SEPUP
Issue-Oriented Science

ISSUES and Earth Science

SECOND EDITION

SEPUP
Issue-Oriented Science

ISSUES and Earth Science

SECOND EDITION

THE LAWRENCE HALL OF SCIENCE
UNIVERSITY OF CALIFORNIA, BERKELEY

LAB-AIDS
Experiencing Science

This book is part of SEPUP's middle school science course sequence:

ISSUES AND EARTH SCIENCE, 2nd Edition

Studying Soil Scientifically
Rocks and Minerals
Erosion and Deposition
Plate Tectonics
Weather and Atmosphere
The Earth in Space
Exploring Space

ISSUES AND LIFE SCIENCE, 2nd Edition

Experimental Design: Studying People Scientifically
Body Works
Cell Biology and Disease
Genetics
Ecology
Evolution
Bioengineering

ISSUES AND PHYSICAL SCIENCE, 2nd Edition

Studying Materials Scientifically
The Chemistry of Materials
Water
Energy
Force and Motion
Waves

Additional SEPUP instructional materials include:
SEPUP Modules: Grades 7–12
Science and Sustainability: Course for Grades 9–12
Science and Global Issues: Biology: Course for High School Biology

This material is based upon work supported by the National Science Foundation under Grant No. 0099265. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

For photo and illustration credits, see pages I-17 through I-23, which constitute an extension of this copyright page.

The preferred citation format for this book is SEPUP. (2012). *Issues and Earth Science*. Lawrence Hall of Science, University of California at Berkeley. Published by Lab-Aids®, Inc., Ronkonkoma, NY

Second Edition

R3 4 5 6 7 8 9 16 15 14 13

ISBN+13: 978-1-60301-508-0
ISBN: 1-60301-508-6

SEPUP
Lawrence Hall of Science
University of California at Berkeley
Berkeley CA 94720-5200

e-mail: sepup@berkeley.edu
Website: www.sepuplhs.org

17 Colt Court
Ronkonkoma NY 11779
Website: www.lab-aids.com

A Letter to *Issues and Earth Science* Students

As you examine the activities in this book, you may wonder, “Why does this book look so different from other science books I’ve seen?” The reason is simple: it is a different kind of science program, and only some of what you will learn can be seen by leafing through this book!

Issues and Earth Science uses several kinds of activities to teach science. For example, you will observe and test the properties of soil, rocks, and minerals. You will examine a model of the way water moves earth materials to change the surface of the land. You will conduct a computer simulation to investigate the causes of earthquakes and volcanoes. You will also analyze data about Earth and the solar system. A combination of experiments, readings, models, debates, role plays, and projects will help you uncover the nature of science and the relevance of science to your interests.

You will find that important scientific ideas come up again and again in different activities throughout the book. You will be expected to do more than just memorize these concepts: you will be asked to explain and apply them. In particular, you will improve your decision-making skills by using evidence to weigh outcomes and to decide what you think should be done about the scientific issues facing our society.

How do we know that this is a good way for you to learn? In general, research on science education supports it. In particular, the activities in this book were tested by hundreds of students and their teachers, and then modified on the basis of their feedback. In a sense, this entire book is the result of an investigation: we had people test our ideas, we interpreted the results, and we then revised our ideas! We believe the result will show you that learning more about science is important, enjoyable, and relevant to your life.

SEPUP Staff

ISSUES & EARTH SCIENCE PROJECT

Director (2003–2012): Barbara Nagle

Director (2001–2002): Herbert D. Thier

Coordinator: Janet Bellantoni

AUTHORS

Unit A: Janet Bellantoni, Manisha Hariani

Unit B: Manisha Hariani, Kevin Cuff, Daniel Seaver, Janet Bellantoni

Unit C: Daniel Seaver, Barbara Nagle, Janet Bellantoni

Unit D: Manisha Hariani, Daniel Seaver, Janet Bellantoni, Barbara Nagle

Unit E: Manisha Hariani, Daniel Seaver, Sara Wilmes

Unit F: Barbara Nagle, Janet Bellantoni, Daniel Seaver

Unit G: Janet Bellantoni, Daniel Seaver, Barbara Nagle

OTHER CONTRIBUTORS

Lee Trampleasure, Kathaleen Burke, Ryan Chinn, Asher Davison, Gayle Gutierrez, Kate Haber, Laura Kretschmar, Donna Markey, Linda Mead, Mike Reeske, Suzanne Scott

CONTENT AND SCIENTIFIC REVIEW

Ian Carmichael, Professor of Earth and Planetary Science, University of California at Berkeley, Berkeley, California *(Studying Soils Scientifically, Rocks and Minerals, Erosion and Deposition, Plate Tectonics)*

Isabel Hawkins, Research Astronomer, Space Sciences Laboratory, University of California at Berkeley, Berkeley, California *(Exploring the Solar System)*

Bill Martin, Chief Meteorologist, KTVU, Oakland, California *(Weather and Atmosphere)*

William Prothero, Professor of Geological Sciences, University of California at Santa Barbara, Santa Barbara, California *(Complete course)*

Greg Schultz, Education/Outreach Scientist, Space Sciences Laboratory, University of California at Berkeley, Berkeley, California *(The Earth in Space, Exploring the Solar System)*

Doris Sloan, Adjunct Professor of Earth and Planetary Science, University of California at Berkeley, Berkeley, California *(Studying Soils Scientifically, Rocks and Minerals, Erosion and Deposition)*

Zan Stine, Department of Earth and Planetary Science, University of California at Berkeley, Berkeley, California *(Weather and Atmosphere)*

PRODUCTION

Coordination, Design, Photo Research, Composition: Seventeenth Street Studios

Editing: Trish Beall

Administrative Assistance: Roberta Smith

Field Test Centers

The classroom is SEPUP's laboratory for development. We are extremely appreciative of the following center directors and teachers who taught the program during the 2003–04 and 2004–05 school years. These teachers and their students contributed significantly to improving the first edition of the course. Since then, *Issues and Earth Science* has been used in thousands of classrooms across the United States. This second edition is based on what we have learned from teachers and students in those classrooms. It also includes new data and information, so the issues included in the course remain fresh and up-to-date.

ATLANTA, GEORGIA

Geeta Verma, *Center Director*

Felecia Bell, Wanda Ellis, Lillian Harris, Patricia Lewis, Millicent McCaskill, Demetra McCoy, Melanie Robinson, Nicole Satchell

BUFFALO, NEW YORK

Kathaleen Burke, *Center Director*

Delores Anderson, Dianne Johnson, Deborah Kimble, Steven Koch, Corean Lofton

DALY CITY, CALIFORNIA

Andrew Coblentz, *Center Director*

Andrew Coblentz, Ken Klein, Catherine Macay, Benjamin Moser, Lucy Schoening

GREELEY-EVANS, COLORADO

Ray Tschillard, *Center Director*

Joann Angus, Djems Domerson, Nick Durham, Christina Kauffman, Jason McLaughlin, Gemarie Romero, Ruby Sabzevari, Mark Wiegers

LEMON GROVE, CALIFORNIA

Samantha Swann, *Center Director*

Jennifer Bates, Jim Haynes, Linda Schultz, Patti Sherillo, John Tessier

PINELLAS COUNTY, FLORIDA

Dr. Chin-Tang Liu and Nancy Stitt, *Center Directors*

Shirley Green, Lisa Mackey, Jennifer Sinphay, Nancy Stitt

WAKE COUNTY, NORTH CAROLINA

Michael Tally, Kim Gervase, and Catherine Norris, *Center Directors*

James Akins, Jon Corcoran, Karen Farnham, Jennifer Koch, Carla Steger

WINSTON-SALEM/FORSYTH COUNTY, NORTH CAROLINA

Jim Bott, *Center Director*

Amelie Bartolino, Ed Beiles, Mary Kay Bell, John Cardarelli, Megan Clayton, Jennifer Sasser, Barbara Strange, Jane Trace

VISTA, CALIFORNIA

Donna Markey, *Center Director*

Amy Alexander, Melissa Boeche, Nicole Buchanan, Dorothy Jones, Stacy Robe, Zamaria Rocio

Contents

UNIT A Studying Soil Scientifically

UNIT B Rocks and Minerals

UNIT C Erosion and Deposition

UNIT D Plate Tectonics

UNIT E Weather and Atmosphere

UNIT F The Earth in Space

UNIT G Exploring Space

Studying Soil Scientifically

A

Studying Soil Scientifically

"Why do you have so many different bags of dirt?" Chris asked his mother. They had just moved into a new house, and he was helping her put some of their old plants into new pots.

"I need to use different soils for different plants," she said. "Sometimes, I even need to mix together soil from different bags."

"But why don't you just dig up some dirt from the backyard? There's plenty back there!" said Chris.

"Each plant has its own needs. Look at the difference between the orchids and the cactus plants in the pots over there, Chris," she said. "Whether they grow inside the house or outside in a garden or a field, all plants need different amounts of light, different amounts of water, and even different soils."

"Different kinds of soil?" asked Chris. "Isn't all dirt the same?"

"Take a look in these bags," answered his mother. "What do you observe?"

• • •

Why do plants need soil to grow? What are the differences among soils from different places?

In this unit, you will learn how scientists describe and study soil. You will learn what is found in soil and how it helps crops grow.

1 Into the Field

Every day, people are surrounded by many objects and events. Scientists often spend time observing objects and events carefully. In this activity, you will observe objects with a scientist's eye.

CHALLENGE

How completely can you describe a group of objects?

MATERIALS

For each group of four students

1 **set of objects**

1 **set of Object Labels**

For each student

1 **Student Sheet 1.1, "Recording Observations"**

PROCEDURE

1. Study the set of objects for one minute.
2. After the objects have been removed, write down the names of as many objects as you can remember in Row A of Student Sheet 1.1, "Recording Observations." Describe them as completely as you can.
3. Discuss your list with the rest of your group. In Row B of Student Sheet 1.1, create a single list that names (or describes) each object your group observed.
4. Have one person from your group get a set of Object Labels from your teacher.
5. With your group, place each label next to the correct object. Compare the labeled objects with your group's observations in Row B.
6. In the last column of Student Sheet 1.1, record the number of objects that you and your group completely described.

   Hint: If someone else can identify an object based on your description, it is completely described.
7. In Row C, add the names of any objects that your group did not identify.
8. In Row C, under "Total Number of Objects," record the number of objects that your group missed.

ANALYSIS

1. Read your object descriptions again. Select one that you think could be more complete and rewrite it, giving a more complete description of the object.
2. Modern scientists often work together in groups. What are the possible benefits of this?
3. When is it important for scientists to describe objects completely?
4. You are an explorer who has discovered a mountain, which is then named after you. You tell a friend how to get to your mountain. Should you tell your friend the name of the mountain, describe how it looks, or both? Explain.

5. Many of the objects you observed are used for measurement. The system of measurement most commonly used in the United States is known as the English system. In most other countries, the metric system is more commonly used.

   Look at the table below.

   a. What units are familiar to you?

   b. Which of the units below were found on the objects you observed in this activity?

   c. Choose three of the units listed below and give an example of something commonly measured with each one.

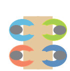
Units of Measurement

	Common English Units	Common Metric Units
Length	inches, feet, yards, miles	centimeters, meters, kilometers
Mass	ounces, pounds	grams, kilograms
Volume	cups, quarts, gallons	milliliters, liters

Key to Analysis Icons

 = Answer the question by yourself.

 = Discuss with your partner.

 = Discuss with your group.

 = Discuss the question in class.

2 The Garden Problem

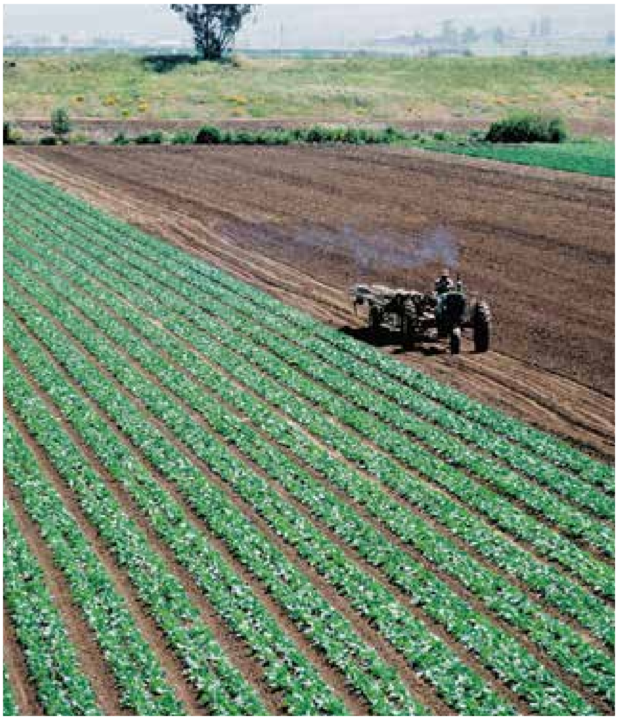
It was the beginning of the school year. Chris was nervous about starting at a new school. His first class turned out to be science. His science teacher, Ms. Clayson, told the class that they would begin the year by trying to solve a problem with the school garden. Most of the garden plants were dying, even though they had been planted recently.

CHALLENGE

Why won't plants grow in the school garden?

MATERIALS

For each student
Student Sheet 2.1, "KWL: The Garden Problem"
Student Sheet 2.2, "Evidence or Opinion?"



Gardeners and farmers often have to solve similar problems. About 20% of the land in the United States is used to grow crops, such as the fruits and vegetables shown above.

READING

Use Student Sheet 2.1, "KWL: Analyzing the Garden Problem" to guide you as you complete the following reading.

THE SCHOOL GARDEN

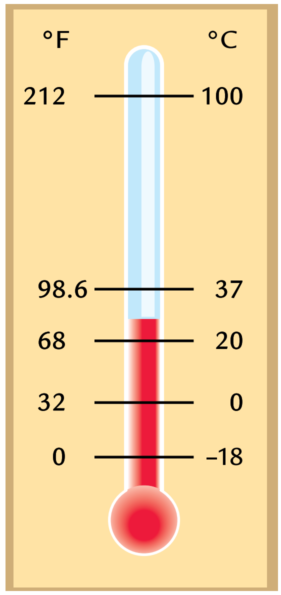
Chris learned from his classmates that his new school was built 10 years ago on old farmland where cotton grew. When the farmer decided to sell it and move away, the city bought the land and built the school. Two years ago the school started a small garden, but most of the plants had either died or were dying. Ms. Clayson told Chris's class that the principal agreed to let the class study the school garden and make recommendations for improvements. If their recommendations were accepted, the students would be allowed to plant and care for a vegetable and flower garden. They could observe the plants growing and eat the vegetables that grew. Before the class could plant anything new, however, they had to investigate why the plants in the last garden grew so poorly.

Ms. Clayson reviewed the steps they would follow.

- First they would research the garden by studying the current conditions.
- Next they would form hypotheses, providing possible explanations for the problems in the garden.
- They would test their hypotheses by conducting investigations.
- They would then analyze the data they collected and draw conclusions.
- Finally, based on their conclusions, they would propose a garden plan for the principal to review.

Every day for a week, Chris's class went into the garden to make observations about the current conditions. The first day everyone picked up a handful of soil. It felt dry and sandy. On one side of the school there was a yard as dry and bare as the school garden. On the other side of the school there was a yard with healthy green plants growing in it. Chris saw someone watering those plants one day and noticed that the soil was a different color than the soil in the school garden. He wondered if the soil color and amount of water the garden received could affect the garden's ability to grow plants.

Each day that week they observed that the weather was sunny and warm. They measured the temperature every day at noon and found that it



COMPARING FAHRENHEIT AND CELSIUS TEMPERATURES

averaged 21° Celsius (°C), or 70° Fahrenheit (°F). You can see the data that they collected in the table "Conditions in the School Garden," below.

The following week, Ms. Clayson reviewed the things that most plants need to grow: water, air, sunlight, and soil. She said that most plants need all four of these things. If even one were missing, it is likely that the plant can't make food for itself and survive. "Air can't be the problem," thought Chris. "The plants in the neighbor's garden look healthy, and they're really close by." He noticed the sun was shining on both the school garden and on the neighbor's yard, so it couldn't be the amount of sunlight. He wondered what was preventing the plants from growing.

He remembered the soil in the school garden was a different color than the soil on the other side of the school. He wondered what the soils were made of and how that might relate to the garden's ability to grow. One day, Chris and his friend talked to their parents about the class project. "That old cotton farm used up everything in the soil," said Chris's mother. "There are no nutrients left in the soil for plants to grow in the garden."

His friend's mother disagreed. "There was plenty of cotton growing there when it was a farm. The soil must be good. It must be something else, like the amount of water the land gets."

Chris thought a garden would make his new school a better place, and, besides, it might be fun to eat food that he had helped grow. He decided that he wanted to help make the garden productive.

Conditions in the School Garden

	Temperature (°C)	Sunlight
Monday	20	mostly sunny
Tuesday	19	partly cloudy
Wednesday	21	sunny
Thursday	22	sunny
Friday	23	bright sun
Average	21	

ANALYSIS

1. The reading gave evidence and opinions about the garden.

   a. Complete Student Sheet 2.2, "Evidence or Opinion?"

   b. What is the difference between scientific evidence and an opinion?

2. Your aunt tells you that she gets cold when the temperature falls below 60 degrees. Does she mean degrees Celsius or degrees Fahrenheit? How do you know?

3. Why do you think plants won't grow in the garden at Chris's school? Support your ideas with evidence from the reading.

3 Observing Soil

After talking about it, Chris's class decided that the garden did not get enough water. They planted several flower and vegetable seedlings. After watering the plants carefully for a month, the garden still looked bare. Now the healthy seedlings they had put in at the beginning of the month were dead. Ms. Clayson suggested that the students take a closer look at the soil in the garden.*

CHALLENGE

What does soil look like?

In commercial farming, irrigation systems are used to water crops over a large area.

MATERIALS

For each pair of students

1 sample of Soil A
1 sample of Soil B
1 magnifying lens
1 white plastic spoon
2 pieces of white paper
2 index cards

PROCEDURE

A level spoonful

1. Use the spoon to put a level spoonful of Soil A on one piece of white paper. Put a level spoonful of Soil B on the other piece.

   Note: Do NOT label the soils A and B.

2. Work with your partner to observe the soils with the magnifying lens.

3. As you examine the soil closely, move the spoon through the soil.

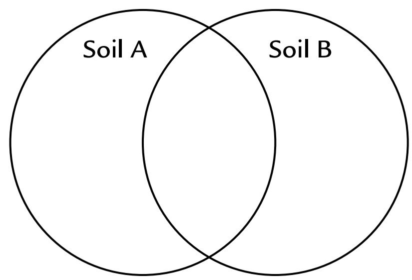
4. Write a description of Soil A on one index card. Write a description of Soil B on the other index card.

   Hint: Make your descriptions complete enough so that someone else could use them to identify the soils.

5. Exchange descriptions of the soils with another pair of students. Read the descriptions and place them next to the soils they identify. Check each other's work to see if you were able to correctly match the soil samples to the descriptions.

ANALYSIS

1. What words were helpful in describing and identifying the soils?
2. Were you able to identify the soils based on the description from the other pair of students? Explain why or why not.
3. In your science notebook, create a larger version of the diagram shown below (called a Venn diagram). Record the characteristics of each soil in the circle with that label. In the space that overlaps, record features that are common to both soils.



4. Use your observations and your own words to answer the question: "What is soil?"

EXTENSION

Gather a sample of local soil to observe. Compare the local soil with Soils A and B by using it in the Procedure with the other two soils.

4 Soil Columns

Soil found in one place can be very different from soil found somewhere else. This can be true even if the two places are quite close to each other, because the soils may have different ingredients. The specific ingredients in a soil are referred to as its **composition** (com-po-ZI-shun). One way to learn more about a soil's composition is to mix it with water in order to separate the materials in the soil.

CHALLENGE

How does the composition of soils vary?

MATERIALS

For each group of four students

- 1 sample of Soil A
- 1 sample of Soil B
- 1 cup of water
- 1 SEPUP tray
- 2 large clear plastic tubes with caps
- 1 magnifying lens
- 1 30-mL graduated cup
- 1 50-mL graduated cylinder
- 1 plastic spoon
- 1 ruler

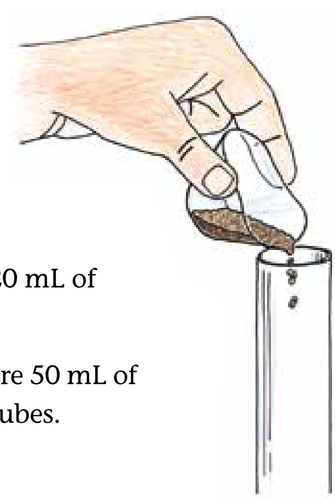
For each student

- 1 Student Sheet 4.1, "Soil Column Observations"

PROCEDURE

1. Place one tube in Cup A of the SEPUP tray. Place another tube in Cup B.
2. Use the 30-mL graduated cup to measure 20 mL of Soil A. Pour this soil into the tube in Cup A.

   Hint: Squeeze the cup slightly, as shown at right, to make pouring the soil into the cylinder a little easier.



3. Use the 30-mL graduated cup to measure 20 mL of Soil B. Pour this soil into the tube in Cup B.
4. Use the 50-mL graduated cylinder to measure 50 mL of water. Add 50 mL water to each of the two tubes.
5. Cap each tube.
6. Place your thumb over the cap and gently shake each tube 10 times.
7. Stand the tubes back in the correct cups of the SEPUP tray and observe the changes that take place inside each tube.

8. On Student Sheet 4.1, "Soil Column Observations," record your observations for 5 minutes or until you observe no more changes taking place inside the tubes.

   Hint: Be sure to lift each soil tube from the SEPUP tray to see the entire tube while making your observations.

9. Use your ruler to measure the height of each soil section. Record your height measurements on Student Sheet 4.1.

10. Sketch and describe the appearance of the contents of each tube on Student Sheet 4.1.

ANALYSIS

1. How were the sections in Tube A similar to or different from the sections in Tube B? Support your answer with your observations.

2. Were the particles at the bottom of Tube A larger, smaller, or the same size as the particles at the top?

3. Is the composition of Soil A the same as that of Soil B? Support your answer with evidence from this activity.

EXTENSION

Use Student Sheet 4.1, "Soil Column Observations," to estimate the percentage of each layer of material in the overall soil composition. Explain why this calculation is only an estimate.

5 Soil Composition

Chris knew that his class had watered the plants in the school garden and that they hadn't survived. He wondered if previous classes had watered their plants. Students in his class found a science notebook showing the watering schedule of two classes from the year before. They had watered the garden regularly, but their plants hadn't grown either. Chris thought there was enough air and sunlight in the garden. He decided it was time to find out more about soil.

CHALLENGE

What is the composition of soil?

READING

When reading, answer the Stopping to Think questions in your mind. They can help you find out whether you understand the main ideas.

