used to refer to groups of trees growing together, depending on the density of the trees and the extent of the space occupied. A small group of trees growing together is called a grove or copse, and a large area covered by a dense growth of trees is called a forest. A landscape of trees scattered or spaced across a grassland is called a savanna.

Dendrochronology

The term *dendrochronology* is derived from the Greek terms *dendron* (tree), *chronos* (time), and *logos,* meaning "science of," and so refers to the science or study of time by using trees. Dendrochronology, often called tree-ring dating, is the method of scientific dating based on the analysis of tree-ring growth patterns. Andrew Ellicott Douglass of the University of Arizona pioneered dendrochronology in the early 20th century. It is based on his observation that wide growth rings of certain species of trees were produced during wet years and, conversely, narrow rings during dry seasons. Therefore, over a long period of time, examination of some tree trunks reveal a sequence of tree rings with a pattern of wider and narrower rings indicating climatic conditions like droughts, cold summers, and so on. Thus, the annual growth rings of a tree reveal not only its age (by counting the rings), but also the changing environmental conditions during its lifetime.

Until relatively recently, radiocarbon dating was the only method known for dating wooden objects; that is, determining their age or the length of time since they were built or constructed. Dendrochronology is much more precise than radiocarbon dating, being accurate to a single year. Thus, the use of tree-ring data makes possible the establishment of precise dates for wooden objects, structures, and prehistoric events.

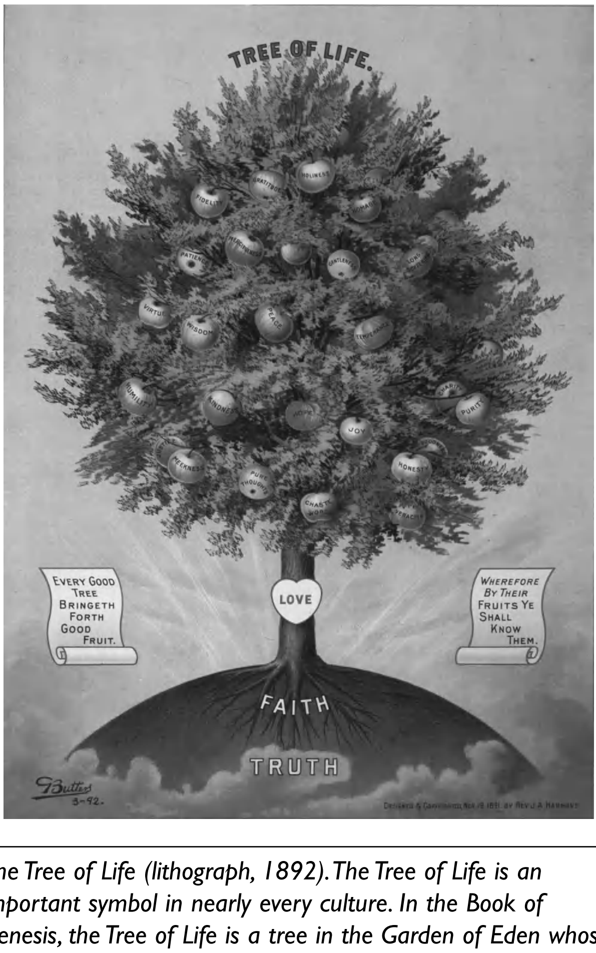
Cornell University researchers have used applied dendrochronology not only to determine the age of old houses in northeastern New York state, but also to date wood buried beneath the volcanic ash of the famous Santorini volcanic eruption, one of the largest in the last 10,000 years. They showed that this eruption occurred most likely in the late 17th century BCE, 100 years earlier than previously believed. Researchers at the University of Arizona have also used tree-ring data to examine the increases in levels of heavy metals (tungsten) over time in the small town of Fallon, Nevada, in the United States, that was the site of a cluster of childhood leukemia cases. Dendrochronology has also been used to date a previously unvalued portrait of Mary Queen of Scots in the National Portrait Gallery in London. Interestingly, it had been dismissed as an 18th-century copy, but dendrochronology established that the panel on which it was painted was from between 1560 and 1592, thus making it an authentic original portrait.

Trees in Mythology, Culture, and Religion

Trees exist as an element in many legends and myths worldwide. Trees have also become incorporated in symbolism and are used to convey messages connected to the qualities that certain trees are thought to possess. For example, trees are often used as a symbol for life. Pre-Christian

Europeans and many others associated trees with longevity and fertility. The tree also appears in religions worldwide, where it is worshipped directly or used as a place around which to worship. For example, the Druids frequently worshipped and practiced their rites in oak groves, whereas some ancient pagans worshipped the trees themselves. The tree also forms an important part of Christian scriptures. One notable scripture makes reference to two trees in the Garden of Eden (the Tree of Life and the Tree of the Knowledge of Good and Evil). *Etz Chaim,* Hebrew for Tree of Life, is a common expression in Judaism.

In Norse mythology, Yggdrasil is the giant ash tree located at the center of the universe that links and shelters the nine worlds of Norse cosmology. Yggdrasil has three main branches and roots, and was believed to have sprung from the beginning of time. Its roots are believed to represent all time (i.e., past, present, and future).



The Tree of Life (lithograph, 1892). The Tree of Life is an important symbol in nearly every culture. In the Book of Genesis, the Tree of Life is a tree in the Garden of Eden whose fruit gives immortality.

Source: Library of Congress, Prints & Photographs Division.

The Greeks, Romans, Celts, Slavs, and Teutonic tribes venerated the oak tree. In each case, it was associated with their supreme god, as oak was sacred to Zeus, Jupiter, Dagda, Perun, and Thor, respectively. In Indian culture there is a sacred tree called the Manorathadayaka that is believed to grant human wishes. Generally, in Asia, ancient trees are associated with temples, pagodas, and shrines. In North America, Native Americans have a special regard for trees, using these in many of their ceremonies and ritualistic dances (often using cottonwood trees).

Record-Breaking Trees

One can rate the world's record-breaking trees based on several factors, namely height, trunk diameter or girth, total size (volume), and age. The world's record for the tallest tree is a coast redwood (*Sequoia sempervirens*) that is 379.1 feet (115.55 m) tall and is located in Redwood National Park, California. The stoutest living single-trunk tree species in diameter (excluding baobabs, which store large amounts of water in their trunks, making accurate measurement difficult), is a Montezuma cypress (*Taxodium mucronatum*) named El Árbol del Tule (Spanish for "the Tule Tree") located in the Mexican state of Oaxaca. Its diameter is 38.1 feet (11.62 m). The largest tree in total volume (tall and of large diameter) is a giant sequoia (*Sequoiadendron giganteum*) known as the General Sherman tree; it has a volume of 55,040 cubic feet (1,489 m^3) and is found in Sequoia National Park in California.

Other Meanings

The term *tree* is also used to refer to any representation of hierarchical relationships that uses the analogy of trunk, stem, and branches, such as a decision tree, genealogy or family tree, or binary tree. In computer studies, a *tree* is a group of domains that have the same domain name server (DNS) name; for example, *def.com* (the top domain), and *sales.def.com* and *techsupport.def.com* (the child domains).

The Tree of Life Web Project is a collaborative effort of biologists from around the world. Its Web pages are linked to one another hierarchically in the form of the so-called evolutionary tree of life. On more than 9,000 World Wide Web pages, the project disseminates information about the diversity of organisms on Earth, their evolutionary history, and their characteristics. It starts with the "Root of All Life on Earth" and moves out along diverging "branches" to individual species.

Although hierarchical structures or trees often represent subordinate relationships or ranks, these trees can also represent an order of precedence and so sometimes characterize the time at which events or processes occur in relation to others in the tree. The term *tree* is also used to represent physical objects that contain branches like a tree (e.g., the hat and coat tree, with pegs on which to hang things).

Jennifer Papin-Ramcharan

See also Dating Techniques; Ecology; Evolution, Organic; Genesis, Book of; Ginkgo Trees; Mythology

Further Readings

Baillie, M. (1997). *A slice through time: Dendrochronology and precision dating.* London: Taylor & Francis.

Fritts, H. C. (2001). *Tree rings and climate.* London: Blackburn Press.

Hageneder, F. (2005). *The meaning of trees: Botany, history, healing, lore.* San Francisco: Chronicle Books.

Nash, S. E. (1995). *Time, trees, and prehistory: Tree-ring dating and the development of North American archaeology, 1914–1950.* Salt Lake City: University of Utah Press.

Pakenham, T. (2003). *Remarkable trees of the world.* New York: Norton.

Stokes, M. A., & Smiley, T. L. (1995). *An introduction to tree-ring dating.* Tucson: University of Arizona Press.

Swetnam, T. W. (1993). Fire history and climate change in giant sequoia groves. *Science, 262,* 885–889.

Tudge, C. (2005). *The secret life of trees: How they live and why they matter.* London: Allen Lane.

Trilobites

The trilobites are a remarkable group of extinct arthropods that lived in the seas of the Paleozoic era (542–251 million years ago [mya]) and went extinct before dinosaurs dominated the earth. Trilobites were early arthropods with a hard, segmented exoskeleton, and therefore easily fossilizable. Although all share a similar body plan, there was a great diversity of size and form. They are grouped in the extinct class Trilobita, which is subdivided into 10 orders, over 150 families, about 5,000 genera, and more than 17,000 described species. With such a diversity of species, it is very probable that the ecological role of trilobites was very extensive. They surely included planktonic, swimming, and crawling forms as well as a varied set of trophic niches (mostly detritivores, carnivores, and scavengers). Because of their great diversity and abundance in the fossil record, trilobites are important key taxa in Paleozoic biostratigraphy, chronostratigraphy, paleoenvironmental reconstruction, paleogeography, and even plate tectonics.

The body plan of all trilobites consists of three main body parts: a cephalon (head), a segmented thorax, and a pygidium (tail). Its name "trilobite" means "three lobed," but this term does not refer to these three body parts. Instead it points to the fact that they have a long central axial lobe flanked on each side by right and left pleural lobes. Their exoskeleton was composed of calcite and calcium phosphate minerals in a protein lattice of chitin. Many trilobites had compound eyes, in addition to antennae used perhaps for taste and smell.

Trilobites first appeared during the early Cambrian, and flourished throughout the lower Paleozoic. When they first occur in the Cambrian fossil record, they are already highly diverse and geographically dispersed, suggesting a previous evolutionary origin. It is reasonable to assume that the trilobites shared a common ancestor with other arthropods before the Cambrian period. Trilobites have been often included within subphylum Chelicerata, which groups the arachnids (spiders, scorpions, etc.), xiphosurans (horseshoe crabs), eurypterids (sea scorpions), and pynogonids (sea spiders). All of them together with the trilobites seem to share a pre-Cambrian common ancestor, forming the taxon called Arachnomorpha. The ancestors of the trilobites are probably to be found in the arthropod-like, segmented animals called trilobitomorphs, which lived during the Ediacaran period of the Neoproterozoic era, more than 550 mya. They include fossil taxa like *Spriggina* and *Parvancorina* found in the Ediacara Hills (South Australia). These taxa have been classified as vendobionts, annelids, or arthropods, but their morphology bears a striking resemblance to that of trilobites, and they therefore may be excellent candidates for ancestors of trilobites.

Except perhaps for the order Phacopida, whose first record occurs in Ordovician sediments, all trilobite orders appeared during the Cambrian period. The nine trilobite orders and some of their main genera are: Agnostida (e.g., *Agnostus, Condylopige*), Redlichiida (e.g., *Redlichia, Paradoxides*), Corynexochida (e.g., *Corynexochus, Illaenus, Leiostegium*), Lichida (e.g., *Lichas, Odontopleura, Damesella*), Phacopida (e.g., *Phacops, Calymene, Dalmanites, Cheirurus*), Proetida (e.g., *Proetus, Phillipsia, Cyphaspis, Bathyurus*), Asaphida (e.g., *Asaphus, Ampyx, Dikelocephalus, Cyclopyge, Ramopleurides*), Harpetida (e.g., *Entomaspis, Harpes*), and Ptychopariida (e.g., *Ellipsocephalus, Ptychoparopsis, Conocoryphe, Elrathia*). The first true trilobite is probably contained in the order Redlichiida. The olenellids of the order Redlichiida include some of the most primitive trilobites, such as *Olenellus* and *Fallotaspis*. The orders Corynexochida, Lichida, and Ptychopariida evolved from Redlichiida during the Middle Cambrian. The rest of the orders (Asaphida, Harpetida, Proetida, and probably Phacopida) evolved from Ptychopariida during the Middle and Late Cambrian. There are doubts concerning the origin of the order Agnostida. The systematic position of this order within the class Trilobita remains uncertain since ontogenetic evidence suggests they descended separately from crustaceans. However, other specialists support the hypothesis that the agnostids evolved from some group of ptychopariids. In spite of the doubts about their true origin and the phylogenetic relationships among their orders, trilobites have become an essential group for estimating the rate of speciation during the evolutionary radiation known as the Cambrian explosion, since they are the most diverse fossil group during this so-significant period of life history.

The exact reason for the extinction of the trilobites is not clear. Before the end of Devonian, their species richness began to decrease, perhaps due to the arrival of the first sharks, efficient predators of trilobites and other marine animals. Trilobites declined strongly after the great Late Devonian extinction event 374 mya. All trilobite orders disappeared in that event except for some species of the order Proetida. The last members of this order were extinguished in the Permian–Triassic boundary mass extinction event 251 mya. Horseshoe crabs may be the closest extant relatives of trilobites.

Ignacio Arenillas

See also Anthropology; *Archaeopteryx*; Chronostratigraphy; Dinosaurs; Evolution, Organic; Extinction and Evolution; Fossil Record; Fossils, Interpretations of; Geologic Timescale; Paleontology ; Stromatolites

Further Readings

Fortey, R. A. (2001). Trilobite systematics: The last 75 years. *Journal of Paleontology, 75,* 1141–1151.

Kaesler, R. L. (Ed.). (1997). *Treatise on invertebrate paleontology, Part O, Arthropoda 1, Trilobita, revised: Vol. 1. Introduction, order Agnostida, order Redlichiida.* Boulder, CO: Geological Society of America; Lawrence: University of Kansas.

Twins Paradox

The supposition that time differences between events are not absolute in reality was first expressed by Einstein in his famous work of 1905. He deduced from the equation for the dilation of time that the relation between the time data $\Delta\tau$, Δt of clocks situated at the equator and at the pole, respectively, will be the result of the rotation of the earth with the circumferential velocity $u \approx 0.465$ km/s ($c \approx 300{,}000$ km/s is the speed of light):

$$\Delta\tau = \sqrt{1 - u^2/c^2}\ \Delta t. \tag{1}$$

Thus a clock at the equator should be delayed approximately 8/100 microseconds per day with respect to the clock at the pole.

Equation (1) determines the *proper time* of a moving clock in the inertial system of reference. In the case of time-dependent velocity $u(t)$ it is necessary to take it as a differential equation and integrate it. Equation (1) represents a special case of the conclusion of the relativity theory that the actual time is (apart from the constant multiplying factor) equal to the length of a section of the world line between the events (spacetime points) P and Q:

$$\tau = \frac{1}{c}\int_{P}^{Q} \sqrt{g^{ik}dx^{i}dx^{k}} \ . \tag{2}$$

The *clock paradox* in its broadest sense means the existence of a difference between the actual times measured by the clocks moved in different directions between two meetings. From the geometrical point of view, this means different lengths of appropriate parts of world lines in spacetime. In the case of long and rapid motions, this difference will be reflected also in the biological age of organisms (according to A. Eddington, our faces represent clocks indicating passing years). Thus it is especially impressive when speaking about the *twins paradox*.

The most common and most often discussed form of the paradox is the following: One of two identical twins will remain on the earth while the second makes a cosmic flight proceeding with the constant velocity u close to the speed of light. In the vicinity of a distant star the wandering twin will change the direction of his flight in a very short time interval compared to the total duration of the flight, and he will return to Earth. When the twins meet, the difference in their respective ages, corresponding to equation (1), will be immediately apparent.

The word *paradox* as used here refers primarily to the strangeness of the conclusion, whose theoretical and experimental legitimacy is beyond doubt. Nevertheless, even now (and sometimes even in physics publications) opinions are offered that the contradiction is real. They are based on the *relativity of time*. From the point of view of the wandering twin, motionless in his own system Σ, it is the earth-bound twin (at rest in the system S) who recedes and then again approaches with the velocity u. Could not the comparison of times give the opposite result for him?

The standard answer claims that the systems S and Σ are not equivalent. Only system S is inertial for the whole time (no regard is taken of negligible effects connected with the motions and gravity of the earth and the sun). In order to return to the earth, the wandering twin changed the direction of his flight and felt great inertial forces in connection with this. His system is not permanently inertial and the use of equation (1) is consequently justified only in system S.

Although this answer is in principle correct, it is not quite sufficient to overcome objections. The accelerated period of the astronaut's flight could be negligibly short with respect to the duration of flight that had a constant velocity. Moreover, the astronaut could be accompanied on his route away from Earth by a friend in another rocket. After the astronaut reaches velocity u, his friend turns his flight in the same way the wanderer will do after reaching the distant star. So he will experience the same periods of accelerated motion as the astronaut before landing back on Earth. Nevertheless, the difference between the respective ages of the earth-bound twin and of the attendant friend will be negligible according to equation (1).

There are at least three apparently different explanations, which in fact do not exclude but rather complement each other.

Four-Dimensional Geometry

Let us compare the lengths of world lines of the twins (see Figure 1). The world line of the earth-bound twin (a) is depicted in the middle; the world line of the wanderer twin (b) and the world line of his attendant friend (c) are on the right; and the extreme case (d), where the direction of the flight in the same direction changes in an infinitely short moment, is on the left. In Euclidean geometry, the broken line, is longer than the direct joining of two points. But in Minkowski geometry, the set of points at equal distances from the beginning is not a circle, but an equiaxial hyperbole. Thus the case is opposite: the broken line is shorter as the direct join of points over the quantity ΔT depicted in bold in the figure. In both geometries the difference of lengths is created by mere existence of the "corner," not by some length adherent to the corner. The noninertial (curved) parts of world lines do not essentially contribute to their lengths, but the existence of a break on the distant place will influence the length significantly.

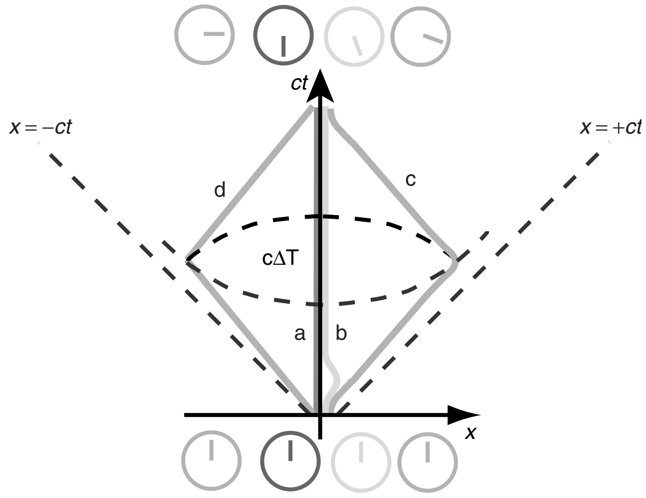


Figure 1 Twins Paradox: World Lines
Source: Illustration courtesy of Jana Jurmanová.

Potentials in Noninertial Systems

Let us write equation (2) in noninertial systems with the help of components of metrics ($g_{\alpha\beta}$ are space components, $g_{\alpha 0}$ mixed components, g_{00} time components). Thus we obtain

$$d\tau = \sqrt{1 + \frac{2\varphi}{c^2} + \frac{2\gamma_\alpha u^\alpha}{c} - \frac{u^2}{c^2}}\, dt \tag{3}$$

where

$$g_{00} = 1 + 2\varphi/c^2, g_{\alpha 0} = \gamma_\alpha, u^2 = -g_{\alpha\beta}u^\alpha u^\beta, u^\alpha = dx^\alpha/dt. \tag{4}$$

So in addition to the velocity *u,* the scalar potential φ and the vector potential γ increase in the equation connecting the element of the actual time *d*τ and of the coordinate time *dt*. These potentials express the influence of the force fields in the noninertial system on the flow of time. The relationship between the finite sections of proper and of coordinate times can be obtained by the integration of equation (3). Let us note that in the case of nonsynchronized time (nonzero mixed components of metrics), other definitions of velocity and vector potential also can be found in the literature, leading to more complicated equations.

At the point when the astronaut's flight changes direction, the force field with the scalar potential φ increases in his reference system Σ. This field (from the point of view of Σ) turns the direction of motion of the earth with its twin. The potential on the earth increases with the distance from the astronaut and with the rate of his acceleration, and thus its influence does not vanish even in the case of the nearly zero duration of the turn. According to equation (3), this potential causes a faster flow of time on Earth during the astronaut's turn, which overbalances its slower flow due to the velocity. In this way, the calculation performed in the noninertial system will affirm the younger age of the astronaut in the moment of meeting.

In the case of the zero velocity of the clock, equation (3) reduces to

$$d\tau = \sqrt{1 + \frac{2\varphi}{c^2}}\, dt \tag{5}$$

and expresses the influence of the potential on the flow of time. According to general relativity, this potential could be produced not only by the accelerated motions of the reference system in flat spacetime, but also by the gravity of matter. Einstein's conclusion on the difference between the data of clocks at the pole and at the equator was made before the advent of general relativity. So the earth was considered to be like a traffic circle, and not influenced by its own gravity. In fact, however, the potential φ on Earth is influenced by its mass and the surface of the rotating Earth at the equipotential level (the earth is an oblate spheroid). Consequently, clocks in different places on the earth's surface with the same potential (e.g., at sea level) run at the same rate, contrary to Einstein's original opinion.

Contemporary standards for precise measurement allow testing the clock paradox by using airplanes. The influence of velocity as well as the influence of potential in different altitudes has been convincingly confirmed by these experiments. These results are at present given practical application by the GPS system.

Mutual Observations

Suppose that the twins are able to perform mutual optical observations during the flight. Their observations will be influenced not only by the dilation of time (1), but also by the usual Doppler effect caused by the receding or approaching of the observers. The resulting *relativistic Doppler effect* consists of the relationship between the frequency f_O recorded by the observer and the frequency f_S emitted by the source (the relative velocity u is taken as positive when receding and negative when approaching):

$$f_o = \sqrt{\frac{1-\frac{u}{c}}{1+\frac{u}{c}}} fs \quad . \qquad (6)$$

Consequently, each twin sees his fellow twin grow older more slowly while the twin is receding—he sees the delay of his clock and the red shift of his colors. While his twin is approaching, the opposite is true—both see their twin's clock speed up and a blue shift in his colors. The observations are completely symmetric and the duration of the astronaut's accelerated flight can be (even from the observer's point of view) negligibly short. Why, then, is the reason asymmetrical?

It is essential to realize that the astronaut sees the change of red shift to blue shift in half of his flight when he uses the rocket's engine to turn toward Earth. In contrast, the twin on Earth will see the blue shift together with the turning of his brother's rocket because in this moment the signum of u in formula (6) is changed. So he sees it in the moment, where the astronaut is long ago on his way to Earth (as a consequence of the finiteness of the speed of light). Consequently, the faster aging of astronauts endures in the earthly observation much shorter as the slower aging. The calculation again affirms the results obtained by other methods.

Jan Novotný

See also Einstein, Albert; Relativity, General Theory of; Relativity, Special Theory of; Space Travel; Time, Relativity of; Time, Reversal of; Time Dilation and Length Contraction; Time Travel

Further Readings

Møller, C. (1952). *The theory of relativity.* Oxford, UK: Clarendon Press.

Rindler, W. (2001). *Relativity: Special, general, and cosmological* (esp. pp. 64–68; 195–198). Oxford, UK: Oxford University Press.

Sartori, L. (1996). *Understanding relativity: A simplified approach to Einstein's theories.* Berkeley: University of California Press.

Schild, A. (1960). Time. *Texas Quarterly, 3*(3), 42–62.

Roberts, T., & Schleif, S. (2007). *What is the experimental basis of special relativity?* Retrieved August 1, 2008, from http://math.ucr.edu/home/baez/physics/Relativity/SR/experiments.html

Tylor, Edward Burnett (1832–1917)

Edward Burnett Tylor, often considered the founder of cultural anthropology as a field of study, made enormous contributions to the development of the discipline as it has come to be known. He was a contemporary of other important contributors to the field, such as Herbert Spencer, Charles Darwin, Sir James Frazer, and Lewis Henry Morgan, among others. It was in Tylor's definitive work, *Primitive Culture* (1871), where his greatest contribution would be made to anthropology, in particular through advancing the idea of sociocultural evolution, a process of change in human societies that occurs over time.

Tylor was born in Camberwell, London, England, on October 2, 1832. His parents, Joseph Tylor and Harriet Skipper, were Quakers. Being brought up in a household dominated by the Society of Friends, along with being educated at a local Quaker school in Tottenham, was no doubt influential on his life and later works, where his focus was on religion and its evolution, one of the key features of *Primitive Culture.*

Tylor worked a while in his father's business, a brass foundry. Around the age of 20, however, he showed signs of tuberculosis and was forced into an early retirement. It was during this time that he was granted a chance to embark on an overseas trip to the United States, which he toured extensively in 1855 and 1856.

In Cuba, he met the famed British ethnographer and archaeologist Henry Christy, also a Quaker. The two embarked on a journey to Mexico, which resulted in the production in 1861 of Tylor's first published work, *Anahuac,* a memoir of the trip containing relevant anthropological notes on the people he had encountered.

Tylor returned to England and married, then published his *Researches Into the Early History of Mankind* in 1865. This publication would prove the foundation for his grand opus, *Primitive Culture: Researches Into the Development of Mythology, Philosophy, Religion, Art, and Custom* in 1871. Following this work was the also-popular *Anthropology: An Introduction to the Study of Man and Civilization* in 1881.

Tylor was awarded many titles throughout his career. Beginning in 1871, he became a Fellow of the Royal Society, received a Doctor of Civil Laws degree from Oxford in 1875, Reader in Anthropology (1884), and then became first Professor of Anthropology at Oxford in 1896, the first academic post in the field of anthropology. In recognition of his achievements, Tylor was knighted in 1912, only 5 years before his death.

Tylor's contributions to the field of ethnology and cultural anthropology are monumental. He is well known for his ideas of sociocultural evolution and work with animism (a "primitive" religion whose beliefs include spiritual beings, as well as attributing life in terms of a soul to inanimate objects in nature, e.g., rocks and water). Tylor claimed that religion followed a unilinear track of evolution from simple animism, through polytheism, to complex monotheism. A contemporary of Charles Darwin, Tylor was influenced heavily by Darwin's works. In fact, the two maintained a close correspondence, with Tylor offering the opportunity for one of Darwin's sons to help him with *Anthropology*.

Tylor believed that cultures evolved in a manner similar to biological evolution, in a unilinear fashion. Eventually the small-scale societies (tribal) would reach the goal of large-scale civilization. Like Morgan's, Tylor's idea of cultural evolution involved stages, beginning with "primitive or savage" through "barbarism" to "civilization." Progress is marked by rationality, and all societies will eventually reach the point of "civilization," though it will be at their own rate.

Another key feature of Tylor's work is the idea of "cultural survivals" or cultural ideas and materials that withstand the test of time. One of these survivals can be found within religion. Tylor illustrates this by comparing notions of the afterlife in animistic religions to ones found within monotheism. Monotheism in itself is a cultural survival, a product of progression from earlier animistic and polytheistic religions from belief in the Many to belief in the One.

Tylor's death in 1917 was preceded by a slow progressive dementia. In spite of this, his passion for anthropology remained lively until his death. As a key figure in cultural anthropology he influenced other scholars of the late 19th and early 20th centuries, including Sir James Frazer and later Leslie A. White. Since then many of his ideas have been reworked, but they remain a cultural survival.

Dustin B. Hummel

See also Anthropology; Evolution, Cultural; Evolution, Social; Harris, Marvin; Morgan, Lewis Henry; White, Leslie A.

Further Readings

Leopold, J. (1980). *Culture in evolutionary and comparative perspective: E. B. Tylor and the making of* "Primitive culture." Berlin: Dietrich Reimer Verlag.

Tylor, E. B. (2006). *Primitive culture: Researches into the development of mythology, philosophy, religion, language, art and custom* (Vols. 1 & 2). Whitefish, MT: Kessinger. (Original work published 1871)

Whitney, S. B. (2006). Edward Burnett Tylor. In H. J. Birx (Ed.), *Encyclopedia of anthropology* (pp. 2234–2235). Thousand Oaks, CA: Sage.

U

Unamuno y Jugo, Miguel de (1864–1936)

Taking the Darwinian perspective seriously, the Basque philosopher, writer, and poet Miguel de Unamuno y Jugo grappled with the stark implications of evolution and time for understanding and appreciating all life forms (particularly our own species). Giving preference to feelings and emotions rather than to science and reason, he longed for immortality despite the fact of personal death and species extinction. He lamented the existential condition of the human predicament, but gazed into the starry vastness of changing reality for a solution to the cosmic fact of pervasive finitude. Critical of Darwinism, Unamuno rejected both its mechanism and materialism. He developed an interpretation of evolution that is essentially mystical. His speculations extended far beyond the confines of this planet in order to embrace sidereal time and the entire universe.

Unamuno was not content with those evolutionary ideas that were espoused by Charles Darwin, Thomas Huxley, Ernst Haeckel, and Herbert Spencer; his own process interpretation of the world did not give priority to science and reason. Instead, Unamuno's passion for life caused him to have a deep sympathy for the finite existence of all living beings on the earth. No doubt, it pained him to see organisms perish, never to return to the realm of the living. Likewise, stars and planets appear in the universe, only to vanish into cosmic oblivion. Even so, Unamuno intuited that something everlasting would eventually emerge out of the ongoing struggle in, and pervasive suffering of, the organic world. He was especially concerned about the destiny of our own species. Unamuno focused intensely on human consciousness, which he hoped would never return to the silent nothingness from which it had once emerged. His longing for personal immortality caused him to adopt a mystical view of evolutionary time and its final goal.

Unamuno presented his unique worldview in his major work, *The Tragic Sense of Life* (1912). This book is a radical departure from those established scientific facts and those traditional religious beliefs that pervaded the end of the 19th century. Its basic theme is the quest for eternal life: the overcoming of finality through the attainment of the personal immortality of the human soul. The result is a remarkable vision of the future in terms of an organismic view of this dynamic universe. Unamuno saw the evolving cosmos as an emerging organism analogous to a developing person. He envisioned the whole universe as a totality that is evolving into a single cosmic entity. Just as cells make up organs and organs make up an organism, stars make up galaxies and galaxies make up this universe. Through extensive extrapolation, Unamuno saw this evolving universe preparing itself for the emergence of God in the distant future.

For Unamuno, the entire world will never be extinguished. The end of cosmic evolution will be the formation of God as a Supreme Being. This cosmic entity will emerge when all the finite beings of this universe converge, creating a single collective consciousness. Since personal consciousness emerges in a human being as the result of the interaction of innumerable cells, so a center of cosmic consciousness will emerge in this universe as a result of the interaction of countless galaxies. The end result will be the appearance of God, in which everything is preserved forever in the eternal memory of this supreme consciousness. Consequently, immortality is achieved throughout all future time as a result of the eternal God sustaining everything as endless consciousness in God's own supreme consciousness.

H. James Birx

See also Alexander, Samuel; God and Time; Renan, Joseph Ernest; Teilhard de Chardin, Pierre; Universe, Evolving; Whitehead, Alfred North

Further Readings

Basdekis, D. (1970). *Miguel De Unamuno*. New York: Columbia University Press.

Unamuno, M. de. (2007). *The tragic sense of life* (J. E. C. Flitch, Trans.). New York: Cosimo Classics.