Weathered Rocks in Soil

All soil may seem alike, but soils in different places are different. One thing that all soils have in common is that they are mixtures of many things. Tiny pieces of rock are found in most soils. How do rocks become so tiny? Over time, rocks crack, crumble, and are broken apart by water and wind. Drops of water on a rock may repeatedly freeze and melt, causing the rock to crack. Water may react with some of the chemicals in a rock and cause part of the rock to wear away. Rocks sometimes fall from higher places, breaking as they fall and roll. All of this wearing down of rocks by natural forces is called **weathering.**

STOPPING TO THINK 1

The paragraph above describes three examples of rock weathering. Think of another example. Need help? Consider the different ways that water moves over the surface of the earth.

Scientists have names for the different-sized rocks found in soil. **Sand** is the word used for the largest pieces of rock in soil. Compared to rocks, sand is still very small, with the largest piece being less than 1/5 of a centimeter! Individual pieces of sand, or *grains*, are easily visible, but they are not as big as small pebbles.

Four different kinds of sand show a variety of grain sizes and compositions.

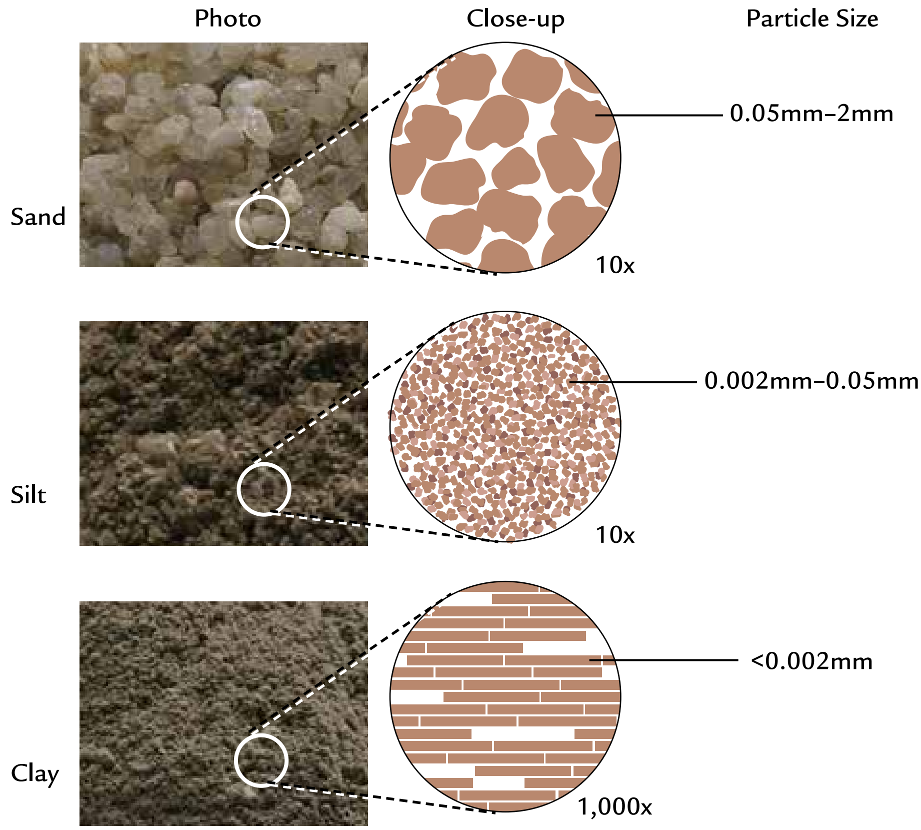
Pieces of rock that are smaller than sand are called **silt** and **clay.** Pieces of clay are so small they cannot be seen without a microscope. Pieces of silt are smaller than sand, but bigger than clay. You can compare the relative sizes of these rock pieces in Figure 1, "Comparing Rock Pieces" on the next page. Together, sand, silt, and clay are the main components of soil.

Soil from different places contains different amounts of sand, silt, and clay. For example, the soil from a desert may have a lot of sand in it. Soil scientists can often tell which part of the world a soil sample is from, based on the amount and type of sand, silt, and clay in the sample.

STOPPING TO THINK 2

A student examines some soil. She notices a small rocky piece that measures 1 millimeter (mm) across. Is this particle likely to be a rock, sand, silt, or clay? How do you know? Use Figure 1 on the next page to help you decide.

FIGURE 1:
COMPARING
PARTICLE
SIZES IN SOIL



Organic Matter in Soil

Have you ever watched what happens to a very ripe piece of fruit that has been forgotten? It begins to change color, becomes soft, and starts to smell. It is **decomposing** (dee-kum-POZ-ing), or breaking down. If left outside on the ground, it will decay further until it is no longer recognizable as fruit.

Soil contains a lot of decomposed material. Fruit may fall to the ground and decompose to the point that it becomes part of the soil. The same thing happens to animal waste and to dead plants and animals that are not eaten by other animals. Decomposing plants and animals, including insects, leaves, and flowers, contribute to the **organic** (or-GAN-ik) **matter** in soil. The word "organic" refers to material from living organisms.

Bacteria and mold are decomposing these lemons.

As time passes, bacteria and other microorganisms help break down organic material into smaller and smaller particles that may look like dark brown clumps in the soil. Eventually, organic matter breaks down into basic chemicals. These chemicals, called **nutrients** (NEW-tree-unts), can dissolve in water and be absorbed by plant roots. The word *nutrient* comes from the Latin root *nutr-*, which means "to feed." Plants use nutrients produced from decomposing organic matter to grow. Organic matter is an important part of soil.

STOPPING TO THINK 3

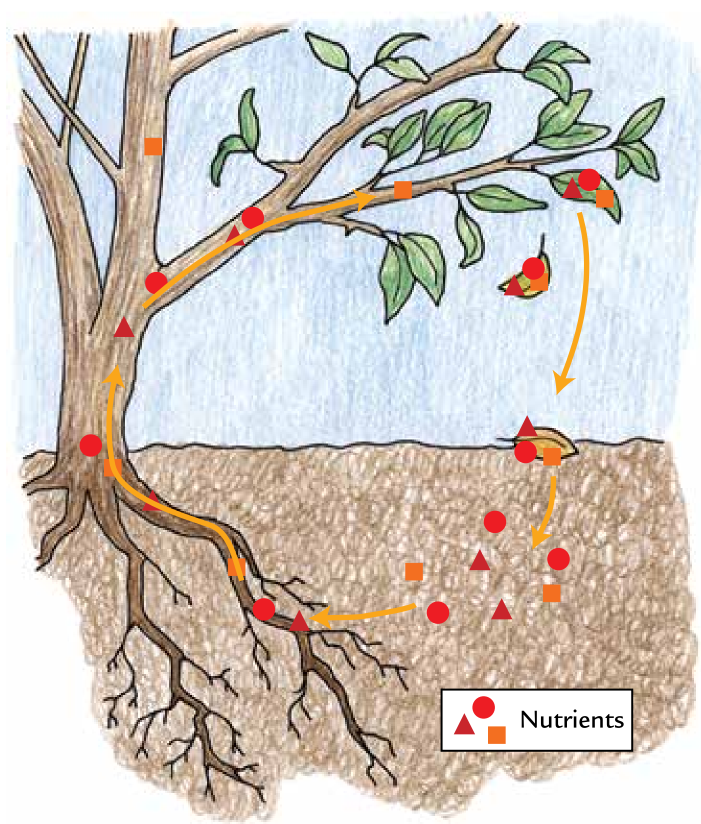
Why is it important for plants to grow in soil containing organic matter?

There can be different amounts of organic matter in the soil. In areas where many plants and animals live, grow, and die, there is more organic matter in the soil. Plants remove nutrients from the soil, but eventually they also give them back, as shown in Figure 2 below. When a plant dies, it may fall to the ground and decompose, adding to the organic matter (and the amount of nutrients) in the soil. This cycle of organisms living and dying helps enrich the soil with organic matter.

STOPPING TO THINK 4

How can a dead plant help another plant live?

FIGURE 2: THE CYCLE OF NUTRIENTS



Soil Layers

Topsoil is the soil in the uppermost layer of soil on the surface of the earth. It is the soil layer that you normally see, although it is only one of many layers. Each layer above bedrock has different characteristics. The different characteristics of each soil layer and bedrock are described below.

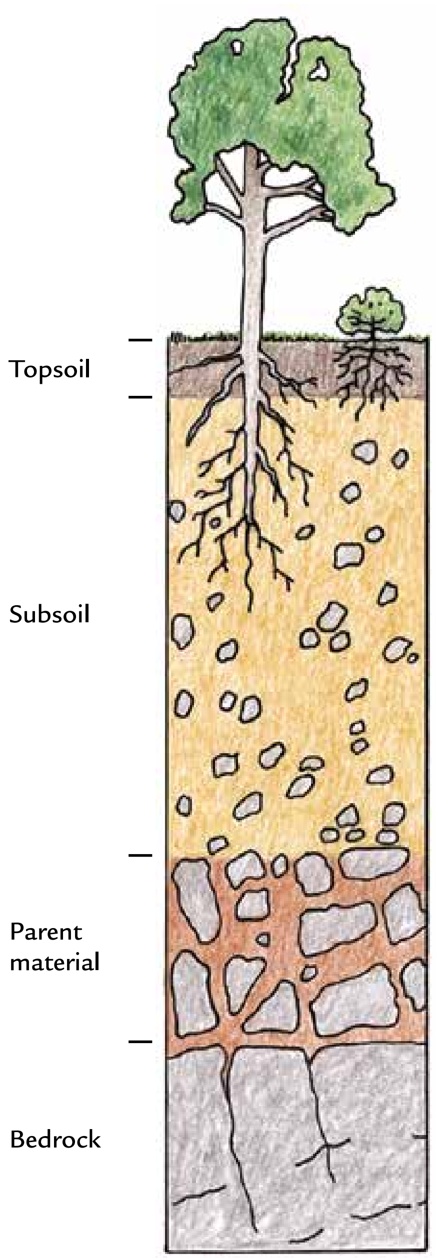


FIGURE 3:
CHARACTERISTICS OF SOIL LAYERS AND BEDROCK

TOPSOIL is a combination of rock, sand, silt, clay, organic matter, air, and water. Plants grow roots in this layer, which is rich with biological activity. Topsoil is about 20 centimeters deep, but it may be thinner or thicker depending on the location.

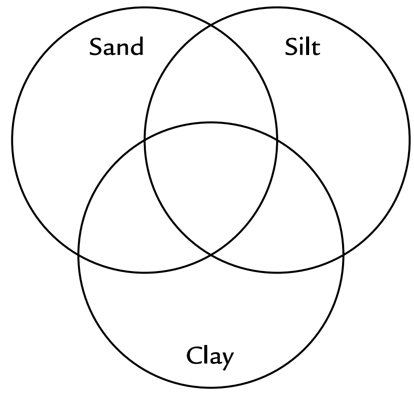
SUBSOIL contains some of the chemicals found in the topsoil as water drips from the soil above and washes these nutrients down. There is not much organic material in this layer.

PARENT MATERIAL is made up of slightly broken-up bedrock. Plant roots usually do not penetrate into this layer. Very little organic matter is found here.

BEDROCK is hard rock that lies beneath all the soil layers.

ANALYSIS

1. Create a larger version of the Venn diagram shown below. Record the characteristics of sand, silt, and clay in the circle with that label. In the spaces that overlap, record common features.



2. A dead leaf falls from a tree to the ground. If left undisturbed, what will happen to it?

3. Earthworms help organic matter decompose. In what soil layer do earthworms live? Explain your answer.

4. Look at your data on Student Sheet 4.1, "Soil Column Observations," from the last activity.

a. Compare your data with what you now know about soil. Label sections of the soil column with words that you learned in this activity. Hint: Every section will not get a label.

   b. Which soil layer(s) did Soils A and B come from?

   c. Which soil, A or B, do you think is a better soil for gardening? Support your answer with evidence.

5. Look at your answer to Analysis Question 4 of Activity 3, "Observing Soil."

   a. Revise your answer to the question: *What is soil?* Write as complete a description as you can.

   b. Explain how your definition has changed since you began this unit.

6. What could be wrong with the soil in the school garden? Make a list of your ideas.

EXTENSION

Observe the decomposition of a piece of fruit. Find an appropriate place on the ground outside to place an old banana, avocado, or apple. (Remember that decomposing fruit may attract insects or small animals that help in the decomposition process.) Mark the area as a science experiment. Make observations every day for a few weeks and record your findings in your science notebook.

6 Describing Soil Scientifically

The next day, Ms. Clayson brought two bags of soil to class. One of the bags contained soil from the school garden. She brought it in so that the class could find out what might be wrong. The other bag contained soil from another garden in which plants were growing well. Unfortunately, she forgot to label the bags, and she couldn't tell them apart! She asked the class to help her figure out which soil came from the school garden.

Like the students in Chris's class, you will try to identify each soil by closely examining some soil characteristics. These include color, texture, and consistence. **Color** of soil can vary from grayish to yellow to deep red brown to black. **Texture** (TEKS-chur) describes the size of the particles. Rubbing soil between your fingers tests the soil's texture. **Consistence** (con-SIS-tens) describes how easily the soil clumps can be broken apart.

CHALLENGE

How do scientists describe soil?

Scientists use a variety of tests to determine soil composition.

MATERIALS

For each pair of students

- **1 sample of Soil A**
- **1 sample of Soil B**
- **1 cup of water**
- **1 Soil Color Chart**
- **paper towels**

PROCEDURE

1. In your science notebook, make a table like the one below.

Table 1: Soil Observations

Soil Composition	Soil A	Soil B
Color		
Consistence		
Texture		

2. Compare the color of each soil with the Soil Color Chart. Record your observations in your data table.
3. Compare the consistence of the soils by trying to break apart a small clump of each soil. Record your observations in your data table.

   The soil consistence is

   loose if the soil breaks apart when held.

   friable if the soil breaks apart with a small amount of pressure from one finger.

   firm if the soil breaks apart with a lot of pressure between two fingers.

4. Compare the texture of each soil by wetting one finger and rubbing a little soil between your fingers. Record your observations in the data table.

The soil texture is

grainy if the soil is made up of large-sized pieces and feels gritty, like sand.

silky if the soil is made of medium-sized pieces and feels powdery, like silt.

sticky if the soil is made of small pieces and feels gummy, like wet clay.

ANALYSIS

1. Copy the lists of words shown below:

List 1	**List 2**	**List 3**
color	loose	rocks
brown	sticky	layers
red	consistence	organic matter
grayish	firm	cylinder
texture	friable	soil

a. In each list, look for a relationship among the words. Cross out the word or phrase that does not belong.

b. In each list, circle the word or phrase that includes the others.

c. Explain how the word or phrase you circled is related to the other words on the list.

2. **a.** Read the following descriptions of soils.

SCHOOL GARDEN IN PHOENIX, ARIZONA
This soil is light brown to grayish. The consistence is firm because it takes some pressure to break apart small clumps. Its texture is gritty and sandy. This soil is found all over the southwestern United States, particularly in Arizona, New Mexico, and parts of Texas.

GARDEN IN ORLANDO, FLORIDA
This soil is a light to medium brown color. The consistence is friable because it falls apart with only a little pressure. With the exception of the twig particles, this dirt feels silky to the touch. This soil is rare in the United States, but can be found near the marshes of central Florida.

b. In your science notebook, make a table like the one below.

Table 2: Composition of Soils

	School Garden in Phoenix, AZ	Garden in Orlando, FL
Color		
Consistence		
Texture		

3. Compare the descriptions of the soils from each garden to your observations of Soils A and B.

   a. Which soil is from the school garden in Phoenix, Arizona? Support your answer with evidence and data from this activity.

   b. Which soil is from the garden in Orlando, Florida? Support your answer with evidence and data from this activity.

4. The best soil for plants in the school garden is a dark, silky soil that is loose or friable. Which would be better for the school garden—Soil A or B? Explain.

7 Mapping Soils

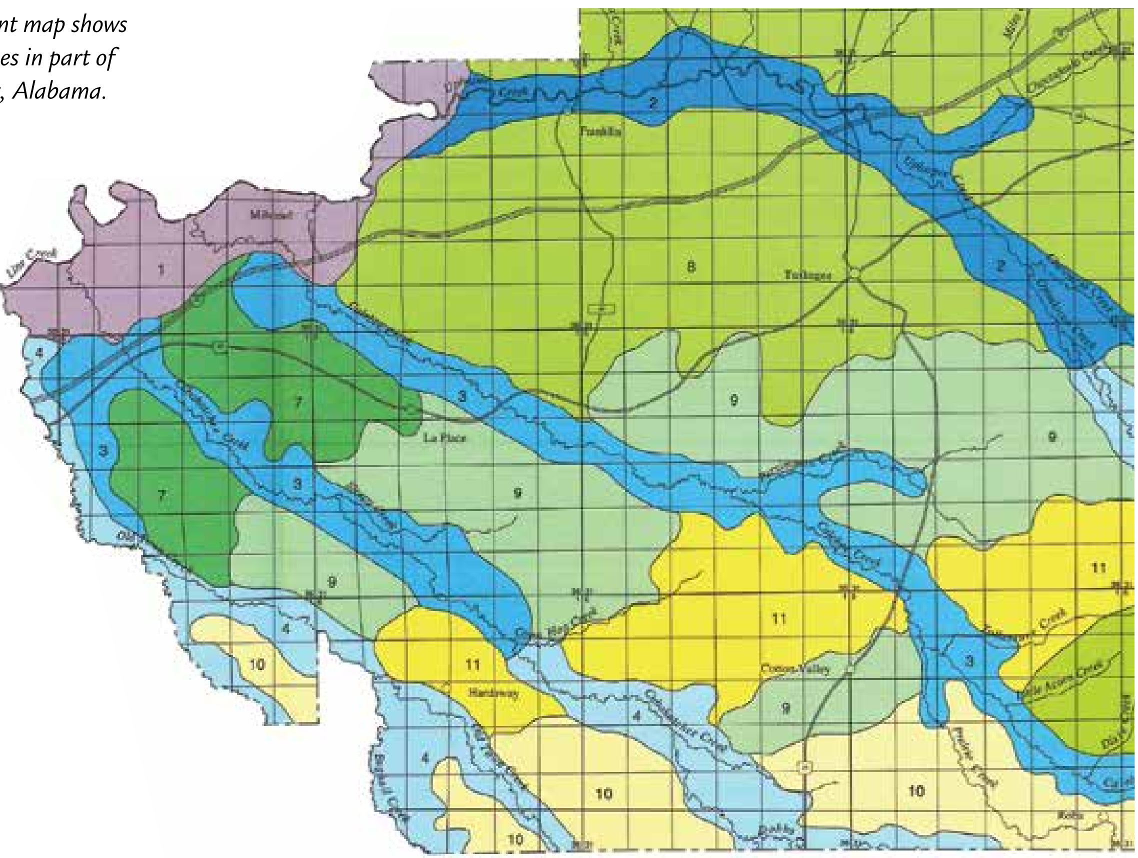
INVESTIGATION

When soil scientists investigate the composition of soil in an area, they collect samples from many different locations. They organize all of their data on a map that shows where different soil types can be found. Such maps help compare the soil from one location, like the soil from the school garden, with soil in other locations.

There are thousands of different soils in the world. Scientists organize them into 12 major categories. In this activity, the soils found in the United States are grouped into 4 broad categories.

CHALLENGE

How does the soil in the school garden compare to the soil in other parts of the United States?



This government map shows general soil types in part of Macon County, Alabama.

MATERIALS

For the class

2 sets of 16 Soil Data Cards

colored pencils (green, orange, brown, red)

For each student

1 Student Sheet 7.1, "Mapping U.S. Soils"

PROCEDURE

1. Work with your group to read the descriptions of the four major categories of soil on the next page.
2. Each person in your group will play the role of a scientist studying the soil from one area of the United States. Decide which person in your group will be the scientist who investigates soil from each of the following areas:
   - eastern United States
   - east-central United States
   - west-central United States
   - western United States
3. At the regional meeting, collect sample soil data by examining the Soil Data Cards provided by your teacher. Use colored pencils to fill in your region of the map on Student Sheet 7.1, "Mapping U.S. Soils." Use the Key on Student Sheet 7.1 which lists the color to use for each soil category.
4. Discuss the following questions about your region with other scientists from this region. Listen to and consider the ideas of others. If you disagree with others in your group, explain why you disagree.
   - What are some of the states in our region?
   - What is (or are) the most common soil type(s) in our region?
   - What shall we tell scientists from other regions about our findings?
5. Return to your original group and share the soil data that you collected. Use this data and colored pencils to fill in the map on Student Sheet 7.1.

MAJOR SOIL CATEGORIES

DESERT

Desert soils form in places that do not have a lot of rainfall and that have high temperatures all year long. The soils tend to be dry, sandy, and contain a limited number of plants. These soils are easily moved by wind and water. Desert soils are light in color and have a firm consistence and gritty texture.

GRASSLAND

Grassland soils form in areas that have both wet and dry seasons but less overall rain than areas with forest soil. The top layer is rich in nutrients because a large amount of plant matter dies and decomposes in the soil. Grassland is good for farming. These soils are reddish brown, with a loose consistence and silky texture.

FOREST

Forest soils form in areas that have hot and cold seasons and receive enough rain year round to support a lot of tree growth. These soils are often good for farming. Forest soils are grayish brown to reddish brown due to small amounts of iron or aluminum. Forest soils have a loose consistence because they are very moist.

TROPICAL GRASSLAND

Tropical grassland soils are found in areas that are very warm all year long, with both wet and dry seasons, unlike tropical areas that are always wet. The soil tends to be weathered and greyish brown. Because of the large amount of fine particles in the soil, the texture is sticky.

6. Work with your group to locate the following three places on the map. Mark each with an "X" and label the map with their names.
   - Chris's school (Label it "Phoenix.")
   - Orlando, Florida (Label it "Orlando.")
   - Your school (Label it with the name of your city.)
7. Work with your group to identify U.S. soil patterns by discussing the following questions:
   - What is (or are) the most common type(s) of soil in the United States? How do you know?
   - What is (or are) the least common type(s) of soil in the United States?
   - What is the most common type of soil in your state?
   - What is the most common type of soil in Chris's state?
8. When you are done, compare your completed Student Sheet 7.1 with the transparency shown by your teacher.

ANALYSIS

1. Create a table that summarizes:
   - the four major soil categories found in the United States.
   - the composition of each of the soils.
   - the average weather conditions (temperature, rainfall, or seasons, for example) in which the soils are found.
2. Your cousin from central Nebraska calls you and says that the soil where she lives is the same as the soil in the school garden. Do you agree or disagree with your cousin? Explain your answer.
3. Compare the four soil categories with your own data on the school garden soil in Table 1, "Soil Observations," from Activity 6. What category of soil matches the soil in Chris's school garden? Explain your answer.

EXTENSION

How does the soil at or near your school compare to the soil at Chris's school? Examine a sample of local soil. Go to the *Issues and Earth Science* page of the SEPUP website to find links to more information about soil maps.

8 The Dust Bowl

ROLE PLAY

After school one day, Chris's great-grandfather asked him what he was studying in his science class. Chris began to tell him about the garden. When he described the problems they were having, Chris's mother, a soil scientist, became interested. Then his great-grandfather told them all a story about when he was growing up on a farm in Oklahoma.

CHALLENGE

What happened in the Dust Bowl in the 1930s?

MATERIALS

For each student

1 **Student Sheet 8.1, "Intra-act Discussion: The Dust Bowl"**

PROCEDURE

1. Assign one of the following roles to each person in your group.
   - *Chris, a middle school student*
   - *Jennifer, his older sister*
   - *Mother*
   - *Great-grandfather*
2. In your group, read the role-play aloud. As you read, think about what each character is saying.
3. Discuss whether you think a disaster like the Dust Bowl could happen again.
4. Mark whether you agree or disagree with the statements on Student Sheet 8.1, "Intra-act Discussion: The Dust Bowl." Predict what you think other members of your group will say.
5. Discuss the statements with your group. Have a person share his or her opinion about each statement and explain why he or she agreed or disagreed.

THE DUST BOWL

Great-grandfather: You know, I can tell you something about growing things. I was raised on a farm.

Jennifer: We know that, Grandpa.

Great-grandfather: But do you know why my family left Oklahoma?

Chris: No, why?

Great-grandfather: Dust.

Jennifer: Dust?

Great-grandfather: Yep, dust.

Chris: Why did dust make you leave?

Mother: Well, really, it was more like dirt.

Workers harvest peas on a farm in 1929.

Great-grandfather:	Our family had a farm in Oklahoma for almost 100 years. When they started the farm, they took out the native prairie grasses and planted vegetable crops. It was a productive farm and a good living for many years.
Jennifer:	So what does that have to do with dust?
Great-grandfather:	In the 1930s, there were several years with very little rain. The topsoil dried out and the crops died, leaving the soil bare.
Mother:	The native grasses of Oklahoma could adapt and survive with hardly any rain, but the vegetable crops planted by farmers could not. The way the plants were watered wasn't very good either, so the crops dried out.
Jennifer:	So once the crops died, you had to move?
Great-grandfather:	No, not yet. It got worse.
Chris:	Worse? How can it get worse than having all your crops die?
Mother:	The farmed soil didn't have much moisture or organic matter in it. The soil was dry because there wasn't any rain, but the lack of moist organic matter was due to the way they were farming.
Chris:	I read about this somewhere. When land is farmed, the natural recycling process of organic matter is broken. When crops are harvested and removed, the topsoil is left with fewer nutrients.
Mother:	These days some farmers try to return nutrients to the soil with fertilizers. Or they try not to remove all the nutrients in the first place. But in the past, it was common for farmers to abandon the land that lacked organic material and grow the next crop in a new place.
Jennifer:	So what you're saying is that the land would be farmed until there was nothing organic left in it?

Mother:	That's right. Often the abandoned soil created an area where it was difficult, even impossible, for plants to grow again. Near Grandpa's farm, there was a lot of dry nutrient-poor soil that could be picked up by the wind.
Great-grandfather:	And that is what happened. There was a lot of wind and it picked up the soil and created huge dust storms. Probably it would be better to call them "dirt" storms.
Jennifer:	I think I remember hearing about this in history class. They called it the "Dust Bowl" because all the dirt that was blown in the air was as fine as dust.
Great-grandfather:	Yes, and all of that dust was one of the most incredible things I have seen in my whole life! The windstorms were so fierce that they were called "black blizzards."
Mother:	The dust mainly blew east, from Oklahoma to Vermont and New York. Some of it was lifted high into the air and was carried over the Atlantic Ocean.

FARMING TECHNIQUES TO SAVE SOIL

a. Contour plowing on hills slows down water flow so that less soil is washed away.

b. When trees are used as windbreaks, they slow down the wind so it cannot easily lift soil up and move it.

c. Crop rotation, or changing crops yearly, reduces the loss of nutrients in the soil.

d. Native plants hold soil together and are well equipped to thrive in local conditions.

Chris: So everything got covered in dirt?

Great-grandfather: Yes. The dead crops were covered, the farm equipment, and even the house. We sealed up the house, but the dust was so fine it got inside and covered the furniture. It was everywhere. I remember that the dust storms made it so dark outside that the streetlights were left on during the day!

Chris: That explains why you left the farm.

Mother: Grandpa was only one of the millions of people affected by the Dust Bowl. It covered more than 100 million acres of land in Oklahoma, Kansas, Colorado, Texas, and New Mexico.

Great-grandfather: We packed up the whole family and moved to Chicago. It was hard for a while, but eventually my father got a job in a factory.

These historical photographs show a "black blizzard" in the Dust Bowl. The picture at the top shows a car trying to escape the dark clouds of dust, and the one at the bottom shows how the dirt from the storm has almost buried buildings on a farm.

THE DUST BOWL
IN THE UNITED STATES

Jennifer: Wow, Grandpa, that's an amazing story. Dust!

Chris: Is Oklahoma still covered in dirt?

Mother: The winds died down and farmers improved how they farmed, so the crisis is over. But dust storms haven't disappeared. They are an ongoing natural hazard in the world.

ANALYSIS

1. Describe what it was like to be in the Dust Bowl.

2. A combination of conditions caused the Dust Bowl. What were three things that contributed to the Dust Bowl?

3. The photographs on page A-34 show how modern farmers use a variety of techniques to prevent soil loss. How could the following actions help prevent another Dust Bowl? Explain how each single action could help.

   a. Keep soils wet.

   b. Listen to weather reports.

   c. Plant tall trees along the edges of fields.

   d. Plant more native plants.

4. **Reflection:** Do you know of anyone whose life has been affected by farms or farming? Describe his or her experience.

9 Nutrients in Soil

Some people think that soil is "food" for plants, but that is not true. Plants make their own food through a process called photosynthesis (foe-toe-SIN-thuh-sis). This food is stored in the plant as sugar or starch. Sugar and starch provide the plant with the energy it needs for growth.

Plants use certain chemicals from the soil. Because these chemicals also help the plant grow, they are called nutrients. Three important nutrients that plants need are nitrogen (NI-troh-jen), phosphorus (FOSS-for-us), and potassium (po-TASS-ee-um). When the soil does not contain enough of these nutrients, **fertilizers** containing these chemicals are sometimes added to the soil.

CHALLENGE

How does soil help plants grow?

The labels of both manufactured and organic fertilizers often show the levels of nutrients they contain. The three numbers seen on the front of each fertilizer refer to levels of nitrogen, phosphorus, and potassium.

MATERIALS

For each group of four students

1 **piece of chart paper**

markers

For each pair of students

1 **Plant Puzzle (containing 5 pieces)**

6 **Soil Cards**

3 **Nutrient Cards**

For each student

1 **Student Sheet 9.1, "Comparing Soils"**

PROCEDURE

Part A: Finding Missing Nutrients

1. Place all of the numbered Soil Cards face down on the table.
2. With your partner, put together the Plant Puzzle. This puzzle will tell you what plants need for growth.
3. Record what plants need for growth in your science notebook.
4. To imagine trying to grow a plant in a different type of soil, remove the Nutrient-Rich Soil Card from the Plant Puzzle.
5. Select a Soil Card from the face-down cards.
6. Place the Soil Card under the plant in the puzzle.
7. Record the Soil Card number and the nutrients this soil contains on Student Sheet 9.1, "Comparing Soils."
8. Use the Nutrient Cards to fill in any nutrients this soil is missing. Record the missing nutrients on Student Sheet 9.1.

9. Each kind of fertilizer may contain different amounts and proportions of nitrogen, phosphorus, and potassium. The plant in your puzzle requires equal amounts of each of these nutrients.
   a. Look at which nutrients this particular soil is missing. Compare the missing nutrients to the nutrient levels of different fertilizers in the table below.
   b. Select the best fertilizer for use with this soil.
   Hint: The best fertilizer provides more of the missing nutrients.
   c. Record your recommendation on Student Sheet 9.1.

Percentage of Nutrients in Fertilizers

Fertilizer	Nitrogen (N)	Phosphorus (P)	Potassium (K)
A	20	10	20
B	25	5	5
C	16	16	8
D	20	20	20
E	0	0	22
F	5	15	15

10. Repeat Steps 5–9 until you have examined all of the Soil Cards.

Part B: Making a Concept Map

11. Work with your group to create a list of at least 15 words related to soil from this unit. It may help to think about these questions:
   - What is soil?
   - What is the role of soils in plant growth?
   - What do plants need in order to grow?
   - Why are fertilizers used?

12. Discuss with your group how all of the words on your list are related to soil. Sort your list of words into 3–5 categories based on these relationships. For example, words such as *nitrogen, phosphorus,* and *potassium* could all be in one category because they are all chemicals that plants need to grow.

    Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain why you disagree.

13. Identify words that can be used to describe each category. For example, *nitrogen, phosphorus,* and *potassium* could all be described as nutrients.

14. Work with your group to create a concept map for soil. Follow these steps:
    - **a.** Write the word *soil* in the center of your paper and circle it.
    - **b.** Place the words describing each category around the words *soil*. Circle each word.
    - **c.** Draw a line between the word *soil* and each category. On each line, explain the relationship between the word *soil* and the category. For example:

    - **d.** Repeat Steps 14b and 14c as you continue to add all of the words on your list to your concept map.
    - **e.** Add lines to connect other related words. Explain the relationship between the words on the line.

15. Look at the concept maps created by the other groups. Observe similarities and differences between their maps and your own. Discuss your observations with other members of your group.

ANALYSIS

1. What do plants need to grow?

2. Describe the relationship among

   a. plants, soil, and nutrients.

   b. plants, soil, and fertilizers.

3. Sometimes plants are grown without soil, as shown below. These hydroponic (hi-druh-PON-ik) plants are grown by putting nutrients usually found in soil in the plant's water supply. Which is more important—soil or water—for plant growth? Why?

Hydroponic plants, like these strawberry plants, are grown without soil.

4. Do you think the school garden needs more nutrients? How do you think you could find out?

5. **Reflection:** How did constructing a concept map for soil help you understand more about soil?

10 Organic Matter Test

Chris wondered whether the soil in the school garden contained enough nutrients. He was pretty sure that the plants were getting the water, sunlight, and air they needed, so he thought the problem might be the lack of good nutrients. He thought of two more reasons why the answer to his problem could be the lack of nutrients in the soil. First, Chris knew that the history of farming on the land could have caused a shortage of nutrients. A second explanation could be that the soil had a sandy composition.

How do nitrogen, phosphorus, and potassium get into the soil? As you learned in Activity 5, "Soil Composition," nutrients are released into the soil by decomposing plants and animals. The organic matter in soil produces most of the nutrients that plants need to grow. Did the soil at the school garden have these nutrients? In this activity, you will test soil to find out how much organic matter it contains.

CHALLENGE **Is there enough organic matter in the school garden soil?**

Soil scientists often test soils in the field.

MATERIALS

For each group of four students

2 SEPUP trays
1 sample of Soil A
1 sample of Soil B
1 cup of water
3 plastic tubes
3 tube caps
1 30-mL graduated cup
1 50-mL graduated cylinder
1 bottle of Organic Matter (OM) testing solution
1 pipette
1 Organic Matter Color Chart
clock with a second hand
piece of white paper
masking tape

For each student

1 pair of safety goggles
1 lab apron
1 Student Sheet 2.1, "KWL: Analyzing the Garden Problem"

SAFETY

Wear safety eyewear and a lab apron. Do not touch the chemicals. Follow all classroom safety rules. The OM testing solution may stain clothes and skin. Make sure to rinse off any solution that touches your skin or clothes with plenty of water. Wash your hands after you finish the investigation.

PROCEDURE

1. Use the masking tape to label the caps of the plastic tubes A, B, and C.
2. Stand the tubes in Cups A, B, and C of the SEPUP tray.
3. Create a data table in your science notebook to record your results for Tubes A, B, and C. For each tube, you will need to write down your observations, the final color of the liquid, and the amount of organic matter.
4. Use the 30-mL graduated cup to measure 10 mL of Soil A and carefully pour it into the tube in Cup A.
5. Use the 30-mL graduated cup to measure 10 mL of Soil B and carefully pour it into the tube in Cup B.
6. Add 30 mL of water to each of the 3 tubes. Use the 50-mL graduated cylinder to measure the water.
7. Add 5 mL of OM testing solution to each tube using the 50-mL graduated cylinder.
8. Cap each of the tubes with the correctly labeled cap.
9. Gently shake each of the tubes for 2 minutes.
10. Put the tubes back in the tray and leave them for another 2 minutes. Observe the changes that occur during this time and record them in your table.
11. To prevent splattering, put a paper towel over the cap of Tube A and carefully remove the cap. Remove the caps from Tubes B and C in the same way.
12. Using the pipette, remove 2 mL of liquid from Tube A and put it into Cup A of the other SEPUP tray.

    Hint: Avoid getting soil in the pipette! It will clog the pipette and make testing difficult. Remove liquid only.
13. Rinse the pipette in a cup of water by placing the tip in the water and repeatedly squeezing it a few times. Squeeze out any water still in the pipette before going on to Step 14.

14. Repeat Steps 12 and 13 for Tubes B and C. Be sure to place the liquid from Tube B in Cup B and the liquid from Tube C in Cup C of the SEPUP tray.

15. Put the SEPUP tray containing the liquids on a piece of white paper. Compare the color in each of the cups to the Organic Matter Color Chart.

16. Record your results in the table.

ANALYSIS

1. What was the purpose of Tube C?

2. **a.** Does Soil A or Soil B contain more organic matter?

   b. What evidence do you have for your answer?

3. Do you think your test results explain why the garden didn't grow? Explain your ideas using the results from this activity as well as other activities in the unit.

11 Garden Action

The school principal wanted to know what the class planned to do before he would allow the students to dig up the garden. Chris had some ideas. Ms. Clayson wanted the class to discuss everyone's ideas before they made a decision.

When plants grow, they slowly remove the nutrients from the soil. In natural environments, dying plants decompose back into the soil, releasing more nutrients. In farms and gardens where plants are harvested, soils can become low in nutrients as time passes. More nutrients must be added for new plants to be healthy and strong.

Farmers and gardeners often add fertilizers to the soil to replace the nutrients that have been removed. Both manufactured and organic fertilizers can be used. Manufactured fertilizers contain concentrated amounts of nitrogen, phosphorus, potassium, and other nutrients. Organic fertilizers contain natural material, such as manure, compost, or peat, that will slowly decompose and release nutrients into the soil.

CHALLENGE

What should be done about the soil in the school garden?

MATERIALS

For each group of four students

1 **Student Sheet 11.1, "Garden Actions: Weighing Advantages and Disadvantages"**

For each student

1 **Student Sheet 11.2, "Role-Play Analysis"**

PROCEDURE

1. Decide which group member will play each of the roles shown below.
2. Each person should read his or her role aloud while the rest of the group listens.
3. Discuss the advantages and disadvantages of each role with your group. Use Student Sheet 11.1, "Garden Actions: Weighing Advantages and Disadvantages," to record your ideas.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain why you disagree.

ROLES

Rudy

I'd like to see the garden ready as soon as possible. We should go to the store and buy some manufactured fertilizer. Organic fertilizers are slow and you need to apply more. Their nutrient content is lower than manufactured fertilizers. We need the concentrated nutrients and fast release of chemicals found in manufactured fertilizers. Then we can put the nutrients back into the soil quickly and grow vegetables. Manufactured fertilizers are more expensive, but we can sell the vegetables faster and buy more fertilizer.

Nicole

We should start a large compost pile on the edge of the garden and make our own organic fertilizer. Organic fertilizers may work slowly, but they release nutrients over a longer period of time. It will take a little while to get the compost and the garden going. But once they're started, we won't have to go back to the store and pay for fertilizer all the time. Also, the nutrients in organic fertilizers are less likely to wash away than the ones in manufactured fertilizers, so we won't pollute the rest of the environment with chemicals.

Ananda

We have to make sure that the soil will hold the nutrients we put in. Right now, the garden soil is pretty sandy, so I think we should mix in another soil with more clay and organic matter. The clay will hold water and nutrients better than sand does. The organic matter will slowly release nutrients. We can buy some nutrient-rich forest soil from the eastern United States and mix it in with the current soil.

Carl

The problem isn't with the garden at all. Plants grow everywhere all over the world—even in the desert. Matching the right plant to the soil environment is really important. The story of the Dust Bowl shows what happens when you pick the wrong plants. Plants grow naturally in their local soil and you don't have to add so much water or fertilizer. The garden soil does have some organic matter in it. We should research which plants are native to our area and plant them in the garden.

ANALYSIS

1. Do you agree or disagree with the ideas of the students in the role-play? Use Student Sheet 11.2, "Role-Play Analysis," to record your thoughts. In the last column of the table, explain why you agree or disagree.

2. Write a letter to the school principal that states your recommendation for the school garden. Convince the principal with evidence you gathered in this unit. Be sure to present the trade-offs of your recommendation.

EXTENSION

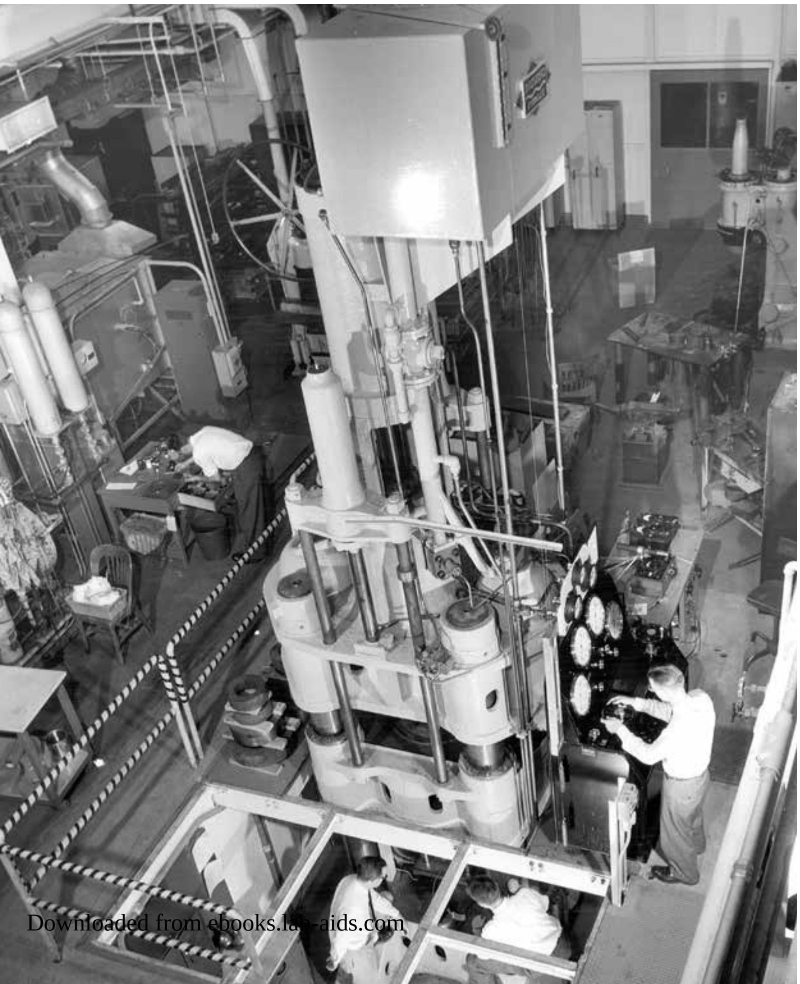
Make a "Super Soil" that could be added to the school garden. Convince your classmates that you should use the soil by explaining how it will fix the garden problem.

Rocks and Minerals

B








Rocks and Minerals

Jessica, it’s time to clean up your closet,” said her dad. “If you want us to give you anything new for your birthday, you have to make some room in there.”

Jessica stood in front of her closet. High on a shelf was a rock collection. Her older sister walked into the room just as Jessica was about to throw the collection away.

“You’re not going to throw those rocks away, are you?” said her sister. “I always loved your collection.”

“Why? It’s just a bunch of rocks,” Jessica shrugged.

“Yeah, but they’re all so different. Look at this one with the shiny crystals. Uncle Andrew gave me one of those too. I wonder where it came from.”

“Well, I guess some of the rocks are cool,” said Jessica. “Look at this one—you can see the outline of a leaf pressed into the rock. This other rock just looks like hardened dirt.”

“I think they’re all interesting, Jessica. Let's keep them. Their colors and shapes remind me of the places we've been.”

“Okay, but they’re going into your closet!”

• • •

Why are there so many different kinds of rocks? Where do they come from, and what are they made of? Why do some people value them? In this unit, you will explore rocks and the minerals that form them. You will also investigate what makes different rocks and minerals valuable.

12 Observing Natural Resources

INVESTIGATION

Humans use a lot of materials that are found naturally on earth. There are many of these materials, including metals such as iron and woods such as pine. Materials that are found on earth and used by people are known as **natural resources.**

CHALLENGE

What do natural resources look like?

Natural resources such as rocks are mined in rock quarries (KWOR-eez) like this one.

MATERIALS

For each group of four students

1 **coal sample**

1 **rock with fossils sample**

1 **rock with garnets sample**

1 **wood sample**

For each pair of students

1 **magnifying lens**

1 **metric ruler**

PROCEDURE

1. Work with your partner to carefully examine one of the natural resource samples. In your science notebook, make a table like the one below.
2. Repeat Step 1 until you have examined all four natural resource samples.

Ranking Natural Resource Samples

Natural Resource	Observations	Ranking	Reason(s) for Ranking
Coal			
Rock with fossils			
Rock with garnets			
Wood			

3. Discuss with your group how valuable you think each sample is and what you think makes it more or less valuable.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain why you disagree.
4. In your table, rank each of the four natural resources with 1 = most valuable and 4 = least valuable.

   Note: You do not need to agree with the other members of your group.
5. Complete the table by explaining why you decided to rank the samples as you did. Be sure to list at least one reason for each sample.
6. Discuss your rankings with the other members of your group. Explain why you ranked each sample as you did.

ANALYSIS

1. a. What was the most valuable natural resource, according to the class?
   b. What was the least valuable natural resource, according to the class?
   c. What reasons did other students have for identifying a natural resource as more or less valuable?
2. What else would you like to know about these natural resources to help you determine their value?
3. Copy the list of words shown below.

   coal

   natural resource

   salt

   garnet

   plastic

   a. Look for a relationship among these words. Cross out the word or phrase that does not belong.
   b. Circle the word or phrase that includes all the other words.
   c. Explain how the word or phrase you circled is related to the other words in the list.
4. **Reflection:** What do you think makes a natural resource valuable?

13 Diamond Dilemma

In the past, people treasured natural resources that are not very valuable today. For example, salt was once so valuable that Roman soldiers were paid with it instead of money! One natural resource that has always been valued by human beings is diamonds. In the past, only royalty wore diamonds and other beautiful stones. Today, many people buy and own diamonds.