UNIFORMITARIANISM

Uniformitarianism, a term introduced by William Whewell in the mid-19th century, refers to a cornerstone of geology. Uniformitarianism is based on the premise that present-day processes have operated throughout geological time. Although the earth is in a dynamic state of change and has been so ever since it was formed, the processes that operate today are the same that shaped it in the past. The expression, "The present is the key to the past" is commonly used to summarize uniformitarianism. Therefore, in order to understand and interpret geological events from evidence preserved in rocks, we must first understand present-day processes and their results. Thus, the earth's past is available to us through understanding the current processes and interpreting them in the strata.

James Hutton (1726–1797) was the precursor of the uniformitarian principle. In his *Theory of the Earth* he believed that "the past history of our globe must be explained by what can be seen to be happening now" and concluded that "the Earth must be millions of years old." Unfortunately, Hutton's ideas were not widely disseminated or accepted, so catastrophism, more easily associated with religious doctrines, continued to be the prevailing geological idea well into the 1800s. It was Charles Lyell (1797–1875) who became the principal advocate and interpreter of uniformitarianism after his *Principles of Geology* was first published in 1830–1833. In this book, one of the most renowned scientific texts ever written, Lyell put forward this principle clearly and concisely, and applied it to the study of the earth's crust. Lyell recognized the tremendous cumulative effect that could have resulted from small, imperceptible changes brought about by still-active geological processes over long periods of time. Not only did Lyell effectively reintroduce and establish the concept of unlimited geological time, but he also discredited catastrophism as a viable explanation of geological phenomena. To model the mountains and valleys, it was not necessary to resort to cataclysms that in a short time would have produced great changes, as catastrophists claimed; weaker forces, acting slowly over long periods of time, were sufficient to explain them. The uniformitarian principle became the underlying philosophy of geology because it provided a much simpler explanation for observed geological phenomena than catastrophism. Philosophers call it the principle of simplicity, or "Occam's razor": one should not invent unknown or extraordinary causes if the usual known procedures are sufficient.

Although Lyell in his development of uniformitarianism surely did a great deal to further the science of geology, he also misrepresented other contemporary theories and mixed together under the banner of uniformity a variety of disparate claims, some of which have been politely ignored so as to avoid embarrassing a key founder of modern geology. Lyell's concept of uniformitarianism should be separated into two different meanings: *methodological uniformitarianism* (of the laws and processes of nature) and s*ubstantive uniformitarism* (of the intensity of the processes and the state of the earth). Stephen Jay Gould, paleontologist, evolutionary theorist, and dialectical biologist, claimed that substantive uniformitarianism is false while methodological uniformitarianism is now a superfluous term that is best confined to the past history of geology.

The assertion that only processes that can be observed to operate in the present should be used to explain events in the past is today, as it was then, a somewhat more controversial claim. This methodological principle is a way of expressing "the uniformity of the laws of Nature throughout time," a postulate or "the rules of the game" put forward by Isaac Newton in the late 17th century. The uniformity of the laws of nature is a self-evident proposition, so it is known to be true by understanding its meaning without any demonstration or proof. The uniformity of the processes is a consequence of this postulate. It is important to note that while English-speaking geologists always use the term *uniformity,* continental Europeans prefer the use of the term *actualism* (because in romance languages the words derive from the Latin *actualis* meaning present, present-day). In fact, "the uniformity of laws" is an application in natural sciences of philosophical actualism, the ontological view that stands in opposition to possibilism and denies that anything not actual (real and existing as a fact) can be said to exist. Thus, the idea of uniformity is a necessary condition for starting even any scientific task, so the principle turns out to be close to a commonsense rule.

Uniformity in the intensity of the processes or gradualism is not a methodological rule, but a theory that must be demonstrated. The argument as to whether the rhythm, velocity, and intensity of the geological processes have been variable or constant throughout the history of Earth, and to what degree, is a debate that continues today. Scientists generally agree on a preference for invoking presently observable processes to explain the past, but some scholars suggest that certain past events (such as mass extinctions) require the inference of causes that are no longer acting or are now acting at markedly lower rates or intensity. We know that in the history of the earth there have been times of calm and times of crisis. Some crises affected only a region, while others were global. This assertion of Lyell's that the rate of geological change was uniformly "slow, gradual, and steady, not cataclysmic or paroxysmal" surely provided the basis for Darwin's gradualism. An appreciation of the immensity of geological time was central to understanding the evolution of Earth and its biota. The recognition of virtually limitless time was also instrumental in the acceptance of Darwin's theory of evolution. Lyell's uniformitarianism and gradualism and Darwin's theory of organic evolution would dominate the earth sciences for nearly 150 years.

Lyell has also been criticized for his supposition of the uniformity of state or antiprogressism. In his effort to refute catastrophism, he assumed that in the history of the earth everything occurred at a slow and uniform pace, in a succession of cycles that repeat themselves indefinitely without advancing in any direction. This supposes that there is no vector of progress and that, although details are modified, nothing really changes. In other words, the earth is effectively in a dynamic steady state. In this claim, Lyell found it hard to accept that throughout the history of life on Earth, substitutions and renovations of species of animals and plants had taken place. It took years before Lyell was finally convinced of organic evolution. This is the component of Lyell's uniformitarianism that is most typically ignored by modern geologists, because a large body of evidence indicates that the earth has changed dramatically over its history. In the past few decades new theories have developed in the geoscience community recognizing that both major catastrophic events and rhythmic environmental cycles play significant roles in geological processes and the evolution of life.

Beatriz Azanza

See also Catastrophism; Earth, Age of; Evolution, Organic; Extinctions, Mass; Geologic Timescale; Geology; Hutton, James; Lyell, Charles; Paleontology; Saltationism and Gradualism

Further Readings

Camardi G. (1999). Charles Lyell and the uniformity principle. *Biology and Philosophy, 14,* 537–560.

Gould, S. J. (1965). Is uniformitarianism necessary? *American Journal of Science, 263,* 223–228.

Oldroyd, D. (1996). *Thinking about the earth: A history of ideas in geology.* Cambridge, MA: Harvard University Press.

Virgili C. (2007). Charles Lyell and scientific thinking in geology. *Comptes Rendus Geoscience, 339*(8), 572–584.

Wicander, R. ., & Monroe J. S. (2003). *Historical geology: Evolution of earth and life through time* (4th ed.). London: Brooks-Cole.
York, R., & Brett, C. (2005). Natural history and the nature of history. *Monthly Review, 57*(7), 21–29.

Universe, Age of

In 1926 the American astronomer Edwin P. Hubble discovered that all distant galaxies are rapidly moving away from us. This pioneering observation was (and still is) broadly interpreted as a global expansion of the universe. Hubble's discovery, together with the cosmological Friedmann-Lemaitre-standard model, led to the general insight that the universe should have a temporal origin, which, since the 1950s, has been called the big bang. The hot big bang picture received what is considered final confirmation in the mid-60s when the cosmic microwave background radiation (CMBR) was first observed. The CMBR is broadly considered as a leftover of an early hot and dense universe. We define the age of the universe by the time t_0 that has elapsed since the big bang.

After his observations, Hubble estimated the universe to be expanding with a current rate of $H_0 \approx 500$ kilometers/second/Mpc (1 Mpc = 3.26 million light-years = 30,840,000,000,000,000,000 km). In cosmology, H_0 is called the Hubble parameter. If we could assume the cosmic expansion to be constant over the whole history of the universe, we could simply determine its age as the inverse Hubble parameter $1/H_0$. According to Hubble's first estimate, t_0 would obtain a value of 2 billion years, in contrast to what we know about the lifetimes of our earth and many other celestial objects. During the following decades, until the 1970s, the value of H_0 was dropping to a range of 50 . . . 100 km/sec/Mpc due to major advances in our knowledge of stellar populations and more sophisticated measuring methods. Accordingly the estimates of t_0 were increasing to about 10–20 billion years.

Certainly the cosmic expansion has not proceeded at a constant rate throughout its history. Thus one has to keep in mind that the $1/H_0$ estimate can be only a very rough approximation for the age of the universe.

Other independent methods of age determination are thus in great demand. For a start, it is possible to extract a lower t_0 limit from *geochronology,* that is, from the determination of our planet's age. One can access reliable radiometric methods for this purpose. It has been known for a century that uranium-235 is decaying to the stable lead-207 with a half-life-period $t_{1/2} \approx 700$ million years. For uranium-238, on the other hand, it takes 4.5 billion years to (finally) decay to lead-206 by 50%. In order to determine the age of rock, one has to measure the mass fractions of such long-living radioactive elements as well as their stable decay products. Once knowing the "mother"- and "daughter"-elements' mass ratio, it is simple to reliably calculate the ages of the earth's crust's oldest rocks, as well as those of meteorites and the moon. By this method one could assign the age of 4.6 billion years to the earth and the solar system.

From stellar evolution theories, anyway, it is known that there must have been existing earlier generations of stars before the sun. One can tell from the solar metal content. Heavy elements (or *metals,* as denoted by astronomers) are formed over millions and billions of years in the inner regions of massive stars and admixed to the interstellar medium during nova- and supernova explosions. If the sun were a first-generation star, it should contain heavy elements in much lower amounts than observed.

Among the oldest objects within the universe are so-called globular clusters (GCs). These are stellar aggregations of spherical shape and high density, located predominantly in the periphery, or halo, of our galaxy (and other galaxies as well). The up to 10 million stars in a GC are widely assumed to have formed coevally, more or less. We know about the old ages of GCs from their comparable low metallicities (i.e., the abundance of heavy elements) on the one hand and from their stellar population composition on the other: According to our present knowledge, stars change their temperature-luminosity relationship after the end of a certain life cycle (the main sequence cycle), the duration of which is strongly correlated with the mass of the star. If one is plotting the temperatures of GC stars against their luminosities in a so-called color-magnitude diagram, most of the data points will be located along a narrow straight line, the main sequence. Color-magnitude diagrams of GCs show a common feature: the straight main sequence line does not continue above a certain temperature but experiences a sharp bend. At this location, stars are assembling whose main-sequence evolution is just ending. One can tell the age of particular GCs from the position of this "knee" by applying stellar-evolution theories.

Independently, one can make use of so-called white dwarfs (WDs) to determine the age of stellar systems. WDs represent the final stage of low-mass stars (m < 1.4 M), cooling down without any further energy production over billions of years. The current temperature together with its mass allows one to calculate the age of a white dwarf. The analysis of numerous of GCs' stellar populations finally yields ages of 11–13 billion years. Following the theories of early cosmological structure and star formation, the universe has to evolve for at least some hundreds of millions of years before the appearance of the first stars. Finally this suggests the universe has an age of 12–14 billion years.

Since the beginning of the new millennium the NASA space probe WMAP (Wilkinson Microwave Anisotropy Probe) has been sending data from cosmic microwave radiation measurements down to earth. WMAP provides the opportunity to measure and analyze the tiniest variations within the otherwise homogeneous microwave background. These fluctuations represent the birth sites of the billions of galaxies we observe today, but moreover, the detailed distribution of these fluctuations is closely connected to the values of the fundamental cosmological parameters like the density parameter Ω, the cosmological constant Λ, or the Hubble parameter H_0. A statistical analysis of the background fluctuations therefore allows the accurate calculation of these parameters and hence the reconstruction of the detailed expansion history and age of the universe. From the most current WMAP data, cosmologists calculated an age of $t_0 \approx 13.7$ billion years, in excellent concordance with the stellar evolution results.

Helmut Hetznecker

See also Big Bang Theory; Big Crunch Theory; Cosmogony; Light, Speed of; Pulsars and Quasars; Stars, Evolution of; Universe, Evolving

Further Readings

Coles, P. (Ed.). (1999). *The Routledge critical dictionary of the new cosmology.* New York: Routledge.

Kragh, H. (2005). The discovery of the finite-age universe (American Astronomical Society, DPS meeting #37, #05.01). *Bulletin of the American Astronomical Society, 37,* 625.

Longair, M. S. (1998). *Galaxy formation.* New York, Berlin, Heidelberg: Springer.

Universe, Closed or Open

The density parameter, a ratio of the real density of matter in the universe to a specified critical density, describes the shape of our universe. The shape of the universe will determine its ultimate fate. A closed universe would have a density value greater than the critical density value of 1, while an open universe, a value less than 1. Critical density, at 1, is the point where just enough matter exists to maintain a balance between collapse and infinite expansion. A closed universe is of finite size and matter cannot spread far enough apart to cease having a gravitational effect on neighboring matter during expansion. The result is eventual collapse, the big crunch. In an open, unbounded universe expansion is infinite and matter, spread ever thinner, has a decreasing gravitational effect on other matter.

The shape of the universe may also be described by the geometry of its curvature. Relativity describes gravity as the curvature of spacetime by an object's mass, the whole universe curved by the total content of its mass. There are three possible curvatures. All take into account an assumption about the way matter is distributed and how gravity works, along with the manner in which the universe first appeared in the big bang.

A positively curved universe, a sphere, is closed and finite. The angles of a triangle in this universe would add up to more than 180 degrees. The density of its mass would cause an eventual halt and reversal of expansion, followed by collapse. A negatively curved, hyperbolic universe, imagined as saddle-shaped, is infinite and unbounded. The angles of its triangles add up to less than 180 degrees, its negative critical density causing it to expand forever. A third possibility exists, that of a flat universe, where the balance is just enough to enable the expansion to approach zero, yet not support collapse. A flat universe conforms to Euclidean geometry, where the angles add up to 180 degrees. Today, scientists generally regard our universe as flat, although the exact amount of mass present has not yet been determined. Most of the universe seems to be composed of little-understood invisible dark matter and dark energy.

Observations of temperature and other variables in the cosmic microwave background radiation, the afterglow of the big bang, have yielded more information about the likely geometry of space. These measures suggest a flat universe. A recent study, using information from the Sloan Digital Sky Survey, looked at the distribution of a great number of giant elliptical galaxies sufficiently distant to measure the evolution of these galaxies over the past 5 billion years. The resulting yardstick for measuring cosmic expansion again led to the conclusion that the universe is flat.

Isabelle Flemming

See also Cosmogony; Eternity; Universe, Contracting or Expanding; Universe, End of; Universe, Origin of

Further Readings

Livio, M. (2000). *Accelerating universe: Infinite expansion, the cosmological constant, and the beauty of the cosmos.* New York: Wiley.

Shellard, P. (Ed.). (1996). Low density inflationary universes. Retrieved June 29, 2008, from University of Cambridge, Relativity and Cosmology Web site: http://www.damtp.cam.ac.uk/user/gr/public/inf_lowden.html

Wheeler, J. C. (2007). *Cosmic catastrophes: Exploding stars, black holes, and mapping the universe* (2nd ed.). New York: Cambridge University Press.

Universe, Contracting or Expanding

In the 1920s the physicists Alexander A. Friedmann (1888–1925) and George Lemaître (1894–1966) succeeded in describing the global dynamics of the universe by simplifying the field equations of the general theory of relativity with the help of symmetry assumptions. The equations they found do not allow for a stable, static universe. This result led Albert Einstein to add a so-called cosmological constant to his equations in order to achieve an equilibrium state for the universe. In 1926, however, the American astronomer Edwin P. Hubble (1889–1953) observed all distant galaxies as moving away from the earth, the more distant stars receding the fastest. After this discovery, the expansion of the universe was considered a fact, and even Einstein finally removed the cosmological constant from his field equations. There are nevertheless local deviations from the global expansion, if the gravity between close-by objects manages to overcome the global Hubble drag. For example, the Milky Way and the Andromeda galaxy are approaching each other at the rate of some dozen miles per second to merge in 2 to 4 billion years.

It is generally thought that right after the big bang, the beginning of space and time, the universe ran through a very short period of extremely fast expansion called *inflation.* This very enormous expansion passed over to the moderate one still taking place today. One usually assumes a phase transition of a spatial homogenous scalar quantum field that exerts a negative pressure as a reason for inflation. The detailed origin and course of inflation is still a matter of speculation.

Based on numerous observations, especially by the NASA space probe WMAP, cosmologists are today in a position to characterize the state of the universe via just a few parameters. The most important of these are the mean cosmic density Ω; the Hubble parameter H_0, characterizing the current expansion rate; and finally the cosmological constant, which is, along with the mean density Ω, crucial for the future of the cosmic expansion. Depending on the values of these numbers we live in a universe that either will bring its expansion to a halt and maybe even convert it to contraction in a far distant future–or that will expand forever. The connection between H_0, Ω, and Λ on the one hand and the history and fate of the universe on the other is given in a simple way by the Friedmann-Lemaître equations. Following the parameters, it is widely assumed today that out universe will even *accelerate* its expansion in the future, instead of slowing it down.

This knowledge makes any philosophical speculation needless concerning the so-called arrow of time. In his most famous book, *A Brief History of Time,* astrophysicist Stephen Hawking speculates about the direction of time and a decrease of entropy in a contracting universe. The possibility of a time inversion is, however, generally not accepted. Rather, the "cosmological arrow of time" is interpreted in a way that the particular size of an exclusively expanding universe allows us to distinguish both globally and uniquely between the past and the future.

Helmut Hetznecker

See also Big Bang Theory; Big Crunch Theory; Cosmogony; Cosmology, Inflationary; Universe, Closed or Open; Universe, End of; Universe, Origin of

Further Readings

Hawking, S. W. (2001). *A brief history of time.* New York: Bantam Books.

Longair, M. S. (1998). *Galaxy formation.* New York: Springer.

Universe, End of

The end of the universe is a concept that has been used to define timelessness itself. Something lasting to the end of the universe used to be synonymous with eternity. Using the latest cosmology theories, contemplating the end of the universe is still considering some of the largest spans of time in human imagination. At this moment in the lifespan of the universe we are standing a short way down a long road with an uncertain ending. Three current possible ends are: an endless expansion, a big crunch, or a big rip of everything in the universe.

Until the early 1900s the universe was thought to be static and eternal. Ideas about the beginning and end of the universe were in the philosophic realm. Although astronomers understood that the stars in the sky were other suns, no one imagined that the hundreds of billions of suns in our galaxy were only a tiny proportion of the suns found in hundreds of billions of galaxies. When Albert Einstein developed his theory of relativity in 1912 he suggested that matter and energy were interchangeable under the right conditions. Calculating the total matter and energy in the universe combined with astronomical observations gives a defined beginning and end.

Researchers have agreed that the universe began as a "big bang" around 14 billion years ago when all matter and energy were collected together in an infinitesimally small point. From that beginning, it suddenly expanded out in all directions. Initially extremely high temperatures dominated it, so that atoms and matter could form only when it had cooled down. That matter then formed into stars and galaxies, and that expansion continues today.

The question of the ultimate fate of the universe is dependent on whether it is open or closed. Either the amount of matter and energy in the universe will allow it to expand forever in all directions from its single point of origin, or the universe has enough matter and energy in it that after expanding a while, it will slow its expansion and gravity will draw everything back into a single infinitesimal point. It is also possible that we do not know enough yet to eliminate other possibilities, such as dark energy ripping the universe apart.

Collapse as a Final Fate

Current theory still suggests that the universe is open and that the universe will not collapse into a single point. However, the discovery of the possibility of dark energy has led to a theory known as the big crunch. If this theory is true, its effects would not be noticeable for billions of years. The big crunch predicts it will be 12–14 billion (10^{10}) years before the universe collapses again into a single point. It is theorized that dark energy could change in character as the universe ages from a force that opposes gravity to a force that increases the power of gravity. This change would result in the expanding universe eventually stopping and beginning to contract.

If a collapse does happen, the first effect would be a slowing of the stars' and galaxies' tendency to spread apart. The stars would slow until for a brief time they would not move apart at all. At that point, billions of years in the future, stars will be very far apart and they will have aged. The lifespan of a star like ours is about 10^{10} (10 billion) years. Star formation will have slowed as the universe ages and matter for condensation into new stars (in the form of exploded stars) will be more diffuse.

As matter begins to be gathered back together, matter for star formation will be easier to find again as everything becomes closer together. An observer in space with sufficient lifespan would see the sky fill again with stars, growing over billions of years to become crowded. Also, because of the shrinking closed universe, rays of light would be able to cross the universe and come back from the opposite directions. The sky would fill with "ghosts" of galaxies and stars that have burned out although their light continues.

As the stars become even more crowded and the universe becomes one thousandth of its present size, the background stellar radiation would interfere with the planets until they became uninhabitable. Eventually the stars themselves would begin to tear each other apart through gravitational interactions. Suns would form out of the debris, only to be destroyed again. The last few million years before the end, the universe would be a fiery, lethal place as matter rushes into multiple black holes and those black holes begin to combine with each other into one final black hole. The final second of the universe would be instantaneous as all light and matter disappear behind the black hole event horizon into a single dimensionless singularity. What would happen beyond that singularity is still unknown.

Infinite Expansion

If the universe continues to expand, the end of the universe will be very similar to the famous line from T. S. Eliot's 1925 poem "The Hollow Men": "This is the way the world ends—not with a bang but a whimper."

Scientists currently believe that the universe is expanding and even accelerating as it flies apart. As the eons pass, the universe will get thinner, colder, and darker. As stars go through their life cycles, more and more stars will go out. Even low-mass long-lived stars, like white dwarfs, will gradually burn their fuel and cool down, pulsars will gradually lose their spin, and black holes will continue to add to their masses.

For an imaginary observer where the earth currently exists, 3 trillion (3×10^{12}) years from now the nearest galaxies will have receded beyond the cosmic light horizon. The galaxies will appear to be dark and difficult to observe. As the energy of the universe runs down, visible light will shift to lower-energy infrared light. This process of dimming will continue as galaxy and star formation stops as the universe reaches the age of 100 trillion (10^{14}) years.

An observer at the end of the life of the universe would see a long quiet time as all matter in the universe becomes either part of super-massive black holes or scattered stellar debris. The universe would slowly change until all the matter outside of black holes experiences proton decay at around 10^{40} years. The final stages of the universe may last for 10^{100} years when the black holes themselves evaporate into photons (via Hawking radiation). After that, all matter in the universe may consist only of photons and leptons as the universe winds down to the ultimate low-energy state.

Other Ends

Another end that has been contemplated involves dark energy behaving in a different way. The idea is that of a big rip, where increasing dark energy gradually opposes gravity and dominates the universe. It has been speculated that if the dark energy–driven expansion of the universe fed back on itself, expansion could trigger a growth of dark energy resulting in an increasing strength of the dark energy, making the expansion accelerate even more rapidly. If this were true, the universe would end violently in 21 billion years, as all material objects in the universe were ripped apart into subatomic elementary particles.

John Sisson

See also Big Crunch Theory; Black Holes; Cosmogony; Cosmology, Cyclic; Heat Death, Cosmic; Relativity, General Theory of; Stars, Evolution of; Time and Universes; Universe, Age of; Universe, Closed or Open; Universe, Contracting or Expanding; Universes, Baby

Further Readings

Nicolson, I. (2007). *Dark side of the universe: Dark matter, dark energy, and the fate of the cosmos.* Baltimore, MD: Johns Hopkins University Press.

Steinhardt, P. J., & Turok, N. (2007). *Endless universe: Beyond the big bang.* New York: Doubleday.
Weinberg, S. (2008). *Cosmology.* Oxford, UK: Oxford University Press.

Universe, Evolving

The general theory of relativity by Albert Einstein (1879–1955) forms the basis of any discussion about the fate and the evolution of the universe. The theory's principal feature is a system of differential equations that connects the cosmic matter content with the intrinsic geometry of spacetime: A massive particle curves the space in its vicinity, and the deformed space exerts influence on the motion of another particle. The Einstein system of equations reduces to only two independent equations if applied to the universe as a whole. This is due to the assumption that the universe is homogenous and isotropic on very large scales (e.g., above a 100 million light-years). The remaining two equations describe the course of cosmic expansion via three free parameters (the expansion rate H_0, the mean energy density Ω, and the cosmological constant Λ). The time dependence of the expansion also determines the behavior of the global temperature, which (together with matter and radiation density) again defines the conditions for any physical process in the early universe.

Today it is widely accepted that the universe was brought into existence 13.7 billion years ago in a very hot and dense state. The current temperature of the universe is 2.7 Kelvin, or 2.7° Celsius above absolute zero. Right after the big bang (BB) the temperature is believed to have been some 10^{32} K. It is assumed that under such conditions the four fundamental forces (gravitation, weak, strong, and electromagnetic interaction) were unified as a single force, described by a hypothetical *theory of everything* (TOE), which has not yet been put forth. In the course of the (initially very rapid) cooling, the fundamental forces we know today separated from the unified interaction one after another. Coevally the first elementary particles could freeze out of the high energetic matter/radiation mixture: Following quantum field theory, particle/antiparticle (*P/AP*) pairs can form from radiation and decay instantaneously again, while the Einstein relation $E = mc^2$ is preserved. Here E is the energy of the radiation quantum, that is, the photon; m the P/AP mass; and c the speed of light. Due to a not completely understood asymmetry during the *grand unification* (of strong, weak, and electromagnetic force) epoch, there was a tiny excess of matter compared to antimatter (1,000,000,001: 1,000,000,000). So, after the decay of all P/AP pairs there was some extremely small amount of matter left over, which provides the substantial content of the universe today.

Quarks and antiquarks were the first particles to freeze out 10^{-33} seconds after the BB. Their high energies prevented them from forming bound states with each other. They instead constitute a so-called quark-gluon-plasma consisting of free (anti)quarks and gluons, the mediator particles of the strong interaction. Via permanent crashes most quark-antiquark pairs annihilated each other instantaneously, producing radiation until the one-billionth-excess was finally left over. After a millionth second, the temperature had dropped enough to allow for bound states of various quark species (*flavors*), the best known of which we know as protons and neutrons. After about one second all electron-positron (= *anti-electron*) pairs also annihilated except for the above-quoted excess, so that the substantial basis of the "normal" matter we know today (in contrast to *dark matter*) was provided.

Subsequently, the next hierarchical level of matter was formed in a 3-minute-process called *nucleosynthesis*—the assembling of atomic nuclei, consisting of various proton/neutron combinations: helium (2 protons + 2 neutrons), deuterium (1p+1n), as well as tiny amounts of helium-3, lithium, and beryllium were brought into existence during this epoch. The hydrogen cores, the lightest of all, had already been in existence in the form of single protons. At that time electrons could not become bound to the positively charged nuclei via electromagnetic forces, because of the still enormous cosmic temperature. In fact, such electron-nucleus bonds could happen at any time, but due to a permanent barrage of high-energy photons, those were extremely short lived. Thus, a few minutes after the BB, all the *baryonic* matter in the universe (basically protons, neutrons, nuclei, and electrons) was provided in the form of a highly ionized plasma, standing in thermal equilibrium with radiation.

For the next 10,000 years the universe evolved without any outstanding events. The expansion simply continued, as temperature and matter density dropped accordingly. And so did the energy density of radiation, in a particular manner: First, the number density of the photon reduces as R^{-3}, where R is the cosmic *scale parameter,* that is, the *"diameter"* of the universe. In addition, electromagnetic radiation suffers a so-called *redshift:* the wave trains are simply being stretched while they float through an expanding space. This leads to a further loss of energy, known as R^{-1}. Thus radiation, the dominant energy component in the early universe, is losing its energy density much faster than matter (R^{-4} and R^{-3}, respectively). After approximately 10,000 years, matter becomes predominant in the cosmic energy budget. By today radiation has lost any relevance for cosmic evolution.

It took almost 400,000 years for the next milestone of cosmic history to occur. By then the photons had lost such a large amount of energy that they were no longer able to destroy the bonds between electrons and nuclei as they had done earlier. Within a very short period a substantial amount of the universe transformed from an ionized state to a neutral hot gas. This brought the permanent photon scattering to an end, since it is not possible for photons to interact with electrically neutral particles. After this event of *decoupling,* radiation for the first time was able to drift freely through space without any deflection. The universe has been transparent since that time. The radiation released then is still detectable as *cosmic microwave background radiation* and provides one of the fundamental supporting pillars for the hot BB picture.

Once matter and radiation were decoupled, the formation of large structures in the universe was possible. Prior to the decoupling event, structure formation was prevented by ongoing matter-radiation interactions. Within a few hundred millions of years the tiny density fluctuations, which must have been present right after the BB, were amplified sufficiently to collapse locally through the influence of their self-gravity. This allowed the first galaxies and stars to form. These first stars had to get by on the available elements hydrogen and helium, present at that early epoch of the universe. Presumably they were quite massive and accordingly very short lived. They were thus able to enrich the interstellar matter quickly with progressively heavier elements up to iron, which had been created by the stellar interior fusion processes. Only from these heavy elements was it possible for (terrestrial) planets to form, together with stars of later generations. After the onset, star formation experienced a continuous boom and reached a maximum after 3 billion years to decline again later on. Stars form within larger structures, the so-called *dark halos,* which also accommodate massive galaxies like our Milky Way or the Andromeda galaxy. The very first dark halos, some hundreds of millions of years after decoupling, had comparable small masses of some million solar masses (M_{sol}). In the course of time, near flybys and mergers between smaller halos happened, causing larger and larger structures to form in the universe. Today one can find enormous accumulations, herds of galaxies, so-called *superclusters* with masses up to 10^{15} M_{sol}.

In the future we can expect further growth of the largest structures due to ongoing merger events. As shown by observations in 1998, the universe has been expanding at a slightly increasing rate for about the past 5 billion years. In fact, this acceleration seems to increase continually. This is expected to counteract structure formation more and more in a far distant future.

Helmut Hetznecker

See also Big Bang Theory; Cosmogony; Cosmology, Inflationary; Evolution, Cosmic; Forces, Four Fundamental; Gamow, George; Lemaître, Georges Edouard; Nebular Hypothesis; Stars, Evolution of; Time, Cosmic; Time, Cyclical; Time and Universes

Further Readings

Börner, G. (2003). *The early universe: Facts and fiction.* New York: Springer.

Coles, P. (2001). *Cosmology: A very short introduction.* Oxford, UK: Oxford University Press

Longair, M. S. (1998). *Galaxy formation.* New York: Springer.

UNIVERSE, ORIGIN OF

In the last two decades of the 20th century, observational cosmology grew from a crude science to one of exquisite precision. Observations made from Earth and from space uniformly confirm a picture of a visible universe composed of a hundred billion or so galaxies, each containing typically a hundred billion or so stars, flying away from one another as if from an explosion that is dubbed the *big bang*. According to current best estimates, the big bang began 13.7 ± 0.2 billion years ago.

Hubble Expansion and Inflation

The expansion of the universe was discovered by Edwin Hubble in 1929 and until recently has appeared to be linear; that is, the average recessional speed of galaxies from Earth was proportional to their distance. In 1998, two independent research groups made the surprising discovery, since confirmed by further independent observations, that the expansion is actually accelerating. The universe is falling up!

The latest data also strongly support a model proposed in the early 1980s called *inflation,* in which the Hubble expansion was preceded by an exponential expansion lasting only about 10^{-35} seconds during which the universe increased in size by hundreds of orders of magnitude. This implies that by far the greatest portion of the universe that exploded from the same source lies beyond our visible horizon, the farthest distance we can see given the finite propagation speed of light. This rapid expansion flattened out the geometry of the universe analogous to the surface of a large balloon and further implied that the energy density of the universe is very close to what it should be if the universe began with zero total energy. That is, no energy from outside was required to produce the universe. The birth of the universe did not violate the law of *conservation of energy* or any other basic principle of physics.

Various models of inflation predict the existence of other universes besides our own, each appearing by the same process. Although we have no way of empirically verifying these universes, neither do we have a way of ruling them out. While some people have contended that science should not consider objects that cannot be directly observed, this argument is refuted by the fact that science has done so many times with great success, such as with the theory of atoms in the 19th century.