You have probably seen diamond earrings in jewelry store windows. At least, you thought they were diamonds because they were clear, they sparkled, and they were expensive. What else could they be? How could you find out? The first step is to gather more data about the material from which the earrings were made.

Stones used in making jewelry, even these colorful diamonds, come out of the ground looking a lot like other rocks found in the ground. Each pair shown here consists of a rough diamond and a polished diamond of the same color. Gemstones such as diamonds are then cut and polished until they are shiny and beautiful.

CHALLENGE

What data can you get from examining a material?

MATERIALS

For each group of four students

1 copper strip

1 glass scratch plate

For each pair of students

1 sample of earring material

1 magnifying lens

1 metric ruler

For each student

1 Student Sheet 13.1, "Data on the Earring Material"

CAUTION

Many soft materials, such as plastic, are easily scratched. Test with your lab materials only those surfaces described in the Procedure.

PROCEDURE

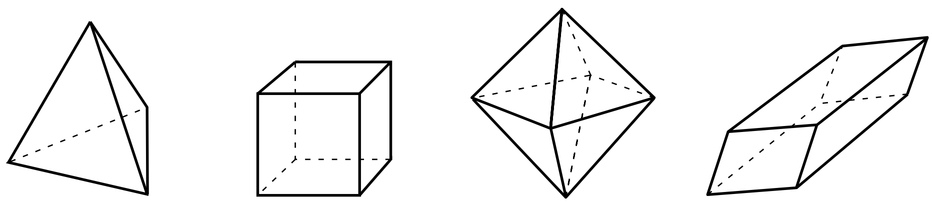
1. Work with your partner to examine a sample of the material from which the earrings are made. Use the magnifying lens to observe it more closely.

2. Describe the color of your sample on Student Sheet 13.1, "Data on the Earring Material."

3. Place the earring sample on a printed page and try to read the letters through the sample. Record the results of the transparency test for your sample on Student Sheet 13.1. **Hint:** Try looking through more than one side of the sample.

   - If you cannot see through the earring sample, it is *opaque* (oh-PAKE).
   - If you can see through the sample, but the letters are blurry, it is *translucent* (trans-LEW-sunt).
   - If you can see through the sample clearly, it is *transparent* (trans-PAIR-unt).

4. Try to reflect light off of your earring sample and then record its *luster* (how shiny it is) on Student Sheet 13.1.
   - If it reflects lots of light and is very shiny, it is *brilliant*.
   - If it reflects some light and is only somewhat shiny, it is *glassy*.
   - If it does not reflect any light and is not shiny, it is *dull*.
5. Use the drawings below to describe and draw the crystal shape of your sample on Student Sheet 13.1.



a. tetrahedron (4 sides) b. cube (6 sides) c. octahedron (8 sides) d. rhombohedron (6 sides)

SOME GEOMETRIC SOLIDS

6. Use a ruler to measure the length of the longest edge of your earring sample in centimeters (cm). Record this length measurement as the approximate size of your sample on Student Sheet 13.1.
7. Try to scratch the surface of a copper strip with your sample.

   Hint: To make sure a mark is really a scratch, use your finger to try to rub away the scratch. If it does not disappear, it is a scratch.
   - If the sample *did* scratch the copper, it is harder than copper.
   - If the sample *did not* scratch the copper, it is softer than copper.

   Record your results on Student Sheet 13.1.
8. Try to scratch the surface of a glass scratch plate with your sample.

   Hint: To make sure a mark is really a scratch, use your finger to try to rub away the scratch. If it does not disappear, it is a scratch. (You can also run your fingernail along the surface to see if you can feel the groove created by a scratch.)
   - If the sample *did* scratch the glass, it is harder than glass.
   - If the sample *did not* scratch the glass, it is softer than glass.

   Record your results on Student Sheet 13.1.

ANALYSIS

1. Compare your data with the other pair of students in your group.
   a. Which of your observations were the same?
   b. Which of your observations were different?
2. Every group received a sample of the same material. Compare your data with the rest of the class. Which observations do you predict will be the most useful in identifying the material? Why?
3. Do you think the material is a diamond? Support your opinion with at least three observations from this activity.

14 Analyzing Diamond Data

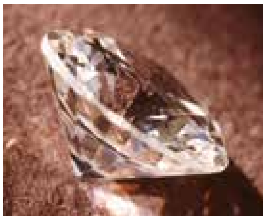
Scientists use observations and measurements to gather data. They compare this data to known information before making a conclusion. In this activity, you will compare your data on the earring sample with the information for four different materials: acrylic (uh-KRILL-ik), diamond, calcite (CAL-site), and glass. You can use this information to determine whether or not the material is diamond.

Each of these materials is used to make jewelry. Some of these materials are more valuable than others. How can you tell which material is which?


acrylic


diamond


calcite


glass

CHALLENGE

How can you use additional information to identify the earring sample?

MATERIALS

For each student

1 **completed Student Sheet 13.1, "Data on the Earring Material"**

1 **Student Sheet 14.1, "Properties of Different Materials"**

PROCEDURE

1. Review the data on Student Sheet 14.1, "Properties of Different Materials."

2. a. Discuss with your group which properties are likely to be the *most* useful in telling the four materials apart.

   Hint: Think about whether a particular property is the same or different for all of the materials. Consider whether similar or different properties would be better for identifying a material.

   b. Put a plus sign (+) next to the most useful properties on Student Sheet 14.1.

3. a. Discuss with your group which properties are likely to be the *least* useful in telling the materials apart.

   b. Put a minus sign (–) next to the least useful properties on Student Sheet 14.1.

4. Circle each piece of data for **acrylic** that matches your observations of the earring material.

5. Circle each piece of data for **diamond** that matches your observations of the earring material.

6. Circle each piece of data for **calcite** that matches your observations of the earring material.

7. Circle each piece of data for **glass** that matches your observations of the earring material.

ANALYSIS

1. Could the earring material be acrylic? Why or why not?
2. Could the earring material be diamond? Why or why not?
3. Could the earring material be calcite? Why or why not?
4. Could the earring material be glass? Why or why not?

5. Review your answers to Questions 1–4 and Student Sheet 13.1.
   a. What material are the earrings made from?
   b. Support your identification with data from your observations and data about the material.

6. The jewelry store sells a necklace made of the same material as the earring. Would the material in the necklace be softer, harder, or the same as the material in the earrings? Explain your reasoning.

15 Mineral Properties

READING

You now know that there are many materials that can be mistaken for diamonds. Yet diamonds are usually the most expensive. What makes diamonds special? Find out more about diamonds in the reading below.

CHALLENGE

What makes diamonds a valuable natural resource?

MATERIALS

For each student

1 **completed Student Sheet 13.1, "Data on the Earring Material"**

1 **Student Sheet 15.1, "Three-Level Reading Guide: Mineral Properties"**

READING

Use Student Sheet 15.1, "Three-Level Reading Guide: Mineral Properties" to guide you as you complete the following reading.

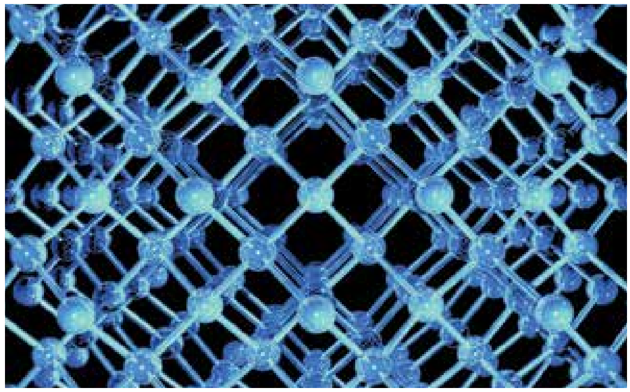
Diamonds are Minerals

Gemstones such as diamonds, rubies, and emeralds are highly valued because they are rare, beautiful, and last a long time. All of these gemstones are **minerals** (MIN-er-uls). Minerals are non-living materials that are found naturally on earth. Most minerals are solids and each one has a particular internal structure, because each one is made of a specific set of atoms that are arranged in a repeating pattern, called a crystalline (KRIS-ta-lin) structure. In the right environment, minerals form large crystals because of their crystalline structure.

Fluorite is a non-living solid found naturally on earth. It is made of calcium and fluorine atoms arranged in a crystalline structure similar to that of diamonds (see Figure 1). For these reasons, fluorite is a mineral. Acrylic and glass are not minerals. Acrylic is a plastic that is made by people, and glass does not have an internal crystalline structure. The table on the next page lists some common minerals. Which of these minerals do you recognize? Which of these minerals do you use?

FIGURE 1:
DIAMOND CRYSTAL

Diamonds are made of carbon atoms arranged in the crystalline structure in the diagram at right. This structure results in the octahedral crystal shape of many rough diamonds, shown far right.



Some Common Minerals		
Mineral	**May Also be Called**	**Some Common Uses**
corundum	rubies, sapphires	jewelry
fluorite	fluoride, fluorspar	toothpaste, industrial processes
galena	lead	ceramics, electronics, ammunition
halite	salt, rock salt	table salt, melt snow on roads
native copper	copper, pure copper, elemental copper	wiring, plumbing (past) mineral specimens (today)
quartz	quartz crystal	watches, radios, jewelry
silver	—	jewelry, electronics, photography

There are more than 2,000 different minerals, and most of them are not as expensive as diamonds. This is because minerals are found in something that you see everyday: rocks. Rocks are made of minerals. Some of these minerals are very common, while other minerals are harder to find. Large pieces of certain minerals, like diamond, are the hardest to find and are the most valuable. The minerals in most rocks are small, as you can see in Figure 2, below.

FIGURE 2:
MINERALS IN ROCKS

Most rocks, like those shown in the photo, are made up of more than one mineral. It is easier to see the different minerals in some rocks than it is in others.

Identifying Minerals

With so many different minerals, it is important to be able to tell one mineral from another. In Activity 13, "Diamond Dilemma," you made many observations of a mineral. Observations like the ones you made can be used to identify different minerals, and are called **properties.** Minerals can be classified according to their properties—the characteristics that make them unique.

Color is one property that people sometimes use to identify minerals. Many minerals that are used to make jewelry are known for their beautiful colors. Diamonds are usually colorless, but sometimes they are gray, yellow, or even pink. Because a mineral like a diamond may be found in different colors, color alone cannot be the only property used to identify a mineral.

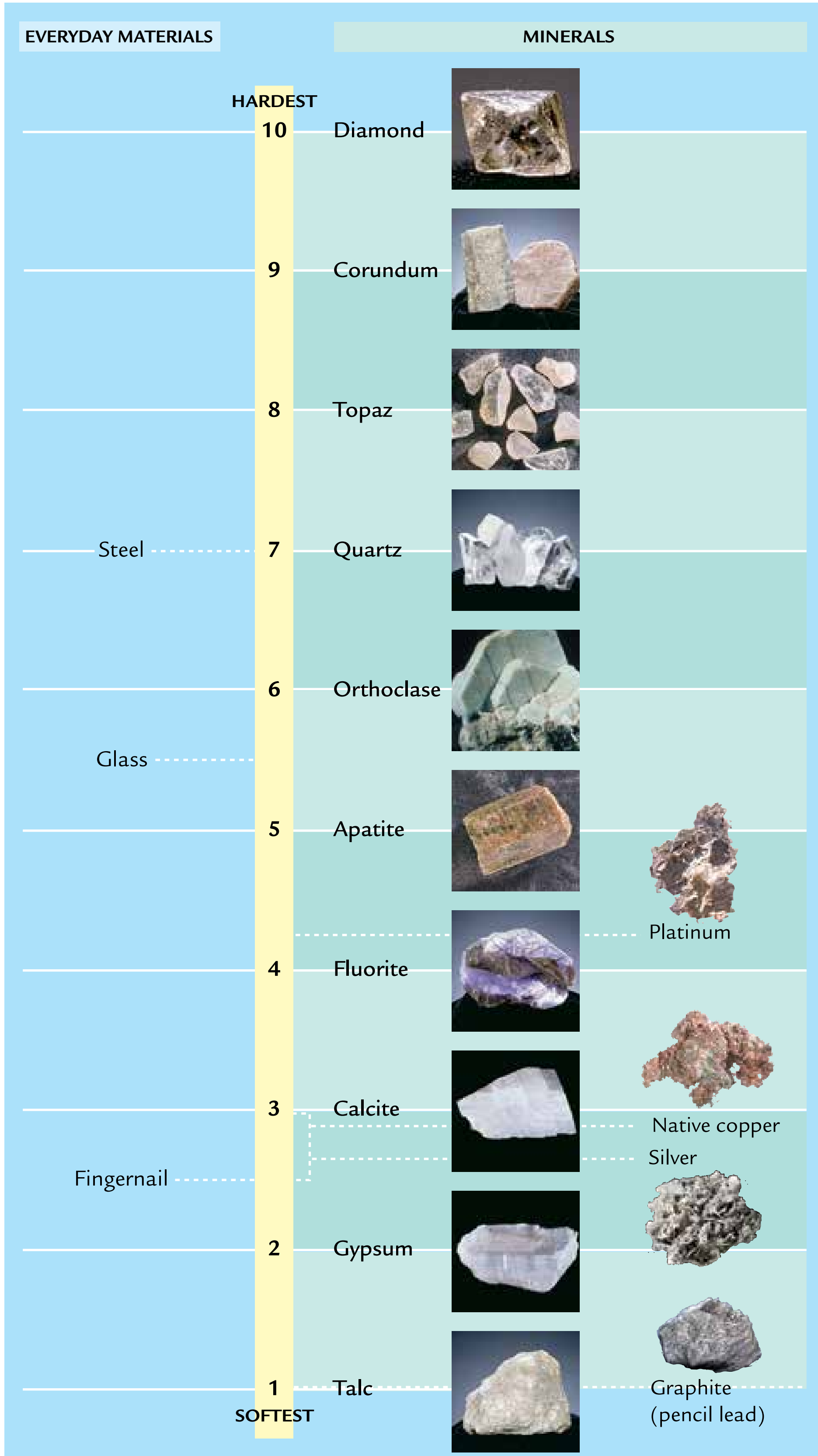
Some minerals are soft, while others are hard. Hardness is another property used to identify minerals. In 1822, the German scientist Friedrich Mohs created a scale to rank the hardness of a mineral from 1 to 10. He scratched one mineral with another. The mineral that was scratched was softer than the other. Talc, a soft mineral used in talcum powder, has a hardness of 1. Diamond, the hardest mineral on earth, has a hardness of 10. You can see the Mohs Hardness Scale in Figure 3. Today, scientists have created other hardness scales, but the Mohs Scale is still the easiest to use.

On the Mohs Scale, minerals with higher numbers can scratch minerals with lower numbers. Diamonds can be used to scratch any other mineral, but no other mineral—except another diamond—can scratch a diamond. This doesn't mean that a diamond cannot break. If hit hard enough, a diamond will break into smaller pieces.

There are many other properties that can be used to identify minerals. **Geologists** (gee-ALL-oh-jists) are people who study rocks, minerals, and other non-living parts of the earth. Geologists also use properties, such as the color a mineral makes when rubbed on a white ceramic plate (called streak color) and the way a mineral usually breaks (called cleavage), to accurately identify a sample. Since each mineral has a unique set of properties, geologists can tell when a yellow stone is a diamond and not another yellow mineral, like topaz.

FIGURE 3:
MOHS HARDNESS SCALE

Compare the hardness of the minerals to some everyday materials. What material(s) could scratch fluorite? What material(s) could scratch corundum?



Finding Minerals

Many valuable minerals were formed in the earth over thousands of years. Most of the easy-to-find, valuable minerals have been collected already. To gather minerals today, people usually have to dig into the surface of the earth. They remove large pieces of rock and break them into smaller pieces to find particular minerals. This process is known as mining. The world's deepest diamond mine is in South Africa, and it is already over 3.5 kilometers (2.1 miles) deep.

Because not all minerals are found everywhere on earth, people mine for particular minerals in certain parts of the world. For example, diamonds are commonly mined in the countries of Canada, Botswana, South Africa, Russia, and Australia. (See Figure 4.)

FIGURE 4: SOME COUNTRIES THAT PRODUCE DIAMONDS

Countries that produce a lot of diamonds are shown in orange.

Today, not all minerals are mined from the earth. Some can now be created in laboratories and are called **synthetic** (sin-THET-ik). Even though synthetic mineral substitutes are made by humans, they are not fake. They have the same structure and other properties as the natural mineral. But synthetics are not defined as minerals since they are not found naturally on earth.

ANALYSIS

1. **a.** Create a concept map using the following 10 words:

rocks	properties
minerals	color
diamonds	hardness
fluorite	Mohs Hardness Scale
geologists	crystalline structure

   b. Add at least five more words related to minerals to your concept map. Choose words that show what you now know about minerals.

2. What makes diamonds a valuable natural resource?

3. Does the size of a mineral affect its properties?

4. Look at Student Sheet 13.1, "Data on the Earring Material," from Activity 13, "Diamond Dilemma." Besides color and hardness, what are some other properties that can be used to identify a mineral?

5. Look at Student Sheet 13.1 again. Compare your observations to the Mohs Hardness Scale. Is the hardness of the earring material most likely to be 1, 4, or 8? Explain your reasoning.

EXTENSION 1

Do you want to see more minerals? Bring in any minerals you may have collected to share with your class or go the *Issues and Earth Science* page of the SEPUP website to link to sites with photos of valuable gemstones and other minerals.

EXTENSION 2

Minerals like diamonds get their shape when they are formed in the earth when molten rock cools. Minerals that can dissolve in water form crystals as the water evaporates. To try this yourself, dissolve as much salt or epsomite (epsom salts) as you can in some warm water. Pour the solution into a large open jar. Next, tie a piece of string around the middle of a pencil and place the pencil across the mouth of the jar. Let a small length of the string dip into the solution. Keep the jar as still as possible as you allow the water to evaporate (the more water you use, the longer it will take to evaporate). Examine the crystals that form on the string, either with a magnifying lens or a microscope. Will all of the crystals from a single mineral have the same crystal shape? What is your prediction?

16 Mineral Identification

Minerals are found in many everyday materials such as bricks, ceramics, and even toothpaste. And lots of different minerals, including diamond, corundum, and silver, are used for jewelry. But not every mineral makes good jewelry. Calcite (KAL-site) and quartz (KWARTZ) are two common minerals. Which of these two minerals would make better jewelry? It depends on their properties. In this activity, you will receive an unidentified mineral sample. Your first task is to determine whether the sample is calcite or quartz. Then you can decide which would make better jewelry.

CHALLENGE **Can you design an investigation to identify a mineral?**

MATERIALS

For the class

- copper strips
- glass scratch plates
- white ceramic streak plates
- 30-mL bottles of 0.5 M hydrochloric acid
- cups of water
- droppers
- SEPUP trays
- magnifying lenses

For each pair of students

- 1 mineral
- 1 paper clip
- paper towels

For each student

- 1 pair of safety goggles

Minerals are used to produce many everyday objects besides jewelry, such as coins, keys, table salt, metal tools, musical instruments, dishes, pencils, and even medicine.

SAFETY

The hydrochloric acid solution can cause skin irritation and damage clothing. Always handle acids carefully and wear safety goggles. Wash your hands after completing the activity.

PROCEDURE

1. The unidentified mineral is either calcite or quartz. Examine Table 1 below and discuss with your partner which properties will be the most useful in identifying the unknown mineral. **Hint:** Think about whether properties that are similar or different are more useful in identifying a material.

Table 1: Mineral Properties

Property	Calcite	Quartz
Color	colorless, white, pink, red, green, blue, brown, yellow	colorless, white, pink purple, blue, yellow
Transparency	translucent or transparent	translucent or transparent
Luster	dull	glassy
Hardness (Mohs Scale)	3	7
Streak color	white	white
Reaction with acid	small bubbles, fizzing	no reaction
Light refraction	sometimes shows two images	always shows single image

2. Select five properties to observe or test. Remember to select the five properties that are most useful in identifying the mineral.

3. Review how to test these properties by examining Table 2, “Conducting Tests,” on the next page.

Table 2: Conducting Tests

Property	Test
Color	Observe the color of the mineral.
Transparency	Place the mineral on a printed page and try to read the letters through the mineral. • It is opaque if you cannot see through it. • It is translucent if you can see through it but letters are blurry. • It is transparent if you can see through it clearly.
Luster	Try to reflect light off of your sample. • It is brilliant if it reflects lots of light and is very shiny. • It is glassy if it reflects some light and is somewhat shiny. • It is dull if it does not reflect any light and is not shiny.
Hardness (Mohs Scale)	Try to scratch copper and glass with the mineral. Use your results to decide if the hardness of the mineral is: • less than 3 (hardness of copper) • between 3 and 5.5 • more than 5.5 (hardness of glass) **Hint:** You may want to use the Mohs Hardness Scale on page B-17.
Streak color	Use the mineral to draw a line on a white ceramic streak plate and observe the color of the streak.
Reaction with acid	If the mineral surface is shiny, scratch it slightly with the end of a paper clip. Place the mineral in Cup A of a SEPUP tray and add 1 drop of hydrochloric acid to the surface of the mineral. Observe if small bubbles form or if you hear a fizzing sound when you put your ear close to the mineral sample. After completing the test, use the dropper to rinse the mineral with water and then pat dry the mineral.
Light refraction	Place the mineral on a printed page and look at a word through the mineral. Record whether you see one or two images of the word.

4. Design an investigation to identify the unknown mineral. When designing an investigation, think about the following questions:
   - What is the purpose of your investigation?
   - What properties will you observe or test? (Test only five properties.)
   - Why did you choose these five properties?
   - What materials will you need to investigate these five properties?
   - How will you record your data?
   - How will you use the data to make a conclusion?

5. Record your planned investigation in your science notebook.
6. Make a data table that has space for all the data you need to record. You will fill it in during your investigation.
7. Obtain your teacher's approval of your investigation.
8. Conduct your investigation and record your results.

ANALYSIS

1. Which properties did you decide to test? Why did you choose these properties?
2. Did everyone have the same data for each property of the unknown mineral? Why or why not?
3. **a.** What is the unknown mineral: calcite or quartz?

   b. Support your identification with at least four pieces of evidence from your investigation. Be sure to compare your laboratory results to the properties of both calcite and quartz.
4. Jewelry is made from many different materials. Would you prefer to buy jewelry made of calcite or quartz? Explain your answer using information from this activity.

EXTENSION

Some minerals have another property called *fluorescence* (flur-ESS-ens). This means that the mineral will glow under ultraviolet (UV) light. Look at mineral samples under UV light. Which minerals are fluorescent? How could you use this property to help identify a mineral?

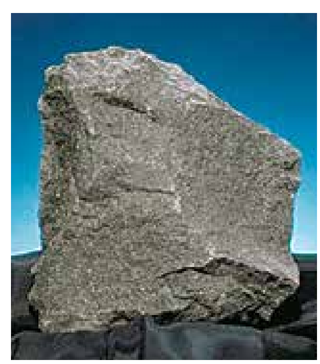
17 The Minerals in Rocks

You now know that minerals like diamonds and calcite come from the earth. You might be surprised to find out that the crystal size of most minerals is very small. Look at a rock—can you see its individual crystals? Rocks are made of minerals, and the size of each particle is pretty small.