Dark Matter, Dark Energy, and Quintessence

Today visible matter, which constitutes all stars and galaxies seen with the most powerful optical telescopes, comprises only 0.5% of the mass of the universe. In fact, normal atomic matter, including that which is nonluminous, such as the matter in planets or dead stars, totals only 4%. The remainder of the universe is composed of some yet-unidentified substance called *dark matter,* comprising 26% of the mass of the universe, and an even more mysterious *dark energy* that is the largest component, fully 70% of the universe's mass. The dark energy is responsible for the repulsive gravity that drives the accelerated expansion. Furthermore, it is expected that this acceleration will continue to increase with time so that the universe is destined to become more and more dilute.

Although gravity is normally thought of as purely attractive, Einstein's 1916 *general theory of relativity,* the modern theory of gravity, predicted repulsive gravity for matter with sufficiently negative pressure or if empty space has positive curvature described by a term in Einstein's equations called the *cosmological constant.* Current observations tend to favor the cosmological constant option, but have not totally ruled out the possibility that dark energy is composed of a yet-unidentified material field that has been dubbed *quintessence.*

It should be mentioned that cosmologists are still studying various alternatives to the picture presented above, which remains the current consensus.

Order, Chaos, and "Nothing"

While electromagnetic radiation, composed of the photons in the *cosmic microwave background,* makes only a tiny contribution to the total energy of the universe, the number of photons outnumbers the number of atoms in normal matter by a factor of a billion. These photons move around almost completely randomly with a thermal blackbody energy spectrum characterized by an average temperature of 2.7 degrees on the absolute Kelvin scale. Their deviation from randomness is only one part in one hundred thousand. The common but mistaken belief that the universe is very orderly is a bias based on humanity's location on Earth, a tiny speck of order in a vast sea of disorder.

According to current cosmological models based on both general relativity and quantum mechanics, inflation originated from a tiny region of space on the order of 10^{-33} centimeter across that is indistinguishable from a primordial black hole. This implies that the universe as we know it started from a state of maximum entropy, that is, maximum disorder. It began in total chaos. This chaos, being without structure, is about the closest we can come to describing a state of nature that we can label as *nothing*. The structure of the universe evolved as the universe exploded out of the initial chaos. Because of the expansion of the universe, there is increasing room for order to evolve as time goes on.

For three decades, the *standard model of particles and forces* has successfully described all empirical data from both laboratory and astronomical instruments. This model utilizes the methods of relativistic quantum field theory. A relativistic quantum field consists of particles called quanta, and every elementary particle is the quantum of a field. Within the mathematical formalism, annihilation and creation operators are used to add or subtract quanta from a field. When the annihilation operators are applied a sufficient number of times, we are left with a perfectly well-defined quantum state of zero particles we can identify as "nothing." The basic laws of physics still apply in this state.

One objection that might be raised is that if this region of chaos we call "nothing" still can be described by the laws of physics, then it is something with structure and not "nothing." However, it must be recognized that the laws of physics are human inventions and not to be viewed as structural properties of the system being described by physical models.

When we perform the annihilation process on the particles of the universe in its current state of matter, the vacuum that we get when all particles are removed still has a net *zero-point energy* and so is not quite "nothing." However, the very early universe is expected to be *supersymmetric,* that is, equally balanced between the two kinds of elementary particles: *bosons,* which are characterized by integer spin (spin is the intrinsic angular momentum of a particle) and *fermions,* which are characterized by half-integer spin. In that situation, the zero-point energies exactly cancel and we have zero particles and zero energy.

The state of "nothing" is related to the well-studied situation in quantum mechanics where particles can tunnel through barriers that will not permit particle transmission according to classical mechanics. Quantum theory allows for the wave function of an external particle to pass through the barrier. This is called *quantum tunneling*. The region inside the barrier is termed "unphysical" because the momentum of the particle is an imaginary number (that is, its momentum contains the factor $\sqrt{-1}$). Such a particle is unmeasurable but still describable mathematically. The theory of quantum tunneling has been verified empirically and used to explain the radioactive *alpha decay* of nuclei with great precision. The s*canning tunneling microscope,* which can be used to view objects as small as atoms, is based on quantum tunneling.

In a crude sense, quantum tunneling can be viewed as a process by which the energy of a particle undergoes a spontaneous fluctuation, which is allowed by the *Heisenberg uncertainty principle,* one of the basic principles of quantum mechanics. Momentarily, the particle has sufficient energy to surmount the barrier. It is as if a dog confined to a yard by a fence too high for him to jump, gets a boost from nowhere enabling him to go over the fence. Many scenarios for the spontaneous origin of the universe are vaguely described as "quantum fluctuations." However, the tunneling phenomenon is well established and can be fully described mathematically.

Reputable physicists have published in peer-reviewed journals a number of proposals for the formation of the universe by natural means from an initial state of "nothingness" or chaos. While none of these can be proven to represent the precise manner in which the universe appeared, the fact that all these scenarios are consistent with existing knowledge and violate no known laws of physics suffices to demonstrate that no nonnatural forces were necessary to bring the universe into existence.

Assuming an isotropic universe, Einstein's theory of general relativity leads to the *Friedmann equation* that, in turn, can be used to derive a simplified form of the *Wheeler-DeWitt equation.*

That equation, in this case, is mathematically equivalent to the nonrelativistic *Schrödinger equation* for a particle of mass equal to half the Planck mass (and zero energy moving in one dimension within a specific potential energy field). Solving this equation gives the "wave function of the universe."

At least two solutions have been proposed. A solution proposed by Alexander Vilenkin has the universe tunneling out the chaos described above and thus "coming from nothing." A solution proposed by James Hartle and Stephen Hawking has no boundary conditions but describes a universe, existing before the chaos, that tunnels through that chaos to produce our universe. From our point of view that prior universe undergoes a contraction and deflation that is the opposite of our inflation and expansion. However, in this other universe the arrow of time is reversed from ours. Thus, from the point of view of an observer in that universe, inflation and expansion such as ours also takes place—just in the opposite direction of time. However, since so many spontaneous (random) phenomena are responsible for the evolution of structure in both universes, they are not expected to be exact mirrors of one another.

Again it must be emphasized that the origin of the universe cannot be proven to have taken place in exactly the fashion of either of the two scenarios presented; they can simply be viewed as plausible ways that the universe could have arisen from nothing by natural means, demonstrating that no supernatural input was required.

Finally, it should be noted that the state of "nothing," that is, the unphysical state that we have labeled chaos where the quantum wave function does not describe measurable particles, is actually less probable than the physics state that describes real particles. Many physical systems undergo spontaneous phase transitions from simpler, more symmetric states to more complex states with less symmetry and more structure. The most familiar example is the way water vapor turns to liquid and then ice. While the reverse processes also happen, they require the input of heat energy. Take away that heat and the natural progress is from simplicity to complexity. Since nothing is simpler and more symmetric than "nothing," the state of matter in which there is something rather than nothing is more natural. The reason we have something rather than nothing is that nothing is unstable.

Victor Stenger

See also Big Bang Theory; Cosmogony; Gamow, George; Lemaître, Georges Edouard; Planck Time; Quantum Mechanics; Relativity, General Theory of; Time, Arrow of; Time, Emergence of; Universes, Baby

Further Readings

Atkatz, D. (1994). Cosmogony; Quantum cosmology for pedestrians. *American Journal of Physics, 62,* 619–627.

Guth, A. (1997). *The inflationary universe.* New York: Addison-Wesley.

Hartle, J. B., & Hawking, S. W. (1983). Wave function of the universe. *Physical Review, D28,* 2960–2975.

Linde, A. (1984). Quantum creation of the inflationary universe. *Lettere Al Nuovo Cimento, 39,* 401–405.

Rundle, B. (2004). *Why there is something rather than nothing.* Oxford, UK: Clarendon.

Stenger, V. J. (2006). *The comprehensible cosmos: Where do the laws of physics come from?* Amherst, NY: Prometheus.

Tryon, E. P. (1973). Is the universe a quantum fluctuation? *Nature, 246,* 396–397.

Vilenkin, A. (1988). Quantum cosmology and the initial state of the universe. *Physical Review, D37,* 888–897.

Vilenkin, A. (2006). *Many worlds in one: The search for other universes.* New York: Hill and Wang.

UNIVERSES, BABY

The term *baby universe* can be applied to any newly formed universe, including the initial stages of our own universe. More commonly, the term has been applied in speculation about the existence of other universes that could have developed before or after our own universe came into being—universes that have existed, are existing, or will exist outside of the framework of our own cosmos. Since such universes would inhabit a different time and space, we are unable to verify or observe them.

The popularization of the term baby universe apparently had its genesis in astrophysicist Stephen Hawking's lecture "Black Holes and Baby Universes," presented at the University of

California, Berkeley, in 1988. The contents of that lecture were later included in a collection of his essays with the same name.

A black hole has generally been defined as a region in space and time with such a strong gravitational field that nothing can escape from it. Hawking, however, speculated that there could be an exception because the uncertainty principle would allow particles and radiation to travel faster than light for a very short distance. These emissions would eventually result in the loss of mass, with the black hole completely disappearing. Nothing coming out of a black hole would resemble what fell into it, though it would retain the same energy. A separate intriguing question is what would happen to the objects that fell into the black hole. Hawking suggested that they might enter a baby universe of their own that would branch off from our own part of the universe. If the baby universe was ever able to rejoin our region, it would appear as another black hole.

The idea of the existence of other universes has led to some speculation in the past about time travel. But Hawking added the important qualification that the baby universes would occur in imaginary time, defined as existing at right angles to real time. Though imaginary time is a well-established scientific concept and an important one for the understanding of quantum mechanics and the uncertainty principle, it in no way resembles our own subjective view of time. If human beings fell into a black hole, their history in real time would come to an end, and they would be torn apart by gravitational forces. In imaginary time, the changed particles would enter a baby universe and come out again from another black hole. Because of the small size of baby universes, we are unable to observe them or to predict their numbers or patterns. However, Hawking thought that their existence might help explain such values as the cosmological constant, which gives the universe its natural tendency to expand or contract.

In 2004, Hawking surprised some cosmologists by stating that he now considered himself wrong about the existence of baby universes that branched off from our own. He now claims that as a black hole begins to die it simply sends its contents back out into the universe in a transformed state. Other cosmologists, however, continue to speculate about the possible existence of baby universes and/or multiple universes, sometimes referred to as the multiverse.

Cosmologist Alan Guth is credited with introducing the theory of inflation, which allowed the universe to grow from only about an ounce of primordial material. Guth further concluded that the idea of the existence of multiple universes is a logical consequence of inflation. Furthermore, cosmologist Lee Smolin speculates that black holes created after the explosion of a star might give birth to other universes by a process sometimes referred to as a "bounce." The more black holes a universe has, the more it could eventually produce. The laws of physics would likely evolve to encourage this process.

A new universe could possibly develop into one similar to ours, with intelligent beings. The concept of time in this different region of space and time would probably seem as real to those observing it as our definition of time is to us. In our own universe, we have defined time as having its beginnings following the big bang, which we now believe occurred about 14 billion years ago. Observers have made considerable efforts to measure the passage of time in a uniform way.

Dave Shiga reported on a model whereby the universe might shatter into pieces, each of which would grow into a new universe. This theory could explain why our own universe began in such a well-ordered state, with the natural process of entropy, or disorder, increasing through time as the universe inflated. Moreover, cosmologist Sean Carroll suggested that our being part of a large group of universes might also explain why entropy has not occurred as rapidly as might be expected.

Physicists have investigated the possibilities of scientists actually being able to produce baby universes in their laboratories. The big bang involved the production of a new spacetime in a very tiny space. That conclusion led to the speculation that if energy could be concentrated to a high enough degree, it might reproduce the same process in a laboratory. An example is seen in the 2006 work by Nobuyuki Sakai and colleagues at Japan's Yamagata University. They hoped to create a baby universe using the Higgs field, which would ensure that the density of energy inside bubbles of a false vacuum would remain constant. If successful, then the baby universe would presumably break off into a spacetime of its own. It would have no direct effect on our own universe and even be hard to verify as having taken place. Despite inherent problems and doubts, interested physicists are not likely to abandon such efforts.

There may be no reason to think that baby universes will ever serve as a means of time travel or as a means of escape in the event that our own universe would become uninhabitable. But scientists and laypersons alike should be interested in what further observation and testing might tell us about the real or theoretical possibilities of their existence, including the implications regarding the origin of our own universe and our concepts of time and space.

Betty A. Gard

See also Black Holes; Cosmogony; Cosmology, Inflationary; Hawking, Stephen; Multiverses; Time and Universes

Further Readings

Coleman, S., Hartle, J. B., Piran, T., & Weinberg, S. (Eds.). (1991). *Quantum cosmology and baby universes.* Teaneck, NJ: World Scientific.

Hawking, S. (1993). *Black holes and baby universes and other essays.* New York: Bantam Books.

Smolin, L. (1997). *Life of the cosmos.* New York: Oxford University Press.

Universes, Multiple

See Multiverses

Ur

Ur was a Sumerian city in southern Mesopotamia, located near the mouth of the Euphrates River. The site is significantly inland in present-day Iraq, but in ancient times the Persian Gulf extended much farther north, making Ur a seaport on busy land and sea trade routes. The city was both historically and culturally significant for over 2,000 years.

The city of Ur was founded in the 5th millennium BCE, during the Ubaid period. By 2800 BCE, Ur had become one of the most prosperous Sumerian city-states. Over time, Ur had three dynasties of rulers who extended their control over all of Sumer. Ur is referred to in the Bible as Ur of the Chaldees, birthplace of the Prophet Abraham. Chaldeans settled the area about 900 BCE, placing the city of Ur and the Bible in the same historical context.

The founder of the First Dynasty of Ur was the conqueror and temple builder Mesanepada, who reigned about 2670 BCE. The city was a leading urban center, with control over much of Sumer. The First Dynasty is known best through the extraordinary collection of grave goods found in the royal tombs excavated by Sir Leonard Woolley of the British Museum and the University of Pennsylvania Museum in the 1920s. The elaborate jewelry and personal items were made of many precious and semiprecious materials imported from as far away as Afghanistan and Pakistan, an indicator of the extensiveness of trade in the region.

Ur was captured about 2340 BCE by King Sargon of Akkad. This Akkadian period marked an important time in the blending of Sumerian and Semitic cultures. After this dynasty, there is a long gap in the historical record where practically nothing is known except that a second dynasty rose and fell.

Ur-Nammu, the first king of the Third Dynasty of Ur, reigned from 2113–2095 BCE. He revived the empire of Sumer and Akkad, and by controlling the outlet to the sea, made Ur the wealthiest city in Mesopotamia. This was an important time of political expansion in the area. His reign also marked the beginning of a renaissance of Sumerian art and literature. He wrote the first law in recorded history and built great walls around the city. His son and successor built a monumental ziggurat to worship the Sumerian moon god Nanna. The massive ziggurat, one of the best preserved in Iraq and most recognized monuments in the world, still looms more than 20 meters over the desert today. Many other iconic buildings were constructed during this neo-Sumerian period.

The descendants of Ur-Nammu held power for more than a century, until just before 2000 BCE, when the Elamites captured the current king and destroyed the city. Rebuilt shortly after, the city was eventually assimilated into Babylonia. Ur remained a provincial capital and an important religious center throughout the period of Assyrian rule in Babylonia.

King Nebuchadnezzar II of Babylonia initiated another period of intense building at Ur. Temples were remodeled and the great ziggurat was increased to a height of seven levels, making an imposing landmark that rivaled other buildings of the time.

Ur began to decline after Persia gained control of the region. By the 4th century BCE, the city was uninhabited. The relatively quick decline was probably due to a combination of factors, including drought in the region, the Euphrates changing its course, and the silting of the outlet to the Persian Gulf.

The architectural history of Ur documents the city's continuous historical, cultural, and political significance for a span of over 2000 years. It was an economic and religious center for most of its history. It remains one of the best preserved Sumerian cities in Mesopotamia today. Ur documents a lengthy time period of achievements by Sumerian society.

Jill M. Church

See also Anthropology; Archaeology; Evolution, Cultural; Evolution, Social; Pompeii

Further Readings

Moorey, P. R. S., & Woolley, L. (1982). *Ur of the Chaldees: A revised and updated edition of Sir Leonard Woolley's excavations at Ur.* Ithaca, NY: Cornell University Press.

Roaf, M. (1990). *The cultural atlas of Mesopotamia and the ancient Near East.* New York: Facts on File.

Roux, G. (1992). *Ancient Iraq*. London: Penguin Books.

Utopia and Dystopia

Generally, a utopia is an imaginary perfect place in space or time, in particular a not or not yet attainable type of society. Within literature, fictions emphasizing the social, political, and moral aspects of an ideal community constitute the utopian genre. Utopia, in its various expressions, is the conception of a successful life and living together and thus the denunciation of existing conditions. Literary utopias can be separated into utopias of time and utopias of space. In addition to a positive and optimistic understanding of utopia, there are concepts that subvert the utopian ideals: The so-called dystopia or anti-utopia is a negative utopia that proceeds from the assumption of a selfish and imperious human nature. As a negation of idealistic romance, dystopias emphasize the dark side of mankind and the consequent worst state of society.

Definition

The term *utopia* is a made-up word from the Greek words *ou* (no) and *topos* (place) that means "no place" or "nowhere." Its first verifiable mention is in the Latin title of the novel *Utopia* (1516) by Sir Thomas More, which was originally published as *De Optimo Reipublicae Statu, deque Nova Insula Utopia* ("Concerning the best state of the republic and the new island Utopia"). The very antithesis of More's humanistic ideas is the thinking of his contemporary Niccoló Machiavelli, who developed in his dystopia *The Prince* (1513) a society ruled by pure power.

With the increasing use of the term *utopia* in 17th-century European literature, it soon became part of the everyday language. In its metaphoric meaning, utopia described a nonexisting albeit cogitable place of a commonwealth superior to the existing one. The contradiction of this place was related to its impossibility and for this reason utopia turned into a pejorative term referring to an unrealistic or naïve idea. During the 19th century the significance of utopia changed to more temporal aspects, and perfection was created in the future. The ambiguity of utopian ideas expressed in the criticism and hope of progress persisted into the 20th century. In recent times, utopia is often used as a term for economic, political, historical, religious, scientific, and technological improvements.

Temporalization of Utopia

Until the end of the 18th century, *utopia* referred to an imaginary country, often supposed to be situated in an isolated or undiscovered territory on Earth. Utopias of place assume a succeeding model of socialization in the present within an unreachable or unknown spatial distance. Due to the discovery of the world it became more and more difficult to create an earthly place of perfection. Even though More and his contemporaries wrote in the century of great voyages of discovery, they refused the idea of a fully mapped world.

With Louis Sébastien Mercier's novel *The Year 2440: A Dream If Ever There Was One* (1771) the concept changed from utopias of place to utopias of time. Utopia became an ideal place in the future, and the anywhere was substituted by an anytime. The essential new element was the optimistic way in which time was used. Within the classical understanding of time, the ideal society on earth existed only in the past; all events in the present and in the future will be inferior to former times. Already in the *Republic,* Plato referred to a special conception of time by creating a society that can reach the perfection of the world of ideas only in retrospection. Similar conceptions of time can be traced in the utopian writings of the European Renaissance. Various philosophers and authors believed in the myth of a past or current golden age that could be followed only by a worsening situation. Despite the introduction of a prospective view, the 18th century remained a period of transition from space to time.

The first novel demonstrating a social development from present to future is *Looking Backward: 2000 to 1887* (1888) by Edward Bellamy. It is a primary utopia of time in the proper sense of illustrating successive and plausible moral and technical improvements. Instead of caricaturing the existing deteriorated conditions by outlining a better state, Bellamy offered practical solutions to reach a reform. Due to the progress in science and the advanced philosophy of history, the revaluation of the future enabled the temporalization of the literary utopia. In particular, the developments in modern science caused the hope of a better life in the future.

Utopia and Dystopia in Literature

Utopia and dystopia are strongly connected with the ambiguity of satire, which is often concealed in utopian writings. Consequently, anti-utopian satires can also be read as utopias. Already in early Greek writings utopian thoughts are articulated, and the conception of an ideal state of society as a normative model goes back to Plato's *Republic* (c. 380 BCE). The visionary theocratic thinking in the Middle Ages is expressed in, for example, *The City of God* by Saint Augustine of Hippo. Important utopias in the 16th century were written by Thomas More, Françoise Rabelais, and Michel de Montaigne. The most popular literary utopias since More are *Christianapolis* (1619) by Johann Valentin Andreae, *The City of the Sun* (1623) by Tommaso Campanella, and Francis Bacon's *The New Atlantis* (1626), as well as those of Joseph Hall, Cerrard Winstanley, Margaret Cavendish, and James Harrington. A great writing of the 17th century is the satire *Gulliver's Travels* (1726) by Jonathan Swift. Nineteenth-century utopias concerning idealistic communism are works in the tradition of Karl Marx and Friedrich Engels. Examples of political and economic utopias are found in the writings of Samuel Butler, Edward Bellamy, William Morris, and Theodor Hertzka. Notable 20th-century authors include H. G. Wells, Charlotte Perkins Gilman, Yvgeni Zamiatin, and B. F. Skinner. Pure dystopias are George Orwell's *Nineteen Eighty-Four* (1949) or *Brave New World* (1932) by Aldous Huxley.

Franziska Kümmerling

See also Augustine of Hippo, Saint; Evolution, Cultural; Evolution, Social; More, Saint Thomas; Orwell, George; Plato; Wells, H. G.

Further Readings

Claeys, G., & Sargent, L. T. (1999). *The utopia reader.* New York: New York University Press.

Koselleck, R. (2002). *The practice of conceptual history: Timing history, spacing concepts* (T. S. Presner et al., Trans.). Stanford, CA: Stanford University Press.

Kumar, K. (1987). *Utopia and anti-utopia in modern times.* Oxford and New York: Basil Blackwell.

Levitas, R. (1990). *The concept of utopia.* Syracuse, NY: Syracuse University Press.

Manuel, F. E., & Fritzie, P. M. (1979). *Utopian thought in the Western world.* Cambridge, MA: Belknap Press.

V

Values and Time

The term *value* has many meanings. It can have a purely economic meaning regarding monetary worth (i.e., shareholder value), an epistemological meaning of coherency and simplicity, an aesthetic meaning as in the beautiful, or it can carry an ethical meaning. Common to all these meanings, however, is that humans consider that which has "value" to be something worth striving for. This is the case even if there is no consensus about which specific things are properly considered to have value. This problem is intensified by the time dimension. Values that were formerly esteemed may fall from high regard while other values rise to take their place. The crucial question is, therefore: Are there any values that are universal, or are all values subjective? Similarly, are there any criteria that can establish an objective validity for values? Does it mean that there are values that are timeless? Or is another relation to time possible if there exists an objective validity for values?

The Concept "Value" in History

Plato (427–347 BCE) argued that values possessed an objective validity. They are eternal and universal, and thus they remain valid for all times and all places. His basic understanding can be described in the following way: There exists an objective realm of the ideas, and values such as the True and the Good belong to this realm. Plato sought to demonstrate his philosophy by separating the true ideas from the "shadows" that dim human perception. Using the now-famous Analogy of the Cave, he argued that human understanding can be freed from the shadows, but it involves a laborious process. Christianity incorporated much of Plato's philosophy, including that on the nature of the True and the Good.

Christians consider that Jesus Christ, as the revelation of God, is the incarnation of true value. This belief, which is the central Christian mystery, entails that value is to be known in the person of Jesus, as revealed in Christian scriptures. As such, value is considered to be personal and at the same time transcendent and immanent. God is the epitome of truth and goodness, whose holiness is worth striving for. In the Gospel of John, for example, Jesus says about himself: "I am the way, the truth and the life."

The savagery of religious wars in Europe and elsewhere, however, has in modern times led to an ethical reevaluation. No longer are the Good and Value in the foreground. They have been replaced in ethical and political thought by contractually secured rights. The philosopher Thomas Hobbes (1588–1679) developed a new ethic to ensure domestic and international peace and security. He passed over the ethics of values in favor of an ethical contract theory. It is true that his work continued to emphasize values, namely the values of property and "commodious living," but the contract theory emphasized the value of security above all. The social contract ensures that the one essential right, the right to life, is secure.

Immanuel Kant's (1724–1804) highly rational obligation ethics also belongs here. It is not objective values, or God as an absolute objective value, that is worth striving for as a value. On the contrary, according to Kant's ethical principle, the categorical imperative, one has the duty to act according to those maxims that can be universalized by a general legislation. Kant moved away from the "natural law" theories of value, and strove for objectivity by constructing a system based upon reason. Just as pure reason is not affected by time, the dimension of time does not play a role in Kant's ethics. The categorical imperative is therefore eternally and universally valid. That said, Kant did acknowledge the importance of appreciating value in the area of aesthetics.

Rejecting this form of ethics, Max Scheler (1874–1928) introduced a substantial values ethics system. According to Scheler, objective values exist and they are discovered in the human affect, that is, feelings. These values justify themselves according to their own form. As values, they differ from rules or duties. On the contrary, humans are drawn to follow them automatically. They are just as objective as logical thinking. Ethical relativism is unthinkable for Scheler, as is the dependence of value upon temporal circumstances. Nevertheless, values are dependent upon time because humans are temporal beings and are dependent upon values for personal fulfillment. In the course of a lifetime, humans develop according to a regimen of values. Persons mature by discovering values and, in freedom, using them to guide their lives. By living according to these true values, they show themselves to be loving, and thereby share in the love of God, who is the ground of all value.

In this way, authentic humans discover and experience the true order of values. Accordingly, lust is the lowest value. Higher on the order are the biological values, then aesthetic values that recognize the beautiful and what is ugly, and then personal values that know what is moral and good. Finally, the highest value is the value of holiness, namely the value of God. In a way, Scheler returns full circle to Platonic-Christian convictions.

Genesis of Values

These convictions of Christian values and the sacredness of values in general were already under criticism a generation before Scheler. The most notable of these critics, Friedrich Nietzsche (1844–1900), formulated a fundamentally different view from that of Christianity: Values have no objective validity, but are simply the product of particular points of view. He ascribed Christian values to a slave mentality—and its morality resulted from its resentment against its former masters. Priests were the ones responsible for inculcating those "slave" values. According to Nietzsche, this explains the genesis of such values as "good" and "evil." And with the passage of time, the slave values became internalized, especially values of so-called altruism, Christian charity, and sacrificing love.

Nietzsche argues for a reevaluation of these notions—a devaluing of values. Rather than eternal, they are to be found precisely in space and time. Values do not belong to a realm of ideas, but are concrete and should be understood as affirmations of life. For Nietzsche, accordingly, what most affirms life is the will to power. This value is realized precisely within time, by humans exercising their fullest powers first to overcome the self, and thereby to assert the human will generally. Such notions as justice and generosity dissipate the will, and therefore are countervalues. Principles of Christian slave morality cannot be affirmations of life, but rather the opposite. These antivalues have the effect of making people servile to those few who are able to assert their will to power.

At the same time that Nietzsche systematically challenged the Christian understanding of values, one of the founders of modern sociology, Max Weber (1864–1920), developed a perspective on values that had far-reaching implications. Weber studied human interaction from what was to become known as a sociological perspective, from a "meta-level," and provided a descriptive analysis of values. Refraining from value judgments himself, his descriptive analysis began from a framework where values are temporal and subjective. The term itself, *value,* corresponds to those concepts that his subjects valued, as determined through careful and neutral observation. Corresponding Platonic and Christian ideas of Value and the Good can be compared because the systems share similar philosophical methodologies. It is also relatively easy to see how they frame analogical notions of eternal truths. However, as soon as the notion of an objective truth is, per methodology, excluded as a possibility, the notion of value is necessarily considered subjectively.

Weber's project was not to find Truth or the Good, both metaphysical ideas; it was to find what societies found to be true and what they held to be relatively valuable. Relevant for his system, therefore, is the dichotomy between fact and value. Circumstances (facts) are stable, and values result from subjective valuations. Creation stories, for example, are interesting because they reveal a culture's subjective account of values to sociologists, ethnologists, and philosophers. Natural scientists, on the contrary, study the "facts" or what can be objectively quantified or explained.

Yet this strict separation between objective and subjective sciences was found to be unsustainable—between the study of objective circumstances, accessible to an objective science, and the study of subjective values, which can at best be scientifically described. The classical pragmatists (Charles Sanders Peirce, William James, John Dewey, George Herbert Mead) already held that values permeate all our experiments. Already by the 1960s, philosophers of science had demonstrated that all descriptions of circumstances are affected by valuations (epistemic and ethical values). We see through the lenses of those values. Naturally, this especially applies to the descriptions of ethical situations, such as the "circumstances" of human interactions in social situations. Cultural anthropology expressed this with the following conviction: Ethical values are culturally embedded.

Historically Emergent Values

Is it possible to develop a set of values that are not subjective, dependent upon time, and culturally determined? Stated differently: Do all values come into being and pass again from existence in the flow of time? Are they all dependent upon specific cultures? If this were the case, then a universalistic ethics would be possible only on the level of rights, if at all. Or would it be possible to return to Plato's realm of the ideas, if we wanted to establish universally valid values? If that were the case, however, we would have to deal with all the problems of Platonic philosophy.

The great philosophers of pragmatism, James, Dewey, and Mead, and their successors such as Hans Joas have suggested an alternative: Though values are bound in time, and develop with the times, they also retain validity over the course of time. The term *emergence* describes a concept with a meaning that lies somewhat in between the concepts of "construction" and "discovery." On the one hand, the term *discovery* conveys a meaning that values preexist—as in an objectively given realm. On the other hand, *construction* conveys the sense of a voluntary creation, such that a created value has only a voluntary appeal.

By describing values as "emergent," there is a recognition that they are indeed historical innovations. Yet many products of distinct social periods, such as human rights, can be shown to be values that will stand the test of time. They have sticking power because they represent stable and defensible social values. The metaphor of a birth, as described by Michel Foucault or J. Bottéro, helps illustrate this process of a historically emergent concept whose validity is acknowledged once it has been formed and generally recognized. This birth metaphor demonstrates the importance of hermeneutics for understanding: Just as the birth of a human child, in a certain sense, is the emergence of an unknown nature, so also with a value; its emergence continues to require interpretation as it matures and takes on a specific role and meaning in society. A value can develop through the course of history and even take on new ethical dimensions and meanings.

We can take, as an example, Saint Thomas Aquinas's (1224–1274) concept "human dignity" that many centuries later continues to be developed. For Kant, human dignity is expressed by the insistence that humans never be used as means, but are always ends in themselves. Certainly, Aquinas would not characterize human dignity in this way, and yet there are important continuities between the philosophers. For both, the killing of an innocent person is a violation of human dignity, whereas capital punishment in the case of a person who is a danger to society can be morally justified. Perhaps today there has been further development such that the killing of any person, even a dangerous criminal, is forbidden because it is a violation of human dignity.

The historical tragedies of the 20th century, with its wars, genocides, and political crimes, provide the context for the emergence of an understanding of human dignity in the world community. With the development of universal human rights there was a recognition that humans are fundamentally equal and worthy of protection, care, and political freedoms. This development emerged as a general rejection of, for instance, Nazi principles that declared: (1) some humans can have no worth, and are therefore expendable, and (2) human worth and moral status can be judged on the basis of racist criteria. The Nazis' history of violence forced the world community to discern and declare the value of human dignity in the concrete formulas of the United Nations's Declaration of Human Rights.

New debates continue to focus understanding of human dignity. One example is the debate regarding the use of torture for political reasons, such as spawned by the U.S. actions in the U.S. military base in Guantanamo, Cuba. Related are questions about whether innocent civilians may be killed to prevent greater evils, whether the death penalty is justifiable and other questions. Ideally, at least, this process of continual debate should result in deeper understanding and consensus. Yet important questions remain unresolved regarding the extension and application of moral dignity. Social consensus does not exist regarding the moral status of human fetuses, for example. It is therefore difficult to grasp how society can provide guidelines regarding their protection. Similar questions emerge at the end of life, with debates surrounding organ donation. If with "brain death" a patient is no longer considered a human being, then the implications and protections of human dignity no longer apply, and bodily organs can be ethically harvested for medical reasons.