Rocks can often be identified by the minerals that they contain. Each rock may contain one or many different minerals. In this activity, you will investigate two rocks: granite (GRAN-it) and limestone. Each rock contains one of the two minerals you investigated in the last activity, either calcite or quartz.

CHALLENGE

Can you identify one of the minerals found in a rock?



The mineral olivine (above), which is sometimes cut and polished into the gemstone peridot, is found in both of the rocks shown at right. The size of the mineral crystal in the rocks is much smaller than in this specimen of the mineral.

MATERIALS

For the class

copper strips
glass scratch plates
white ceramic streak plates
30-mL bottles of 0.5 M hydrochloric acid
cups of water
droppers
SEPUP trays
paper towels
safety goggles

For each group of four students

2 magnifying lenses
1 piece of granite
1 piece of limestone

For each student

1 Student Sheet 17.1, "Rock Observations"

SAFETY

The hydrochloric acid solution can cause skin irritation and damage clothing. Always handle acids carefully and wear safety goggles. Wash your hands after completing the activity.

PROCEDURE

1. Work with your partner to examine one of the rocks carefully, using a magnifying lens.

2. Record your observations on Student Sheet 17.1, "Rock Observations." Based on what you saw, write whether you think the rock is made up of one mineral or more than one mineral.

3. Switch rocks with the other half of your group and repeat Steps 1 and 2.

4. Each rock sample contains either calcite or quartz. Discuss with your partner which property you would most want to test to identify the mineral in each rock. You can only choose one property.

   Hint: You may want to review the data in Table 1, "Mineral Properties," from Activity 16, "Mineral Identification," to review the properties of calcite and quartz.

5. Record the one property that you would like to test on Student Sheet 17.1. Plan to test the same property on both rocks.

6. Obtain your teacher's approval of your plan.

7. Gather the materials and perform your test. Be sure to record your results on Student Sheet 17.1.

8. Exchange rocks with the other half of your group and repeat the test for the other rock.

ANALYSIS

1. Which mineral—calcite or quartz—is found in granite rock? Support your answer with evidence from your investigation.

2. Which mineral—calcite or quartz—is found in limestone rock? Support your answer with evidence from your investigation.

3. How do the rocks you have observed look different from minerals you have observed? Explain.

4. Copy the three lists of words shown below.

List 1	**List 2**	**List 3**
fluorite	rock	limestone
quartz	property	granite
mineral	streak color	calcite
granite	transparency	rocks
diamond	luster	

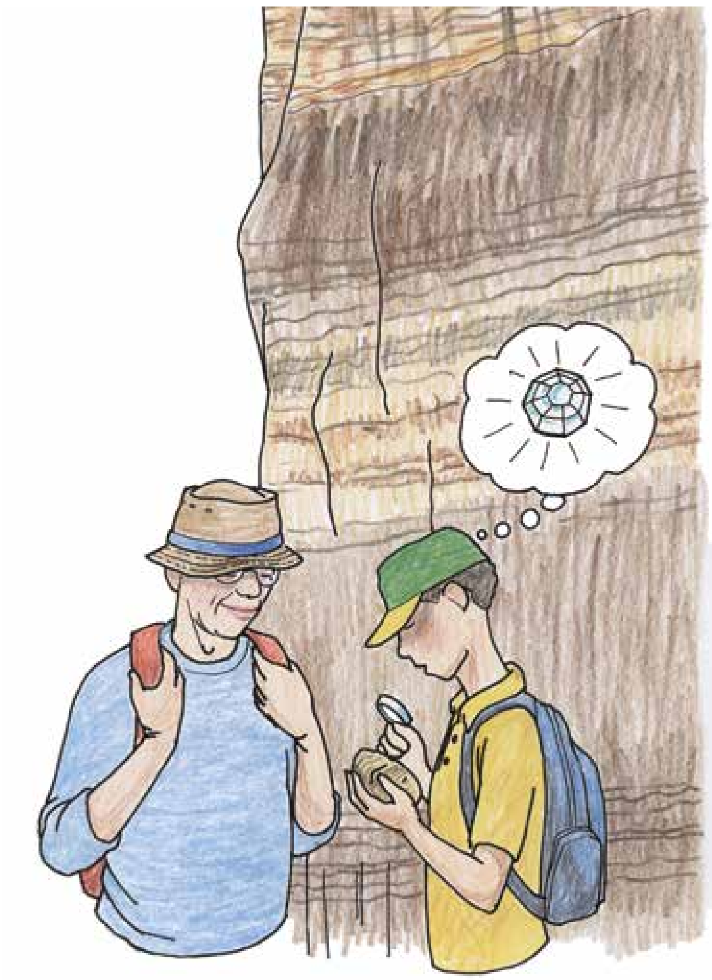
   a. Look for a relationship among the words in each list. Cross out the word in each list that does not belong.

   b. Circle the word in each list that includes the others.

   c. Explain how the word you circled relates to the other words in the list.

18 Every Rock Tells a Story

A newspaper headline catches your eye. Some hikers may have found diamonds in a national forest that you visited last summer.



CHALLENGE **How can rocks be used to find minerals?**

MATERIALS

For each student

1 **Student Sheet 18.1, "Anticipation Guide: Roughpoint Story"**

1 **Student Sheet 18.2, "Intra-act Discussion: Roughpoint Story"**

PROCEDURE

Use Student Sheet 18.1, "Anticipation Guide: Roughpoint Story" to prepare you for the newspaper article on the next page.

1. Carefully read the newspaper article on the next page.
2. Mark whether you agree or disagree with the statements on Student Sheet 18.2, "Intra-act Discussion: Roughpoint Story." Predict what you think other members of your group will say.
3. Discuss the statements with your group. Have each person share his or her opinion about each statement and explain why he or she agreed or disagreed.
4. Discuss with your group what you think Ranger Ormond should do next.

   Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain why you disagree.
5. Now complete Student Sheet 18.1. Be sure to explain how the activity provided evidence for your initial ideas or caused you to change your thinking.

Rocky Flats Examiner

Discovery of Diamonds in Roughpoint National Forest?

Two hikers may have found diamonds when they were exploring an out-of-the-way section of Roughpoint National Forest. Victor Lin, one of the hikers, said, "We saw something sparkle in a layer of folded rock halfway up a cliff. The rock layers looked like they had been squeezed together. It was too high up for us to get a sample. We did collect a rock that looked like it had broken off from the upper part of the cliff."

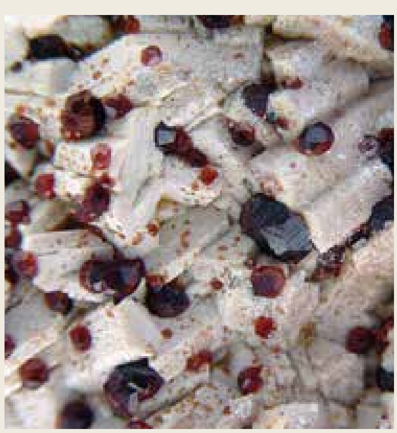
According to Roughpoint Forest Ranger Elisa Ormond, it takes several days of hiking to get to that part of the forest. The only other way to reach it is by helicopter. "Before we spend a lot of time and money going out there, we want to make sure that they could really be diamonds," said Ranger Ormond. "One way to do that is to examine the rock they found. Some minerals are more common in certain types of rocks. For example, diamonds are found in a rock called kimberlite (KIM-berr-lite). If the hikers' rock is kimberlite, there is a greater chance that they saw diamonds."

Ranger Ormond explained why it might matter if the hikers saw diamonds. "There are many different kinds of lands owned by the U.S. government, including national forests, national parks, and wilderness areas. Most of these places allow hiking, camping, hunting, and fishing. Only some of these places allow the removal of natural resources. The government sets different rules for each kind of area. Mining is allowed in Roughpoint, and if diamonds are really there, people will be allowed to collect or mine them."

While rocks can be many different sizes, they are all made up of minerals.

The earth is covered in rocks, and these rocks are made of minerals. **Rocks** are naturally formed solids made up of one or more minerals. Quartz and calcite are two of the more common minerals found in rocks. Most minerals, such as diamond, are rare. Of the more than 2,000 minerals on earth, about 30 are very common. These 30 minerals make up about 90% of the minerals in the earth's crust.

Geologists searching for rare and valuable minerals look for clues to help find them. One clue that geologists sometimes use is their knowledge that some minerals are found in certain rocks. For example, native copper is often found in basalt rock. Because of this, a geologist looking for native copper might be more interested in searching an area containing basalt rock than an area full of kimberlite.



Large crystals of a particular mineral are usually found embedded in rock.

ANALYSIS

1. Look at the table below. It lists some rocks that are more likely to contain certain minerals. Which minerals or rocks do you recognize?

Finding Minerals

Rocks Such As	Can Contain
basalt	native copper
granite, rhyolite	topaz
kimberlite	diamond
marble, travertine	calcite

2. How can rocks be used to find minerals?

3. **a.** Why did the hikers think they saw diamonds?

   b. Think about what you now know about minerals. Besides diamonds, what other minerals could the hikers have seen?

   c. Why might these minerals be mistaken for diamonds?

4. Imagine that the hikers brought back a sample of the shiny mineral they had seen. Describe at least three tests that could be done to identify it.

19 Rock Formation

READING

Roughpoint Forest Ranger Ormond wanted to help the hikers identify their rock. Her plan was to figure out if the rock was kimberlite by using her knowledge of how rocks are formed.

In this activity, you will gather more information on rock formation to help Ranger Ormond identify the hikers' rock.

CHALLENGE

How are rocks formed?

MATERIALS

For each student

1 **Student Sheet 19.1, "Talking Drawing: Rock Formation"**

1 **Student Sheet 19.2, "Directed Reading Table: Rock Formation"**

READING

Use Student Sheets 19.1 and 19.2 to prepare you for the following reading.

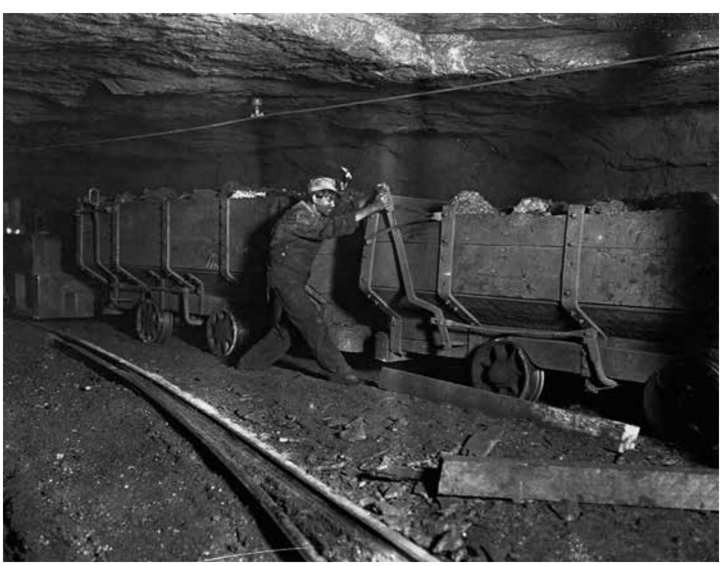
Finding Resources

People have been trying to dig down into the earth for hundreds of years. One reason is to collect more information about the earth itself. Another reason is to gather the natural resources that are found in the earth's crust.

For example, the coal that you examined in Activity 12, "Observing Natural Resources," is mined from the earth's crust. Coal is burned to produce the energy needed to generate electricity. The first coal mines were shallow, but over time, people have had to dig deeper. Modern coal mines are as deep as 1 kilometer (km) below the surface.

Coal: A Sedimentary Rock

Digging deeper doesn't always mean you'll find more coal. Coal is a special type of rock. It formed when large numbers of dead plants in swampy areas collected on top of each other. Over millions of years, these plants were buried by layers of **sediments** (SED-ih-ments). Sediments are parts of rocks, shells, and dead organisms that have been worn down into small pieces, often by the effects of wind and water. When sediments settle on top of each other, they form layers that can eventually harden together. These hard layers form **sedimentary** (sed-ih-MENT-air-ee) rocks. The pressure of these layers on top of the buried plant material caused it to change into coal.



This photo from the 1930s shows a miner deep below the earth. Wagons carrying coal were rolled out of the mine on the tracks.

Some areas of the world have more of one kind of natural resource than other areas. Coal is found all over the world, though the United States, China, and India are three countries that have a lot of buried coal. Because coal is burned to produce electricity, countries that have a lot of coal usually sell it to countries that have less. The cost of a ton of coal can range from $17 to $60, with an average price of about $46 per ton.

The most common igneous rock on earth is basalt (buh-SALT). It forms as iron- and magnesium-rich lava cools and solidifies.

Kimberlite and Pumice: Igneous Rocks

Igneous (IG-nee-us) rocks form when very hot, "liquid rock," called **magma** (MAG-muh), cools down enough to solidify. Kimberlite, which you are familiar with from previous activities, is an igneous rock that can contain diamonds. The value of kimberlite depends on whether it contains diamonds. When it does, the size, quantity, and quality of the diamonds can change its value. Magma is usually found deep inside the earth. Sometimes magma cools within the earth's crust and forms intrusive igneous rocks, such as granite. We can find intrusive rocks when the natural forces of uplift and erosion expose them at the surface. We can also find them by digging mines below the earth's surface.

Sometimes magma erupts from volcanoes and cools on top of the earth's crust. This forms extrusive igneous rocks, such as pumice. Pumice is a natural resource that is a key ingredient in various products, including lightweight concrete, cosmetics, and abrasives (such as pencil erasers, toothpaste, and facial scrubs.) The price of pumice depends on the type and quality needed for a product. It can range from less than $20 to more than $100 per metric ton. Igneous rocks are found all over the world, including the United States.

Marble: A Metamorphic Rock

All types of rocks can become buried in the deeper layers of the earth's crust. These deeper layers are under more pressure and are hotter than the surface. Over time, high temperature and/or high pressure can cause one rock to change into another. For example, limestone, a soft sedimentary rock, can become marble, a much harder rock.

The outside of the Washington Monument in Washington, D.C. is made from white marble from the state of Maryland.

Rocks that have changed because of heat and/or pressure are known as **metamorphic** (met-uh-MOHR-fik) rocks. People use many metamorphic rocks, such as marble, in their homes and other buildings because of their beauty and strength. Marble can be found naturally all over the world in countries such as Belgium, France, and the United States. On average, the cost of marble is about $200 per ton, depending on its quality.

People continue to dig into the earth's crust to gather natural resources and learn more about this planet. As they go deeper, they too are faced with the challenge of handling high temperatures and pressures. How far down will humans be able to mine safely? Only time will tell.

Finding Fossils in Sedimentary Rock

Most fossils are found in sedimentary rocks. Fossils are often formed during the gradual layering of sediments such as sand. For example, when a plant or animal died millions of years ago, sometimes it quickly became covered with a layer of sand or mud. If the soft remains of the plant or animal broke down, leaving an imprint of its shape (or its shell) in the rock, it became a fossil. You examined this type of fossil in Activity 12, "Observing Natural Resources."

In other cases in which fossils were formed, the organic material of the plant or animal was slowly replaced with minerals, creating a rock that shows details of the dead organism. There are all kinds of fossils in countries all over the world, but they are not always easy to find.

The cost of fossils varies even more than the price of coal. Some fossils are inexpensive enough to be sold by weight, with hundreds of fossils costing only a few dollars. In other cases, a single fossil can cost thousands of dollars. The price of fossils can go into the millions when everyone wants the same fossil. Factors that influence the cost of a fossil include its quality and rarity. Regardless of its price, each fossil provides information about the life that has existed on earth.

ANALYSIS

1. What are the three different ways in which rocks can form?
2. Why is coal a non-renewable resource?
3. Copy the three lists of words shown below.

List 1	**List 2**	**List 3**
heat	magma	rock formation
pressure	igneous	sedimentary
kimberlite	volcano	metamorphic
metamorphic	sediments	plastic

   a. In each list, look for a relationship among the words. Cross out the word or phrase that does not belong.

   b. In each list, circle the word or phrase that includes all the other words.

   c. Explain how the word or phrase you circled is related to the other words in the list.

4. Create a concept map using the following 14 words.

coal	marble
fossils	metamorphic
igneous	sedimentary
layers	rock
kimberlite	volcanoes
magma	temperature
minerals	pressure

5. Do you think fossils are still being formed on earth? Why or why not?
6. **Reflection:** Do you think the cost of an object reflects its true value? Why or why not?

20 Identifying Rock Types

Ranger Ormond took the hikers' rock back to forest headquarters. She wanted to know whether it was an igneous rock like kimberlite. Igneous, metamorphic, and sedimentary rocks often look different from each other because they are formed differently.

Ranger Ormond wanted to compare the hikers' rock to samples of igneous, sedimentary, and metamorphic rocks that were stored at headquarters. Unfortunately, the labels became separated from the rock samples. Can you help her figure out which rock is which?

CHALLENGE

How well can you identify different rock types?

MATERIALS

For each group of four students

1 **rock sample collected by the hikers**

8 **rock samples**

For each pair of students

1 **magnifying lens**

For each student

1 **Student Sheet 20.1, "Rock Data"**

PROCEDURE

Part A: Identifying Rock Types

1. Working with your partner, use the magnifying lens to examine a rock sample. Note: When making your observations, ignore the spot of paint used to help identify the rock.
2. Compare the rock to the identifying characteristics shown in Table 1, below.

Table 1: Rock Characteristics

Rock Type	Formed by	Some Identifying Characteristics
Igneous	cooling of magma	Surface can be as smooth as glass. OR Individual crystals can be large enough to be seen by the human eye. If crystals are visible, they often appear to interlock, like pieces of a puzzle.
Sedimentary	tiny rock pieces cementing together	Can contain fossils. Can sometimes see or feel individual sediments such as sand or pebbles. Can be more crumbly than other rock types. Can sometimes feel lighter than other rock types.
Metamorphic	high heat and/or high pressure of the earth	Often may see bands, like the rock was pressed together. Bands may be the same or different colors. Crystals may be very small and hard to see.

Crystal size

● large

· small

3. Discuss with your partner which identifying characteristics the rock appears to have. You may want to compare the size of crystals in the rock to the figure on the left.
4. Record these observations on Student Sheet 20.1, "Rock Data." Focus on those observations that help you identify it is as either an igneous, metamorphic, or sedimentary rock.
5. Identify the rock as being igneous, sedimentary, or metamorphic on Student Sheet 20.1.
6. Repeat Steps 1–5 until you have examined all eight rock samples.

Part B: Identifying the Hikers' Rock

7. Your teacher will now give you a sample of the rock collected by the hikers.
8. Work with your group to compare the rock with the identifying characteristics shown in Table 1 on the previous page.

   Hint: Your samples may contain garnets, which are large reddish-brown crystals. When examining crystal size, ignore the garnets and focus instead on the size of the crystals in the rest of the rock.
9. Record your observations of the hikers' rock on Student Sheet 20.1.
10. Identify the hikers' rock as being igneous, sedimentary, or metamorphic on Student Sheet 20.1.

ANALYSIS

1. Do all rocks of the same type, such as all igneous rocks, look the same? Support your answer with evidence from your observations.
2. What characteristic was most useful in identifying each type of rock listed below? Explain.
   a. igneous
   b. metamorphic
   c. sedimentary

3. Help Ranger Ormond identify the hikers' rock by examining the table below.

Table 2: Comparing Rocks

	Kimberlite	Garnet Schist
Rock type	igneous	metamorphic
Color	gray	gray
Contain garnets?	sometimes	yes (but not always visible in every sample)
Contain diamonds?	yes (but not always in every sample)	no

a. Based on your observations of the rock sample, which rock do you think the hikers found?

b. Support your answer with evidence from your investigation.

c. Could the hikers have seen diamonds? Explain.

4. Imagine having to identify another rock. Which of the following facts would be the most helpful to you? Explain your reasoning.

The rock is light gray in color.

The rock is shiny.

The rock was found high on the slope of an extinct volcano.

The rock is small enough to fit in a kid's hand.

EXTENSION

Bring in any rocks you may have collected to share with your class. Compare your rocks to other rocks that students have brought to class. What similarities and differences do you observe among the rock samples? Are you able to identify how each rock was formed?

21 Modeling Rock Layers

MODELING

Victor Lin, one of the Roughpoint Forest hikers, said he saw "something sparkle in a layer of folded rock halfway up a cliff. The rock layers looked like they had been squeezed together."

All types of rocks—sedimentary, metamorphic, and igneous—can be found in layers on the earth's surface. In Unit A, "Studying Soils Scientifically," you learned that soils are found in layers. Below these layers is bedrock. Bedrock can be made up of many rock layers. In this activity, you will model the formation of layers made up of sedimentary rock.

CHALLENGE

Which rock layers are the oldest?

You can see layers of sedimentary rocks at the Grand Canyon in the western United States.

You may also see rock layers alongside roads that have been built in hilly areas.

MATERIALS

For each pair of students

1	clock with a second hand
1	50-mL graduated cylinder with base
1	metric ruler
20	light brown game chips
20	dark brown game chips

PROCEDURE

1. Make a table like the one shown below.

Forming Rock Layers

	Time	Height of Rock Layer (in cm)
Rock Layer A	15 seconds	
Rock Layer B	15 seconds	

2. You will use chips to represent sediments. Each person should use chips of a single color. Decide which chip color you will use during this activity.

3. Use one hand to hold the base of the graduated cylinder to keep it steady. Use your other hand to practice picking up one "sediment" at a time and placing it in the cylinder while your partner counts how many "sediments" you put in.

4. Switch roles and have your partner complete Step 3.

5. Empty the cylinder.

6. The first person placing sediments in the container will form Rock Layer A. With your partner acting as the timer, try to put as many sediments as you can into the cylinder in 15 seconds. Be sure to pick up one sediment at a time and to use only one hand to put the sediment in the cylinder. (You can use your other hand to hold the base of the cylinder steady.)

7. Switch roles and have your partner complete Step 6. Your partner will form Rock Layer B.
8. Use a ruler to measure the height of each "rock layer" in centimeters (cm).
9. Share your data for each layer with the class.
10. Record the class range of rock layer heights.

ANALYSIS

1. a. Was the thickness of the rock layers always the same?

   b. Which rock layer—A (on the bottom) or B (on the top)—formed first?

2. Look again at the photo on page B-41 showing rock layers at the Grand Canyon. Which layer (the highest or lowest) is most likely to be the oldest? How do you know?

3. Look at the diagram of rock layers at left. Imagine digging through the rock layers shown in the diagram. As you dig, you find fossils! The S marks the place where you find a snake fossil. The F marks the place where you find a fish fossil.