In a new and developing context, in which the value of human dignity is continually reconsidered in terms of its emergence from a 20th-century context of violence, the question of euthanasia takes on an interesting dimension. How is human dignity to be understood in this context? Advocates of euthanasia argue that allowing a patient to make a considered decision to end his or her life is consistent with human dignity. Opponents, however, demand a recognition that every human life is inviolable, and thus euthanasia is contrary to human dignity.

Possible Timeless Dimension of Historically Emergent Values

The example of the value of human dignity can further the discussion regarding the expansion of values. What is meant by the epistemological value of "simplicity"? What is meant by the aesthetic value of "beauty"? What is the precise meaning of such values as "truth," "love," and the like? Assuming at this point that all values develop in time within specific historical circumstances, it is possible to propose that the meaning of these values can never be exhausted. Is a timeless dimension of values then possible?

In order to answer this question, several distinctions must be made: first, regarding the emergence of values; second, regarding the exact meaning of values; and third, regarding the distinction between values. The emergence of values is always timebound. Their validity is not simply a given, but rather they develop in the course of history. Therefore, they are not carved in stone, so to speak, and, as such, are valid for all time; instead, their meaningful content continues to be dependent upon time. Because the intelligible content of values is related to historical experiences, the possibility exists that their meaning can develop with time—and that they can pass into oblivion. Values depend on historical events, on the genius of certain personalities, on nature, and on cultural and scientific discoveries. Nevertheless, a fundamental meaning can be found that emerges in time but is nevertheless not relativistic. Rather, it can be argued that it maintains a validity that is independent of time.

The best example to illustrate this is the historical condemnation of slavery and the value of human freedom. Aristotle as well as many Christian philosophers and historical figures had no moral qualms concerning the institution of slavery. They assumed that for some persons, the exercise and enjoyment of liberty was not appropriate or necessary. Rather, the fact that some people are born into a state of slavery was seen to be consistent with justice. The value of a fundamental freedom of every person, such that slavery was inherently unjust, became generally recognized only in the period of the Enlightenment. Yet, despite its historical emergence, this insight is valid universally, such that there is no place on earth where slavery is justly permitted.

This argument regarding the value of freedom applies as well to aesthetic value. By way of example, we can point to the historically composed great musical works of art. Created "in time," the music remains timelessly valuable. This is the case even if, in the future, there comes a time when no one appreciates the music. Finally, regarding the epistemological values of, for example, simplicity and coherence, they share this timeless and universal validity even though being discovered in the course of time.

The Continuing Importance of Time

The recognition of universally valid ethical, aesthetic, and epistemological values can be seen as important historical achievements of human culture. Unlike Platonic philosophy, they do not depend upon an objective and eternal world of value. And, in contrast to philosophies that neglect the temporal emergence of values, the position presented here recognizes how important insights regarding human values emerged historically. Time was necessary for their emergence, but there is no time in the future when these values would be invalid. In this sense, therefore, we can speak of them as having achieved a status of universality and timelessness.

Nikolaus J. Knoepffler

See also Aristotle; Christianity; Ethics; Humanism; Kant, Immanuel; Morality; Nietzsche, Friedrich; Plato; Scheler, Max; Weber, Max

Further Readings

Joas, H. (2001). *The genesis of values.* Chicago: University of Chicago Press.

Putnam, H. (2002). *The collapse of the fact: Value dichotomy and other essays.* Cambridge, MA: Harvard University Press.

Scheler, M. (1973). *Formalism in ethics and non-formal ethics of values: A new attempt toward the foundation of an ethical personalism.* Evanston, IL: Northwestern University Press.

Weber, M. (1949). *The methodology of the social sciences.* New York: The Free Press.

Vampires

In contemporary popular culture, vampires are fictitious immortal creatures of the night who sustain themselves by drinking the blood of the living. These undead creatures might be the unsettled souls of criminals or suicide victims. They may have been victims of other vampires, as those who are attacked by vampires are fated to become vampires themselves.

By convention, vampires are often depicted as aristocratic; male vampires are tall, handsome, and dressed in a black cape draped over formal attire. Women vampires are most often subordinate to male vampires, and they may be called brides or sisters of the patriarchal vampire. Regardless of the gender, male and female vampires have compelling seductive power over their victims. Modern vampires have a hypnotic stare that captivates the victim. Their canine teeth become prominent and their eyes turn blood red as they prepare or are compelled to feed. The teeth are used to penetrate the flesh of a victim's neck, from which the blood is then drawn.

Vampires have no shadows, and cannot cast a reflection in any mirror or reflective surface. They walk most often in the cover of darkness but can walk about in daylight. They sleep in unhallowed ground or in earth that is taken from their native lands. They are immortal, unaffected by mortal wounds, disease, or old age.

Repelling a vampire is difficult, but they are uncomfortable with garlic and religious icons. Their ability to withstand these items strengthens, however, as they age. That is to say, a new vampire is more susceptible to suffering ill effects from being in contact with holy water and is repelled by a crucifix, a consecrated communion host, or other religious icon. Vampires can travel as mist or fog. They must be invited to enter a home where they seek to take a victim; they cannot enter except by invitation.

Vampires such as the notorious Count Dracula, created by Bram Stoker in 1897, are believed to be almost invincible. They can easily move in daylight, but with diminished powers. They control and transform into beasts such as wolves and bats. They can control the minds of even the strongest character, and enslave them into their power. Stoker's vampire is based on the historic 15th-century Prince Vlad Tepes (the Impaler) of Wallachia and other long-standing folklore legends.

In vampire folklore, it was commonly believed that vampires could come from those born between Christmas and the Epiphany. If one was the seventh son of the seventh son, or was born with a harelip or with teeth, vampirism was suspected. Evidence that the mania spread is revealed by the exhumation of graves 3 or more years after the death of a child. Most believed the vampire treatise: Vampires need not feed every night; victims might linger for days before death; and that in death they become the undead.

According to legend, vampire hunters would cut off the creature's head, fill its mouth with garlic, drive a wooden stake through its heart, and cut out the heart and burn it. When the evil vampire is killed, all evil that it created also dies.

Debra Lucas

See also Devils (Demons); Dracula, Legend of; Evil and Time; Immortality, Personal; Satan and Time

Further Readings

Melton, J. G. (1998). *The vampire gallery: A who's who of the undead.* Detroit, MI: Visible Ink.

Stoker, B. (1897). *Dracula.* New York: Modern Library.

Twitchell, J. (1985). The rise and fall of Dracula. In *Dreadful pleasures: An anatomy of modern horror* (pp. 105–159). New York: Oxford University Press.

Verne, Jules (1828–1905)

Jules Gabriel Verne was born on February 8, 1828, in Île Feydeau, in the city of Nantes, France. He was the first of five children born from the marriage between his father Pierre, a Parisian attorney who came from a lineage of jurists from Provence, and Sophie Allotte de la Fuÿe, of Breton and Scottish origin. Verne began the study of law in Paris but chose instead to pursue his passion for literature and the theater. When Pierre Verne realized his son's ambitions no longer included jurisprudence, he withdrew all financial support. Verne never practiced law, but his writings, which explored the themes of time and the future, would earn him a secure place in world literature.

During the 1850s Verne attempted to survive financially as a playwright and published several works, including *Blindman's Bluff.* In 1856, Honorine Deviane, a widow with two children, was introduced to Verne at a friend's wedding. Eight months later, on January 10, 1857, the two were married. At some point after their introduction Jules became a stockbroker and it is speculated he made this career change in order to provide for his family. Four years later, on the August 3, 1861, the couple's first and only child, Michel, was born.

"De la Terre a la Lune" ("From the Earth to the Moon," 1865). Here the space travelers board the moon-projectile in Jules Verne's account of space travel.

Source: Mary Evans Picture Library/The Image Works.

In January 1863, when Verne was 30, his first novel, *Five Weeks in a Balloon,* was published. The text described a futuristic hot-air balloon adventure set in Africa, an area relatively unknown to Europeans. Although his work had both geographical and scientific flaws, Verne's book was ahead of its time. *Five Weeks in a Balloon* proved to be the first in a series of novels that described technology that did not yet exist or was in only the earliest stages of development.

From 1862 to 1886, Verne lived in Amiens with his family but traveled to the United States to visit New York City and Niagara Falls. During this period he also visited many European countries and gained both worldwide fame and a modest fortune.

On March 9, 1886, Verne's mentally unstable nephew, Gaston, shot him with a pistol. A bullet entered Verne's left shin, giving him an incurable limp. Gaston was judged to be mentally ill and spent the rest of his life in an asylum. The time of the shooting coincided with the deaths of Jules Verne's mother and his longtime friend and publisher Pierre-Jules Hetzel.

Following Verne's death on March 24, 1905, his son Michel began to publish his works after substantial revision; the revised works began to appear in 1919.

Four of Jules Verne's best-known novels include *Journey to the Center of the Earth* (1864), *From the Earth to the Moon* (1865), *Twenty Thousand Leagues Under the Sea* (1870), and *Around the World in Eighty Days* (1873). From oceanographers in submarines to space walks on the moon, the author sparked the imaginations of millions. Prophetically, descriptions of such later developments as television, automobiles, skyscrapers, high-speed trains, and many other modern technologies resonate throughout his novels. It is not an exaggeration to state that Verne's ideas produced a greater interest in technological advancement and influenced modern-day society.

As one of the pioneers of the science fiction genre, along with others such as H. G. Wells, Jules Verne led the way for others to dream and create. In the 20th century Verne's novels were translated into 140 different languages and were the basis for a number of popular movies.

Jennifer R. Fields

See also Clarke, Arthur C.; Futurology; Novels, Time in; Wells, H. G.

Further Readings

Lottman, H. R. (1997). *Jules Verne: An exploratory biography.* New York: St. Martin's.

Martin, A. (1990). *The mask of the prophet: The extraordinary fictions of Jules Verne.* Oxford, UK: Oxford University Press.

Virtual Reality

The term *virtual reality* is used to describe a variety of computer-generated environments, experiences, and activities that range from existing technologies like computer games to futuristic visions as pictured in popular movies like *The Matrix*. A virtual reality (VR) is created by specific technologies that enable the user to perceive and interact with virtual objects in an artificial environment that has its own spacetime continuum and follows its own laws that are implemented as the properties of the virtual objects. The development of powerful microcomputers, head-mounted displays (HMD), datagloves, and the CAVE (Cave Automatic Virtual Reality) laid the foundations for VR. Since then, the ability to create and experience virtual worlds has drawn much attention in the humanities and in public discourse. Current VR technologies allow a primarily audiovisual experience of the virtual environment. Future technologies are expected to include the other senses as well. Along with spatial properties, VRs can also be provided with temporality. Online VRs, such as Second Life or World of Warcraft, have introduced their own virtual time, which passes whether the user is logged into the virtual world or not. Yet, the characteristics of virtual time can significantly differ from those of real time; for example, virtual time can be made reversible.

Jaron Lanier, one of the pioneers in developing VR technologies, is widely recognized as having coined the term *virtual reality* in the 1980s. It is notable that this term superseded other proposals like Artificial Reality, which was suggested by Myron W. Krueger, and Phantomology as the writer Stanisław Lem proposed—even though the term is paradoxical. The English word *virtual* (lat. virtus: manliness, excellence, character, worth, courage) stands for "practically" and "as good as" as well as "almost" and "nearly, but not completely," whereas the term *reality* refers to the way things really are in contrast to their mere appearance. Taken literally, a VR is something that appears to be real and that is practically as good as the real thing but is not entirely real. In a driving simulation game one can steer a virtual car looking and acting like a real one, yet crashing the virtual car of course does not have the same effects as in real life.

Various attempts have been made to define VR more thoroughly. In the early years, technology based definitions were prevalent. This understanding proved to be insufficient to grasp the characteristic features of VR. In an attempt to find a more appropriate understanding, the focus shifted from the technologies at hand to the specific modes of experience a VR creates. Thus, VR is mainly understood as a medium to create an experience that can be characterized as an immersive simulation, which is artificial, interactive, and communicative, and that creates the experience of telepresence. An experience is immersive when the user becomes absorbed in the sensations of the VR. This might lead to the impression of being present in the artificially created environment, which is called telepresence. Immersion in a virtual environment is a gradual experience. One can feel immersed into a game played on a desktop computer with a regular computer screen. Technologies like the HMD, which was developed in 1968 by Ivan Sutherland and Bob Sproull, are even more immersive because they cut off all visual sensations of the outside world. Stereoscopic images are shown on two displays that are placed right in front of the eyes. Furthermore, the movement of the head is traced by the HMD, and based on head movement the corresponding visual information is given. Another approach to creating immersive virtual environments is the CAVE that was developed in 1991 by Carolina Cruz-Neira, Dan Sandin, and Tom DeFanti. The user is placed in a cube (approximately 3 by 3 by 3 meters in size), and the virtual environment is projected onto the transparent walls of the cube by rear projection. A regular keyboard or mouse can be used to interact with virtual objects. Again, to give the user a more realistic impression other devices like the dataglove were invented. This glove-like interface, developed by Thomas G. Zimmerman and Lanier, allows the user to grab and modify a virtual object almost like a real object. Elaborate datagloves give a haptic feedback when touching a virtual object and thereby create an even more realistic impression.

Today's existing technologies allow the user to immerse and interact in virtual environments. However, unlike as envisioned in science fiction, they have not yet become indistinguishable from the real world. Still, the idea that technological progress will render this development possible has become an intriguing thought for the humanities as well as the social sciences. But even though this futuristic vision has become something like a yardstick in the assessment of virtual environments, the current technological possibilities raise questions about the social, ethical, ontological, and economical effects of virtual reality. To address this problem one could ask for the status of actions in virtual environments. Theoretically, events that happen in a virtual environment do not have an effect on the real world. A person killed in a war game is not really dead outside the virtual world. Furthermore, it is in principle possible to undo actions, and thus time is reversible. A virtual game can be played over and over again. It is for this reason that VR applications are used in the training of soldiers. Yet this fundamental openness can be undermined technologically and socially. Every implementation of a virtual world codifies certain rules about how objects in a virtual environment react. Virtual objects are subject to their own laws that determine their behavior. By adjusting the physics of virtual worlds to the actual laws of physics, real-world behavior of objects can be simulated and predictions can be made, like in simulations of crash tests. In addition to that, social rules can be established in VRs. Virtual communities, that is, communities in VR such as Second Life, have their own rules for social interaction. Nevertheless, it is the subject of ethical and juridical discussions how virtual crimes should be treated in real life. The moral implications of VR are considered to pose a serious challenge for ethics.

Marcus Burkhardt

See also Ethics; Information; Time and Computers

Further Readings

Grau, O. (2004). *Virtual art: From illusion to immersion.* Cambridge: MIT Press.

Heim, M. (1993). *The metaphysics of virtual reality.* New York: Oxford University Press.

Packer, R., & Jordan, K. (Eds.). (2001). *Multimedia: From Wagner to virtual reality.* New York: Norton.

Rheingold, H. (1991). *Virtual reality.* London: Secker & Warburg.

Voodoo

An African-based religion, voodoo's ancestral roots extend into the remote past. Three African groups had the strongest influence on voodoo: The Yoruba of present-day Nigeria, the Fon of Dahomey (Benin), and the Kongo of present-day Zaire and Angola. Voodoo consists of complex rituals, duties, and symbolic actions that are carried out by its practitioners. The word *voodoo* means "spirit" or "deity" in the Fon language and traces back to the West African Yoruba people living in Dahomey as late as the 18th and 19th centuries.

History

The religion of voodoo originated on the sugar plantations of Haiti. Some of the voodoo prayers and invocations hold fragments of West African languages; however, Haitian Creole is the primary language of voodoo. Creole is the only language spoken by 80% of contemporary Haitians. Its grammatical structure is strongly influenced by West African languages, and it uses a largely French vocabulary. Although many of the names of voodoo deities can be traced back to their African origins, these spiritual beings were transformed and adapted to a new land and sociocultural context; interactions among slaves created this amalgamation of beliefs, deities, and ritual practices. Voodoo arrived in North America when the first Africans landed in Jamestown in 1619 as indentured servants. As the number of indentured servants and, later, slaves increased through the West Indies and into North America, voodoo worshippers became most prevalent in Haiti and New Orleans. Unfortunately, little is known about the formation period of voodoo in Haiti.

Voodoo and Popular Culture

Sensationalized in novels and in Hollywood films, many misconceptions about voodoo have come about in the minds of Westerners over the years. Voodoo has been portrayed as sorcery or evil magic involving orgies, human sacrifices, and cannibalism. A sensational novel written in 1884 by S. Saint John, *The Black Republic,* described voodoo as a profoundly evil religion and was responsible for most of the misunderstandings. These misconceptions have been portrayed in Hollywood films since the 1930s and continue today. Since voodoo involves divination, manipulation, and herbalism, it gives the appearance of magic rather than religion. It was seen as something to be feared and was actively suppressed during the U.S. colonial period when many priests were killed or imprisoned. Such practices can be attributed to the prejudices and fears of blacks by slave owners faced with the ever-present threat of rebellion. Haiti's independence was attained relatively early, around 1804, at a time when most other countries in the western hemisphere were still heavily dependent on slave labor. In fact, the organizing of the slaves' revolt is important as its role is apparent in the downfall of President Jean-Claude Duvalier in February 1986. In addition, "antisuperstition campaigns" carried out in the 1940s aimed to alleviate some of the persecution carried out by the Catholic Church. Currently, there is an uneasy peace between the Catholic Church and voodoo.

Catholic Influences of Voodoo

Despite their obvious differences, voodoo was heavily influenced by Catholicism. Because the French slaveholders were Catholics, they made baptism mandatory. Consequently, many voodoo practitioners hid their beliefs and rituals but continued to practice them under the guise of Catholicism. Among slaves, Catholicism was viewed as a way to continue and expand their religion at the level of rite and image rather than theology.

Syncretism With Voodoo Deities and Catholic Saints

Over the years, parallels have developed between voodoo spirits and Catholic saints. For example, Dambala, the snake god of the Fon peoples, is worshipped along with Saint Patrick whose Irish legend also involves snakes. The ancestral homeland of Africa is a powerful concept in voodoo. Haitians call to the spirits as *frangine* or "frank Guinea," meaning truly African, to convey that the spirit is good, ancient, and proper. Voodoo spirits go by several names: *Iwa* (from the Yoruba word for "spirit" or "mystery"), *sint* ("saints"), *envizil* ("invisible"). In the countryside, the spirits are grouped into *nanchon* ("nations"). The names of the voodoo nations refer to peoples and places in Africa. For example, Wangol stand for Angola and Mondon for Mandingo.

In voodoo, the person consists of various parts: the body or the physical being and after death, the soul, which can consist of two to four souls, the most common being the *gro bonanj* and the *ti bonanj*. *Gro bonanj* is related to consciousness or personality while the *ti bonanj* or "little guardian angel" is regarded as spiritual energy. A person's spirit is connected to certain *Iwas,* and a person who venerates particular spirits can petition for help from those spirits and the qualities and powers that they possess, linking humans with the divine.

Voodoo is an inseparable part of Haitian art, literature, music, and film. Hymns are played on the radio and voodoo ceremonies are broadcast on television along with Christian services. Music and dance are key elements to voodoo ceremonies. The purpose of the dancing ritual is an expression of spiritually to connect with the spirits. Gifts and animal sacrifices are offered to gain favor. People petition the spirits for an abundance of food, to have a better standard of life, for love, and for good health. Ceremonies also serve to build community ties and reinforce history and traditions. Participants come before the priest to ask for spiritual guidance and advice. The priest or priestess offers aid in the form of knowledge, herbs, medicines, or healing through faith. Voodoo also teaches respect for the natural world.

Voodoo in the 21st Century

Today voodoo survives as a legitimate religion and millions of people practice voodoo worldwide. The struggle to survive as a religion has endured for 3 centuries. Religions that are similar to voodoo are found in the Caribbean and South America: Quimbanda, Candomblé, Santería, and Umbanda.

Luci Latina Fernandes

See also Christianity; Religions and Time; Tylor, Edward Burnett

Further Readings

Gaston, J. R. (1990). The case of voodoo in New Orleans. In J. E. Holloway (Ed.), *Africanisms in American culture* (2nd ed.). Bloomington: Indiana University Press.

Lovell, N. (2002). *Cord of blood: Possession and the making of voodoo.* Ann Arbor: University of Michigan Press.

McCarthy Brown, K. (2005). Voodoo. In A. C. Lehmann, J. Myers, & P. A. Moro (Eds.), *Magic, witchcraft, and religion: An anthropological study of the supernatural* (6th ed.). Boston: McGraw-Hill.

W

Wagner, Richard (1813–1883)

In the history of the arts, liberal activist Richard Wagner looms as an extraordinary genius whose prodigious creativity produced 10 remarkable music-dramas that deal with time. For subject matter, he used both legends and myths from the Germanic, Icelandic, and Scandinavian worlds of objects, characters, emotions, and events. Throughout his work resounds the theme of the search for one's identity, or the longing for one's salvation. As such, Wagner's symphonic operas reflect both psychological and philosophical issues ranging from the lust for power to the existence of evil. The concept of time is especially relevant in his epic tetralogy *Der Ring des Nibelungen* and sacred work *Parsifal*.

In Wagner's three early music-dramas, the finitude of human time is essential to the legend. *Der Fliegende Holländer* (1843) is the tale of a brash Norwegian captain who, after making a conceited claim, is condemned by the devil to sail endlessly around the world on his phantom ship. This seaman is doomed until he meets a maiden who will sacrifice her life, through faithful love unto death, in order to bring salvation to his accursed existence. Similarly, in *Tannhäuser* (1845), the main character seeks forgiveness and redemption from sin through his long journey from the valley of the Wartburg to Rome and back; not having received forgiveness from the Pope, only the death of Elisabeth releases Tannhäuser from his guilt-ridden anguish for having once preferred the physical passion of Venus rather than her spiritual love for him. In *Lohengrin* (1850), the identity of a mysterious visitor to Antwerp remains a secret until Elsa begs to learn from him his name and place of birth; upon revealing his identity, Lohengrin must now return to Monsalvat, never again to visit this kingdom. Finite time gives a dramatic element of anticipation to each of these three operas.

Wagner's *Tristan und Isolde* (1865) focuses, however, on eternity. Because the two star-crossed lovers longed to be united forever in the darkness of night, only in death will they become free from the separating realm of earthly daylight as well as the brute reality of time and change. But, in *Die Meistersinger von Nürnberg* (1868), the medieval plot stresses the transition from a rigid style of singing with its old-fashioned restrictions, to a new mode of vocal expression with loftier aspirations and creative innovations. The two opposing orientations are each represented by a singer: One sings a traditional song according to established rules, while the other offers a beautiful love-inspired song that clearly breaks from the past. Thereby, to the delight of the wise shoemaker Hans Sachs, this unique prize song announces the dawn of a new age of enlightenment.

Nevertheless, it is in Wagner's massive four-opera masterpiece *Der Ring des Nibelungen* (1876) that the composer reveals the significance of time for comprehending both the evolution of characters and the passing of events. The saga spans a complex sequence of dramatic situations, from the origin of the world, through the emergence of diverse individuals and pivotal circumstances, to the end of the godly domain. The flux of reality is best represented by the flowing Rhine River, raging storms, and magic fire.

In this tetralogy, Wagner's use of the leitmotif technique is particularly important. Musical themes represent objects, characters, emotions, and events. By using, modifying, and developing these leitmotifs, the symphonic musical web allows the listener to move backward and forward through time; during a performance of the *Ring* cycle, the listener is reminded of past situations and can even anticipate future circumstances. Musical themes also allow the listener to know the subjective intentions of a character, particularly if the words being sung differ from what the audience recognizes in the music to be what is actually being thought by the same individual. Thus, the fluidity and diversity of the music complements and intensifies both the flow and complexity of the drama.

Wagner instructed that his *Ring* cycle be presented over the course of an evening and three days. Concerning time, however, the tetralogy itself actually spans many years. Furthermore, over time, conflicts emerge between duty and inclination, as well as between compassion and selfishness. The beginning of *Das Rheingold,* the first opera of this series, is a musical representation of the origin and unfolding of this universe in general, and our evolving Earth in particular. The age of this planet is indeterminate, but its recent history consists of a sequence of events that alter the living world. The inhabitants of this three-tiered Earth include the dwarfs who exist in Nibelheim deep under the ground, the giants who live in Riesenheim on the planet's surface, and the immortal gods and goddesses who rule from Valhalla (a castle stronghold high in the towering mountains). The epic story focuses on a magic ring that was fashioned by Alberich, the Nibelung, out of reddish gold from the Rhine River where it had been enjoyed by three beautiful Rhine maidens. Whoever possesses this ring becomes master of the universe. Along with the Rhine River, this magic ring endures throughout the four music-dramas as a symbol of eternity. However, this twice-cursed ring brings certain death to its loveless owner. Nevertheless, over time, the ring passes through the hands of several characters who lust after its awesome power—Alberich the ugly dwarf, Wotan the insecure god, Fafner the stupid giant, and Hagen the evil Gibichung.

In *Die Walküre,* human beings emerge and Siegfried, the naïve hero of this saga, will be born from the sister-brother union of Sigmund and Sieglinde. It is now the intention of Wotan, the head of the gods and goddesses, that this hero, free of the cursed magic ring, will eventually save their world from its forecast doom, prophesied by Erda the eternal earth mother. Next, in *Siegfried,* the hero comes into possession of the ring after killing Fafner (who had changed himself into a dragon). Upon finding the now-mortal Brünnhilde, Wotan's favorite daughter, Siegfried proclaims his love for her but leaves the mountain-top Valkyrie rock for adventurous undertakings.

In *Götterdammerung,* the three Norns weave the future into their rope of time, but the cord of destiny breaks, symbolizing that the end of the old order of gods and goddesses is imminent. Although ignorant of its awesome power, Siegfried refuses to return the ring to the Rhine maidens. Unfortunately, he is later murdered by the treacherous Hagen, who fails to gain possession of the magic ring. Brünnhilde secures the ring and sets the great hall of the Gibichungs on fire; the roaring flames spread to and consume Valhalla. Thus, after many years, this fatalistic cycle ends. A new era now dawns to replace the old order, and the evil of the ring has temporarily vanished from the world. It may be argued that, quintessentially, the existence of ugliness (personified by Alberich) in this imperfect world set the story of the *Ring* cycle on its tragic trajectory. Interestingly enough, one wonders if this dwarf did in fact die at the end of this tetralogy. Perhaps there were previous cycles. In time, ongoing events may even generate an endless sequence of the same or similar cosmic cycles.

In *Parsifal,* the search for one's identity and the longing for one's salvation meet in a medieval, mystical legend where time itself may be said to dominate the opera. Home of the Holy Grail and Sacred Spear, the Gothic temple of Monsalvat in Spain seems to be removed from the ravages of change; even its inhabitants seem to be in a state of quasi-suspended animation beyond the natural world. Throughout this opera, time is relative; some events happen gradually, while others occur instantaneously. Parsifal is the naïve seeker who, after years of wandering and avoiding sensuous temptations, discovers himself to be the savior of a sanctified knighthood. Parsifal thereby redeems both himself and those who have suffered from evil in the world, and he becomes the new king at Monsalvat. Furthermore, the Holy Grail itself endures as the metaphysical focus of changeless eternity.

Time pervades Wagner's operas, whether it is manifested in changing characters, altering situations, or developing events. No doubt, while working on *Der Ring des Nibelungen* over 28 years, Wagner must have imagined himself living among the diverse characters of this epic saga. He was able to transcend both his severe critics and public situations, immersing himself in a mythological realm of incredible events. One may also argue that his own genius reflected each of the characters in this cycle. Nevertheless, in *Parsifal* Wagner gave to the world of opera a timeless story of human salvation. In doing so, he transcended even his own personal shortcomings by stressing the eternal value of selfless compassion.

H. James Birx

See also Feuerbach, Ludwig; Mann, Thomas; Music; Mythology; Nietzsche, Friedrich; Schopenhauer, Arthur

Further Readings

Beckett, L. (1981). *Richard Wagner: Parsifal*. Cambridge, UK: Cambridge University Press.

Donnington, R. (1984). *Wagner's "Ring" and its symbols* (3rd ed.). London: Faber & Faber.

Grey, T. S. (2008). *The Cambridge companion to Wagner.* Cambridge, UK: Cambridge University Press.

Magee, B. (2000). *The Tristan chord: Wagner and philosophy.* New York: Henry Holt.

Millington, B. (2006). *The new Grove guide to Wagner and his operas.* Oxford, UK: Oxford University Press.

Wahhābism

Wahhābism is an Islamic religious sect that first arose on the Arabian Peninsula in the 18th century. The sect was founded by Muhammad ibn 'Abd al-Wahhāb (1703–1787), who wanted to preserve the purity of Islam. Adherents of this religion are called Wahhābīs or *Muwahhidūn* ("Unitarians"), a name that reflects their extreme approach to monotheism. Wahhābism is a revivalist or puritanical interpretation of Islam that requires its followers and other Muslims strictly to observe the traditional duties and observances of Islam, including using the Islamic or *Hijri* calendar, which has 354 days in a year, divided into 12 lunar months of either 29 or 30 days (29.5 days is the time taken by the moon to complete a full circle around the earth). This calendar is used both to date events and as a way for devout Muslims to track the observance of Islamic holy days.

History

Born in 'Uyaynah in Arabia, Ibn 'Abd al-Wahhāb preached a very austere interpretation of Islamic doctrine that attempted to return Islam to its original form by forbidding some of the practices and customs (such as Sufism) that had crept in over time and that did not have their basis in the Qur'an or *sunnah* (those religious practices that were instituted by Muhammad or his companions). Adherence to traditional means of marking the passage of time and the celebration of religious holidays was instituted as a mandatory practice for all Wahhābīs, who follow the *Umm al-Qura* calendar (based on precise observations of the new crescent moon in Riyād), whereby Islamic months begin at sunset of the day when the *hilāl* or lunar crescent is first visually sighted.

The Ibn 'Abd al-Wahhāb considered those who disagreed with his teachings, including the dating of religious observances and holidays, to be heretics, and justified the use of force in imposing his doctrine on others through the concept of *jihād,* or "holy war." He eventually settled in the Nejd desert, and through an alliance with the ruling Sa'ūd family clan, was able to resist the suppression of the Ottoman emperors and those Muslims who resisted his extremist views. The Sa'ūdis rapidly expanded their territory during the 18th and 19th centuries, establishing a new capital in Riyād and founding the present-day Kingdom of Saudi Arabia, and adopting Wahhābī doctrines and practices as the official state religion.

Beliefs

Wahhābism is a monotheistic religion that is founded upon the principle of *tawhīd,* a belief in the Divine Oneness. Tracking and observing religious events at the times ordained by the Qur'an is an important element of Wahhābism, since it both reflects and reinforces the centrality of God in everyday life. Wahhābīs follow only the teachings and writings of the Prophet Muhammad and his companions and those of the generation immediately following, and consider any Islamic customs and practices that were introduced by the generations that came after the prophet as *bid'ah* (innovations) that are forbidden to Wahhābī followers—such practices include any use of modern or Westernized means of tracking time or calculating the placement of religious holidays (such as the Gregorian or Julian calendars). Adherence to Wahhābī and Islamic doctrinal practices is enforced by the *muṭawwi'ū* or religious police ("enforcers of obedience"), who monitor private as well as public observance of Islamic and Wahhābī doctrine. Wahhābīs emphasize the simplicity of Islam, including traditional ways of observing the passage of time, believing that religious observance must inform every part of public and private life in order to create a just and holy society.

Helen Salmon

See also Calendar, Islamic; Islam; Qur'an; Religions and Time

Further Readings

DeLong-Bas, N. J. (2004). *Wahabbi Islam: From revival and reform to global Jihad.* New York: Oxford University Press.

Glassé, C. (1991). *The concise encylopedia of Islam.* San Francisco: HarperCollins.

Kheirabadi, M. (2004). *Islam.* Philadelphia: Chelsea House.

Lunde, P. (2002). *Islam.* New York: Dorling Kindersley.

WATCHES

The watch has long been an integral part of everyday life for many people. Throughout the years of its development, the basic definition of the watch has remained the same—a portable timepiece, usually encased, and small enough to be carried or worn. The first watches appeared in the 15th century through the efforts of clock-making centers established in Italy, France, Germany, and England. By the late 16th century, Geneva had become an important center of watchmaking. Early American watches were produced mainly by mechanization, a process that achieved success by the middle of the 19th century.

Because clocks were weight-driven, they remained mainly stationary until the invention of the coiled mainspring made portable versions possible. Producing miniaturized versions was a natural development, also demanding greater accuracy in craftsmanship.

Early mechanical watches had only one hand and were inaccurate because they ran more slowly as they wound down. By 1700, improvements had been made so that watches normally lost only 5 to 10 minutes each day. A minute hand was also added.

The portability of the watch served as a symbol of progress and individualism. Early watches were generally worn hung from the neck or belt or carried in a pocket. Wristwatches did not become common until the 19th century and were worn mainly by women. World War I saw a major increase in their use by those engaged in the war effort. Wristwatches were eventually commonly worn by both sexes.

In 1891, the importance of accuracy was dramatized by a head-on collision of trains at Kipton, Ohio. That catastrophe led to a system organized to standardize and inspect railroad watches, which were expected to vary less than 30 seconds within a 2-week period.

The use of electricity in clocks had already occurred by the 19th century, and, by 1929, the use of the quartz crystal had improved the accuracy of clocks. With the development of high-energy batteries it became possible to apply both electricity and quartz vibrations to watches. The first commercial versions were introduced by Seiko in Japan in 1969 and by Hamilton in America in the early 1970s. While the Swiss, noted for their careful craftsmanship, used quartz crystal, they continued to produce mostly mechanical watches.

Efforts were made to further miniaturize the components of electric watches. Electric watches now feature integrated circuits, or chips, so that time can be read digitally.

Anyone wanting to acquire a new watch today can find a wide variety of styles and price levels to choose from. Watchmakers naturally have some reason to be anxious about the future of the industry. Some people, particularly members of the younger generation, express the opinion that watches are no longer necessary because of the advent of cell phones and various electronic devices. Nevertheless, positive news about sales continues to be reported. Accuracy has always been a crucial measure of the worth of a watch, but its decorative value has not lagged far behind. Collectable watches are a big business, ranging from antique and uniquely designed watches to formerly mass-produced watches, such as Rolex sports watches.

Betty A. Gard

See also Clock, Doomsday; Clocks, Atomic; Clocks, Biological; Clocks, Mechanical; Time, Measurements of; Timepieces

Further Readings

Christianson, D. (2002). *Timepieces: Masterpieces of chronometry.* Toronto, ON, Canada: Firefly Books.

Landes, D. S. (1983). *Revolution in time: Clocks and the making of the modern world.* Cambridge, MA: Belknap Press.

Watchmaker, God as

The identification of God as a supernatural watchmaker, a being equated with the Creator in the Book of Genesis 1–2, remains one of the most famous analogies in the history of religious thought, especially in ongoing discussions about creation and the beginning of time. Though other scholars like Robert Boyle had compared the universe to a clock, William Paley (1743–1805), the English clergyman, theologian, and Christian apologist, popularized this particular analogy in the opening paragraph of his 1802 classic work, *Natural Theology; or, Evidences of the Existence and Attributes of the Deity, Collected From the Appearances of Nature.* In Paley's scenario, a thoughtful person finds a watch while crossing a heath; the walker notes the difference between the watch's complex mechanism, as opposed to a simple stone on the path. Paley suggested that this observer might well assume that the watch did not assemble itself or come together by accident. Instead, he said that the watch reflected design and function. Paley closed his argument by pointing to an inevitable inference: The watch's structure was no accident, and it must have had an intelligent maker, an artificer (or artificers) who designed and created it for a purpose.

This watchmaker analogy reflects Paley's background and special interest in "Christian apologetics" or "Christian evidences"—the title of another of his famous books, published earlier in 1794. The book also illustrates the Enlightenment tension between orthodox faith, materialism, and various forms of Deism, all of which found support for their positions in the work of Newton and other scientists and philosophers of that day. When William Paley wrote *Natural Theology,* he took his place in a long tradition of scholars (e.g., John Ray, William Derham) who acknowledged two kinds of revelation—that is, the printed word/scripture and nature. In this "Watchmaker Analogy," which is actually a parable about the Creator, he reflected the spirit of Psalm 19:1 and related biblical texts: "The heavens declare the glory of God; and the firmament sheweth his handywork" (King James Version, as read and quoted in Paley's era). Archdeacon Paley listed many examples of complex designs in the realms of biology and astronomy and, especially, anatomy (e.g., the eye, ear, heart, hand) and argued that such evidence points to the existence of a purposeful and good God. A reasonable observer accepts this inevitable inference, said Paley, because the amazing phenomena discussed in *Natural History* reflect far more complexity in form and function than the relatively simple mechanism of a watch. He argued like a lawyer as he enumerated example after example, though Paley claimed that the mechanism of human vision alone made the case for God's existence. Of course, a naturalistic explanation for the eyeball's gradual evolution became a cause célèbre for those who rejected supernatural intervention (e.g., Charles Darwin, and later, Richard Dawkins).

From the time of its original publication in 1802, Paley's version of the argument from design or the teleological argument for the existence of god met with various reactions—from skeptics who found the analogy weak and unconvincing to believers who found the evidence reasonable and compelling. Students of Paley's metaphor must consider the critical questions raised by the earlier writings of Hume and the later conclusions reached by Darwin, most of whose teachers at Cambridge accepted the watchmaker analogy. Surprisingly, both Darwin and, more recently, Dawkins have praised Paley's literary style and logical method. Dawkins prefers Paley's willingness to propose answers to fundamental questions over Hume's skepticism. Even though Dawkins rejects Paley's watchmaker analogy, he appreciates the archdeacon's attempt to explain the way things work, while Hume merely criticized other points of view but proposed no alternative.

Some critics claim that the watchmaker analogy is flawed from the start, insisting that Paley's comparison between a watch and the world "compares apples with oranges." Others object to Paley's analogy by pointing to flaws and suffering in nature that neutralize any talk about a careful, beneficent Designer. Still other critics have accused Paley of "begging the question"—of making a facile leap from whatever kind of creative agent his argument from design might reasonably require to the Judeo-Christian God, a reflection of Paley's parochial background and education. In other words, Paley and his ilk assume the existence of God who created all things "in the beginning," but the argument from design in itself cannot prove that this deity exists. In a series of popular books and public appearances, Dawkins—who has assumed Huxley's role as "Darwin's bulldog"—argues against the conscious designer theory and insists that natural selection is a purposeless "blind watchmaker." Though he admires William Paley's work in some ways, Dawkins claims that what Paley and others interpret as a beneficent, planned creation is just an illusion. So, in the terminology of William Paley's analogy, Darwin and Dawkins (and many other scientists) say that the gradual evolutionary changes by natural selection provide the only "design" needed in the "living watches" of the biological realm.

Paley's watchmaker analogy has made a comeback in the modern controversy over origins and in the latest round of debates over creation and evolution. For many, naturalism or scientific materialism, based on the laws of physics and chemistry, offer a convincing explanation as to the origin of all things. Others find this worldview inadequate and insist that an impersonal and purposeless process of natural selection strains credulity and cannot answer fundamental questions (e.g., the "irreducible complexity" of biochemical systems). In the most general terms, there is not much difference between Paley's simple watchmaker analogy and the so-called anthropic principle, since both depend upon a "finely-tuned universe." In courts of law, opponents of the intelligent design movement, the most recent form of creationism, regularly encounter Paleyian arguments. Of course, Paley's 1802 classic analogy represents a modern version of the argument from design taught by Greek philosophers (e.g., Plato) and medieval European theologians (e.g., Thomas Aquinas). In fact, the Judeo-Christian tradition has no monopoly on the teleological argument, and representatives from a number of religious and philosophical systems advocate something akin to Paley's simple premise and attribute order and complexity to a Designer.

Gerald L. Mattingly

See also Aquinas, Saint Thomas; Darwin, Charles; Design, Intelligent; Evolution, Organic; God as Creator; Gosse, Philip Henry; Newton and Leibniz; Paley, William; Plato; Teleology

Further Readings

Behe, M. J. (2006). *Darwin's black box: The biochemical challenge to evolution* (2nd ed.). New York: Simon & Schuster.

Dawkins, R. (1996). *The blind watchmaker: Why the evidence of evolution reveals a universe without design* (Rev. ed.). New York: Norton.

Dembski, W. A., & Ruse, M. L. (Eds.). (2004). *Debating design: From Darwin to DNA.* New York: Cambridge University Press.

Ferré, F. (1973). Design argument. In P. Wiener (Ed.), *Dictionary of the history of ideas* (Vol. 1, pp. 670–677). New York: Scribner.

Manson, N. A. (2003). *God and design: The teleological argument and modern science.* New York: Routledge.

McPherson, T. (1972). *The argument from design.* London: Macmillan.

Oppy, G. (2002). Paley's argument for design. *Philo, 5,* 161–173.

Paley, W. (2006). *Natural theology.* New York: Oxford University Press. (Original work published 1803)
Pennock, R. T. (Ed.). (2001). *Intelligent design creationism and its critics: Philosophical, theological, and scientific perspectives.* Cambridge: MIT Press.
Sweet, W. (1999). Paley, Whately, and "Enlightenment evidentialism." *International Journal for Philosophy of Religion, 45,* 143–166.

WEAPONS

A weapon is a device or instrument used as an aid in fighting. It can be an object or device but may also include psychological tactics, diplomacy, or any other means that destroys, defeats, or forces an adversary into submission or compliance. Weapons developed over time as humanity gained knowledge in metallurgy and other technologies as well as tactics and strategies, and eventually the sciences of physics and chemistry.

Early Weapons

The earliest weapons were most likely sticks and stones. Paleolithic cave drawings suggest that the club—a shaped piece of wood—was the first fabricated weapon. From this the mace was developed by the addition of a weight, such as a stone or metal head, to the end of the club. The addition of blades led to the development of the battle-axe. By the 5th century CE, such axes had been refined and developed into the throwing axe.

From observation early humans learned that round stones flew straighter than flat ones. The invention of the sling added accuracy and distance to thrown stones. Split stones were used as crude knives, then later as tips for spears and arrows. The Sumerians were the first people known to use copper, a metal with a relatively low melting point, for knives and blades early in the Third millennium BCE. Bronze quickly replaced copper because this alloy of copper and tin had a superior hardness. Iron, which requires higher temperatures to be worked, replaced bronze by the first millennium BCE. As metal became the common material for weapon making, the knife became larger and developed into the sword.

The swords of Sultan Mehmed (II), Sultan Selim (I), Bayezid (II), and Constantine kept in the Imperial Treasury. The sword became the primary weapon for close-quarter fighting and remained so up to the 16th century CE. Even today, the sword remains a common symbol of the warrior as some modern militaries still wear swords with formal dress uniforms.
Source: Library of Congress, Prints & Photographs Division.

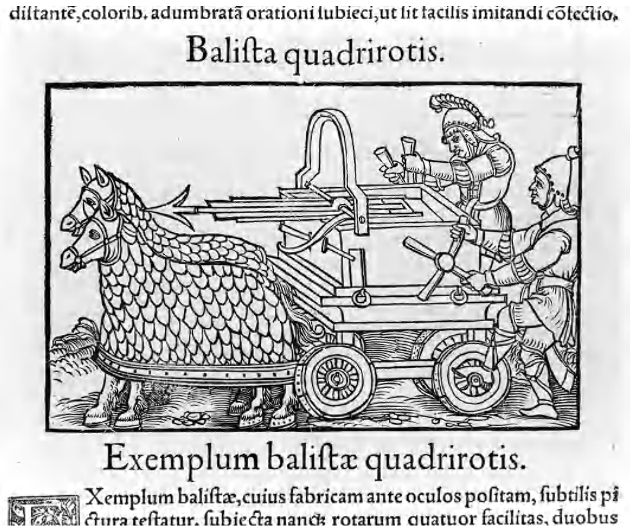
Early weapon development included the arrow, a small version of the spear that could be shot from a bow. Bows and arrows added distance, accuracy, and quantity since many arrows could be carried. By 8000 BCE, people throughout the world were using the bow and arrow and it remained a primary weapon of many cultures until the end of the 16th century CE. Western Pacific and South American cultures developed the blowpipe and dart, a weapon based upon human lung power. The blowpipe usually was made of a hollow reed and varied in length from a few inches up to 15 feet. Darts varied in size from 3 to 18 inches.

As nations formed armies and carried out warfare, weapons developed to give superiority on the battlefield. The chariot was developed in the mid-second millennium BCE. The chariot was highly effective against infantry on flat terrain because it provided maneuverability and a raised platform from which to employ weapons. The Chaldeans began using cavalry, a new development in tactics, around 1000 BCE.

With every weapon came a defense against it. The first known depiction of shields is found in Egyptian paintings from around 4000 BCE. Helmets appear around 2500 BCE, and scale armor made of small metal plates appears about 1000 years later. Around 300 BCE, the Celts invented chain mail, a fabric made of interlocking metal rings. The Romans used both chain mail and leather for armor.

By the Second millennium BCE, cities began to build enclosure walls in order to defend against invading armies. The Assyrians were the first people to build siege engines to counter wall defenses. By the 800s BCE, they had developed the battering ram, a wheeled engine designed to wedge between and pry out stones in a defensive wall. The Romans developed the catapult, a device capable of throwing a heavy object a great distance with good velocity and accuracy against or over a city wall. They also developed a ballista, an oversized bow that was capable of shooting very large arrows.

The ancient Egyptians, Phoenicians, and Greeks used specially designed ships in warfare. Most of these people fought from the ships using methods similar to those of land warfare or hand-to-hand combat. However, the Greeks developed ships with a bronze ram on the bow that could be used to puncture an enemy vessel.



Print from 1552 shows two Roman soldiers with a horse-drawn ballista. The device, mounted on a wagon, is manipulated like a crossbow, shooting large arrows at enemy fortifications. The horses are well covered with armor.

Source: Library of Congress, Prints & Photographs Division.

Medieval Weapons

Most medieval weapons simply tended to be improved versions of ancient weapons. The first leap in weapons technology came with the Chinese invention of gunpowder in the 800s CE. The Chinese used gunpowder to make incendiary bombs, which they tossed by catapult. They also used gunpowder to propel rockets. In the latter half of the 13th century, the Chinese invented the cannon, which fired projectiles from metal barrels. The first projectiles were arrows; later, shot began to be used. By the late 14th century, cannons reached Europe and became common weapons in warfare.

The oldest known handgun was found in Tannenberg (East Prussia) and dates to the second half of the 14th century. This gun was simply a small version of the cannon, measuring 12.5 inches long and weighing 2.5 pounds. It was fired by touching a lit match to its rear vent. Because the gunner held the gun under one arm and had to look at the match to fire it, aiming was difficult.

The first long arms were long versions of the handgun and appeared early in the 15th century. By the 1500s, improvements led to the mechanical firing gun, which could be aimed easier. The stock, wood attached to the barrel, began to be shaped to fit into the shoulder in order to absorb the recoil and to allow aiming the weapon with some precision. These developments led to the first flintlock muskets, which appeared in 1547 in Spain. By the mid-19th century, improvements such as rifled barrels, breech-loading cartridges, and the cylindro-conoidal bullet made the long gun both more accurate and faster to operate.

The "Little Boy" bomb was the first nuclear weapon used in warfare. It was delivered by the B-29 Enola Gay, *which is on display at the Smithsonian Institution's National Air and Space Museum. The bomb was detonated at an altitude of 1,800 feet over Hiroshima, Japan, on August 6, 1945. It weighed about 9,000 pounds and had an explosive force (yield) equal to about 20,000 tons of TNT.*

Source: U.S. Air Force.

The Venetians were the first to place cannons on ships. These were small in caliber and were used against personnel. By the mid-16th century, iron cannons were commonly mounted on heavy merchant ships. Nations soon learned that heavy merchant ships were not the best choice for warships, which needed to be light and fast. This led to the development of the specialized naval warship and professional navies.

Modern Weapons

Many modern weapons are improved versions of older weapons; however, several new weapons emerged with the 19th- and 20th-century technology explosion. Airplanes, tanks, machine guns, land mines, torpedo-firing submarines, and chemical weapons were introduced in World War I. World War II ushered in the use of rockets and the atomic bomb, which began the nuclear age. During the arms race of the cold war (1950s and 1960s), humankind became capable of total self-annihilation for the first time in history with the proliferation of nuclear-armed strategic missiles. Later 20th- and 21st-century testing includes space-based weapons, lasers, particle beams, and other sophisticated weapons.

Terry W. Eddinger

See also Egypt, Ancient; Evolution, Cultural; Industrial Revolution; Peloponnesian War; Rome, Ancient

Further Readings

Brodie, B., & Brodie, F. (1973). *From crossbow to H-bomb* (Rev. ed.). Bloomington: Indiana University Press.

Gilbert, A. (2000). *The encyclopedia of warfare: From earliest times to the present day*. Chicago: Fitzroy Dearborn.

Hogg, I. V. (1992). *Encyclopedia of weaponry.* Secaucus, NJ: Wellfleet Press.

Weber, Max (1864–1920)

Maximilian Carl Emil Weber was a German sociologist, political economist, lawyer, and politician. His early study of the sociology of religion, *The Protestant Ethic and the Spirit of Capitalism* (1904/1905, revised 1919/1920) is still regarded as one of his most influential works. In this book, Weber points to a new conception of time that emerges with the development of modern capitalism. Time becomes an economic quantity, a factor of human action, and an object of rationalization.

From 1882 to 1886, Weber had studied law, political economy, philosophy, and history in Heidelberg, Berlin, and Göttingen. After 1892, he held posts as a professor of economics at Freiburg, Heidelberg, Vienna, and Munich. He was politically active, and served as a member of the German delegation to the Peace Conference that concluded the Treaty of Versailles. Weber is considered to be one of the founding fathers of modern sociology and an influential analyst of modern society. Weberian concepts, such as those of the freedom from value-judgment (*Werturteilsfreiheit*), ideal types, and *Verstehen* (understanding), provided an important contribution to the methodology of the social sciences. At the center of this work is the question of the origins of modern capitalism. For Weber, the fundamental quality of capitalism is economic rationalism. The economy is determined by strict mathematical calculation aimed at the maximization of profit.

The thesis of Weber's investigation is that there is an intrinsic relationship between characteristics of the Protestant spirit and modern capitalism. Both share an ethic that sees acquisition as an end in itself, and not a means to the satisfaction of needs. Historically important for the formation of this ethic was the development of an idiosyncratic concept of vocation (*Beruf*) in the Reformation. Vocation is understood in the sense of a divine calling (*Berufung*). The fulfillment of this calling becomes an end in itself, a duty to be fulfilled in order to live a godly life. Worldly work thus experiences a positive revaluation in contrast to the Roman Catholic conception.

According to Weber, particularly responsible for the development of the modern capitalist spirit are the characteristics of ascetic Protestantism, such as Calvinism. The doctrine of predestination held here presents the psychological drive for the development of this particular ethic. According to the doctrine of predestination, one part of humanity has been predestined by God to eternal salvation, and the other to damnation. The fate of each person is therefore determined by God and not by one's own deeds. There is therefore no way to ensure or to attain the salvation of one's soul. This resulted in religious doubt and inner loneliness of the individual. In order to bear this doctrine, believers made it a duty to regard themselves as chosen and found, in unceasing work, a remedy against their doubts. Even though one's works could not lead to blessedness, they were a sign of chosenness. This drive for self-assurance led to a rational ethical way of life, a "worldly ascetism." Belief is preserved not in monasteries, but rather in worldly life, and belief finds expression in professional activity. The striving for profit is thereby regarded as intended by God, while the ascetic aspects of the movement work against the enjoyment of possessions. Vocational performance and wealth become mere ends in themselves. Finally, with the fading of its religious roots, the ethic described by Weber experiences its full economic effect. It is reflected in the bourgeois professional ethic and is an essential constituent of the modern capitalist spirit.

The demand for an ascetic and rationalized lifestyle affects the modern understanding of time. Weber shows how time is given a special place, particularly in Puritan doctrine. Only the continual exercise of vocational work accords with the will of God. Wasting time and resting content with one's property are, on the other hand, considered serious sins. Every lost hour is an hour lost to the labor that serves the glory of God.

This doctrine is reflected in the spirit of capitalism, which Weber illustrates with the example of Benjamin Franklin. Time is understood by Franklin to be equivalent to money. Wasting even just small amounts of time can mean a considerable reduction of capital in the long run, and prudence speaks against it. An adherence to deadlines demonstrates a constant creditworthiness. Time becomes a decisive factor in economic thinking. In contrast to the traditionalist, who aims at the mere satisfaction of his basic needs, the modern capitalist strives for a rationalization of time in order to increase production and accumulate capital. Time itself becomes a limited resource and therefore gains economic value.

Robert Ranisch

See also Determinism; Economics; Ethics; Marx, Karl; Values and Time

Further Readings

Käsler, D. (1989). *Max Weber: An introduction to his life and work.* Chicago: University of Chicago Press.

Weber, M. (2002). *The Protestant ethic and the spirit of capitalism: And other writings* (P. Baehr, Ed. & Trans; G. C. Wells, Trans.). London: Penguin Classics.

Wegener, Alfred (1880–1930)

Alfred Lothar Wegener, a brilliant interdisciplinary scientist born in Berlin (Germany), was a meteorologist, geophysicist, and Arctic explorer who proposed the theory of "continental displacement," or what later was called "continental drift." According to this theory, the continents were once united into a single protocontinent, which he called Pangea. Over time Pangea broke up, and the pieces drifted apart into their present positions. Wegener died in 1930 when he was lost in a blizzard during an expedition to the Greenland icecap.

Alfred Wegener studied the natural sciences at the University of Berlin. He became interested in climatology and joined the 1906–1908 expedition to Greenland to study polar air circulation. In 1911 he published *Thermodynamik der Atmosphäre,* a standard textbook dedicated to the science of weather, and in 1926 he accepted a professorship in meteorology at the University of Graz (Austria). Although most of Wegener's life was spent in the study of the climates of the present and the past, his most notable scientific contribution was his hypothesis of continental drift. In 1915, after his participation in World War I, he published his continental drift theory in *Die Entstehung der Kontinente und Ozeane,* translated into English in 1924 as *The Origin of Continents and Oceans.*

Early 20th-century geologists viewed continents as fixed features that could rise and fall, but not move sideways. Given the difference in density between continents and the deep-sea floor, Wegener proposed that the continents floated somewhat like icebergs in the water. He believed that Pangea originated near the South Pole, and the centrifugal force of the earth's rotation caused its breakup 300 million years ago and the drifting of the resulting fragments toward the equator. The idea of a primitive Pangea arose with Wegener's observation that most of the continents seem to fit together like a jigsaw puzzle. For example, the West African coastline and the east coast of South America provide good evidence of that hypothesis. Searching for further evidence, Wegener found many similarities between the fossil record and paleoclimate between Africa and Brazil; Europe and North America; and Madagascar and India, today separated by oceans but previously united in the Pangea supercontinent.

The continental drift theory remained controversial until the 1960s, when the geologist Harry Hess proposed that the movement of the continents was a result of the existence of mantle convection currents. Geologists now call this process the plate tectonic theory. According to this view, the plates are composed of continents and ocean floor, and float on the asthenosphere. The oceanic ridges are divergent plate boundaries where the rising of magma has created new crust. At the areas where plates have collided, great mountain ranges such as the Himalayas and the Andes are formed.

Wegener's hypothesis was incorrect in certain aspects. For example, today we know that the continents are attached to the plates and do not move independently of them, and that mantle convection is responsible for the breaking and dispersal of these plates. Nevertheless, the continental drift theory can be regarded as a forerunner of modern and paradigmatic plate tectonics theory, and Wegener as an earth science visionary.

José Antonio Arz

See also Fossil Record; Geology; Glaciers; Hutton, James; Ice Ages; Lyell, Charles; Pangea; Plate Tectonics

Further Readings

Schwarzbach, M. (1986). *Alfred Wegener: The father of continental drift.* Madison, WI: Science Tech.

Wegener, A. (1966). *The origin of continents and oceans.* New York: Dover.

Wells, H. G. (1866–1946)

As a novelist, prophet, and gadfly, Herbert George Wells was one of the 20th-century's most multitalented writers. Born on September 21, 1866, in modest circumstances in Bromley, Kent, Wells narrowly avoided a life of penury and obscurity in the drapery trade his mother planned for him. He studied at the Normal School of Science at South Kensington (now the Royal College of Science and part of the University of London) under T. H. Huxley (1825–1895), and taught for a while before being able to earn a living as a writer. Wells's importance as a thinker has long been disputed, but few would deny his influence. Central to his thought was the seriousness with which he took evolutionary time and its implications for all living beings, including *Homo sapiens.* Indeed, Wells's work can be seen as the development of his understanding as to just how deeply and totally all living beings are determined by evolutionary time. His first published writing was a series of what were then known as scientific romances, now known as science fiction. The best of these works, *The Time Machine* (1895), *The*

Island of Dr. Moreau (1896), *The Invisible Man* (1897), and *The War of the Worlds* (1898) remain classics in their field to this day.

Common wisdom says that these works represent Wells at his best, but his writing career lasted another 45 years and included some very significant books. After the scientific romances, Wells moved on to novels about life, the best of which were *Kipps* (1905), *Ann Veronica, Tono-Bungay* (both 1909), *The History of Mr. Polly* (1910), and *The New Machiavelli* (1911). These novels can be read as insightful stories about human interaction and for their specific insights into the mores of Edwardian England. Wells then moved on to what he later called his prig novels: *Marriage* (1912), *The Passionate Friends* (1913), and *The Wife of Sir Isaac Harman* (1913). Less successful as novels, these books revolved around ideas of social reform and personal commitment to living one's life fully and in the public interest.

As it did for most people of his generation, the onset of the First World War produced a new range of conflicts that Wells felt the need to explore. While being suspicious of patriotism, Wells deeply loved England, and his wartime books, both fiction and nonfiction, reflected this tension. The best of his wartime works were *Mr. Britling Sees It Through* (1916) and *The Undying Fire* (1919). The war also brought on a short phase of quasi-mystical religiosity, expounded in *God the Invisible King* (1917), although Wells soon tired of that approach and returned to what he called in his autobiography "the sturdy atheism of my youth."

After the war, Wells embarked on a series of what have been called textbooks for the world. They were the hugely popular *Outline of History* (1920), *The Science of Life* (1931), and *The Work, Wealth, and Happiness of Mankind* (1932). Each of these was very influential despite a generally disdainful reception from the academic community. In each of these works Wells was concerned to place humanity in its natural setting and subject to the same evolutionary pressures of change and development as all other living things. He downplayed the role of great men in history and was suspicious of climactic events and turning points and other historical devices designed, in his mind, to flatter the so-called great men. Wells hoped these books would become tools by which people took control of their destiny and worked cooperatively toward a new planetary humanism.

Largely in the service of this vision, Wells produced a steady stream of novels. The most outstanding works from the interwar years were *Christina Alberta's Daughter* (1925), a study of the dangers of succumbing to transcendental fantasies; *Mr. Blettsworthy on Rampole Island* (1928), a black-humored dystopia about the breakdown of the Edwardian consensus about progress; and *The Bulpington of Blup* (1932), a comic look at human pretensions. *Mr. Blettsworthy,* in particular, deserves much more recognition than it has received, not least because it anticipated better-known dystopias like Aldous Huxley's *Brave New World* (1932).

Wells also became known in his capacity as a prophet of the modern age. He foresaw, for instance, trends such as the abolition of distance, nuclear war, suburbia, committed relationships outside marriage, even the Internet. He was also a strong proponent of the conservation of natural resources half a century before this became part of the cultural mainstream. Against this, as late as 1927, he was oddly unable to see much future for radio.

It is often claimed by Wells's detractors that he ended his days deeply disillusioned with the scientific rationalism he had spent his life advocating. His last work, *Mind at the End of Its Tether* (1945), is usually cited in this respect. This claim, however, is unjustified, because Wells was never the uncritical rationalist his critics make him out to be. Since his earliest scientific romances, Wells had been ambivalent about the power of science and notions of easy, unlimited progress that were commonly said to be the by-product of science. Indeed, the strength of those works lies largely in his powerful articulation of this tension. Wells's career was an ongoing reflection on humankind's capacity to use responsibly the power that science was handing it. This underlies the lasting appeal of his science fiction, and reappears periodically, as in *Mr. Blettsworthy.* What the reader gets in *Mind at the End of Its Tether* is Wells's pessimistic and realistic strands interweaving with each other, and his more optimistic strand playing second fiddle.

Wells continued to produce engaging work until the last years of his life, highlights being *The Brothers* (1938), *The Outlook for Homo Sapiens* (1939), and *You Can't Be Too Careful* (1941), his last novel. During the Second World War, he was instrumental in composing a Universal Declaration of Human Rights, which exerted an influence on Eleanor Roosevelt's work to formulate the United Nations's Declaration of Human Rights. Wells died on August 13, 1946.

Bill Cooke

See also Bradbury, Ray; Futurology; Humanism; Novels, Time in; Time Machine; Verne, Jules

Further Readings

Smith, D. (1986). *H. G. Wells: Desperately mortal.* New Haven, CT: Yale University Press.

Wells, H. G. (1934). *Experiment in autobiography.* London: Victor Gollancz & Cresset.

Wells, H. G. (1942). *The conquest of time.* London: Watts & Co.

Wells, H. G. (1945). *Mind at the end of its tether.* London: Heinemann.

West, G. (1930). *H. G. Wells: A sketch for a life.* London: Gerald Howe.

Werewolves

The legend of the werewolf is a legend that transcends cultures and speaks to a perpetual human fascination with shape-shifting, lycanthropy, and the personal battle framed in terms of good versus evil. According to the tradition, werewolves are human beings who shape-shift into bestial wolf form. Although these transformations can be intentional and purposeful, common legend holds that werewolves are under a spell or curse caused by the bite of another werewolf. The modern werewolf story, derived from legendary sources, has changed significantly over the centuries.

The word *werewolf,* traced to its 11th-century Anglo-Saxon origin, means "man wolf." One of the oldest references was captured by the Roman poet Virgil who, in his eighth *Eclogue* (42–37 BCE), tells a story of voluntary transformations of humans into wolves, achieved by means other than being bitten by another werewolf. In Ovid's *Metamorphosis* (8 CE), the god Jove punished King Lycanon of Arcadia with bestial transformation. Later still, in the *Satyricon* by Petronius (27–66 CE) we read of a werewolf that sustains bodily wounds that remain even after the transformation back to human is complete.

Over time, as is typical of legends, the characteristics of werewolves have changed; modern writers have created new creatures that resemble but are in varying degrees different from the earliest described werewolves. The werewolf was popularized in the 1941 film *The Wolf Man;* writer Robert Siodmak reduced centuries of myth and folklore to represent what are now popular cultural beliefs. In his rendition, the werewolf was an innocent victim who was cursed through a werewolf attack. Other beliefs include the following: Werewolves change shape from human to a wolf at the coming of each full moon; in the werewolf state, the human is unaware of his or her actions and loses consciousness of time; in this condition the werewolf enacts the hunt and slaughter of innocent humans, whether for sport or for sustenance. Injuries that a werewolf sustains while in wolf form linger even in human form. A werewolf is repelled by wolfsbane, which is an attractive but poisonous perennial herb of the buttercup family. Werewolves can live eternally. Silver bullets kill werewolves, who then return to human form upon death.