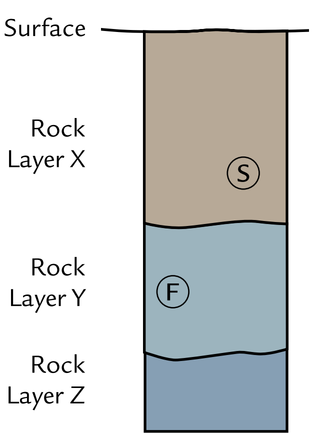


FIGURE 1: DIGGING DOWN

   a. Which fossil—snake or fish—is most likely to be older? Explain how you came to this conclusion.

   b. In a nearby area, coal has been found in a rock layer that is younger than the rocks containing fish fossils. Knowing this, in which rock layer would you first look for coal? Explain.

4. Do you think placing chips in a graduated cylinder was a good model of how rock layers form? Describe the strengths and weaknesses of this model.

5. Sometimes very old rocks are found on the earth's surface. How do you think this may have happened?

EXTENSION

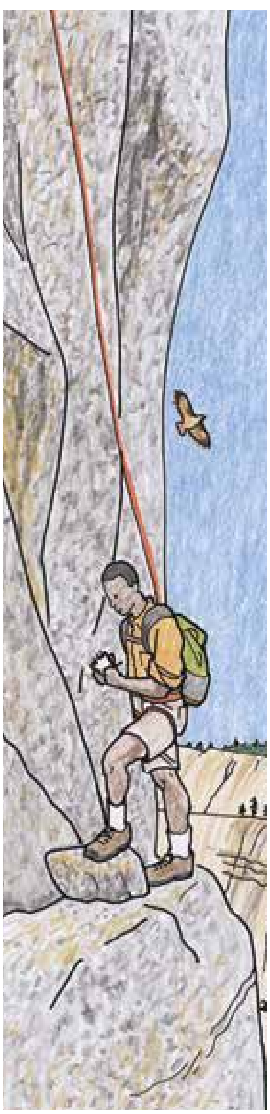
In Question 4, you identified the strengths and weaknesses of this model. Design a different model or explain how you would change this model to better represent rock layering.

22 The Rock Cycle Game

Granite, marble, and coal are all rocks that people use and value. Where did they come from? The surface of the earth has been forming for billions of years, and is still forming today. It contains a variety of rocks. Geologists can identify these rocks by name, such as granite or marble. They also group rocks based on how they formed: igneous, metamorphic, and sedimentary. In this activity, you will learn more how one type of rock becomes another. This process is known as the **rock cycle**.

CHALLENGE

Where do rocks come from?



MATERIALS

For each group of four students

- 1 **Rock Cycle Game board**
- 1 **set of 30 Igneous Rock cards**
- 1 **set of 30 Metamorphic Rock Cards**
- 1 **set of 30 Sedimentary Rock Cards**
- 1 **set of 9 Earth Process Cards**
- 4 **game pieces**
- 1 **number cube**

For each student

- 1 **Student Sheet 22.1, "Geologist's Notes"**

PROCEDURE

1. Carefully look at Student Sheet 22.1, "Geologist's Notes." During the activity, you will use this student sheet to keep track of what happens to your rocks and to explain how you gathered more rocks.
2. Review the Materials list to make sure you have the materials you need.
3. Give each player 9 Rock cards: 3 Igneous Rock Cards, 3 Metamorphic Rock Cards , and 3 Sedimentary Rock Cards. Sort the remaining Rock Cards by rock type and place them on the game board in three separate stacks.
4. Place the Earth Process Cards face down on the game board in a single stack.
5. Place each person's game piece on the Start space.
6. Begin the game by having each person roll the number cube. The person with the highest number should start the game.
7. The first person should toss the number cube and move that number of spaces on the game board. When someone lands on an Earth Process Space, he or she should pick up an Earth Process Card and follow the directions. After reading a card, replace it face down at the bottom of the stack.
8. Continue taking turns and playing the Rock Cycle Game. Remember, each person should record what happens to their rocks on Student Sheet 22.1. All new rocks should also be recorded on this sheet.
9. Stop playing when the second person crosses the Start space again.
10. Work with your group to use your student sheets to answer Analysis Questions 1–5.

ANALYSIS

1. How do igneous rocks form?

   Hint: On Student Sheet 22.1, look at what caused you to collect a new igneous rock or caused some rocks to become igneous. Combine your results with the other members of your group.

2. How do sedimentary rocks form?

   Hint: On Student Sheet 22.1, look at what caused you to collect a new sedimentary rock or caused some rocks to become sedimentary. Combine your results with the other members of your group.

3. How do metamorphic rocks form?

   Hint: On Student Sheet 22.1, look at what caused you to collect a new metamorphic rock or caused rocks to become metamorphic. Combine your results with the other members of your group.

4. Look at the three rock type columns on Student Sheet 22.1. Work with your group to identify the types of rocks that can become:

   a. igneous

   b. sedimentary

   c. metamorphic

5. Make a list of the forces that caused rocks to change from one type to another.

   Hint: On Student Sheet 22.1, look at what caused you to lose rocks. Combine your results with the other members of your group.

6. Create a diagram using words and arrows to describe the relationship between igneous, sedimentary, and metamorphic rocks.

7. Where do rocks come from? Explain your answer.

23 Making Minerals

Natural resources like rocks and minerals have been formed on earth over time. Most people would consider them to be non-renewable. But what happens when people have the technology to create diamonds? How does this affect their value?

CHALLENGE

How do diamonds made in a lab compare to diamonds mined from the earth?

Mining for natural resources can have a big impact on the natural environment.

MATERIALS

For each student

1 **Student Sheet 23.1, "Discussion Web: Making Minerals"**

PROCEDURE

1. Work with your group to read about mined and manufacturerd diamonds on pages B-49–52.

2. Each person in your group will play the role of a different person. Decide which person in your group will be:
   - Simon, who is planning to buy a ring containing a large diamond
   - Anna, who owns a company that sells mined diamonds
   - Kendra, who owns a company that makes manufactured diamonds
   - Mo, who is a geologist with the U.S. Forest Service

3. Have each person from your group attend a meeting with other people playing the role of the same person.

4. At the meeting, discuss the following questions with your group. Answer the questions as if you are the person that you are role-playing. Remember to listen to and consider the ideas of other members of your group. If you disagree with others in your group, explain why you disagree.
   - Compare the information about mined and manufactured diamond gemstones in the table on page B-52. What is the same? What is different?
   - Which type of diamond gemstone—mined or manufactured—is more valuable?
   - What are the most important factors in determining the value of a diamond gemstone?

5. Return to your original group and explain which diamond the person you are role-playing considers more valuable and why.

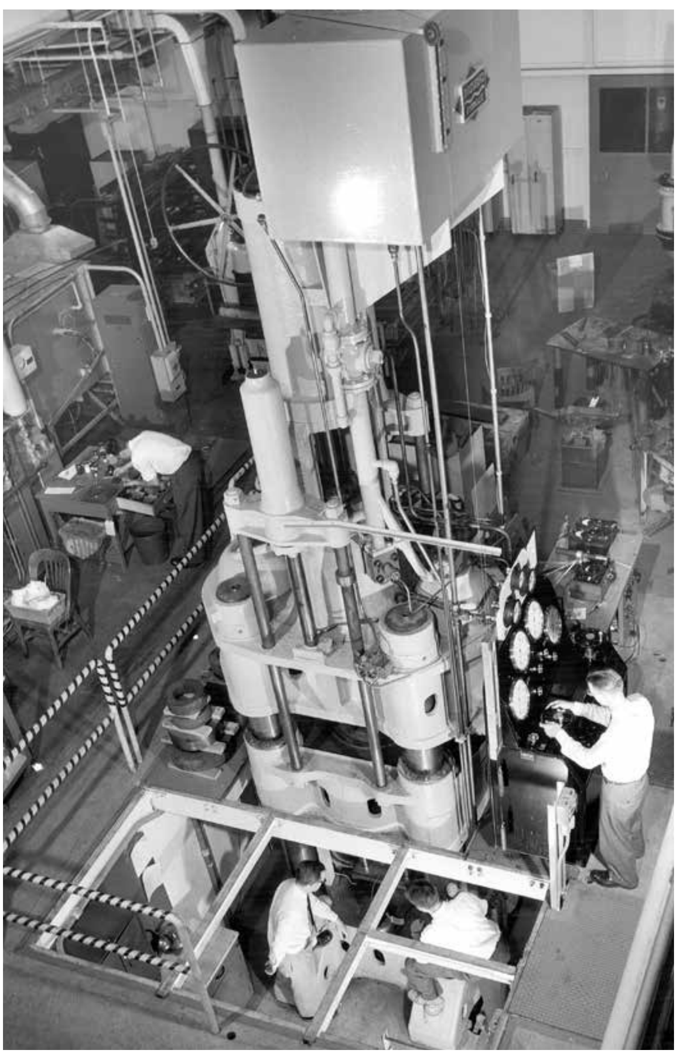
6. As a group, discuss whether manufactured or mined diamond gemstones are more valuable. Use Student Sheet 23.1, “Discussion Web: Making Minerals,” to record reasons why one type of diamond might be considered more valuable than the other.

MINED AND MANUFACTURED DIAMONDS

Imagine Russian scientists renting rooms so they can have a place to make large diamonds. Or a Gem Defense Program in England that looks for ways to distinguish large diamonds mined from the earth from those made in labs. Maybe the Gem Defense lab invents machines that can be used to tell these diamonds apart. Or uses lasers to label mined diamonds with the company name and logo. Sound like fiction? It's all true.

Some companies use materials that resemble diamonds to create diamond look-alikes. These materials include glass, plastic, cubic zirconia, and moissanite (MOY-sun-ite). They share certain properties with diamonds, such as transparency and luster, but not properties such as hardness or crystal shape. These materials are not diamonds.

For most of human history, the only diamonds that existed were those that were mined from the earth. In the 1950s, U.S. scientists at General Electric (GE) discovered a way to make diamonds. Diamonds are made of carbon, and so is the mineral used in pencil lead: graphite (GRAH-fyte). The GE scientists put graphite into machines that could produce high temperatures and pressures, and made diamonds synthetically. Most of these diamonds were small in size and were used for diamond-tipped cutting saws and other commercial applications. Today, 90% of the small diamonds used in industry are made in laboratories.



In the 1950s, GE scientists used this machine (in the center of the photo) to create the high pressure and temperature needed to make small commercial diamonds.

Properties of Diamond Gemstones

Now, a new generation of scientists is discovering less expensive ways to make diamond gemstones, the large diamonds used in jewelry. One lab can make a 3-carat yellow diamond in three days. The world's largest seller of mined diamonds, De Beers LV, says manufactured diamond gemstones are not as valuable as mined diamond gemstones. The companies that manufacture diamonds disagree.

Manufactured diamonds have the same properties as mined diamonds, but are made in a lab instead of being mined. You can compare the properties of these diamonds in the table, "Comparing Diamond Gemstones." The public cannot tell one type of diamond from another by just looking, and only a few diamond experts can identify a manufactured diamond from a mined one without sending it away for special testing.

Manufactured yellow diamonds

Mined diamonds

Comparing Diamonds

De Beers LV has been looking for ways to distinguish between the mined and manufactured diamonds after they are cut and polished. It has not been easy because manufactured diamonds have the same physical, optical, and chemical properties as mined diamonds. The company's Gem Defense Program has identified only one difference so far. They shine a special type of light, known as short-wave ultraviolet light, on a diamond. Nothing happens to mined diamonds, but manufactured diamonds glow in the dark for 3–5 seconds.

Cost is another difference between the two types of diamonds. Impurities cause diamonds to have different colors. For example, yellow diamonds contain the chemical nitrogen. In most cases, absolutely colorless diamonds are the most expensive. But diamonds that have lots of color are also extremely rare in nature and are also very expensive. Gemesis, a Florida-based company that manufactures diamonds, is mostly making large bright yellow diamonds that they sell for about $6,000 per carat. A mined diamond of similar size and color would cost $20,000 or more.

Most diamonds have microscopic imperfections. When jewelers talk about the clarity of a diamond, they are often referring to the number and type of imperfections. Manufactured diamonds often have fewer imperfections than mined diamonds. Some people consider manufactured diamonds "too perfect," especially if the diamond is large and a rare color, such as yellow.

In the early 1950s, the Gemological Institute of America (GIA) developed a diamond grading system that allowed people to compare similar diamonds in order to make a more informed purchase. For a long time, only mined diamonds were graded, but in 2007, GIA began grading manufactured diamonds. Every manufactured diamond that it grades is laser-inscribed with the words "laboratory-grown" so consumers will know what they are buying.

GIA's 4 C's of Diamond Grading	
Color	Ranges from colorless to tinted
Clarity	Ranges from flawless to slightly included (inclusions are flaws, such as air bubbles)
Cut	Refers to how well proportioned the diamond cut is
Carat	Refers to the weight of the diamond (1 carat equals 0.2 g)

You can compare other differences between the two types of diamonds in the table below.

Comparing Diamond Gemstones

	Mined Diamond Gemstones	Manufactured Diamond Gemstones
Where do they come from?	mined from igneous rock in Australia, Canada, Russia, South Africa, and other countries	made in scientific labs in United States and Russia
Color	colorless, yellow, brown, gray, blue, pink, black, green, purple	yellow, colorless, blue, pink, black
Transparency	transparent	transparent
Luster	brilliant (very shiny)	brilliant (very shiny)
Crystal shape	octahedron	octahedron
Hardness	10	10
Made of	carbon atoms	carbon atoms
Amount of time needed to produce	600 million–3 billion years	3–5 days
Equipment needed	large trucks, tunneling machines, explosives, miners	machines, seed crystal, electrical energy, scientists
Environmental impact	requires energy to run drilling machines; about 250 tons of rocks collected and broken apart per diamond gemstone	requires energy to run manufacturing machines
Cost	much more expensive than manufactured diamonds	much less expensive than mined diamonds

ANALYSIS

1. Look at the table above.
   a. Do you think a geologist would consider a manufactured diamond to be a “real” diamond? Why or why not?
   b. Would a geologist consider a manufactured diamond to be a mineral? Why or why not?
2. Are rocks and minerals renewable or non-renewable resources?
3. You’ve decided to buy a large one-carat yellow diamond.
   a. Which type of diamond—manufactured or mined—would you buy?
   b. Support your answer with evidence from the activity.
   c. Identify the trade-offs of your decision.

Erosion and Deposition

C




Erosion and Deposition

When Leah was getting ready for school, it began to rain. "Oh no, there goes our basketball practice again," she thought. "I hope it stops raining by tomorrow."

She ate her breakfast while her mother read the newspaper. "It says here it's going to rain all day today," said her mother. "This is the fourth day in a row. I'll give you a ride to school, but let's leave early. There might be traffic problems because of the rain."

"Thanks, Mom," said Leah, as she grabbed her rain jacket. "Yesterday I walked to school, and I was wet and cold all day."

As they drove along North Street, they had to slow down several times where water had flooded the road. Leah noticed that there was a lot of mud along the curb near the park.

"Where did that mud come from?" she asked.

"I don't know," said her mother, "but it wasn't there before all this heavy rain. It sure has made a mess."

• • •

Where did the mud come from? How was it transported to the road?

In this unit, you will explore the earth processes that move rocks and soil from one place to another. You will learn how they shape the land around you.

24 Where Shall We Build?

Over the last 20 years, the population of Boomtown has been growing steadily. People have built houses and stores on most of the available land. Now, the Boomtown City Council is trying to decide where to build a new development of apartment buildings and houses. Three possible locations for the new homes are being considered.

CHALLENGE

Where should Boomtown construct the new buildings?

MATERIALS

For each group of four students

1 **Student Sheet 24.1, "Street Map of Boomtown Today"**

PROCEDURE

1. Each set of photographs on the next page shows a different location, before and after the construction of buildings. In your science notebook, make a table like the one below.

Observations Before and After Construction

	Appearance Before Construction	Appearance After Construction
Marsh		
Hillside		
Cliff		

2. Carefully examine the photographs, one location at a time. Observe changes before and after the construction in
   - the land
   - the plants and animals
   - the water
3. Discuss these changes with your partner. Then record your observations in your table.
4. After observing the photographs of all three locations, discuss your ideas with the other pair in your group of four. Review your table together and then add any new observations of the three building sites.
5. Examine the map of Boomtown on Student Sheet 24.1, "Street Map of Boomtown Today." Find each of the three sites being considered for the new homes:
   - Delta Marsh
   - Green Hill
   - Seaside Cliff

BUILDING SITES BEFORE AND AFTER CONSTRUCTION


Marsh before


Marsh after


Hillside before


Hillside after


Cliff before


Cliff after

ANALYSIS

1. Marshes, hills, and cliffs are three kinds of landforms. A **landform** is any characteristic physical shape of the earth's surface. Make a list of some other familiar landforms that you can think of that aren't mentioned in this activity.

2. Explain how each of the following places was either changed or not changed by the construction of buildings:

   a. marsh

   b. hillside

   c. cliff

3. Based on what you know so far, on which site do you think Boomtown should build houses? Explain, using the observations that formed your opinion.

4. Explain how the following information about the Delta Marsh, Green Hill, and Seaside Cliffs could help the council make the decision about where to build the new housing.

   a. weather

   b. animals

   c. plants

   d. housing prices

   e. shape of the land

5. **Reflection:** Compare Boomtown to where you live now. How is it similar or different?

25 Making Topographical Maps

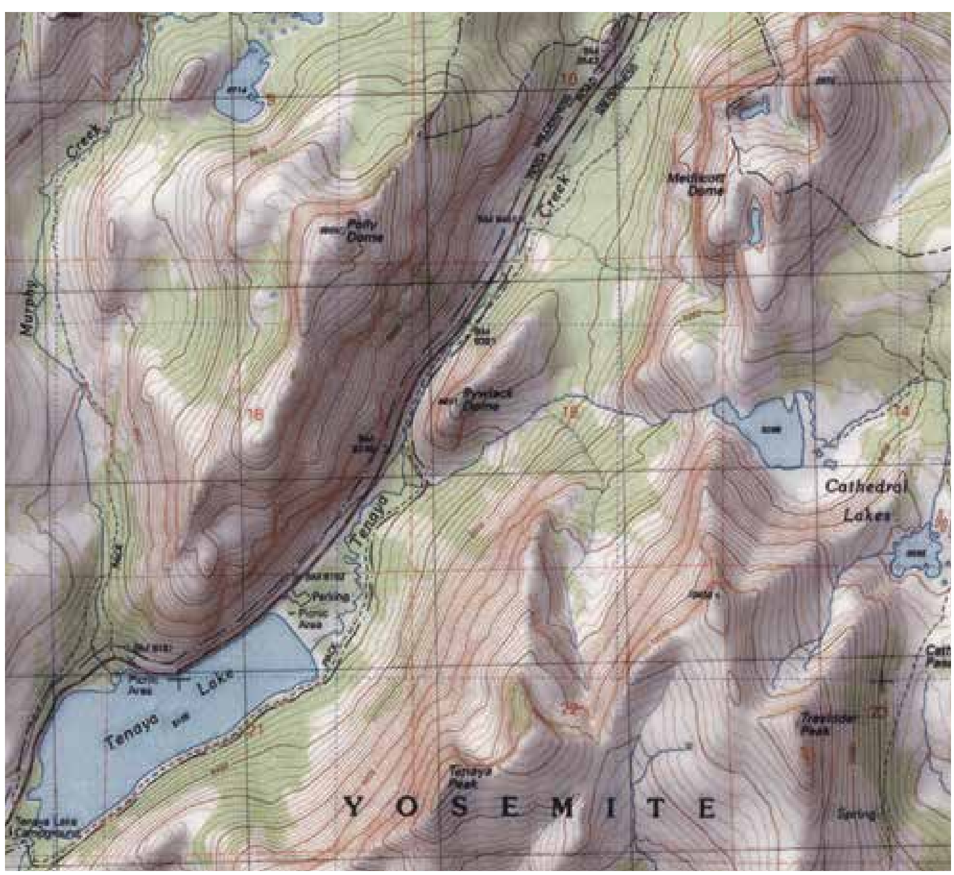
INVESTIGATION

A collection of landforms in an area is called its **topography** (ta-PAH-gruh-fee). In Boomtown, there are many different kinds of landforms that make its topography interesting. For example, the street map of Boomtown shows that it has a hill, river, marsh, cliff, and beach. These landforms can be identified because they are labeled on the street map.

For places that are not clearly named, or where more information about the landform is needed, a **topographical map** is useful. A topographical map uses a series of lines to represent the three-dimensional shape of the land surface. Each line represents a specific elevation (el-a-VAY-shun) above sea level. For example, one line on a topographical map might represent an elevation of 100 meters. Topographical maps can be confusing for those not familiar with them. This activity will help you understand how lines on a topographical map represent the shape of the land.

CHALLENGE

What do the lines on a topographical map show?



This topographical map shows roads, trails, creeks, and lakes in addition to elevation.

MATERIALS

For each group of four students

1 **landform model**
1 **transparent plastic lid**
1 **dry erase marker**
1 **15-mL bottle of blue food coloring**
1 **large container of cold water**

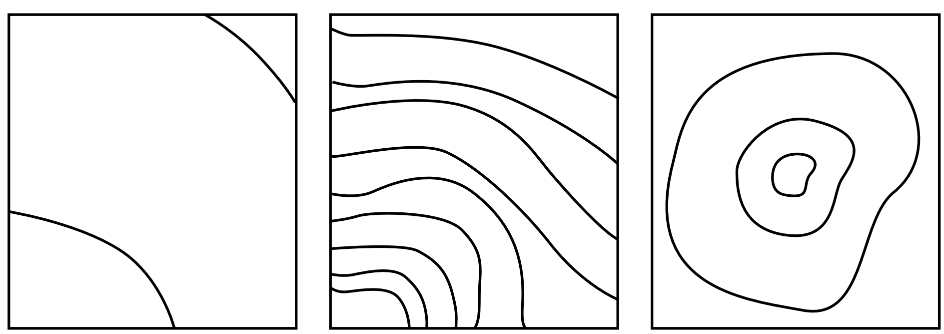
PROCEDURE

1. Place 20 drops of food coloring in your container of water.
2. Place the lid on the box of the landform model and look down at the landform. Use the marker to draw a dashed line on the lid that outlines the edge of the landform.

   Hint: It may help to close one eye when you're viewing the box from above. Make sure to keep your head in one place while you're drawing the line.
3. Being careful not to smudge your line, remove the lid and fill the box with water until it reaches the first step on the side of the box.
4. Place the lid on the box and then use the marker to draw at least one line that shows where the water reaches the sides of the landform.
5. Label any line you draw with a "1."
6. Add water until it reaches the next step, and repeat Steps 2–4. Label the line(s) drawn with water filled to the second step with a "2."
7. Add water to the levels of the third, fourth, and fifth steps of the box, repeating Steps 2–4 each time. Label the lines "3," "4," and "5."
8. Watch carefully as you add just enough water to cover the top of the landform. Use your observations to place an "X" on the lid above the highest point.