Debra Lucas

See also Frankenstein, Legend of; Dracula, Legend of; Ovid; Vampires

Further Readings

Dziemianowicz, S. (2007). The werewolf. In S. T. Joshi (Ed.), *Icons of horror and the supernatural: An encyclopedia of our worst nightmares* (Vol. 2, pp. 653–687). Westport, CT: Greenwood Press.

White, Leslie A. (1900–1975)

Leslie A. White was an American anthropologist well-known for his theories of sociocultural evolution, studies of the Pueblo peoples, and his neoevolutionary stance. He revived and expanded the theory of evolution in anthropology, especially in terms of the origin and development of sociocultural aspects during the emergence of our species over millions of years. In doing so, his sweeping temporal orientation supplemented the merely structural and functional approaches to cultural anthropology that were offered during the first half of the 20th century. It was no coincidence that White's major work, *The Evolution of Culture,* was published in 1959, the year that celebrated the centennial of the appearance of Charles Darwin's *On the Origin of Species*. White's own cultural perspective encompassed a technological focus that spanned from the Stone Age, through the coming of agriculture, to the emergence of civilization and the Fall of Rome.

Born in Salida, Colorado, on January 19, 1900, White grew up in rural farming communities in Kansas and Louisiana and joined the U.S. Navy in 1918. Initially interested in the physical sciences, White was affected deeply by his involvement in World War I, and began studying psychology at the University of Louisiana and then later at Columbia University in New York where he earned his BA (1923) and MA (1924). Coincidentally, this was the same university where Franz Boas, his foremost opponent, was teaching, and it would be under one of Boas's pupils that White's interest in anthropology would be nurtured.

White earned his Ph.D. in sociology/anthropology from the University of Chicago in 1927; during this time he was able to spend some time among the native peoples of America such as the Menominee, Winnebago, and finally the Pueblo. Afterward, White taught at the University of Buffalo, N.Y. until 1929, then the University of Michigan, where he taught until 1970. His remaining years were spent at the University of California at Santa Barbara until his death on March 31, 1975, in Lone Pine, California.

Though he initially wrote in the Boasian tradition, White became enamored of the works of Lewis Henry Morgan, Herbert Spencer, and Sir Edward Burnett Tylor. These three writers all appealed to White's own views of sociocultural evolution. White would write some of his later works specifically on Lewis Henry Morgan, including *Excerpts From the European Travel Journal of Lewis Henry Morgan* (1937) and *Pioneers in American Anthropology: The Bandelier-Morgan Letters* (1940), which earned him a reputation as one of the world's leading scholars on Morgan. At the time, these were not the most popular anthropologists for students of the Boasian tradition because of their reliance on assumptions and judgments made without benefit of measurable information. White revitalized their ideas into what was characteristic of a neo-evolutionist.

His theory of sociocultural evolution relies on the importance of technology. Without technology, there would be no social systems. In fact, White measured progress not by the level of technology that was being used, but rather by the amount of energy per capita that was being produced by the technology. In this way, White was not merely echoing the evolutionists of the 19th century, but rather updating them.

The formula that White used to represent this theory was "$C = E \times T$," where C is equal to the level of cultural development, E is equal to the amount of energy consumed per capita per year, and T is equal to the efficiency of the technology being utilized. Simply put, the progression of a culture relies upon the increase of energy employed, or by the increase in efficiency of the technology.

Like Morgan, White was quick to point out stages of technology that indicate development. On the lowest level are energy and power provided by one's own muscles. The next step up is the use of domesticated animals to help provide energy. The third stage is marked by the use of plants (i.e., agriculture). After this stage is the one White believed the current populace was in: the use of natural resources (i.e., coal, gas, oil). The next step, which White thought was only a matter of time, was the use of nuclear energy.

Because he placed his emphasis on technology and not on areas important to other cultural evolutionists, White was constantly criticized. This emphasis upon materialism led many to believe that White was ignoring other aspects of culture. Culture, though, was a general phenomenon to White, and it operated as a superorganic entity, as it did in Spencer's ideology. Furthermore, culture rested on technology and, in turn, ruled over both the sociological and ideological spheres he had further divided culture into. In response to his critics, White underlined the importance of technology again and laid out quite simply its importance for survival and its ability to help harness energy for human needs. Logically, he concluded that those who harness more energy are at an advantage over other societies, and that must mean they are more advanced in terms of evolution.

White considered himself to be a culturologist (a scientist dedicated to observing and studying culture), rather than what he termed the other two remaining scientists: biologists and physicists. His major works, *The* Science of Culture (1949) and *The Evolution of Culture: The Development of Civilization to the Fall of Rome* (1959), remain classics in the field. It is in *The Science of Culture* that White first introduced the relationship that exists between culture and technology. *The Evolution of Culture* posited White's belief that culture is still evolving, and that cultural development continues to rest on both the technological and the material adjustments of humans to the natural world. His last work, *The Concept of Culture* (1973), was published during his stay at the University of Santa Barbara, and reiterates the inseparability of culture from both human evolution and human sociability.

White's revolutionary counter viewpoints on Boasian tradition in cultural anthropology earned him both reverence and contempt from colleagues. Further outbursts from White, including his acceptance of socialism, scorn for theism, and praise of the former Soviet Union as being more technologically advanced than the United States, severely limited any hopes of advancement for his career. However, his works were the precursor of future studies to be performed in biophysics, and also ecological economics that would develop in the late 20th century. His works would also serve as the backdrop for further expansion by Gerhard Lenski, a sociologist famed for his contributions to ecological-evolutionary social theory.

Leslie A. White's thought and theory have influenced generations of anthropologists. The current emphasis on emerging technology makes his ideas particularly relevant.

Dustin B. Hummel

See also Evolution, Cultural; Evolution, Social; Harris, Marvin; Materialism; Morgan, Lewis Henry; Tylor, Edward Burnett

Further Readings

Birx, H. J. (1988). *Theories of evolution.* Springfield, IL: Charles C. Thomas.

Peace, W. J. (2007). *Leslie A. White: Evolution and revolution in anthropology* (Critical Studies in the History of Anthropology). Lincoln: University of Nebraska Press.

White, L. A. (1949). *The science of culture: A study of man and civilization.* New York: Farrar, Straus, and Giroux.

WHITEHEAD, ALFRED NORTH (1861–1947)

Alfred North Whitehead was born in 1861 in Ramsgate, England. He was a professor of mathematics in Cambridge (U.K.) and London until his 63rd birthday. In 1924 he accepted a chair in philosophy at Harvard University. In the following years, until his retirement in 1937, he developed one of the most impressive philosophical cosmologies of the 20th century. Whitehead's main philosophical work, *Process and Reality,* forms the basis of process philosophy. His academic career can be divided into two distinct periods: his natural-scientific philosophical period and then his metaphysical period. Whitehead died in Cambridge, Massachusetts, in 1947.

Bifurcations

The natural sciences are concerned only with nature, that is, with the object of perceptual knowledge, and not with the synthesis of the knower with the known. The sciences are not concerned with reasons of knowledge but rather with a coherent explanation of nature. This point of fact led to the bifurcation of reality. Whitehead delivers two similar formulations of such bifurcations, both of which he rejects categorically: (1) The distinction between events of nature and events as they are formulated in scientific theories, and (2) the distinction between events of nature as they exist by themselves and as they appear to us.

The first concept maintains a purely conceptual existence of physical entities, such as atoms and electrons. On the one hand, there were phenomena, and on the other hand, logical terms of scientific formulae. For Whitehead, scientific concepts are derived, by way of logical abstraction, from nature. He argues against the bifurcation of reality into the mathematical world and the apparent world. Concepts, as far as they are true, refer directly to facts of reality.

The second formulation of bifurcation is a direct consequence of the first one. Historically, after separating the realm of apparent nature from the realm of its physical description, John Locke asked how both realms could be connected. Isaac Newton developed a kinetic theory of atoms but did not explain how unperceivable atoms in absolute space and time are connected with our spacetime experiences. Locke realized that moving particles can only set other particles into motion, and that they do not produce the quality of redness. Therefore, he thought that there are secondary qualities not in the things themselves but that are, rather, psychological additions of a mental substance. In addition to the first bifurcation between scientific object and sensory perception, a second bifurcation appears between sensory perception and reality itself. This results in the banishing of the observer from nature. Thus, the observer can have knowledge only of his sensory impressions but not of the objects that produced them. The knowledge of reality now requires a theory.

Perception

To avoid these bifurcations, one has to consider the origin of every possible source of knowledge. Whitehead regards this origin as being in everyone's daily experiences and these experiences are the direct starting point for the British empiricists: First, every experience has its origin in perceptions. Second, the primary ideas of perception join secondary ideas deduced by reflection in order to put the sense data into an order. In addition to these two starting points of the British empiricists, Whitehead integrates psychic impressions like emotions, beauty, love, and satisfaction, among others.

If Whitehead had restricted himself to the theory of perception of the British empiricists, he would be subjected to the false conclusion that reality is constituted out of static and isolated substances. But relations do not fit into a substance philosophy. Whitehead can do justice to relations in sensory perception due to the broadening of the theory of perception by the mode of causal efficacy. He realized that sensory perceptions take place only in symbolic reference and that the two modes of sensory perception, presentational immediacy and causal efficacy, are abstractions from symbolic reference. Perceptions in presentational immediacy depend on the spatial relationships between the perceiver and the sense data, while temporal aspects are totally ignored. If all knowledge is traced back to perception at a moment, one cannot have empirical knowledge of relations, nor of the continuum of reality. Contrary to David Hume and Immanuel Kant, Whitehead finds evidence for causal connections and temporal continuity in sensory perception. He asserts that one can perceive them directly. He tacitly assumes the experience of temporal and spatial extension. Temporally adjacent events are perceived directly in a temporal window of perception: the "specious present" (William James). It is perceivable that later events confirm earlier ones. We have knowledge of an extensive continuum of reality because of our perception of spacetime relations. The specious present contains not only immediately observed events; it also includes the immediate past. The presence of immediate past events shows that present and future events have to confirm earlier events in the same way that immediate past events had to confirm more distant past events. Causality in Whitehead's philosophy means that we never perceive a series of events alone, but that later events must emerge from earlier events in the specious present. Perceptions in causal efficacy contain the temporal aspects of the process of reality.

Sensory perception takes place only in the complex mode of symbolic reference connecting the pure modes of presentational immediacy and causal efficacy. As a result of the fusion of the two pure modes of perception, perception in symbolic reference causes errors and misinterpretations. Normally, the pure modes of perception are not identically illustratable in terms of each other. Symbolic reference is an active synthetic element of the perceiver, producing emotions, convictions, and beliefs concerning other elements of reality.

Time

Within each period of his philosophical development, Whitehead expresses the idea that space and time do not exist independently. Spacetime cannot in reality be considered as a self-subsistent entity. It is an abstraction whose explanation requires reference to that from which it has been abstracted. In his natural philosophy, the real world is an extended, continuously flowing process. Later, in his metaphysical period, space and time are seen as abstractions from extended events and are to be experienced empirically.

Time in Whitehead's Natural Philosophy (1914–1925)

An entity is an abstraction from the totality of the continuously flowing process of reality. Temporally extended events do not exist independently. They are parts of an extended nature and have the duration of the specious present of a perceiver. What scientists accept as elements or parts of the whole are actually abstractions. In reality, the elements exist and have meaning only by virtue of the whole and vice versa. Therefore, time does not have any reality in nature but is the property of a perceiver. The reality is characterized by an extensive spacetime continuum. Durations are arbitrary elements that are simplified by abstraction. Any duration is part of other durations; thus, every duration has other durations that are parts of it. Accordingly, there are no maximum or minimum durations. Therefore, there is no atomic structure of durations, and the perfect definition of a duration is an arbitrary postulate of thought. Sensory awareness posits durations as factors in nature, but events in nature do not have any reality independent of a consciousness and do not have definite temporal extensions. Time relations are an expression of an ordering relation by a perceiver. Spacetime is nothing other than a system for the pulling together of assemblages into unities. Physical time deals only with certain formal, relational aspects of our changing human experience. Relative to other abstractions, space and time offer a comparatively simple structure, which is suitable as a basis for objective distinctions in reality. This simplicity is probably the reason why thought chooses them as the permanent ground for objective distinction.

During the specious present one perceives a unit already separated into its parts by the activity of the perceiver. The parts entertain certain characteristics, of which time and space are examples. The common structure of spacetime conforms to the uniform experiences of sensory perception. But the unity of sensory perceptions does not exist without problems. It is not clear how one can proceed from individual experiences to a uniform spacetime structure. Whitehead confesses that what he has termed the "uniformity of the texture of experience" is a mere illusion. This uniformity does not belong to the immediate relations of the crude data of experience but rather is the result of substituting for them more refined logical entities. This process of lifting the uniform time and space of the physical world into the status of logical abstractions takes the extremely fragmentary nature of all direct individual conscious experience into account as well. All speculation must start with individual experiences as its sole data. It is untrue that we are directly aware of a smoothly running world. If Whitehead accepts that reality is a continuously flowing process, then he will have made no progress in his natural philosophy concerning Kant's concept of time. Temporality of perception is not sufficient to account for causality and time as real properties of nature.

The Epochal Theory of Time (1925)

The transition from momentary events to extended actual occasions is initiated not only by the knowledge that perception takes place in the specious present and that causal interactions are directly perceivable. It is also a result of logical difficulties within physical theories and metaphysical outlines. Physical descriptions of dynamic processes like impulse, velocity, and tension and the descriptions of simple physical structures like atoms, or biological organisms, presuppose the existence of temporal events. In addition, becoming is possible only if reality is constituted out of temporal, atomic events. Becoming and continuity are incompatible, according to Zeno of Elea. Here, Whitehead shows that momentary events can be deduced out of extensional events by means of the method of extensive abstraction, one of his central ideas. All these points forced him to conclude that reality is not founded on momentary events, but rather on temporal, extended events.

Despite the fact that Whitehead probably never became acquainted with the post-1924 development of quantum theory, first results motivated him to transfer the new knowledge of philosophy and psychology to all events of reality. In particular, Bohr's model of the atom in 1913 and de Broglie's wave theory in 1924 resulted in a critical examination of his natural-philosophical starting point.

From now on, the particles of reality are no longer material, static forms but spatiotemporal extended events. The change from materialism to Whitehead´s organic realism is characterized by the displacement of the notion of static stuff by the notion of fluid energy. Such energy has its structure from action and flowing and is also conditioned by quantum requirements. Whitehead got his inspiration from scientific discoveries, without necessarily going into their specific formalism. His doctrine of the epochal character of time depends on the analysis of the intrinsic character of an event, considered to be the most concrete, finite entity, which he calls the "actual occasion." But to avoid any bifurcations, a perceiving consciousness may no longer be an exception outside nature. Whitehead's metaphysics is a consequent transition of the internal experiences of human beings to all entities of nature. Every actual occasion has to be a factor equal to other factors residing within the fact of nature. Therefore, they present a physical and a mental pole. This means that an actual occasion shares in the character of being both a physical and a mental occasion. Every internal aspect of time has an external time aspect as an equivalent. In the epochal theory of time, Whitehead unifies four different time aspects one finds in the experience of an actual occasion. There are two internal and two external aspects. The internal time aspects are the passage of thought (becoming and perishing, retentions), and the experience of extension (unlimited act, inner time consciousness, retentions, and protentions). The external time aspects are the potential physical time (extensive continuum), and the actual physical time (passage of nature, becoming and perishing). Experience of extension corresponds to potential physical time; and the passage of mind corresponds to the passage of nature.

The physical concept of time unifies the experience of an extensive continuum and the perception of concrete, actual occasions. It unifies the discontinuity and continuity of the external world into one concept. The physical pole is extended over the whole spacetime continuum and can be divided. The spacetime continuum is derived from this coordinate divisibility.

In contrast, the mental pole does not share in the divisibility of the physical pole. The mental pole has its equivalent in a thought of the mind. It is an act of attention that has the duration of the specious present. The passage of mind is confronted with the experience of an unlimited temporal act in the internal time concept.

An actual occasion is the product of the interplay of the physical pole with the mental pole. In this way, potentiality passes into actuality, and extensive relations mold qualitative content and objectifications of other particulars into a coherent, finite experience. Every actual occasion is a spatiotemporal unit possessing an indivisible volume and time quantum. Coordinate divisibility shows that each actual occasion is composed of a number of subordinated actual occasions. Actual occasions express the uniform spacetime structure of the universe because their external relations fit them into superordinate actual occasions, and their internal relations, the coordinate divisibility into subordinate actual occasions, merge them into an extensive continuum. The spatiotemporal extensive continuum is the general structure to which all actual occasions must conform.

If one takes into account that the actual world is built up of actual occasions that have different temporal extensions that overlap each other, and that one perceives this world in the specious present, one is able to perceive causal connections directly. One can recognize the development of actual occasions on their historical routes and realize how an actual occasion passes and a new one becomes.

Physical time, physical space, and creative advance are abstractions that presuppose the more general relationship of extension. The extensiveness of space is really the spatialization of extension; the extensiveness of time is really the temporalization of extension. Physical time expresses the reflection of genetic divisibility into coordinate divisibility.

The assignment of the different time aspects to the final units of reality becomes possible through the transformation of the natural philosophical concept of momentary events into actual occasions. While in Whitehead's natural philosophy the events still depend on the activity of a perceiver, actual occasions are in his metaphysics the final units of reality. They are the real things of the world and have their own being. They are not momentary cuts through reality but rather forms that have the properties of spatiotemporal extension and creativity. The temporality of the actual occasions determines what time is. Physical time is an abstraction from this temporality.

Joachim Klose

See also Alexander, Samuel; Bergson, Henri; Berkeley, George; Creativity; Hume, David; Idealism; Kant, Immanuel; Leibniz, Gottfried Wilhelm von; Metaphysics; Ontology; Perception; Russell, Bertrand; Teilhard de Chardin, Pierre; Teleology; Time, Subjective Flow of; Zeno of Elea

Further Readings

Whitehead, A. N. (1920). *The concept of nature.* Cambridge, UK: Cambridge University Press.

Whitehead, A. N. (1925). *Science and the modern world.* New York: Macmillan.

Whitehead, A. N. (1929). *Process and reality.* New York: Macmillan.

White Holes

White holes are the theoretical time-reversal opposites of the astronomical bodies known as black holes. In 1916, Karl Schwarzschild used Einstein's general theory of relativity to derive the first model of a black hole. The negative square root solution of the Schwarzschild model of the spacetime continuum provided for the existence of white holes. Since general relativity is time symmetric, the purest definition of a white hole is a black hole running backward in time. The complete Schwarzschild model includes a black hole, a white hole, and two universes connected at their horizons by a wormhole.

The time reversal action of white holes provides for a difference in behavior from black holes. Black holes are known for their high gravitational forces that prevent any matter from escaping the pull of the forces. Because white holes are understood as black holes running backward in time, white holes will repel matter while black holes make matter disappear. In astrophysics, a white hole is postulated to be a celestial body that spews out matter, perhaps because the white hole is a collapsed area of space that is expanding, thus putting matter back into space as it expands. Other researchers theorize that white holes eject matter from the event horizon while black holes absorb matter at the event horizon. However, this behavior is not affected by the time reversal of the entities so it is theorized that both white and black holes attract matter, with the difference in action occurring at the event horizon. Physicists who specialize in relativity generally agree that white holes are essentially time-reversed black holes from which particles must exit but cannot enter. Following on this, a black hole can become a white hole with negative time when the direction of time is reversed. Using the theory of general relativity, one can hypothesize that a rotating black hole in a specific part of the spacetime continuum can be attached to the same hole in another part of the spacetime continuum where, depending on the observer's location, it can appear as a white hole. The existence of white holes expelling matter provides a response to the question of where the matter that is sucked into a black hole ends up. If black holes take in matter, their corresponding white holes expel matter.

In 1962, John Wheeler theorized the Einstein-Rosen bridge as spacetime-matter metric, which involves a wormhole acting as a bridge to connect two universes. The wormhole acts as a shortcut through space and time to allow travel between the two universes. This occurs in areas of space located in the center of a black hole and a white hole. The Schwarzschild model discussed above supports this theory.

White holes are highly theoretical, however, because they cannot be observed, and black holes are difficult to locate because they absorb all light. In addition, white holes violate the second law of thermodynamics, which states that heat moves naturally to a region of low temperature from a region of high temperature, but white holes, by their definition, do not run out of heat or mass. Opening our minds to the possibilities of other universes allows us to consider universes that operate differently than ours. Perhaps the second law of thermodynamics does not apply beyond our universe; thus white holes could indeed exist.

Beth Thomsett-Scott

See also Black Holes; Relativity, General Theory of; Spacetime Continuum; Time, Symmetry of; White Holes; Wormholes

Further Readings

Gribbin, J. R. (1977). *White holes: Cosmic gushers in the universe.* New York: Delacorte.

Gribbin, J. R. (1992). *Unveiling the edge of time: Black holes, white holes, wormholes.* New York: Harmony Books.

Gribbin, J. R. (1998). *The case of the missing neutrinos: And other curious phenomena of the universe.* New York: Fromm International.

William of Conches (1080–1154)

William of Conches (Guillelmus de Conchis), a commentator on the philosophical works known to the first half of the 12th century, is one of the major figures in the circle around the famous school of Chartres. On the topics of time and eternity, William is interested in fine distinctions. Thus, he discusses the different meanings of *eternal* (*aeternum*), *sempiternal* (*sempiternum*), and *perpetual* (*perpetuum*). According to him, the first expression designates something without a beginning and without an end (i.e., God), the second something with a beginning before time but without an end (i.e., the world), the third something without an end but with a temporal beginning (i.e., the human soul). The last two definitions show problems typical of a Christian Platonist, whereas his ancient pagan predecessors had no need of such a distinction because of their assumption of the eternity of the world and of human souls, which migrate from one body to the next one.

While commenting on Plato's *Timaeus* 37c–38b, William defines eternity and gives no fewer than three definitions of time: Eternity, "the presential state of everything what is, what was and what will be," is reserved to God alone, such that he had to create an image of that eternity when creating the material world. This image, time, can be defined in a general way as "the dimension of duration and movement of the changeable things." This definition, which is borrowed verbatim from John Scotus Eriugena, is "general" (*generalis*), according to William, because it designates time both as a whole and regarding its parts. The second definition is "time is that space which has begun with the world and will end with the world." This definition, which William ascribes to the *Timaeus,* is "total" (*totalis*), because it concerns only time as a whole (*totum*). The definition in Cicero's *De inventione,* "time is a certain part of eternity, i.e., of that large space, with the signification of the certain space of a day, a night or a month" (which is discussed also by William's contemporary Peter Abelard) designates, according to William, only the parts of time that in his mind, however, exist in reality (and not only in human language, as Abelard puts it). The difference between eternity and its image, that is, time, is precisely that time consists of a succession of moments, whereas in eternity everything is comprehended at one time (*comprehendetur simul*). By distinguishing two meanings of "day," William attempts to eliminate the difficulty that time is created, according to Plato, at the moment of the creation of the world, while the Bible presupposes that there were already days when God started the process of creation: According to William, the Book of Genesis meant by "day" the span of 24 hours, while Plato meant the determination of the day as the span of time between sunrise and sunset. William can be regarded as one of the first representatives of Christian Platonism in the Scholastic period; similar ideas can be found in many Christian philosophers with a Platonic standpoint up to Nicholas of Cusa (Cusanus).

Matthias Perkams

See also Bible and Time; Christianity; Eriugena, Johannus Scotus; Eternity; God and Time; Plato

Further Readings

Curr, M. (1998). William of Conches: A dialogue on natural philosophy. In *Notre Dame texts in medieval culture* (Vol. 2; I. Ronca, Trans.). South Bend, IN: University of Notre Dame Press.

William of Ockham (c. 1288–1347)

William of Ockham was an English Franciscan friar and philosopher who argued that only individuals exist, not essences or forms, which have no existence apart from the human mind. Ockham's theory of time is an application of his general principle that entities should not be multiplied unnecessarily. Thus, the soundest argument is one that rests on the fewest assumptions, factors, variables, or causes; this principle is still commonly referred to as "Ockham's razor." According to this principle, Ockham acknowledges only a nominal definition (*definitio quid nominis*) of time, not a real one. That is, the word *time* does not signify a particular thing, but just the continuous movement of the heavens. Insofar as that movement can be measured, time also signifies (*consignificat*) the human mind and its activity of ordering things as occurring earlier or later.

Ockham stresses that in order to recognize time, it does not suffice just to be aware of some change; rather, change has to be understood as motion (*motus*), as a continuous process in which the particular instances of change happen. Thus, directly (*in recto*), "time" signifies a processual, continuous motion, and indirectly (*in obliquo*) the awareness of that motion in the human mind. By identifying in this way time and motion, which are distinguished only by activity of the mind, Ockham leads the medieval predilection for defining time via movement as an equivalent of time to its ultimate consequence: While most thinkers before him identified the "matter" of time with motion but granted to it a form of its own as did Albert the Great, Ockham denied that time even had a separate existence in this restricted sense. Consequently, he also denies that the sentence "time is a thing being (*tempus est ens)*" is true in the sense of "time exists"; rather, it is true only by virtue of the truth of other sentences concerning the existence of past time, of present time, and of future time. In reality, however, only the actual moment (*instans*) exists. All prior moments no longer exist, and all future moments do not yet exist; they are "a pure nothing" (*purum nihil*). Because of this, an activity of the mind is necessary to bring about that successive motion that we call time: Our mind is able to recognize things that it itself imports (*importat*) into the world, such that they exist in a certain way outside of the mind (*extra animam*), but due only to the mind's activity. This holds true for past and future moments of time, which do not exist in themselves but whose potential existence as moments that have been and moments that will be can be actualized by our cognition, such that we grasp the continuous succession of such moments, which we call time, though all but one of its elements actually do not exist and especially not apart from things in the process of change. This interpretation of Aristotle's statements in the fourth book of his *Physics* relies heavily on Averroes's interpretation of the same texts, which are quoted frequently in William of Ockham's treatise on time.

Matthias Perkams

See also Aristotle; Cognition; Time, Logics of; Time, Nonexistence of; Time, Perspectives of

Further Readings

Adams, M. (1987). *William Ockham* (2 vols.). South Bend, IN: Notre Dame University Press.

Boehner, P., & Brown, S. F. (1990). *Ockham: Philosophical writings.* P. Boehner (Trans.). Cambridge, MA: Hackett Publishing.

Goddu, A. (1984). *The physics of William of Ockham.* Leiden, The Netherlands: E. J. Brill.

WINE

Throughout the ages, wine has served a variety of purposes. From religious ritual to everyday consumption, this fermented liquid has been a mainstay in various cultures, primarily in the Mediterranean region of the world. Not only does the production and consumption of wine have a long history, but time is also a key factor in improving the quality of wines.

Origin

The beverage wine was most likely stumbled upon by accident and not intent, given that the end product is just a specific point in the natural cycle of grape spoilage. Grape cultivation for the purpose of wine creation began no later than 4000 BCE, and perhaps as early as 8500 BCE, during the Neolithic period. The first activity of this kind is known to have taken place around the Caspian Sea, near the modern-day nation of Iran.

Basic Necessity

Wine has been produced in one capacity or another for well over 6,000 years. Since its discovery, wine has served as a delectable beverage with all the attributes associated with liquids that are alcoholic in nature. Throughout most of that time, however, wine has also been considered a basic necessity for the survival of various peoples. In regions with tainted or unreliable sources of water, the stored product of fermented grapes provided a stable and untainted source of hydration. In addition to serving as a necessary means of hydration, wine has also provided those who consume it with beneficial polyphenolic flavonoids, more commonly known as antioxidants. Wine is also laden with sugars, and therefore calories, making it nutritionally beneficial as a source of energy. In addition, moderate quantities of alcohol have recently been proven to benefit the cardiovascular system and enhance blood circulation.

Religious Connection

For thousands of years, wine has served a variety of cultures and religions in their divine worship. Greek libations to their gods often involved the pouring of wine. In Judaism, a kiddush blessing on Shabbat is required to be spoken over wine, if possible. Similarly, it is customary to drink four cups of wine during the course of the Jewish celebration of Passover.

All Christians use wine for similar yet markedly different reasons, depending on their denomination or sect. Roman Catholics believe the wine to be changed, literally, into the blood of Christ during the weekly rite of the Eucharist, while most Protestant denominations hold wine as an important, more symbolic link to their Creator. Until the mid-19th century, all Protestant groups relied on wine, much like their fellow Christians. Thomas Bramwell Welch, a Methodist minister, applied pasteurization techniques to stop the naturally occurring fermentation of grape juice into wine. Since then, most Protestant churches in the United States have switched to rites held with grape juice, keeping the "wine" name in accordance to scriptural reference. During America's prohibition days of the early 20th century, wine was allowed to be produced and used in the Mass and also domestically for religious ceremonies. Islamic law prohibits the usage of alcoholic beverages. As a result, wine is forbidden to Muslims.

History

From its earliest origins through the present, the uses of wine have varied in keeping with the nature of the society and the times. Little is known of the societal implications of wine for those in the Caspian Sea and Mesopotamian region about 4000 BCE and before. However, during the late Uruk period within Mesopotamia (ca. 3500–3100 BCE), it is known that the upper classes were enjoying this aromatic and palatable drink.

Wild grapevines never grew in ancient Egypt. Yet by the beginning of the Old Kingdom period (c. 2700 BCE) several wines found themselves on a canonical set of provisions for the afterlife of rulers and the elite. In an era when the afterlife was more tangible than spiritual or ceremonial, wine was seen not as an all-powerful magical elixir, but rather as a staple on the "menu" of nutritionally sound consumable goods necessary for one's existence in eternity.

Around 1000 BCE, the Romans began to make substantial contributions to viniculture by applying an empirical method to their harvest. Romans began to observe and take note of the characteristics associated with the ripening of grapes, as well as classifying the grapes into different colors and varietals. Equally as important, they began to identify diseases associated with the cultivation of grapes, and also recognize the types of soil in which the specific varietals thrived or withered. To increase their yield, Romans also began to prune their vines so as to eliminate potential threats from within, while simultaneously initiating irrigation and fertilization techniques. In addition, during this era of Greco-Roman influence, wine storage began to shift from clay jars and animal hides to glass bottles, this serving to increase the life expectancy of a batch of wine.

Points of Reference

The oldest written account of viniculture is referenced in the Hebrew Bible, with Noah planting a vineyard for the purpose of producing wine. In Europe, wine often takes the name of the region in which it is grown; for example, Burgundy, Chianti, Bordeaux, and Champagne. Varietal (specific grape type) names are often associated with New World producers, or with vineyards in countries outside of Europe. Examples of varietal names include Riesling, Merlot, Cabernet Sauvignon, and Sangiovese.

"Sometimes wines" can be produced from the fermentation of fruit other than grapes (e.g., plum, strawberry). They often cannot be specifically referred to as simply a wine, since the word *wine* can often legally refer only to beverages made from the fermentation of grapes.

The cuisine being served is often taken into consideration when pairing wine with a meal. As a general rule, white wines are served with lighter entrees such as seafood or chicken, in order to complement and not overwhelm the meal. Given the generally hearty and robust characteristics associated with red wine, it is often paired with stronger tasting red meats, such as beef. Thomas Bramwell Welch, a staunch prohibitionist in the United States, introduced pasteurization to grape juice so that it did not naturally transform to wine. He is also a founder of the Welch Grape Juice Company, one of the largest fruit juice producers in the world.

Wine is often erroneously stored beyond its peak. More than 80% of wine sold worldwide is meant to be consumed within 1 to 2 years of its corking, so as to prevent overmaturation. Only a select few wines, such as a port, are suitable for aging decades or even longer. Today, rare and prestigious vintage wines are among the most expensive consumable products available. A bottle dating to the late 18th century sold for $160,000 in 1985, and it is not uncommon for some premium vintages to fetch above $10,000 per bottle.

Given the relatively new trend in collecting wine, the temptation to engage in the business of wine falsification and deceit has proved irresistible, and lucrative, for an unscrupulous few. Incidents have been reported of master forgers creating or altering wine labels and even bottle contents so that they are nearly identical to ultra-rare vintages, the result being an overvalued falsity.

Daniel J. Michalek

See also Chemistry; Decay, Organic

Further Readings

Fuller, R. C. (1996). *Religion and wine*. Knoxville: University of Tennessee Press.

McGovern, P. E. (2003). *Ancient wine: The search for the origins of viniculture*. Princeton, NJ: Princeton University Press.

$100,000-a-bottle wine fraud alleged. (2007, March 8). *USA Today*.

The origins and ancient history of wine. Retrieved August 15, 2008, from University of Pennsylvania, Museum of Archaeology and Anthropology Web site: http://www.museum.upenn.edu/new/exhibits/online_exhibits/wine/wineintro.html

Witching Hour

The phrase "the witching hour" refers to the general time of night when, according to popular lore and superstition, spirits of the dead, as well as a variety of other supernatural beings ranging from ghouls to witches, are said to wander the earth and are at the peak of their fiendish strength and devilish effectiveness.

The term may be found in both an 1831 introduction to Mary Shelley's classic novel *Frankenstein* (1818) and Washington Irving's famous tale *The Legend of Sleepy Hollow* (1820) before Ichabod Crane has his fateful encounter with the spectral Headless Horseman. In other forms, the term can be traced to Shakespeare, who uses the phrase "the witching time of night" as a means to set the spooky scene for Hamlet's first attempt at the murder of the conniving King Claudius. Interestingly enough, Hamlet also meets with the ghost of his father at the hour of midnight, the predominant time the witching hour is said to begin.

Historically speaking, the idea of the witching hour, or perhaps as it was more suitably thought of, a time when the unnatural and unorthodox were given free rein, may have arisen from later Roman history when members of pagan cults were persecuted by newly Christianized Romans for carrying out their rituals under the cloak of night when most respectable Roman citizens would be fast asleep. In fact, many neopagans confirm that a true witching hour occurs only at midnight on a full moon. The reasoning behind this seems to stem from the belief that the aura that surrounds the moon is a harbinger of change, and also that the lunar aura carries an apogee of power when the moon is at its fullest. The moon goddess (in her Roman name, Diana) has long been associated with witchcraft and is still worshipped by practitioners of earth religions and other neopagans (or, as some people like to refer to them, witches, but more properly Wiccans) today.

Further speculation upon the correlation between witches and the witching hour would reveal that the typical witches' Sabbath time is around midnight. These particular scenes of the witches' gathering have often been shown in the theater to be at night, with conditions that meet the idea of the witching hour, usually depicting a full moon in the background. One excellent representation of this is in the film *The Crucible,* based upon Arthur Miller's play of the same name. Set at the time of the Salem witch trials, the opening act depicts a nighttime witches' Sabbath in which local teenager Abigail Williams kills a chicken as a sacrifice, aspiring to attain the happily married John Proctor's love through magic.

The temptation of Dr. Faust by Mephistopheles also occurs during the midnight hours, and elements of the witching hour are immortalized later during the Walpurgisnacht (the Witches' Night) scene in Johann Wolfgang von Goethe's *Faust* (1808). Walpurgis Night is the time, according to German folklore, when witches gather upon the Brocken summit of the Harz Mountains in northern Germany to celebrate the coming of spring; this holiday is held during the night of April 30. During the midnight hour of Walpurgis Night, similar to a belief in America (except the date is changed to Halloween), it is said that Satan himself is able to walk the earth due to a weakness in the barrier separating the living and the dead.

The exact time of night that the witching hour is said to begin varies, even though the witching hour is traditionally said to begin at midnight. Depending on how modern the interpretation, it can either begin later than this time, or simply begin at midnight and last until another particular time.

The 2005 movie, *The Exorcism of Emily Rose,* has popularized the witching hour as beginning at 3:00 a.m., when the titular character becomes possessed by demonic entities. In the film, the Catholic priest who is given the task of expelling the demons calls 3:00 a.m. the "demonic witching hour," and he explains that this particular time is a chance for the evil forces to ridicule the Holy Trinity, and also to play upon the traditionally accepted hour of Christ's death, the so-called miracle hour, or 3:00 p.m. Some paranormal investigators have reported that 3:00 a.m. is associated with an increase of phantasmal and psychic incidents, possibly attributable to the influence of the movie on the public imagination.

Dustin B. Hummel

See also Dracula, Legend of; Frankenstein, Legend of; Goethe, Johann Wolfgang von; Vampires; Werewolves

Further Readings

Edwards, K. A. (2007). *Werewolves, witches, and wandering spirits: Traditional belief & folklore in early modern Europe*. Kirksville, MO: Truman State University Press.

Guiley, R. E. (1999). *The encyclopedia of witches and witchcraft* (2nd ed.). New York: Facts on File.

Woolf, Virginia (1882–1941)

Virginia Woolf is one of the major British writers of the 20th century. Mainly known for her novels, Woolf was also a proficient reviewer, essayist, diarist, and writer of letters as well as an influential publisher. Her novels and essays combine psychological, philosophical, and political insights with great literary craft and an experimental style. Although her themes often center around questions of feminine identity and woman's position in society, many of Woolf's writings are also concerned with the complex questions of the nature of reality and time. Her literary works are by now regarded as classics of the modernist canon.

Virginia Woolf was born Adeline Virginia Stephen into the upper-middle-class family of the Victorian man of letters and biographer Leslie Stephen in London on January 25, 1882. She was one of eight children (among them the painter Vanessa Bell) and suffered greatly from her mother's early death when she was only 13. She was educated mainly at home and began writing diaries and short prose pieces at an early age. Her first journalistic piece was published in 1904. She took up teaching female workers in 1905 and worked for the women's suffrage campaign in 1910. Her first novel, *The Voyage Out,* was published in 1915. Together with Leonard Woolf, whom she married in 1913, she started the Hogarth Press in 1917; it was to become an important publishing house for modernist literature, sociopolitical criticism, and psychoanalysis. Living in London and Rodmell (Sussex), they had many famous acquaintances in the fields of literature, music, psychology, economics, and politics of the time. Greatly concerned about German fascism and the ongoing war, and on the verge of another in a series of nervous breakdowns, Virginia Woolf committed suicide on March 28, 1941.

Major Novels and Essays

After having published her two early novels, *The Voyage Out* (1915) and *Night and Day* (1919), which both deal centrally, albeit in different ways, with the question of female identity in early 20th-century society, Virginia Woolf set out to experiment with prose forms in her short story "The Mark on the Wall" (1917) and with her third novel *Jacob's Room* (1920). While having already discursively posed the question of whether and how language, the arts, and science are able to represent reality in her early works, Woolf now started to focus more on the nature of perception and to develop techniques that transformed the philosophical questions of knowledge and representation into a literary experience.

Woolf's next novel, *Mrs. Dalloway* (1925), is not only one of her best-known works but also one in which the philosophical paradoxes of time are most prominently present. Started under the working title *The Hours* and set on one day in the postwar London of the early 1920s, *Mrs. Dalloway* juxtaposes the passing of objective, linear time, represented by the chimes of Big Ben, with the subjective temporal experience of its main characters, Mrs. Dalloway, an upper-class politician's wife, and the mentally disturbed war veteran Septimus Warren Smith. Their continuous movements between present perceptions and past experiences extends the temporal dimension of the novel, juxtaposing narrating and narrated time, while at the same time questioning the nature of what is real in terms not unlike Henri Bergson's distinction between *temps* and *durée.*

This contrast between subjective and objective time is also explored in *To the Lighthouse* (1927). While two of the three main sections of the novel deal with single days in the lives of a female painter, Lily Briscoe, and the Ramsay family, in 1910 and 1920, respectively, the much shorter middle section is about the 10 years that lie in between. Time here is represented as an impersonal theme of the events that happen—among them the death of two characters—indicating the cosmic but also indifferent nature of time's passing.

The passing of time, and the question of history, is also addressed in Woolf's mock-biography *Orlando* (1928). Mixing fact and fiction as well as going beyond the scope of serious historiography, it is about the life of an English aristocrat from the 16th century to the present who not only stays young but also changes sex halfway through the novel.

More earnest in tone, and experimental in style, is *The Waves* (1931) in which short lyrical passages following the diurnal passage of the sun are contrasted with the lives of six characters from early childhood to middle age, narrated in the form of soliloquies. Again, the cosmic dimension of time is set against—or rather: as a frame for—the individual experience of time and its subjective significance in a literary form that offers an extraordinary reading experience.

The title of Woolf's penultimate novel, *The Years* (1937), refers directly to time. Similar to *The Waves,* Woolf juxtaposes the cosmic time of nature—the seasons—with human time—history—in alternating pastoral and narrative passages that give an account of the Pargiter family from 1880 to "the present." More than in *The Waves,* however, Woolf's focus here is on a feminist critique of history. A similar political concern engaged with questions of history and individual agency is at the heart of Woolf's last novel, *Between the Acts,* which was published posthumously in 1941. Setting her novel against the background of the Second World War, Woolf poses the question of whether—and how—civilization might be preserved through artistic endeavors.

Through her work and her diaries—which she kept writing until near her death—Virginia Woolf can be seen as an author continuously engaged with the various dimensions of time—phenomenological, epistemological, historical, and political. By transforming these dimensions into an artistic form, Woolf makes "time" available for her readers as an aesthetic experience that at its best parallels, if not extends, philosophical reflection.

Stefanie Lotz

See also Bergson, Henri; Consciousness; Joyce, James; Mann, Thomas; Novels, Time in; Proust, Marcel; Ricoeur, Paul; Time, Perspectives of

Further Readings

Bell, A. O. (Ed.). (1982). *The diary of Virginia Woolf.* London: Penguin.

Goldman, J. (2006). *The Cambridge introduction to Virginia Woolf.* New York: Cambridge University Press.

Lee, H. (1996). *Virginia Woolf.* London: Chatto & Windus.

Whitworth, M. H. (2005). *Authors in context: Virginia Woolf.* Oxford, UK: Oxford University Press.

Worlds, Possible

By "a possible world" philosophers mean a total state of affairs in the conception of which no contradiction is involved. Our own world—the real world, the actual one—is just one of many possible worlds. Indeed, it is just one of infinitely many, since for any possible world containing, say, n atoms there is another logically possible world containing $n + 1$ atoms, and so on ad infinitum. All possible worlds other than the actual world we inhabit are nonactual.

A world the conception of which does involve a contradiction is said to be an impossible world. An impossible world, of course, is a nonactual one. There are many possible worlds in which you, the reader, exist; the actual world is one of them. And there are possible worlds in which you do not exist; any such world is nonactual. But there are none in which you both do and do not exist; any such world is an impossible one.

The Banality of Possible Worlds

Although the term *possible worlds* entered the philosophical lexicon only in the writings of Gottfried Leibniz (1646–1716), the fact is that we all think about them everyday, though not usually under that description. The idea of worlds different from the actual one is totally commonplace. One wonders what the world would have been like if one had done something different from what one in fact did: if one had chosen a different partner or profession, for instance. One wonders what history would have been like if Hitler had won the Second World War. Equally, one ponders whether one should do this or that, or something else, where each of the possibilities would make a difference in how the world, or one's little part of it, would then turn out. And one makes plans for the future hoping things will turn out one way though conscious of the fact that they may not.

The concept of possible worlds is implicit in all these ways of thinking. To imagine the past as having been different (even in the smallest respect) from the way it was, or the future (even in the smallest respect) as being different from what it will be, is to entertain the concept of different possible worlds branching out from the past (perhaps even from the beginning of the world), or from the present, or from the future.

Thus, there is nothing arcane about the notion of possible worlds, actual and nonactual alike. They feature in our dreams, our imaginings, our hopes and fears for the future, our regrets over past deeds and lost opportunities. We think about how the world *might* have been, and of how it *might* yet come to be.

They also feature in fiction, especially science-fiction novels and films in which we are invited in our imaginations to enter into worlds that often bear only the faintest resemblance to the real world that we in fact inhabit. Some are plausible. Some are not. And still others seem beyond the bounds of belief. Science-fiction stories involving time travel, in particular, often challenge our sense of what is possible and what is not. Are such stories internally consistent or is there a contradiction involved somewhere? Is time travel possible? Is it possible to change the past? Or the future, for that matter?

Theoretical Applications of the Concept

The concept of worlds, possible and impossible, actual and nonactual, can play a valuable role in clarifying our thinking about many issues. In philosophy, the concept has been used to give us a better grasp of matters of logic (leading eventually to the development of temporal logics), semantics, and issues in philosophy of religion, philosophy of science, ethics, and metaphysics. Some examples follow.

Possible Worlds and Logic

The aim of logic, as conceived by its founder, Aristotle (384–322 BCE), was to establish general principles for reasoning such that *if* we started from a set of true premises we could be guaranteed that we would finish with a true conclusion. These principles would ensure that the conclusion follows, as he put it, "of necessity" from the premises.

Leibniz claimed that these principles about what follows of necessity (the principles of logic) *are true in all possible worlds*. This insight has enabled subsequent philosophers to give illuminating accounts of the whole field of logic.

In terms of possible worlds, we can define many of the most basic concepts of logic as follows:

P implies Q	There is no possible world in which P is true and Q false
P is consistent with Q	There is a possible world in which both P and Q are true
P is inconsistent with Q	There is no possible world in which both P and Q are true
P contradicts Q	There is no possible world in which both P and Q are true and no possible world in which both P and Q are false
P is a contrary of Q	There is no possible world in which both P and Q are true but there is a possible world in which both P and Q are false
P is a subcontrary of Q	There is no possible world in which both P and Q are false but there is a possible world in which both P and Q are true

Consider the propositions:

1. The universe began more than 13 billion years ago.
2. The universe began less than 3 billion years ago.
3. The universe began at least 3 billion years ago.
4. The universe began no more than 13 billion years ago.

A little thought will suffice to show

- that (1) *implies* (3)
- that (1) and (4) are *contradictories* and hence, by definition, are *inconsistent* [ditto for (2) and (3)]
- that (1) and (2) are *contraries* (and hence, by definition, are *inconsistent*)
- that (3) and (4) are subcontraries (and hence, by definition, are *consistent*).

Moreover, we can define an argument as *valid* only when its premises imply its conclusion. Thus the simple two-premise argument:

5. Time began when the universe began.
6. The universe began on Sunday, October 23, 4004 BCE.

Therefore,

7. Time began on Sunday, October 23, 4004 BCE

is *valid* since there is no possible world in which its premises are true and its conclusion false. (Note that it would be *sound* only if it was not only valid but also had true premises, i.e., premises that are not only true in some possible world but also true in the actual world.)

The concept of possible worlds also enables us to define some important properties of propositions. Clearly, each of the propositions (1) through (7) is true in some possible worlds (and hence *possibly true*) and false in some others (and hence *possibly false*). Propositions having the property of being possibly true and possibly false have been described, ever since Aristotle, as *contingent*. By way of contrast, propositions such as

8. Not both P and not-P (the so-called law of noncontradiction)
9. 2 + 2 = 4 (a truth of mathematics)
10. If a thing is red then it is colored {a definitional or analytic truth)

are described as *noncontingent,* these all being instances of so-called *necessary truths* (propositions that are true in all possible worlds) while their contradictories

11. Both P and not-P
12. It is not the case that 2 + 2 = 4
13. Some red things have no color

are instances of *necessarily false* or *self-contradictory* propositions (not true in any possible world).

The properties of being necessarily true, necessarily false, or contingent are said to be *modal* properties. Aristotle sketched the foundations of a modal logic in which these properties play a vital role. Medieval logicians appealed to their logical intuitions to elaborate on Aristotle's findings. In 1918, C. I. Lewis developed axiomatic systems for various modal logics. In 1959, Saul Kripke provided some of these with a widely accepted semantic underpinning in what is called *possible world semantics,* and, about the same time, Arthur Prior extended modal logics in the form of *temporal logics* (sometimes known as *tense* logics).

Possible Worlds and Science

The aim of science is to determine which of many possible worlds is actual. Its method is to progressively eliminate from further consideration all those that experience and reason show to be inconsistent with what we already know (or have compelling evidence for believing) to be true of the actual world.

That, in a nutshell, is how Karl Popper (1902–1994) and his followers such as Peter Medawar (1915–1987) view science. On their account, a scientist has an idea of a *possible* world, that is, a way the world might be, and then tests it experimentally to see whether the *actual* world conforms with it. If it withstands the tests, it is accepted provisionally as the best account available to date. But if not, the scientist—if endowed with an open mind and intellectual integrity—will reject it as having been ruled out by experience of how the actual world works.

Consider propositions (1) through (7) again. All are contingent, that is, true in some possible worlds and false in others. But which, if any, is *actually* true?

Although Bishop Ussher (1581–1656) believed he had God's word, as revealed in the Bible, as his authority for claiming (6) to be true (that the universe began in 4004 BCE), only a few diehard biblical creationists would nowadays agree. Edwin Hubble (1884–1933) turned to science for an answer and calculated an age of about 2 billion years based on observations of the rate of expansion of the universe. That was in 1929. In 1947 George Gamow (1904–1968), with new evidence in hand, gave an estimate of 2 to 3 billion years. And current estimates, based on evidence produced by the Hubble Space Telescope among other things, are that the big bang began about 13.7 billion years ago, thereby asserting the truth of proposition (1), and thereby implying the falsity of its contradictory (4) and the falsity of its contraries (2) and (6).

Arguably, it is through a succession of such episodes of conjecture and refutation that the big bang theory of current physical cosmology has replaced Ussher's. We have come, through experiment, to realize that the possible worlds that Ussher, Hubble, and Gamow conceived are *nonactual* ones.

These advances were prompted by observation-based experiments. But not all experiments are observational ones. Some are made in "the laboratory of the mind," by conducting pure "thought experiments." The history of science, and of physics in particular, is replete with such cases. Notable examples range from Galileo's thought experiment refuting Aristotle's belief that heavier objects fall faster than lighter ones to Erwin Schrödinger's "Cat" critique of certain interpretations of quantum mechanics. And they include Einstein's thought-experiment in which he, at age 16, conceived of himself chasing a light-wave—a thought experiment that led him to formulate a new conception of physical time and space.

Possible Worlds in the Philosophy of Time

Thought experiments can help us get clear about how the concept of time relates to other concepts.

Is Time Travel Possible?

It is not just science-fiction writers who entertain the idea of traveling back in time. Some physicists do, too, on the grounds that certain concepts of traveling through time are consistent with both general relativity and quantum theory.

Yet some thinkers have rejected the notion outright. Many argued that time travel would make it possible for individuals to go back in time, kill their own paternal grandfather while they were still a child, and thereby ensure that they themselves were never born. Hence, the so-called grandfather paradox.

But where lies the contradiction? Not in supposing that the laws of nature (of genetics, in particular) would thereby be violated, for there is nothing contradictory involved in that part of the story. The paradox lies elsewhere.

It is tempting to think of traveling through time as akin to traveling through space to visit a place one hasn't been to before. This fosters the idea of visiting a place in the past, even though one hasn't been there before, and of leaving one's mark by changing things once one gets there. But this is where real paradoxes arise. For it is a logical truth—true in all possible worlds—that the past was what it was. It follows that you cannot go back to a previous time unless you have already been there. You can travel to the past only if you already *were* in the past. It follows, too, that you cannot *change* the past from what it was by, for example, killing your grandfather if the fact is that he wasn't killed. There is no possible world in which either can occur.

Some tellers of time-travel tales have been astute enough to avoid any paradox. Robert A. Heinlein is a case in point. His novel *Time Enough for Love* depicts a world that is self-consistent and hence possible.

Must Time Have Begun With the Big Bang?

Most physicists, following Stephen Hawking (b. 1942), would answer "Yes" on the grounds that the big bang model *defines* time that way. The argument is that since physicists can define time only in terms of its observational consequences, and events occurring "prior to" the big bang would have no such consequences, the concept of time prior to the big bang "makes no sense."

But this is conceptually confusing. It would seem to make the proposition

5. Time began when the universe began

true "by definition" and hence a necessary truth. Yet (5) is clearly contingent. We can easily, and without contradiction, conceive of worlds in which the big bang was preceded by phases of expansion and contraction. That is to say, there is no contradiction involved in the supposition that the oscillatory universe model is true. Or the steady state model for that matter. In fact, both models entail that neither the universe nor time had any beginning at all.

So what has gone wrong? There has been a failure to distinguish between *operational definitions* of time (definitions couched in terms of the operations by which time is measured) and the concept of time itself. The concept of time itself has a scope that is not restricted by any particular scientific theory or to any method of measurement used by that theory. Arguably, its ties with other concepts are more a matter of philosophical analysis than of empirical inquiry.

Could Time Pass Without Events Occurring?

It is obvious enough that a series of events (changes in objects or states of affairs) cannot occur without the passage of time. How about the converse? Could time pass if nothing was changing?

Few philosophers entertained this possibility until Sydney Shoemaker (b. 1931) argued for it. He told a possible worlds parable about a world with three parts, A, B, and C, each of which undergoes periodic "local freezes" of, say, one year's duration—periods during which nothing whatever occurs—such that the freezes for all three parts coincide at regular intervals. The inhabitants of each part, he argues, could even have observational evidence for the freezes occurring in the other parts, have evidence from inhabitants of other parts that their part also undergoes periodic freezes, and calculate the times when all the freezes occur at the same time.

It won't do to object that none of the inhabitants could, during the concurrent freezes, observe or measure the passage of time. That would be to appeal to the operational definition of time whose tenability is in question. It won't do to invoke Ockham's razor and say that it is much simpler to suppose that the supposedly concurrent freezes never occur. The principle of parsimony is not a logical one. Nor will it do to object that his scenario affords no causal mechanism by which the freezes of any of the three parts could come to an end. For the issue is not whether his possible-worlds scenario is physically possible. It has to do only with whether it is logically possible.

Unless a strictly logical contradiction can be found in the Shoemaker scenario, we have no option other than to allow the possibility of time passing in the absence of anything whatever occurring.

Raymond D. Bradley

See also Big Bang Theory; Cosmological Arguments; Experiments, Thought; Gamow, George; Hawking, Stephen; Leibniz, Gottfried Wilhelm von; Multiverses; Popper, Karl R.; Time, Logics of; Time and Universes; Time Travel; Universes, Baby

Further Readings

Bradley, R. D., & Swartz, N. (1979). *Possible worlds: An introduction to logic and its philosophy.* Oxford, UK: Basil Blackwell.

Brown, J. R. (1991). *The laboratory of the mind: Thought experiments in the natural sciences.* New York: Routledge.

Loux, M. J. (Ed.). (1979). *The possible and the actual: Readings in the metaphysics of modality.* Ithaca, NY: Cornell University Press.

Medawar, P. (1982). "Two conceptions of science" and "Science and literature." In *Plato's Republic.* Oxford, UK: Oxford University Press.

Veneziano. G. (2004, April). *The myth of the beginning of time.* Retrieved from http://hera.ph1.uni-koeln.de/~heintzma/U/BeginTim.htm

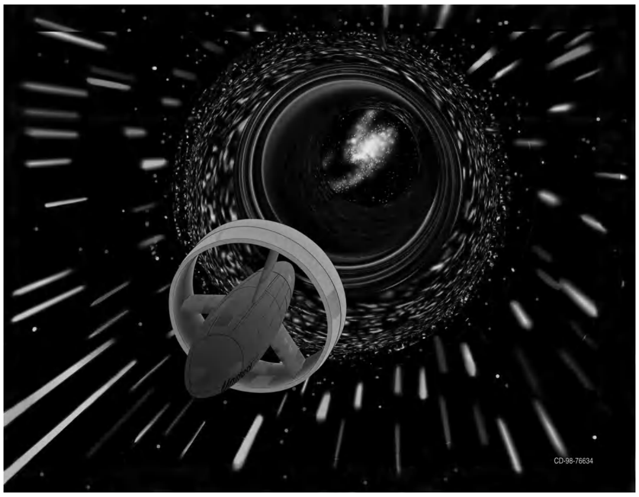
Wormholes

A wormhole is a theoretical connection, often referred to as a tunnel, between two black holes. The two black holes could be in two different locations in the same universe, or they could be located in two different universes. In the case of both the former and the latter, each black hole would necessarily be located in a different time, in keeping with the concept of spacetime as delineated in Albert Einstein's theory of general relativity.

In fact, it was Albert Einstein and Nathan Rosen who discovered the mathematical possibility of wormholes, but they called them "bridges" in 1935. These Einstein-Rosen bridges, as wormholes were first called, would not allow any object to pass through, they theorized, because the middle of the wormhole would twist or pinch until it separated, creating a singularity, a literal dead end.

A black hole is formed when the resulting matter from a supernova explosion collapses until all the matter is squashed into a point at which volume is zero and density, gravity, and the curvature of spacetime are infinite. That point is called the black hole's singularity. A wormhole connects two singularities.

Spacetime is a four-dimensional continuum that consists of three-dimensional space with the traditional x, y, and z axes plus a fourth coordinate—time—added to make four-dimensional spacetime. Einstein theorized that one could not know the location of an object independent of both its place (spatial coordinates) and instance (time coordinate) with respect to the observer or observers. For example, if person A in San Diego observes the location of the sun at time A, and person B in Cairo observes the same object at time B, then the sun exists in different places in spacetime. If one considers that a few time zones separate these observers, as opposed to light-years



Artist's illustration of a spacecraft passing through a wormhole to a distant galaxy. A wormhole is a hypothetical topological feature of spacetime that is essentially a shortcut through space and time. Assuming that general relativity is correct, wormholes may exist. There is no evidence, however, for anything like a wormhole in the observed universe.
Source: NASA.

between celestial objects, the importance of spacetime with respect to location and instance becomes more evident. Expanding the concept from the scale of the earth to the scale of the universe allows one to conclude that two black holes connected by a wormhole must exist in different times if they exist in different locations.

Thus, a wormhole would allow rapid time travel, cutting an interstellar trip from several millennia down to a few days or a few hours. There would be many possibilities for the direction of time travel. If the first black hole lies at point A in the past, and the second black hole lies at point B in the future, then a wormhole could take one forward in time, as well as backward. If, like the Einstein-Rosen bridges, the wormholes pinch, they could close, become attracted to a different singularity, and reopen an alternate pathway through spacetime.

Although the discovery of black holes and the behavior of visible matter that surrounds them lend support to wormholes' existence, the study of wormholes is still considered by most to be speculative in nature.

Karlen Chase

See also Black Holes; Einstein, Albert; Hawking, Stephen; Relativity, General Theory of; Singularities; Space and Time; Spacetime Continuum; Time Travel; White Holes

Further Readings

Hawking, S. W. (2007). *The illustrated brief history of time* (Updated and expanded ed.). New York: Bantam Books. (Original work published 1988)

Toomey, D. M. (2007). *The new time travelers: A journey to the frontiers of physics*. New York: Norton.

X

Xenophanes (c. 570–480 BCE)

Xenophanes, one of the Presocratic philosophers, lived in Colophon (in Ionia, Asia Minor) until about 546 BCE, when he left following a conquest of Ionia by the Medes and began to travel the known world widely. He may have spent time in Elea (southern Italy), and Aristotle reports that he was said to have been a teacher of Parmenides. He observed fossils of sea animals in mountainous regions and conjectured that the sea must have covered those mountains in earlier times. He also is said to have thought that everything comes to be from earth and water (mud), which is why the remains are found in dried mud. Worlds (or world orders) may come and go, perhaps in cycles. Thus there is change in the physical world over time, and the physical world and its inhabitants exist in time.

Xenophanes did not accept the traditional Greek conception of a pantheon of many gods who fought with one another, lied, seduced, and could be placated by gifts from mortals. In the course of his travels to many regions around the Mediterranean, he had observed many different religious beliefs. He wrote that the Ethiopians make their gods snub-nosed and black (like themselves), whereas the Thracians' gods are portrayed with red hair and gray eyes (characteristics of the Thracians themselves). Thus each human race creates an anthropomorphic god in its own image. Xenophanes thus concluded, as reported by Clement of Alexandria: "And if oxen and horses and lions had hands, and could draw with their hands and do what man can do, horses would draw the gods in the shape of horses, and oxen in the shape of oxen, each giving the gods bodies similar to their own." He is thus contemptuous of any such view of the gods, or god, as like any mortal being. There must be one god, concluded Xenophanes, not like any mortal creature in body or in mind. This god "sees all over, thinks all over, hears all over" (Sextus Empiricus), a precursor of the more modern view of a god who is omnipresent, all-powerful, all-knowing, and omnibenevolent. The god imagined by Xenophanes does not move or change (it would not befit a god to do so) but sets all things in motion by pure thought. This anticipates Aristotle's prime mover, Augustine's God, and the mathematician-god of Leibniz. Thus for Xenophanes, one god exists and is the source of the world. (Some conclude that his god is equivalent to the world, that Xenophanes was an early pantheist, like Spinoza, but this would not be consistent, equating a god that does not change with a world full of change.)

One of the problems with the traditional Greek gods of Homer and Hesiod was that they were too much like humans, with all the flaws of humans but in greater measure. Xenophanes seemed to believe that god must represent a kind of perfection, an ideal; thus such a god would have to be one, not many (as the many gods would have to differ from one another to be many and thus be better or worse, more or less strong, and the like, than one another, but god must be the best, the most perfect, and thus be only one). This god is eternal, does not change, does not come into being or pass away. Thus Xenophanes' god is timeless, or outside of time, or in all time.

Stacey L. Edgar

See also Becoming and Being; God and Time; Presocratic Age

Further Readings

Aristotle. (2002). Aristotle's *Metaphysics* (2nd ed.; J. Sachs, Trans.). Santa Fe, NM: Green Lion Press.

Kirk, G. S., Raven, J. E., & Schofield, M. (Eds.). (1983). *The Presocratic philosophers* (2nd ed.). Cambridge, UK: Cambridge University Press. (Original work published 1957)

Robinson, J. M. (Ed.). (1968). *An introduction to early Greek philosophy.* Boston: Houghton Mifflin.

Y

Yeats, William Butler (1865–1939)

William Butler Yeats, Irish playwright and poet, was brought up in Dublin and London and became among the foremost writers of the modernist movement in 20th-century literature. Deeply involved with the Irish literary revival, he took an active part in the creation of an Irish literary theater. Yeats was awarded the Nobel Prize in Literature in 1923. Well aware of the accelerating pace with which the world around him was changing and being a nationalist and a conservative, Yeats was known for his desire to maintain the traditional forms of society and government that he ardently supported.

One of his best-known poems, "The Second Coming," reveals Yeats's belief that history and time are cyclic. The poem describes the destruction of the ruling monarchy as part of an unavoidable collapse of the world order as he knew it. Describing chaos and violence as a product of the foreseen rift in ways of old, the piece concludes with a famous line conveying his belief that the disorder creeping across modern life would give birth to a new beginning, as with the times preceding the birth of Christianity: "And what rough beast, its hour come round at last, Slouches towards Bethlehem to be born?"

Yeats's poem "The Lake Isle of Inisfree" expresses the speaker's desire to abandon modern society with its hurried pace and retreat to a tranquil island. The poem's narrator uses this reflection on an uninhabited island as a stolen moment to escape the onrush of a quickly developing civilization. Describing his island refuge, Yeats writes, "And live alone in the bee-loud glade. And I shall have some peace there, for peace comes dropping slow." The speaker resolves that this quiet life is a mere musing and that such isolation is not something easily found. Writing "while I stand on the roadway, or on the pavements grey, I hear it in the deep heart's core," Yeats reminds readers of the ever-present asphalt world that surrounds us. Retreat to a state of isolation offers the promise of escape from a world that is growing and changing too fast.