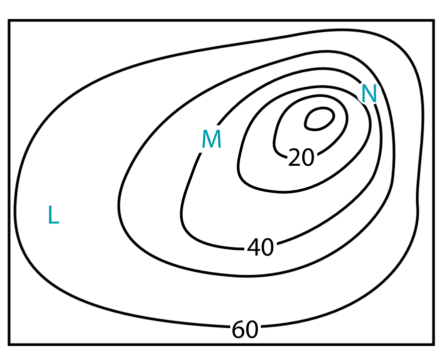
ANALYSIS

1. A **contour interval** is the change in elevation between adjacent lines. If each water line in your landform model represents 25 meters, what is
   a. the contour interval for your topographical map?
   b. an estimated height of the top of the hill?
2. a. What does your topographical map show you about the land?
   b. What does your topographical map *not* show you about the land?
3. Compare the following diagrams that were each drawn with the same contour interval and scale.
   a. Which one shows a fairly flat area?
   b. Which one shows a hill or a valley with a gentle slope?
   c. Which one shows a steep hillside?



x y z

4. Look at the diagram below and answer the following questions.
   a. What kind of landform is this?
   b. Which of the locations marked on the map is the steepest?
   c. Which of the locations marked on the map is the flattest?



26 Boomtown's Topography

An important part of evaluating a building site is determining the stability of the land. Stable areas have landforms that have not changed much over a long time. One way to learn about recent changes to the land surface is to compare the present day topography with past topography.

Although Boomtown has grown quickly in the last twenty years, it was only a small town one hundred years ago. The Boomtown Library has maps that can show you how the area looked in the past.

CHALLENGE

What can topographical maps tell you about the stability of a building site?

MATERIALS

For each pair of students

1 **Student Sheet 26.1, "Maps of Boomtown 100 Years Ago"**
1 **Student Sheet 26.2, "Maps of Boomtown 20 Years Ago"**
1 **Student Sheet 26.3, "Maps of Boomtown Today"**

PROCEDURE

1. Each student sheet shows a street map and a topographical map of Boomtown at different times: 100 years ago, 20 years ago, and today.
2. In your science notebook, make a table like the one below.
3. Carefully examine the maps and compare one location at a time.

Boomtown through Time

Location	100 years ago	20 years ago	Today
Marsh			
Hillside			
Cliff			

Observe changes in

- roads and buildings
- waterways
- landforms

4. Discuss any changes you see in the maps with your partner. Record your observations in your table.
5. After observing all the maps, discuss your ideas with the other pair in your group of four. Review your table together and add any new observations of the three building sites.

ANALYSIS

1. What is the contour interval in the topographical maps of Boomtown?

2. a. What major changes did you observe between 100 years ago and 20 years ago?

   b. What major changes did you observe between 20 years ago and today?

3. Look at the maps of the three locations in Boomtown.

   a. Which of the three locations is the most stable?

   b. Which of the three locations is the least stable?

   c. Explain the evidence that supports your answers to 3a and 3b above.

4. Do the maps indicate possible problems for building at any of the possible locations?

27 Investigating Boomtown's Weather

PROBLEM SOLVING

The shapes of landforms are affected by flowing water. Water comes from several sources, including rain, river flow from mountains, and ocean waves hitting the beach.

One hundred years ago, the Boomtown historian wrote about the Rolling River flooding from heavy rain. The area had 30 centimeters (12 inches) of rain in one month, most of which fell during one week. Main Street was covered with water! The base of Green Hill was flooded, Delta Marsh was full of water, and Seaside Cliff had streams running off its edge.

Flooding from such storms could create problems for housing built at these locations. Looking at the history of Boomtown's average rainfall will help you determine the risk of future flooding.

CHALLENGE

Is Boomtown's rainfall likely to cause flooding?

MATERIALS

For each student

graph paper
1 ruler

PROCEDURE

1. Use the data in Table 1 below to make the following calculations.
   a. Calculate the mean annual rainfall for this 10-year period. **Hint:** Calculate the **mean** by adding up all of the values and dividing by the total number of values.
   b. Calculate the mode for annual rainfall for this 10-year period. **Hint:** The **mode** is the value that appears most often.
   c. Calculate the median annual rainfall for this 10-year period. **Hint:** The **median** is the middle value after the data has been listed from smallest to largest OR largest to smallest. If the data has an even number of values, then the median is the average (the mean) of the two middle values.
2. Use the data in Table 1 to make a bar graph of Boomtown's annual rainfall in centimeters.
3. Draw a horizontal line across your graph to show the mean annual rainfall. Label the line, "Mean: annual."

Table 1: Annual Rainfall in Boomtown: 2002–2011

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Rainfall (centimeters)	92	99	89	94	94	84	97	85	94	72
Rainfall (inches)	36	39	35	37	37	33	38	33	37	28

Data provided by Boomtown Weather Service

Table 2: Average Monthly Rainfall in Boomtown: 2002–2011												
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Rainfall (centimeters)	7	10	7	3	3	0	0	3	7	7	25	20
Rainfall (inches)	3	4	3	1	1	0	0	1	3	3	10	8

Data provided by Boomtown Weather Service

4. Use the data in Table 2 above to make the following calculations.
   a. Calculate the mean monthly rainfall.
   b. Calculate the mode monthly rainfall.
   c. Calculate the median monthly rainfall.
5. Use the data in Table 2 to make a bar graph of Boomtown's average monthly rainfall in centimeters.
6. Draw a horizontal line across your graph to show the mean monthly rainfall. Label the line, "Mean: monthly."

ANALYSIS

1. Look at the graphs of annual and monthly rainfall in Boomtown. Describe any patterns that you see in the rainfall.
2. a. Is there anything unusual about Boomtown's annual rainfall? Explain.
   b. Is there anything unusual about Boomtown's monthly rainfall? Explain.
3. During the same year, a town in California and a city in Maryland both received about 99 cm (39 inches) of rain. In August, the town in California had less than one centimeter of rain while the city in Maryland had 7 cm (3 inches). Explain how these two places could have the same annual rainfall.
4. Which location—Delta Marsh, Green Hill, or Seaside Cliff—would be most affected by
   a. a year of typical rainfall in Boomtown? Explain.
   b. another flood in Boomtown? Explain.
5. **Reflection:** How does Boomtown's rainfall pattern compare to that of your community?

EXTENSION

Use the data in Table 3 below to make a bar graph of Boomtown's monthly rainfall in 2001, in centimeters. Compare it to the graphs you made in this activity.

a. How was the annual rainfall in 2001 both similar to and different from Boomtown's annual rainfall from 2002 through 2011?

b. How was the monthly rainfall pattern in 2001 both similar to and different from Boomtown's average monthly rainfall from 2002 through 2011?

Table 3: Monthly Rainfall in Boomtown in 2001

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Rainfall (centimeters)	0	6	7	7	7	0	0	7	7	5	15	11
Rainfall (inches)	0	2	3	3	3	0	0	3	3	2	6	4

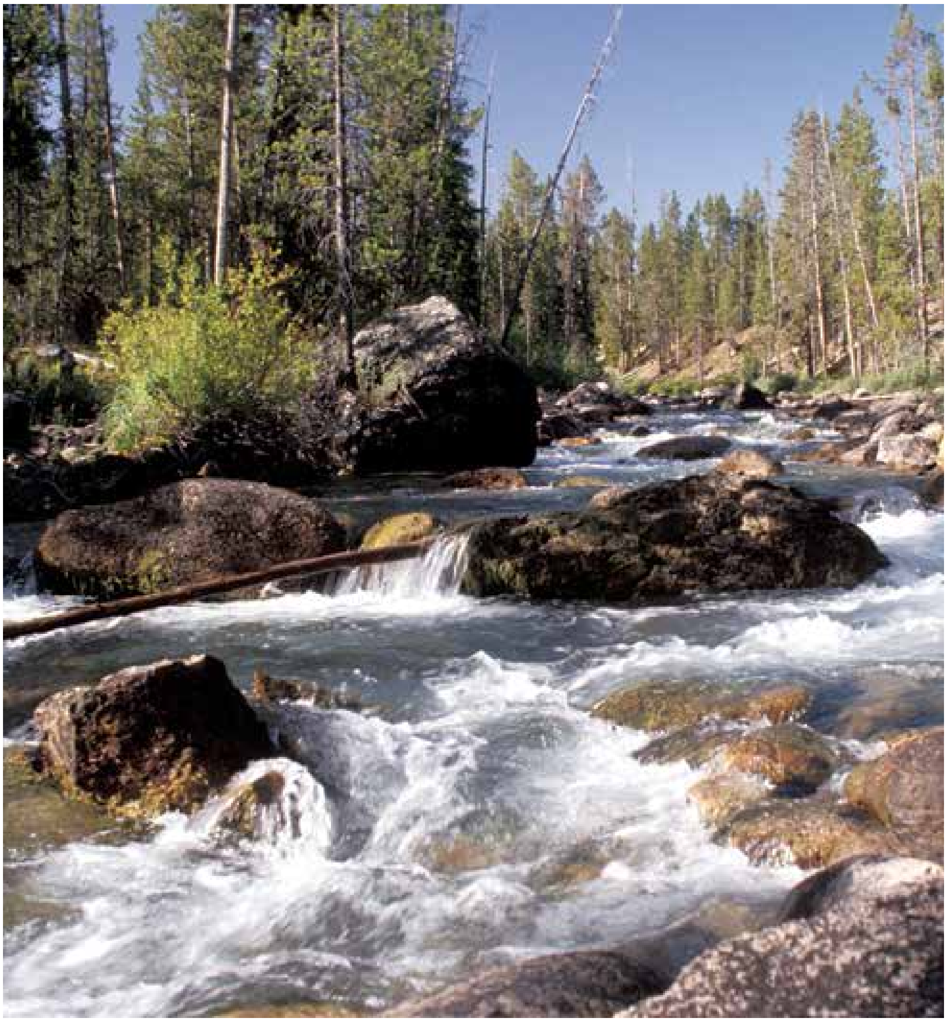
Data provided by Boomtown Weather Service

28 Cutting Canyons and Building Deltas

MODELING

Rivers carry water that is flowing from a higher elevation to a lower elevation. While it travels, water breaks apart and carries away small pieces of rocks and soil. The flowing water carries these sediments downhill until the water can't carry them anymore and they are dropped to the ground again. The water drops these sediments in places where they pile up and create new land.

CHALLENGE **How can moving sediments create problems for construction?**



MATERIALS

For each group of four students

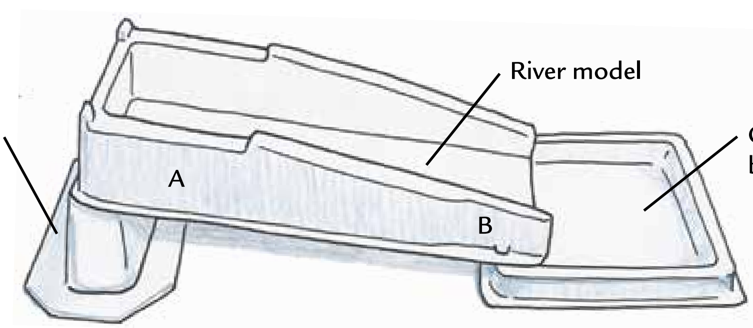
1 river model
1 river model stand
1 river model catch basin
1 rainmaker
1 50-mL graduated cylinder
1 spoon
1 30-mL graduated cup
supply of sand
supply of water
paper towels

For each student

1 Student Sheet 28.1, "River Model Drawings"

PROCEDURE

1. Set up the river model as shown below.

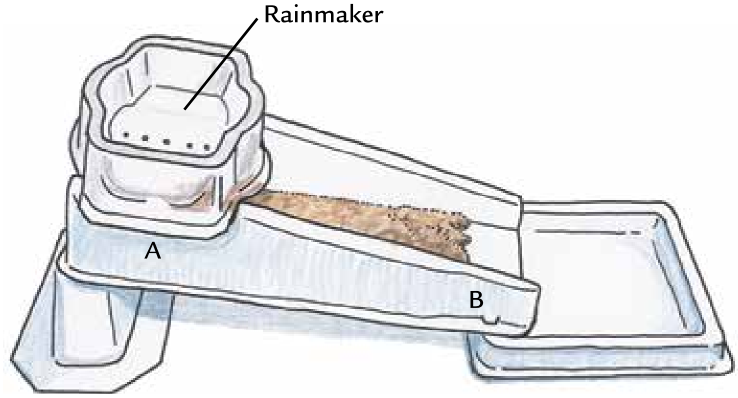


2. Use Student Sheet 28.1, "River Model Drawings," to predict what will happen to the sand and water when water is allowed to flow down the river model. Draw your ideas on the left-hand diagram labeled "Prediction."

3. Using the 30-mL graduated cup, put 3 full cups of sand into the river model between Point A and Point B.

4. Use your fingers or the spoon to pack the sand into a uniform layer that covers the bottom of the river model between Point A and Point B.

5. Place the rainmaker over Point A of the river model, as shown below.



6. Add 50 mL of water to the rainmaker.
7. Observe the effect of the water on the sand. Make sure to watch not only what happens in the river model, but also what happens in the catch basin.
8. Repeat Steps 6 and 7 two more times.
9. On Student Sheet 28.1, draw the water and shape of the sand on the diagram labeled "Observations." Label the diagram as completely as you can.

ANALYSIS

1. a. How is your river model like a real river?

   b. How is it **not** like a real river?

2. Describe the biggest changes that you observed during the river model investigation.

3. Observe the photograph at right. It shows a river at the bottom of a canyon with hard rock walls.

   a. Explain how the water flowing down the river created the canyon.

   b. Explain what happened to the rock that once filled up the canyon.

4. How did the movement of sediments help make each of the following landforms?
   a. marsh
   b. hillside
   c. cliff
5. How could the movement of sediments cause a problem if someone builds on:
   a. Delta Marsh
   b. Green Hill
   c. Seaside Cliff

EXTENSION

Investigate how the steepness of the land affects the movement of sediments in the river model. Model a steeper hill by placing a book or books under the base of the river model and then repeat the investigation. Compare your results from the steeper slope with those from the less steep slope.

29 Weathering, Erosion, and Deposition

READING

Earth processes are dynamic actions that occur both on the earth's surface and inside the earth. Any process that breaks down earth material, such as water eroding the side of a hill, is called a **destructive** process. Processes that build up earth material, such as the deposition of sediments that create landforms such as deltas, are called **constructive** processes.

Destructive forces are not always harmful and constructive forces are not always helpful. The effect of natural earth processes depends on the situation. Before building, it helps to understand how certain earth processes affect the land you plan to build on.

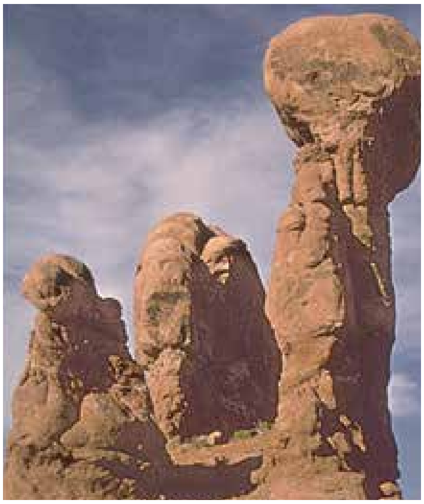
CHALLENGE

What happens when soil and rocks are moved from one place to another?

MATERIALS

For each student

1 **Student Sheet 29.1, "Three-Level Reading Guide: Weathering, Erosion, and Deposition"**



Destructive earth processes helped form these towers of rock, called hoodoos, in Arches National Park.

In Alaska, where this river meets a lake, constructive earth forces built up a delta.

READING

Use Student Sheet 29.1, "Three-Level Reading Guide: Weathering, Erosion, and Deposition," to guide you as you complete the following reading.

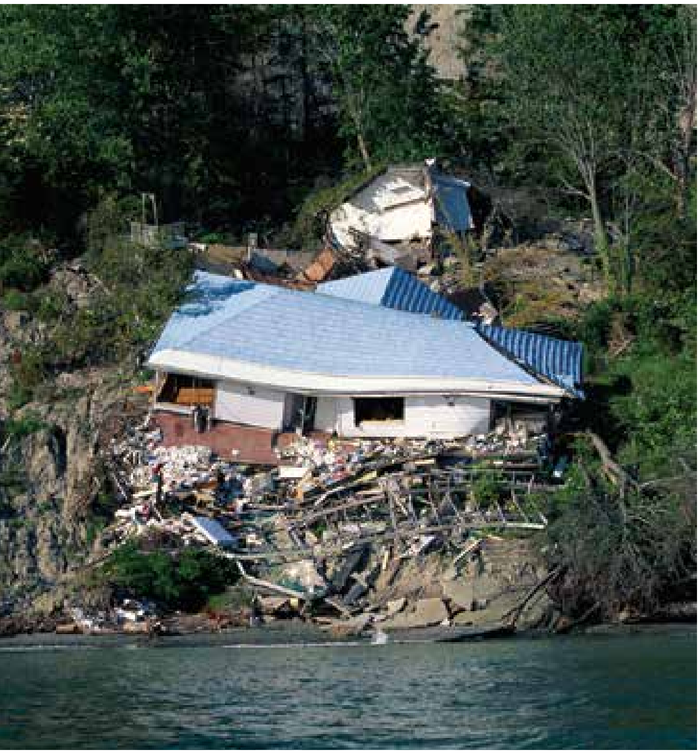
The Process of Weathering

One earth process that breaks down rocks into smaller pieces is called **weathering.** Over time, rocks crack, crumble, and are broken apart by water and wind. Drops of water on a rock may repeatedly freeze and melt, causing the rock to crack. Water may react with some of the chemicals in a rock and cause part of the rock to break down. Rocks sometimes fall from higher places, breaking as they fall. Small animals and the roots of plants also contribute to the weathering of rock when they burrow into the ground. Weathering forms sediments that can be moved by wind and water.

The Process of Erosion

The movement of sediments from one place to another by water, wind, or ice is called **erosion** (e-ROW-shun). When water erodes the earth's surface, it cuts into the ground, forming surface channels. These channels can range from tiny depressions in the earth to huge canyons, such as the Grand Canyon. Slow and steady water erosion over long periods of time has created valuable features of the earth's landscape such as lakes, rivers, hills, canyons, and fertile plains.

Natural events, such as the floods from storms and tsunamis, often cause more dramatic erosion. Shorelines have shifted and rivers have changed their courses as a result of these events. Glaciers—large sheets of snow and ice—also bring erosion. The glacier's weight causes it to move slowly, scraping away the surface of land.



This house was destroyed when the land under it collapsed.

Results of Erosion

Erosion forms important landforms, but it can also be damaging. Serious problems occur when land quickly collapses or slides near buildings or roads, as shown at left. Slower erosion can also cause damage to roads and buildings. A hillside that erodes over many years can cause buildings on it to shift or be in danger of toppling over. Erosion near a road can cause rocks and sediments to suddenly move onto the road. Even worse, the road itself could eventually erode.

Erosion also creates caves. Ocean waves that crash into sandstone or limestone wear pockets of the rock away. Other caves are caused by rainwater that seeps into the earth. Rainwater picks up carbon dioxide from decaying plants and animals, forming a weak acid. This acid dissolves limestone, forming a cave. As the carbon dioxide evaporates, calcium carbonate leaves cone-shaped structures that hang from the roof (stalactites) or project from the floor (stalagmites) of the cave.

Glaciers caused these landforms in Yosemite National Park.

The projections from the roof (stalactites) and floor (stalagmites) in this cave formed from calcium carbonate left behind when carbon dioxide evaporated from the cave.

The Process of Deposition

When erosion carries sediments from one place to another, the sediments are left, or *deposited* somewhere else. This earth process is called **deposition** (de-puh-ZI-shun). It occurs when pieces of rock or soil settle out of flowing water, ice, or wind as they slow down. The rocks and earth materials that a glacier picks up are often deposited far away from their source. The processes of erosion and deposition are closely related because erosion moves the sediments that are eventually deposited. A delta at the mouth of a river is an example of a landform formed by deposition.

In some cases, deposited sediments can be helpful. For example, sediments add important nutrients to the soil. The Mississippi and Nile River valleys have large fertile **floodplains** that are excellent for growing crops. These plains have been formed by the deposition of sediments that occurs when the rivers flood. After very long periods of time, deposited sediments can even form rocks such as sandstone. Deposition also builds landforms in new places. Figure 1 below shows the amount of sediment at the mouths of rivers in different areas of the U.S. Notice the large amount of sediment where the Mississippi River empties into the Gulf of Mexico.

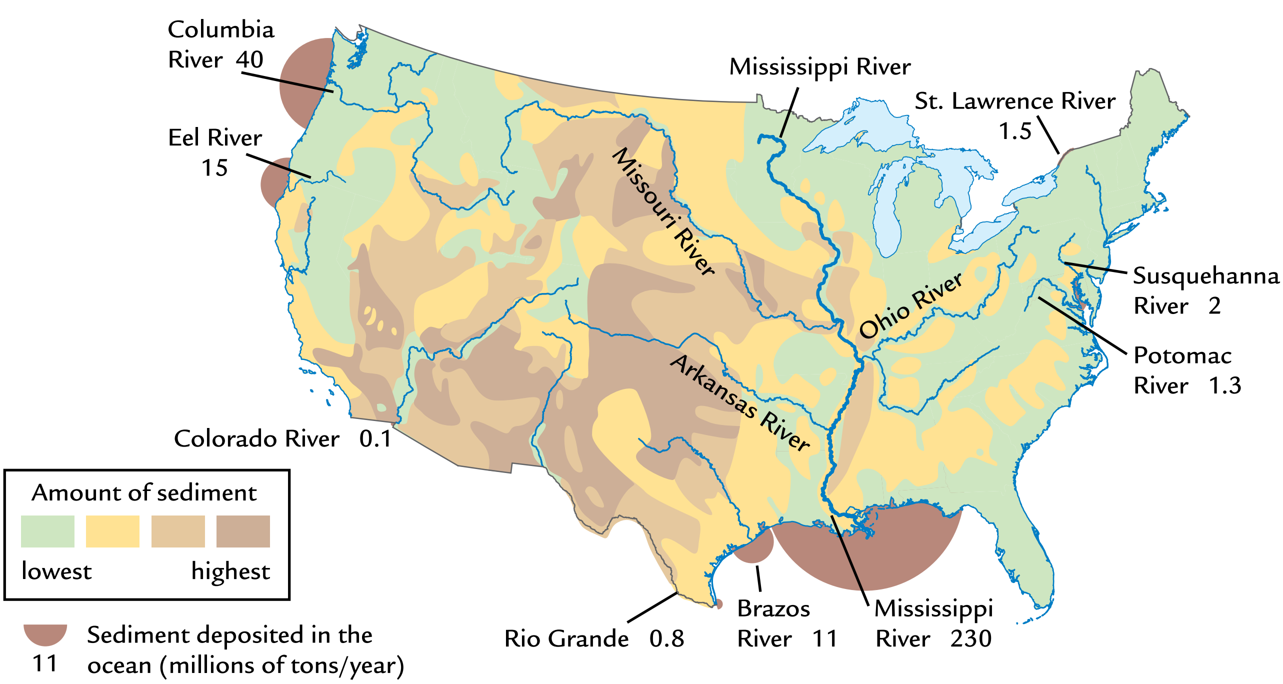


FIGURE 1: SEDIMENT DEPOSITION IN THE UNITED STATES

The size of each brown semicircle indicates the amount of sediment deposited by a river when it empties into the ocean. Darker colors on the land indicate eroded sediments that will be moved by rivers.