Years after the poem's publication, Yeats reflected that the idea for "The Lake Isle of Inisfree" came to him as he paused on the sidewalk of a busy street. Peering into a shop window, he saw an advertisement meant to draw a rushed passerby's attention with a metal ball suspended on a jet of water in a fountain. The lazy trickle of water and simplicity of the attraction moved Yeats; time seemed to slow down, and the reverie he experienced inspired thoughts of a simpler time and place.

Yeats died in France in 1939, and 9 years later his remains were transported to his final resting place in Ireland. His headstone displays a short excerpt from one of his final poems, "Cast a cold eye on life, on death, horseman pass by!" Readers of his epitaph are advised to look on both life and death with equanimity, to continue on their way and not dwell on the end of life but rather go on living it.

Christian Austin

William Butler Yeats, Nobel Prize–winning Irish dramatist, author, and poet.

Source: Library of Congress, Prints & Photographs Division, LC-DIG-ggbain-30167.

See also Joyce, James; Time, Cyclical

Further Readings

Howes, M., & Kelly, J. (Eds.). (2006). *The Cambridge companion to W. B. Yeats*. Cambridge, UK: Cambridge University Press.

Yeats, W. B. (1996). *The complete poems of W. B. Yeats* (2nd rev. ed.; R. J. Finneran, Ed.). New York: Scribner.

YOUTH, FOUNTAIN OF

The Fountain of Youth is a legendary spring whose waters are alleged to have the ability to halt the ravages of time or even reverse the aging process. By drinking or bathing in it, one is supposed to experience the erasure of all signs of age. Legends of the magical spring as told to the early Spanish explorers also included tales of vast riches and precious metals lying alongside the pool, awaiting the discoverer.

Some Fountain of Youth fables have placed its location in eastern Asia, where it was sought after by Alexander the Great. According to other stories, the fountain is located in Hawai'i. The best-known location comes from the 15th and 16th centuries, when Spanish explorers first arrived in the New World. They were told by the natives of modern-day Cuba and Puerto Rico that the magical body of water was located in a land to the north, which they called Bimini (Florida). They told the Spanish of an Arawak (natives of current-day Haiti) chief named Sequene, who sailed north with a ship of men and never returned home. Their failure to reappear was seen not as a failure in which they were lost at sea, but rather as a success. It was believed by many that they did in fact find the supernatural water and stayed to enjoy their recaptured youth in a new land.

Juan Ponce de León (1460–1521) traveled with Columbus on his second voyage in 1493. The Spanish settled in the area, and in 1513, after a stint as the governor of Puerto Rico, de Leon financed his own expedition to travel north in search of the Fountain of Youth. The ship supposedly landed in

Spanish Explorer Juan Ponce de León (1460–1521). This scene depicts his search for the fabulous island of Bimini, where the legendary Fountain of Youth was said to be located.

Source: Getty Images.

the vicinity of what is now St. Augustine, and he proposed that this land be called La Florida. It was in this area of St. Augustine where he claimed to have found the Fountain of Youth.

To some residents of this area of Florida, the Fountain of Youth is more than just a legend. The land containing the supposed spring is now a park where visitors can purchase glimpses of what is touted as the true fountain, on the basis of a landmark cross that was found adjacent to the spring. Discovered at the beginning of the 19th century, the cross is made of 27 coquina stones and is believed to have been placed there by Ponce de León. Authenticity of the cross having been laid by de León himself was verified in 1904 with the further discovery of a nearby salt cellar, which contained a signed parchment declaring a statement of witness to the laying of the stones in 1513. As for the local water itself, thorough testing has disclosed no rejuvenating properties.

Patrick J. Wojcieson

See also Aging; Elixir of Life; Immortality, Personal

Further Readings

Morison, S. E. (1974). *The European discovery of America.* New York: Oxford University Press.

Phillips, W. (1992). *The worlds of Christopher Columbus.* New York: Cambridge University Press.

Z

Zara Yacob (1599–1692)

The African thinker known as Zara Yacob was a rationalist who challenged the status quo by elevating reason over faith in the quest for truth. He did so within a deeply conservative context in which little or no tolerance was shown toward dissenting interpretations of religious writings. Although Zara Yacob lived in a tumultuous time of religious persecutions, he believed that there is no good or bad time as such; rather, it is humans' actions that make the times good or bad.

Zara Yacob was born in Aksum, Ethiopia, in 1599 to a farming family. He attended religious school for many years and later spent his career as a teacher, writer, and philosopher. According to Claude Sumner, a scholar of the life and works of Zara Yacob, Yacob is credited with formulating modern philosophy in Ethiopia at the same time that it was developing in Europe, particularly in England and France. He thus secured an important place in the history of African philosophy.

For Zara Yacob, God is revealed through reason. In working out his understandings of knowledge and human nature, Zara Yacob affirmed a belief in the power of reason, using it to examine the dogma of the Church. Zara Yacob's thoughts parallel the ideals of the European Enlightenment. As a realist, he strongly believed that people should trust the evidence that comes through senses and practical proofs rather than the dogmas of teachers, priests, or prophets. He believed everything must be critically examined and inspected before it is accepted as true. This approach to knowledge and the process of knowing put Zara Yacob at odds with the Church authorities. To escape persecution he took refuge in a cave, where in solitary exile he developed most of his philosophical ideas. During his time, the rift between Catholics and Protestants in Europe also had an impact on Africa. Missionaries of both denominations were working hard to disseminate their respective religious views in Africa, and Ethiopia was a target. The Portuguese were important allies of the then-politically weakened king of Ethiopia, known as Susnios, whose sovereignty was threatened by low-lander Islamic political forces. With the help of the Portuguese, the king won the battle and responded by converting to the Catholic Church. Those Ethiopian Christians who were Orthodox and who openly challenged the king's conversion were persecuted; many were killed. Zara Yacob was among those fortunate enough to survive.

With the benefit of his formal education, Zara Yacob used his time in solitude to critically examine the practices of his time in religious matters—both in Ethiopia and Europe. He had the chance to debate with the European missionaries of the time. Based on his in-depth meditation, Zara Yacob systematically formulated philosophical explanations to some of the perennial questions. In this regard, Zara Yacob's thought can be categorized into three areas of philosophical inquiries: These are the methods of knowing, human nature, and the obligations of humans.

Zara Yacob's method of knowing is called *Hassasa* or *Hatata*—which means to question, search, investigate, examine, or inspect. According to Teodoros Kiros, Zara Yacob's epistemological approach to knowledge and knowing involves discursive subjection and critical examination of truth through intelligence or natural reason. This extends to the acquisition of faith itself through a critical examination and rational reasoning. Thus, faith in God comes only after extensive reasoning. According to Zara Yacob, nothing should be taken for granted unless it is first subjected to critical examination by intelligence or natural reason. Such discursive method also applies to the faith in the conception of God. Meditation, according to Zara Yacob, is a method of thinking powerfully enough to explore the mystery of the notion of God, the principles of Christianity, human nature, and ways of life in general.

According to Zara Yacob, human weakness allows people to be lured by falsehood, wealth, status, and power. He suggests humans need the support from their creator—God. According to Kiros, he identifies two types of laws—the law of God and the law of humans. The law of God makes the law of humans complete. Overreliance on the human law leads to falsehood and deficiencies, whereas the use of the law of God enables humans to attain righteousness and make intelligent decisions. Zara Yacob argues that because humans suffer from falsity, errors, and poor choices, they need guidance from the laws of God. Humans should consult God in their choices and decisions for the reason that, according to Zara Yacob, truth cannot be discerned on the basis of human affairs alone.

Zara Yacob argues that the fundamental obligation of humans is to the service of God. God created humans with intelligence, and that intelligence should be used in turn to know God. It is only then that people can turn their energies to the service of their fellow humans. This involves, according to Zara Yacob, loving others as oneself.

Zara Yacob examined diverse areas of inquiry in his philosophical journey during his solitary life; these include matters of marriage and abstinence from sex, fasting, monastic life, controversies in the interpretation of religious materials, the roles of prophets, differences among various religions, and education. Zara Yacob strongly recommends married life and giving birth to children, as it is the will of the creator God. Thus, he openly challenged the then-monastic and celibate life advocated by the clergy, with the conviction that marriage benefits human society.

In regard to the notion of time, Zara Yacob understands time as a measure of events and actions of humans. He believes that everything needs to be done at the appropriate time. Thus, his notion of time is that there is time for everything. Patience to do things at their right time, in this regard, is considered to be the mark of wisdom. His influence on his disciple Wolde Hiwet is observed in the works of the latter, who continued to develop Zara Yacob's treatise after the latter's death. Accordingly, these thinkers believe that time is what we are and what we do. They reject the idea of celebrating the old days as good and condemning the present as bad. Every period, according to them, has its own goodness and badness. The kernel of the argument is the following: Be good and do good, then time will be good to you; if you do evil, the time also will be evil.

Belete K. Mebratu

See also Becoming and Being; Calendar, Ethiopian; God and Time

Further Readings

Kiros, T. (2001). Zara Yacob: A seventeenth-century Ethiopian founder of modernity in Africa. In T. Kiros (Ed.), *Explorations in African political thoughts* (pp. 69–79). New York: Routledge.

Sumner, C. (1976). *Ethiopian philosophy.* Addis Ababa, Ethiopia: Commercial Printing Press.

Sumner, C. (1985). *Classical Ethiopian philosophy.* Addis Ababa, Ethiopia: Commercial Printing Press.

Zeitgeist

Zeitgeist is a term of German origin, meaning "spirit of the age," or "spirit of the times." In a formal context, zeitgeist presupposes that the time one speaks of has an essential relation to a governing idea or set of ideas, which in turn presupposes that time has a meaning. This idea is venerable. Ancient and medieval thinkers habitually thought of time as a succession of ages, most memorably recalled for us now in Shakespeare's *As You Like*

It (Act II; scene 7). At a more colloquial level, when in the 1950s the American painter Willem de Kooning (1904–1997) spoke of existentialism as "being in the air," he was speaking of zeitgeist.

The notion of zeitgeist is a secular descendant of these ideas. Zeitgeist is a secular concept because it recognizes that it is what people do that gives an age its determining characteristics. Traces of the older versions of the idea reappear when it is assumed that the determining characteristics of the age were also somehow inevitable.

Accounts differ as to the origin of the idea. Some claim it began with the German historian Johann Gottfried von Herder (1744–1803) in 1769 as a translation of the Latin phrase *genius seculi,* or "guardian spirit of the century." An important influence on German Romanticism, von Herder spoke of the *Volksgeist* as the spirit of each people. He also dreamed of the *Volksgeist* being encapsulated in a single individual, the great man who, by virtue of his capturing the needs of the day, can coerce the people to bend to his will.

The most significant philosopher to take up the zeitgeist idea was G. W. F. Hegel (1770–1831). According to Hegel, philosophy is nothing less than the age coming to understand itself. In this way, subscribing to a philosophy not indicative of the zeitgeist was a betrayal not only of the true philosophy but of oneself and one's place in time.

Many of the attempts by teleologically inclined historians to impose rigid periods in history work on the assumption of the power of the zeitgeist. Hegel saw history moving from what he called the Eastern phase, where freedom was held up for want of a coherent idea of individuality, to a Greek phase, where the ethical life was discovered. This was followed in turn by the Roman phase, where people were brought to heel by the rule of law. Only with the Germanic phase of history—the current zeitgeist—was it recognized that humans are free by definition.

Hegel's periodizing of history, each marked by its characteristic zeitgeist, has attracted many imitators. Historical thinkers as varied as Karl Marx (1818–1883), Oswald Spengler (1880–1936), and Arnold Toynbee (1889–1975) all theorized on the zeitgeist. Other thinkers have thought in terms of zeitgeist in different contexts. For example, the Spencerian evolutionist John Fiske (1842–1901) conceived of evolution as moving inexorably and approvingly to the form of laissez-faire capitalism in the United States at the time. The idea can also be put to pessimistic uses, as when Martin Heidegger (1889–1976) spoke of the contemporary zeitgeist in terms of the age of technological frenzy and the consequent dehumanizing of man. More recently, zeitgeist has become a fashionable word among the more popular commentators and apologists of postmodernism to indicate the ubiquity of the ideas they support.

One of the first people to question the teleologically determined zeitgeist was Johann Wolfgang von Goethe (1749–1832), who had Faust declare that the spirit of the times is nothing more than the combined spirit of the people who live through the times. Among philosophers the most thorough critic of the notion of zeitgeist in history was Karl Popper (1902–1994), particularly in *The Open Society and Its Enemies* and *The Poverty of Historicism.* Among historians the Dutchman Pieter Geyl (1887–1966) criticized the notion of zeitgeist in the context of his criticisms of historian Arnold Toynbee.

It is now generally conceded that history does not have an underlying meaning written into its fabric. Although it is true that an age can seem strongly tied up with one idea or another (the "swinging '60s" is an obvious example), it is false to see that particular age as necessarily and exclusively determined and characterized by that idea. Zeitgeist is best understood in the loose sense as the currently predominant, though not necessarily true, idea or family of ideas that can set the tone for the time.

Bill Cooke

See also Goethe, Johann Wolfgang von; Hegel, Georg Wilhelm Friedrich; Heidegger, Martin; Herder, Johann Gottfried von; Marx, Karl; Popper, Karl R.; Teleology

Further Readings

Friedrich, C. J. (1954). *The philosophy of Hegel.* New York: Modern Library.

Geyl, P. (1967). *Encounters in history.* London & Glasgow, UK: Collins.

Popper, K. R. (1957). *The poverty of historicism.* London: Routledge & Kegan Paul.

Zeno of Elea (c. 490–c. 430 BCE)

Zeno of Elea (southern Italy) was a student of Parmenides, who argued that what is real is One, not many. A consequence of this rational position ("being is, non-being is not") is that motion, or change, is an illusion (the Way of Opinion, not the Way of Truth). The consequences of this view affect the possible views of space and time, since motion is generally considered as a change with regard to space over time. Zeno constructed a number of arguments in defense of his master Parmenides; some are measure paradoxes, directed against plurality. Probably his most famous paradoxes are four paradoxes of motion, which all argue that motion is impossible (at least given any accounts that had been put forward regarding the nature of space, time, and motion). Parmenides had come in for a great deal of criticism of his views on the One; Zeno is at least deflecting some of the attacks by drawing out the apparent consequences of opposing views and using Parmenides' own rational principle—that whatever leads to a contradiction must be false—against the attackers.

Zeno constructed four paradoxes of motion. At least two of them clearly examine the consequences of the suppositions that (a) space and time are both continuous, or (b) space and time are both discrete. One might wonder why Zeno put forward exactly *four* paradoxes. Because time can be either continuous or discrete, and space also can be either continuous or discrete, that can lead to four possible combinations: space and time both continuous, space continuous and time discrete, space discrete and time continuous, or both space and time discrete. The first and the fourth paradoxes clearly fit the first and fourth combination possibilities. This entry examines whether the middle two paradoxes might be construed as representing the other two options.

The Bisection Paradox

The bisection paradox (sometimes referred to as the "dichotomy") looks at the consequences if both space and time are viewed as continuous (infinitely divisible). Let us imagine that someone wants to travel from A to B. To get to B, first she must travel halfway; then to get from there to B, she must travel half the remaining distance; and so on ad infinitum. Thus she can never complete the journey from A to B because there is *always* half the remaining distance left to traverse. If one were in a football game, and the defense kept committing fouls that cost them penalties of half the remaining distance to the goal, the offense could never actually score on those penalties, no matter how many of them there were. The path from A to B is divided as follows:

A 1/2, 3/4, 7/8 15/16 . . . B.

To get from A to B is an infinite (endless task), because it amounts to passing through an infinite sequence of points (1/2, 3/4, 7/8, 15/16, . . .) for which there is no last point, so the "end" of the sequence can never be reached.

The Regressive Version

Our intrepid traveler wishes to go from A to B. To get to B, she must first go halfway; but to get to the halfway point, first she would have to travel half the distance to that (i.e., reach the 1/4 point). However, to get to the quarter-point she would first have to go 1/8 of the distance, and so on and so on. Thus we see the following dilemma:

A . . . 1/16 1/8 1/4 1/2 B.

Her task involves beginning an infinite sequence of points of which there is *no first point,* so she can never get off of A to begin the journey, as there is no first point at which to begin. Thus (concludes Zeno), motion is impossible.

The "Achilles"

The Greek athlete and hero Achilles is to be pitted in a race against a tortoise. Being a good sport, as he is the faster runner, Achilles gives the tortoise a head start. The paradox is that Achilles can never overtake or pass the tortoise, even though he is faster, because in the time it takes Achilles to reach the point where the tortoise was, the tortoise has advanced. Again, by the time Achilles gets to the next point at which the tortoise had been, the tortoise has moved on; this pattern continues on without end. Achilles must always get to the point where the tortoise was, but in this time, the tortoise has moved on. A diagram illustrates the dilemma:

$$T_0\, T_1\, T_2\, T_3\, T_4\, T_5 \ldots$$

$$A_0\, A_1\, A_2\, A_3\, A_4\, A_5\, A_6 \ldots .$$

The subscripts indicate starting time (0) and subsequent times (1, 2, 3 . . .) at which Achilles has reached the spot where the tortoise *was;* at time 1, for example, the tortoise has advanced to position T_1, whereas Achilles has only reached level with T_0, the place the tortoise started at but has now vacated. Thus Achilles can never overtake the tortoise.

This could possibly be interpreted as viewing space as discrete and time as continuous. Achilles must always move to a distinct place that the tortoise has left and, in the time (no matter how short) this has taken, the tortoise has moved ahead some distance. If space is discrete, then Achilles must always move from one spatial minimum location to another; if time is continuous (infinitely divisible), these successive spurts to the spots where the tortoise *was* can continue indefinitely, with the tortoise always moving to some new spot.

The Arrow

This paradox begins with the premise that an object is said to be at rest when it is in the place where it is. Thus, argues Zeno, if the arrow is to be moving, it is either moving in the place where it is or in the place where it is not. Clearly, it cannot move in the place where it is not. And if it is in the place where it is, it is at rest. Thus the "moving arrow" is at rest and cannot move. This could be interpreted as looking at discrete time instants (indivisible units), in which the arrow cannot be said to be moving (because it is in the place where it is), and so, even if space is continuous, the arrow cannot move to another spatial location; it must remain "in the place where it is."

The Stadium

This paradox deals with the assumption that space and time are discrete, that they are made up of "minims" (minimal units), which is a view (based on the limits of measurement) advocated recently in modern physics. Zeno looks at a stadium in which two sets of chariots (the A's and the C's) are going to race in opposite directions to each other. Let us also include a set of fixed columns (the B's) at the center of the stadium, to serve as reference points. So the initial starting configuration is

$$\leftarrow A_1\, A_2\, A_3$$

$$B_1\, B_2\, B_3\ t = 0$$

$$C_1\, C_2\, C_3 \rightarrow .$$

Let us assume that the chariots (in groups A and C) move at a speed of one spatial unit (spun) per temporal unit (tun), or speed = 1 spun/turn. After one time unit has elapsed, the positions of the chariots will be as indicated in the picture below:

$$A_1\, A_2\, A_3$$

$$B_1\, B_2\, B_3\ t = 1$$

$$C_1\, C_2\, C_3.$$

The big question here is "*When* did A_2 pass C_1?" and there seems to be no meaningful answer to this question. There seems to be no *time* at which they can be said to have passed one another, because in the minimum time of 1 turn they have *jumped* to their current location, without having passed each other at any specifiable time! If another unit of time passes, the configuration will look like the following:

$$A_1\, A_2\, A_3$$

$$B_1\, B_2\, B_3\ t = 2$$

$$C_1\, C_2\, C_3.$$

Aristotle says about this part of the paradox that "half the time is equal to its double" (*Physics*

VI, 9: 239b). Presumably, this is based on the fact that in t = 1, C_1 has passed *two* A's, but only one B; it takes C_1 *two* units of time to pass two B's. Thus it seems that half the time (1 time unit) to pass two A's is equal to its double (two time units, which it takes to pass two B's). This would seem to be a serious misunderstanding of relative motion (in one case relative to fixed bodies, and in the other relative to bodies that are also moving), one that Zeno would not have committed. The crucial objection seems to be the first one—that there is no time at which C_1 can be said to have passed A_2, and yet at t = 1, C_1 is one spatial unit to the east of (to the right of) A_2. How could this have happened?

Perhaps what Zeno's paradoxes tell us, over 2 millennia later, is that we still do not have a logically adequate account of space and time.

Stacey L. Edgar

See also Parmenides of Elea; Presocratic Age

Further Readings

Kirk, G. S., Raven, J. E., & Schofield, M. (1984). *The Presocratic philosophers* (2nd ed.). Cambridge, UK: Cambridge University Press. (Original work published 1957)

Robinson, J. M. (Ed.). (1968). *An introduction to early Greek philosophy.* Boston: Houghton Mifflin.

Salmon, W. C. (Ed.). (2001). *Zeno's paradoxes.* Indianapolis, IN: Hackett. (Reprint of 1970 edition published by Bobbs-Merrill)

ZODIAC

The zodiac denotes a cycle of 12 zones in a belt along the ecliptic, an apparent path on which the sun travels each year through a series of 12 astrological constellations. The path extends 9° on either side of the ecliptic that encompasses the paths of all planets of the solar system, except Pluto. Each astrological constellation is an arrangement or configuration of stars that make up the astrological signs occupying 1/12 or 30° of the great circle. These planetary constellations were first observed and defined by ancient scholars who determined the dates of each zodiacal sign based on the time in which the sun was visible in its corresponding constellation. This is commonly referred to as a sun sign.

The signs and their corresponding dates include Aries, the Ram (March 21–April 20); Taurus, the Bull (April 21–May 21), Gemini, the Twins (May 22–June 21), Cancer, the Crab (June 22–July 22), Leo, the Lion (July 23–August 23), Virgo, the Virgin (August 24–September 23), Libra, the Scales (September 24–October 23), Scorpio, the Scorpion (October 24–November 22), Sagittarius, the Archer (November 23–December 21), Capricorn, the Goat (December 22–January 20), Aquarius, the Water Bearer (January 21–February 19), and Pisces, the Fish (February 20–March 20).

The ancient Mesopotamians were the first to arrange the constellations into an astronomical map according to zodiacal divisions. Developed around 450 BCE, this arrangement is a numerical scheme or system that divides the ecliptic into 12 equal regions by astrological signs. Modern scholars also note that Babylonian cuneiform tablets with ancient zodiacal signs are dated back to 412 BCE. Some Greek sources also show that the ecliptic was discovered in the late 5th century BCE. The ancient science of astrology, or the reading of the constellations and predicting the effect such movement of celestial bodies would have on earthly affairs, quickly spread in popularity from Mesopotamia to the Arabic world and into India, Europe, and the Orient.

Many ancient societies believed that the first day of the year was the vernal equinox or first day of spring, which astronomers identify as March 20 or 21 in the northern hemisphere. This also marked the first day of the zodiacal calendar. People have long recognized that the sun passes through a given constellation each month, thus explaining the 12 zodiacal signs and their correspondence to the 12 months of the year. At birth, one is assigned a sign of the zodiac, based on the original "tropical zodiac" arrangement of constellations and the path of the sun as determined by the ancients. In astrology, the configuration of the stars at the time of birth determines one's fate in life.

By reading the zodiac, ancient astrologers would interpret daily occurrences and predict future events; astrology was thus the science of the ancients. Astrologers have made many predictions, prophesized the coming of great kings and the fall of great leaders. They foretold pandemics, plagues, and natural disasters and sometimes predicted peace and prosperity. Modern skeptics have observed that most of the astrologers' predictions have fallen short of fulfillment. One of the most prominent criticisms of the zodiacal system relates to the phenomenon called the "precession of the equinoxes." *Precession* refers to the earth's movement, rotation, and revolution over time. The earth's axis swings around in a circle in space, completing a circle about once every 26,000 years, while the sun, moon, and other celestial bodies orbit in the same band of sky. With the passage of time, the earth's wobbling orbit causes it to shift and to point to different parts of the sky. Henceforth, even the lengths of each season of the year vary and are adjusted through the usage of adding a calendar day; a year in which a calendar day is added is called a "leap year." Astrologers do not account for this precession of the equinoxes, even though it has disrupted the location of the zodiacal signs by roughly 3 calendar weeks.

The 12 astrological signs no longer relate to the astronomical constellations in which the sun actually appears. Modern astrologers continue to follow the traditional "tropical zodiac" dates, which follow the vernal equinox observed by the ancient astrologers, so the tropical zodiac now relates more to the time of year than to the relative position of the sun to the constellations. Most modern astrologers ignore the actual positions and relativity of the sun and celestial bodies. A small number of astrologers use a sidereal zodiac, which makes adjustments for the 3-week constellation shift. An Aries in sidereal zodiac is born between April 13 and May 13, whereas in the traditional zodiac the birth occurs between March 21 and April 20.

Debra Lucas

See also Calendar, Astronomical; Equinoxes; Leap Years; Mythology; Prophecy; Seasons, Change of

Further Readings

Bobrick, B. (2005). *The fated sky: Astrology in history*. New York: Simon & Schuster.

Lewis, J. (2003). *The astrology book: The encyclopedia of heavenly bodies*. Canton, MI: Visible Ink Press.

Snodgrass, M. (1997). *Signs of the zodiac: A reference guide to historical, mythological, and cultural associations*. Westport, CT: Greenwood Press.

Zoroaster

Zoroaster (Zarathustra) was a prophet and religious figure in the ancient Persian territory now known as Iran. The exact dates of his life are widely debated among scholars. He is said to have lived anywhere between 1800 and 600 BCE. He founded Zoroastrianism, which was practiced widely in the Persian Empire and is still practiced today in the Parsi community of India. The major text of this religion is the *Avestas,* which consists of small groups of hymns or poems. The *Gathas* are said to be the oldest and most important of these groups, because they are thought to be written by Zoroaster himself. The basic teachings of these texts are that there is one Supreme Being and a cosmic struggle between good and evil spirits. He is considered to be the earliest philosopher to discuss individual morals and the basic principles of right and wrong. If Zoroaster truly lived in 1200 BCE or earlier, then he is the founder of the first religion based on revealed scripture.

What is known about the life of Zoroaster comes from a collection of historical documents, including the *Gathas*. Pliny the Younger writes of him 9 times in his *Natural History.* He was married 3 times and had three sons and three daughters. He started his ministry at the age of 30. The first converts to his religion were his wife, his children, and one of his cousins. He converted the King Vishtaspa, who helped to spread his religion throughout the Persian Empire. He died at the age of 77 fighting in a holy war.

By the age of 40, Zoroaster had seven revelations, each one devoted to one of the seven attributes of the Godhead; these attributes are God the Eternal Light, the Good Mind, Righteousness, Dominion, Piety, Well-Being, and Immortality. He believed that the Supreme Being was a spirit and could not be represented in an image. These are the cornerstones of his faith. Zoroaster believed that there was a constant struggle between good and evil. He preached that humans were free to choose between right and wrong and that these decisions would affect their afterlife. In his teachings, people are seen as weak against temptation, but strong virtue makes it possible to overcome evil. Evil is said to be a delusion and an unawareness of the existence of good. Atheism is considered a great sin against God because it influences others away from the truth of God's goodness. In the *Gathas,* Zoroaster identifies good and bad actions primarily on their consequences for humanity in general. In doing so, he defined a code of ethics in writing for the first time.

Zoroastrianism long predates Judaism, Christianity, and Islam, and the influences are clear in the similarities. Each of these religions speaks of a Creation in 6 days, humans driven from paradise, immortality of the soul, an omnipotent god, and a great flood. Some scholars believe that the Jewish Pharisees come from the word *Parsi* and that this sect was influenced by Zoroaster's followers in ancient Babylon. Zoroastrianism was the religion of the Magi, mentioned in the New Testament as having visited the baby Jesus in Bethlehem.

Jessica M. Masciello

See also Evil and Time; Nietzsche, Friedrich; Zurvan

Further Readings

Dawson, M. M. (1931). *The ethical religion of Zoroaster. An account of what Zoroaster taught . . . accompanied by the essentials of his religion.* New York: Macmillan.

Monna, M. C. (1978). *The Gathas of Zarathustra. A reconstruction of the text.* Amsterdam: Rodopi.

Zurvan

During the past 2,600 years, the Indo-Iranian religious traditions have diverged along a number of different paths. In various times and places—and in a number of languages—several major systems of mythology and theology emerged, though similar concepts and the use of a common pool of divine names reflect the historical connections between these traditions. *Zurvanism,* an offshoot (or heresy) of Zoroastrianism that focuses on the principal deity Zurvan (sometimes spelled Zervan), represents one interesting lineage of this religious family. In the Zurvanite worldview, Zurvan was the god of fate and boundless time, the hypostasis of time itself. As a result, this tradition has special interest in cosmogony, eschatology, and predestination.

The exact origin and chronological development of Zurvanism remains uncertain and is still the subject of considerable debate (e.g., the views of religious historian Robert Charles Zaehner). Some scholars explain this emphasis on Zurvan by pointing to external influences on Zoroastrianism, from Babylonian astrology or Greek philosophy, for example. Zurvanism cannot be associated with a particular temple, ritual, priesthood, or image. Few ancient texts discuss this tradition in a cogent or consistent manner, and many of the references to Zurvanite beliefs come from Christian, anti-Zoroastrian sources. Although its roots go back to Zoroastrian thought of Achaemenian times (by at least the 5th century BCE), the Zurvanite system rose to prominence only under the Sassanid rulers (224–651 CE). By that time, it seems that a circle of devotees adopted a monistic view and accepted Zurvan as the supreme deity and creator—in reaction to the more dualistic outlook of Zoroastrianism (as seen, e.g., in the cosmic conflict between Ahura Mazda and Angra Mainyu). Though interest in Zurvan declined in later medieval Zoroastrian sources, Zurvanite concepts influenced Mithraism, Manichaeism, and Mandaeism.

References to Zurvan in early Avestan and Pahlavi sources identify this god as uncreated and eternal. According to one medieval version of the Zurvanite cosmogonic myth, the creation required 10,000 years. After the first millennium, twins were born to Zurvan—Ahriman (Angra Mainyu) and Ohrmazd (Ahura Mazda), the cosmic adversaries of Zoroastrianism. Zurvan allowed the former to rule for 9,000 years, after which Ohrmazd assumed control. Meanwhile, these two spirits created the world as a battleground between good and evil, though Zurvan had predetermined history's ultimate outcome.

In the Zurvanite perspective, Zurvan was the lord of both limitless time (eternity) and the time of long dominion (finite time). Devotees held that Zurvan presided over history, from creation to the eschaton, but they also maintained that the great god existed prior to the beginning and after the termination of historical time.

Gerald L. Mattingly

See also Cosmogony; Eschatology; Eternity; Evil and Time; Predestination; Zoroaster

Further Readings

Boyce, M. (2001). *Zoroastrians: Their religious beliefs and practices* (2nd ed.). London: Routledge.
Choksy, J. K. (2005). Zurvanism. In L. Jones (Ed.), *Encyclopedia of religion* (2nd ed., Vol. 14, pp. 10011–10015). New York: Thomson Gale.
Duchesne-Guillemin, J. (1969). The religion of Ancient Iran. In C. J. Bleeker & G. Widengren (Eds.), *Historia religionum: Handbook for the history of religions* (Vol. 1). Leiden, The Netherlands: Brill.
Shaked, S. (1994). *Dualism in transformation: Varieties of religion in Sasanian Iran*. London: University of London, School of Oriental and African Studies.
Zaehner, R. C. (1972). *Zurvan: A Zoroastrian dilemma*. Cheshire, CT: Biblo & Tannen.

Index

Entry titles and their page numbers are in **bold**.