Sediments have filled up the opening of this drainage pipe that empties a stream into a lake.

In other cases, deposited sediments can be harmful. Sediments can build up and fill in rivers, lakes, wetlands, bays, and even parts of the ocean. Sediments can cover the habitat areas needed by fish and other animals. For people, deposition in the wrong place can make the water too shallow for boats and clog the pipes that provide water to towns and cities.

People and Earth Processes

The processes of weathering, erosion, and deposition have been occurring for billions of years. Many natural factors affect the rate of these processes. In addition, human activities can accelerate them. For example, the photos below show that clearing plants from the land can result in erosion or deposition. Construction and farming are the two human activities that cause the most erosion. These activities break apart the rocks, soil, and plant roots that hold the land in place. This makes it easier for water or wind to erode the exposed land. In time, the effects of such erosion can make such areas less suitable for building or farming.

Once sediments have been eroded as a result of human actions, they can cause problems when they are deposited. Many rivers, lakes, and ocean areas have been filled in by heavy deposition. In addition, sediments can carry pollution when they are deposited. These sediments can carry toxic materials, such as pesticides used in farming or chemicals that are already present in the soil.

In this suburban neighborhood, sediments were washed into the street by the rain, because the soil was not protected during house construction.

On this farm, rains have damaged crops by eroding soil from one place and depositing it in another location.

ANALYSIS

1. Why is weathering important to the process of erosion?

2. Why does erosion always lead to deposition? Explain and provide an example.

3. Prepare a concept map for weathering, erosion and deposition. Be sure to use the following terms:

earth processes	weathering	erosion
deposition	sediments	wind
water	ice	floodplains
lakes	toxic materials	environment
delta	water	positive effects
negative effects	farming	construction

4. Look back at the topographical maps on the student sheets from Activity 26, “Boomtown’s Topography.” Choose one major topographical change in Boomtown. Describe the change and the earth process(es) that may have caused the change.

5. At which of the three building sites—Delta Marsh, Green Hill, and Seaside Cliff—would you expect:

   a. erosion to have the most effect on the land?

   b. deposition to have the most effect on the land?

EXTENSION

Earth processes such as weathering, erosion, and deposition help make the landforms that are all around you. Some landforms are formed quickly, while others take millions of years. Visit the *Issues and Earth Science* page of the SEPUP website to find more information about specific landforms found in the United States.

30 Challenges of the Mississippi Delta

A **delta** is formed when a river slows down and deposits sediment as it flows into a lake or ocean. The largest delta in the United States is at the mouth of the Mississippi River. The Mississippi River Delta has an area of 3 million km^2 and the river continues to deposit over 300 metric tons of sediment per year.

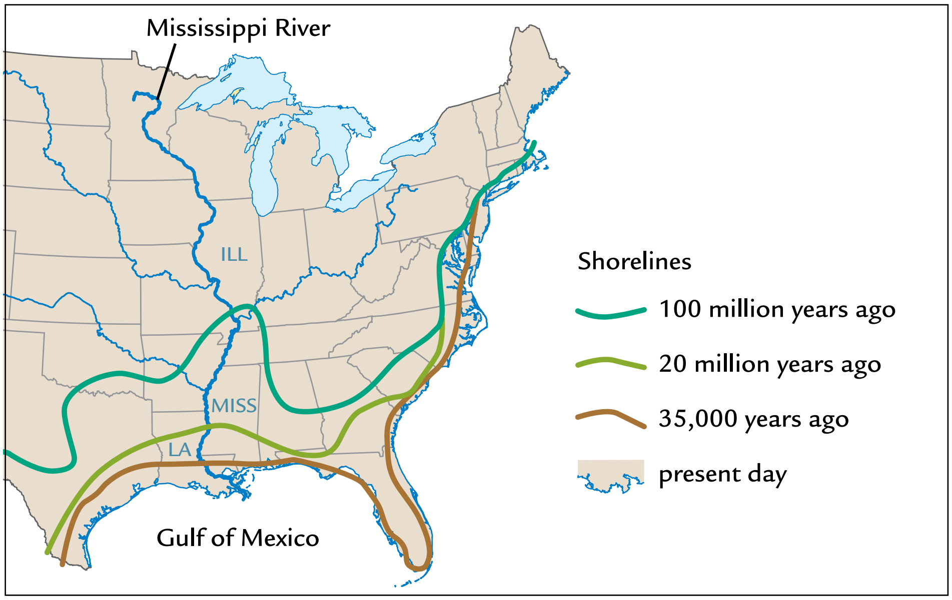
The Mississippi Delta wasn't always so large. Over a period of millions of years, the Mississippi River carried and deposited sediment that eventually built up a huge fan-shaped delta. This ancient delta made up the land from southern Illinois to Louisiana and Mississippi, as shown below.

The city of New Orleans is built on land deposited by the Mississippi River and this location has resulted in many problems for the city. In 2005, the city was affected by a severe hurricane and flood that took over 1,800 lives. Although New Orleans has rebuilt a lot of its downtown area, there is still a lot of damage. The future of the city continues to be uncertain because of the earth processes that shape the area.

CHALLENGE

How has the Mississippi River Delta challenged the people of New Orleans?

CHANGING SHORELINE OF THE MISSISSIPPI DELTA



MATERIALS

For each student

1 **Student Sheet 30.1, "Intra-act Discussion: Challenges of the Mississippi Delta"**

PROCEDURE

1. Assign one of the following roles to each person in your group.
   - *Teresa Corelli, interviewer for the Student Science Hour*
   - *Natalie Ludlow, ecologist*
   - *Dr. K.C. Sandoval, geologist at Boomtown University*
   - *Ethan Porter, engineer from Builders, Inc.*
2. In your group, read the role-play aloud. As you read, think about what each character is saying.
3. Discuss what you think the people of New Orleans can do about the problems they face due to their location.
4. Mark whether you agree or disagree with the statements on Student Sheet 30.1, "Intra-act Discussion: Challenges of the Mississippi Delta." Predict what you think other members of your group will say.
5. Discuss the statements with your group. Have each person share his or her opinion about each statement and explain why he or she agreed or disagreed.

NEW ORLEANS: AN UNCERTAIN FUTURE

Teresa: Welcome to the Student Science Hour. Today we have brought together a panel of experts who will help us explore some of the challenges facing New Orleans because of its location. What can be done to prevent another disaster? Panelists, please introduce yourselves and describe your background.

Dr. Sandoval: Hello, my name is K.C. Sandoval. I am a geology professor at Boomtown University. I study earth processes, such as erosion and deposition, in the Mississippi River Delta.

Ms. Ludlow: My name is Natalie Ludlow. I studied ecology when I was in college. Ecology looks at the relationships between organisms (including humans), and our environment. Some ecologists, like me, are interested in understanding the relationship between the natural world and human activities. I use my ecology background to help politicians preserve the environment for the future.

LOCATOR MAP: MISSISSIPPI RIVER AND NEW ORLEANS

Mr. Porter: And I'm Ethan Porter. I'm an engineer for a large construction company. My company works with the cities along the Mississippi River, building many of the large buildings, roads, and bridges in the area. My expertise is in flood control and in constructing safe structures on soft, wet ground.

Teresa: I'm glad that you could take the time to join us today. Now let's talk about New Orleans and the Mississippi Delta. Dr. Sandoval, I understand that even before Hurricane Katrina, many scientists had warned that New Orleans was in danger.

Dr. Sandoval: Yes, that's right. Its location puts it at great risk. To understand this, you must first understand how the land in southern Louisiana was formed. The powerful Mississippi River erodes many tons of soil every year. When the rapidly flowing river hits the Gulf of Mexico, it slows down and deposits the small bits of dirt and soil that it has been carrying at the mouth of the river. Over thousands of years, these sediments built up until they rose slightly above the level of the water. New Orleans was built on the loose soil of the delta.

Teresa: Mr. Porter, why was the city built on such an unstable place?

Mr. Porter: New Orleans was built on the banks of the Mississippi River because the river was used to ship products between the central United States and the Gulf of Mexico. It has not always been located below sea level. Until one hundred years ago, construction was limited to a more stable area on the naturally higher ground along the river. Much of the rest of the delta at that time was a marshy floodplain that was wet and frequently flooded.

After Hurricane Katrina passed through New Orleans in 2005, flood waters caused even more destruction and forced a complete evacuation of the city.

Teresa: How can parts of New Orleans be located below sea level, but not be under water?

Mr. Porter: As New Orleans expanded, a system made up of levees, canals, and pumps was built to control the water. This system was built to hold back the river and drain the surrounding marsh, so New Orleans could grow. Because of this engineering, parts of the city were built 1 to 6 meters below sea level. The system keeps the land dry by controlling the path of the Mississippi and by removing extra water.

Teresa: Is that why Hurricane Katrina caused such a severe flood in 2005?

Mr. Porter: That is part of it. The levees that held the water back failed in the storm. Very quickly afterwards, water flooded the city and destroyed houses, roads and the pump system itself. Unfortunately, about 1,000 people lost their lives, while many more New Orleans residents lost their homes or jobs.

Teresa: Ms. Ludlow, can you tell us how building a city on the delta can affect the environment?

Ms. Ludlow: When New Orleans expanded onto the delta, the surrounding marsh was drained. It may be good for the city in the short term, but removing a marsh, which is a kind of wetlands, can be a disaster for the environment. It damages plants and animals that can only live in that kind of environment, or habitat. Wetlands might not be attractive to people, but they provide food and homes for fish, shellfish, and birds.

Teresa: How was the ecology affected by the events from Hurricane Katrina?

Ms. Ludlow: It harmed the wildlife in the area, and, even now, we do not know how long it will take to recover. We estimate 150,000 acres of coastal wetlands and bottomland forests were damaged on national wildlife refuges alone. The debris and silt left from the storm damaged habitats and reduced the fish and shellfish populations. This in turn harmed the birds that depended on the fish and shellfish for food. Many endangered animals lived in this area. We know that 50 sea turtle nests were lost, as were 70% of the trees that were home to endangered red-cockaded woodpeckers.

Teresa: Dr Sandoval, New Orleans decided to rebuild and has been successful, at least economically. What are the problems the city will face in the future?

Dr. Sandoval: Of course, there is always the threat that they will be hit with another large hurricane. But in addition, there are problems that are the result of efforts to control the Mississippi River.

Teresa: You mean there is more to the story than just removing the water?

Dr. Sandoval: That's right. The natural processes in the area are disrupted by the city. This is because the sediments that would usually be deposited in the New Orleans area are not allowed to be deposited there. Instead, the river is controlled and the sediments are carried farther downstream to the mouth of the river. So, the land in the New Orleans area is not built back up with fresh sediments.

Teresa: This must be related to the sinking land in New Orleans.

Dr. Sandoval: Exactly. The land under the city has been sinking for quite a while. The land compresses as the water is removed, which causes it to slowly sink as the water is pumped away. Even before the flood, it was not uncommon to see large gaps and cracks under buildings in New Orleans.

Teresa: Mr. Porter, is the water control system in New Orleans making the Delta smaller?

Mr. Porter: Yes, it is. An unfortunate result of the water control system that moves water away from the city is that it prevents the water from depositing sediments. It's successful in keeping the city dry, but Dr. Sandoval is right in that controlling the river flow disrupts the natural balance of erosion and deposition in the area. All of the sediments are sent downstream to another location, while erosion continues to wash away the delta.

Teresa: Ms. Ludlow, is the area near New Orleans the only place where the Mississippi Delta is shrinking?

Ms. Ludlow: No, the entire state of Louisiana is losing its wetlands at an incredible rate. In the southern section of the Mississippi River, the delta is sinking and being washed away faster than it is being replaced.

Part of the Mississippi Delta seen from the air.

Teresa: Dr. Sandoval, I heard that the Mississippi River is trying to change its course. Is this true?

Dr. Sandoval: Yes, that is true. When people built New Orleans and the surrounding area, they created buildings and roads around the natural channel of the river. But over time, the channel of any river will change as erosion and deposition continue. The Mississippi River is no exception. For the last 50 years, the river has been trying to travel a shorter path to the sea. This would take it away from New Orleans.

Teresa: Dr. Porter, it seems like letting the Mississippi River change its channel would reduce the risk to the people of New Orleans. Isn't it a good idea to let nature win this battle?

Mr. Porter: You're right that a change in the river channel would reduce the risk of flooding in the city of New Orleans. But it would destroy homes, roads, and other structures in its new channel. It would also be the end of the port of New Orleans. The economic impact of closing this port is tremendous, since it is one of the largest in the United States.

Teresa: I have one last question for each of you. During Hurricane Katrina, the people of New Orleans suffered terribly. As the city is rebuilt, what do you think could be done to prevent another catastrophe like this?

Ms. Ludlow: I believe as much of the wetlands habitat as possible should be restored to the area. Not only will this help protect the wildlife, but it will also protect the area from flooding. Wetlands can protect an area from floods during storms by absorbing large amounts of water before it reaches the city. Without the wetlands located between New Orleans and the Mississippi River, the city is more likely to flood again.

Mr. Porter: In the future we must focus on maintaining the safety of the large population of New Orleans. We have the technology to protect ourselves from even the worst disasters. It is a question of having enough money to build what we need to keep people safe. I believe that the answer is to do a better job of controlling the water in the future.

Dr. Sandoval: Flooding will be an ongoing problem in the future of the Mississippi Delta region. Having studied the effects of natural processes over a long period of time, I do not believe that controlling the river is good for the people of New Orleans in the long run. I believe that we should allow the river to change its course and that people should learn to work around nature, instead of bending nature to our needs. In the end, I think that nature will win anyway.

Teresa: Unfortunately we have run out of time for the Student Science Hour. Thank you all for joining us today.

ANALYSIS

1. Name three problems that the city of New Orleans faces as a result of its location on the banks of the Mississippi River.

2. How are erosion and deposition related to the problems that New Orleans has experienced?

3. Compare the situation of the Mississippi River in New Orleans to the Rolling River in Boomtown.
   a. List the similarities.
   b. List the differences.

EXTENSION

Investigate careers in ecology, engineering, and geology. Start at the *Issues and Earth Science* page of the SEPUP website.

31 Resistance to Erosion

The amount of erosion that occurs, whether on the banks of the Mississippi River or on Green Hill in Boomtown, depends on two major factors. The first factor is the strength of the force causing the erosion. For example, a fast-flowing river has more force than a trickle of water. Water flowing down a steep slope will erode the land more quickly than the same amount of water flowing down a flatter portion of the same hill, because the water travels faster on the steep slope. The second factor that determines the effect of erosion is the resistance of the material that is being eroded. For example, if granite and sandstone are both undergoing the same erosional force, the sandstone will erode faster because it is "softer," or less resistant to erosion.

In and around Boomtown, there are different kinds of soils and rocks. Green Hill has loose and relatively soft soil. Seaside Cliff has more erosion-resistant, compact soil that is also sticky. In this activity you will investigate the resistance of earth materials to erosion under similar forces.

CHALLENGE **Do all kinds of earth materials erode in the same way?**

The rock layers shown above are made of limestone and shale. Notice how the two kinds of rock erode differently.

MATERIALS

For each group of four students

3 plastic basins
1 rainmaker
1 50-mL graduated cylinder
1 30-mL graduated cup
1 plastic spoon
supply of Earth Material A
supply of Earth Material B
supply of Earth Material C
supply of water
paper towels
masking tape

PROCEDURE

1. In your science notebook, make a table like the one below.

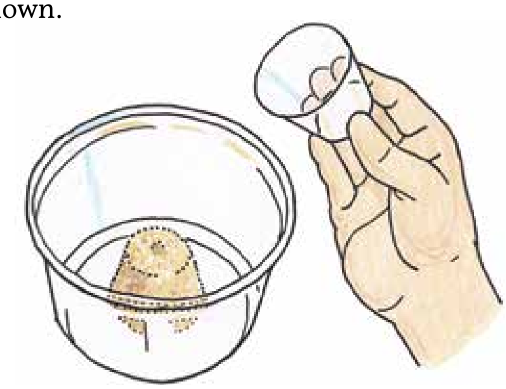
Observations of Erosion Resistance

Basin	Observations	Erosion Ranking	Water Run-off Ranking
A			
B			
C			

2. Place the three plastic basins next to each other on the table. Use the masking tape to label them A, B, and C.

3. Using the spoon, pack the 30-mL graduated cup with Earth Material A.

4. Make a small "hill" by flipping the cup over in the center of Basin A. Remove the 30-mL cup, but leave the material standing in the basin as shown.



5. Repeat Steps 3 and 4 using Earth Materials B and C and their labeled basins.

6. Place the empty rainmaker over the basin that contains Earth Material A.

7. Add 50 mL of water to the rainmaker.

8. Observe any changes that take place as a result of the water on the hill. Pay close attention to how much erosion occurs and how much water runs off the hill. Record your observations in your table.

9. Repeat Steps 3–8 for Earth Materials B and C.

10. Compare the three model hills. In your table, rank how much erosion occurred on each hill with 1 indicating the most erosion and 3 indicating the least erosion. Then rank how much water ran off the hills with 1 indicating the most runoff and 3 indicating the least runoff.

ANALYSIS

1. How are the models you used:
   a. like a real landform?
   b. not like real landform?
2. In this investigation, what variables were:
   a. kept the same?
   b. tested?
   c. not kept the same?
3. In your model, which earth material showed the least erosion? Using evidence from this investigation, explain why this material may have eroded less than the other two.
4. The hills made in this activity model the three kinds of earth materials listed below. Copy the list and then, next to each description, write whether it describes Earth Material A, B, or C. For each one, give the evidence from this activity that helped you make your choice.
   a. loose soil
   b. sticky soil
   c. loose soil with vegetation
5. Would you expect more erosion to be observed at Green Hill or Seaside Cliff?

32 Modeling Erosion

In the previous activities you investigated erosion and deposition caused by rivers, streams, and rain. But erosion can take place anywhere that water, ice, or the wind carries pieces of rock or soil from one place to another. The shores of oceans, seas, and lakes are other sites where erosion and deposition play a role in shaping the land. In this activity you will model the role of ocean waves at Seaside Cliff and examine their effect on the rate of erosion.

CHALLENGE **How do ocean waves affect the shape of the land?**

1987

2002

These photographs show the same cliff in California in 1987 and 2002. Notice how much of the cliff has eroded away from the columns that support the houses.

MATERIALS

For each group of four students

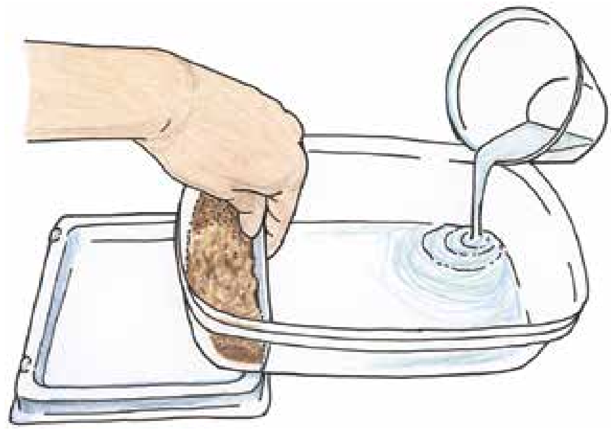
1 plastic box
1 plastic retaining wall
1 wavemaker (2 pieces)
1 river model catch basin
1 30-mL graduated cup
1 spoon
supply of moist earth material
supply of water
2 mesh sleeves of small rocks
2 rectangular blocks, long
2 rectangular blocks, short

PROCEDURE

Part A: Modeling Cliff Erosion

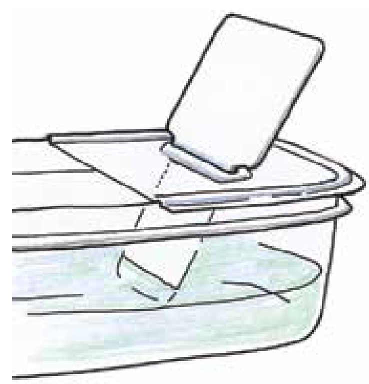
1. Place the plastic retaining wall in the plastic box at the line marked on the box. Hold the wall vertically in the box.
2. Use the 30-mL graduated cup to fill the smaller portion of the box with 150 mL of moist earth material. Level the top of the material with the spoon.
3. Place the sand-filled end of the box on the catch basin from the river model. This will create a gentle slope.

4. While holding the retaining wall in place, gently pour water into the edge of the box opposite the earth material until it just touches the bottom of the cliff.



5. Complete the cliff model by carefully removing the retaining wall. Do this by slowly lifting the wall straight up out of the box.

6. Place the slotted part of the wavemaker on the side opposite the model cliff. Insert the other piece of the wavemaker into the slot, as shown at right.



7. At the rate of 1 wave per 3 seconds, move the wavemaker back and forth along the bottom of the box 5 times. Record your observations in your science notebook.

8. Make 5 more waves and record your observations in your science notebook. Make 2 more sets of 5 waves and record your observations.

9. Observe the bottom of the container and record any additional observations in your science notebook.

10. Place the retaining wall back in the plastic box and use it to push the earth material back into the end of the box. Carefully drain out any remaining water in the box.

Part B: Preventing Cliff Erosion

11. Rebuild the cliff as in Steps 1–2. If the earth material is too wet to form the cliff, mix a little dry earth material into it until it is the right consistency.

12. Place two long rectangular blocks up against the base of the cliff. These blocks represent a retaining wall.

13. Repeat Steps 4–9.

14. With your class, compare the results of the investigation with and without the retaining wall.

Part C: Modeling and Slowing Down Beach Erosion

15. Make a model of a beach by flattening the sand out where you built the cliff. Use the spoon to make an even slope to the water.

16. Based on what you learned in Part A, design and build a structure to reduce erosion on the model beach. Work with the materials provided. The best design will involve as little material as possible to protect the beach. The structure you design should not prevent people from playing on the beach or swimming.

    As you develop your design, make sure to:

    - decide on a standardized way of testing your design, recording what happens, and explaining your design to others.
    - predict what will happen when you make the waves.
    - obtain your teacher's approval of your design, and conduct your investigation.
    - construct diagrams that show the beach before and after you use the wave maker. Include any measurements you take.
    - discuss ways in which the model might be improved, based on the evidence from your investigation.
    - redesign the structure(s), and conduct the investigation again.

17. Present your final design to the class.

18. With the class, discuss the limitations of your design.

ANALYSIS

1. What did the waves do to the cliff model? Explain in terms of erosion and deposition.
2. What was the effect of the retaining rocks on the model cliff?
3. **a.** What kind of landform was created at the bottom of the model cliff?

   b. What earth process was involved?
4. Granite on a mountaintop is likely to erode differently than granite found on a sea cliff. Why do you think this is true?
5. Review your results and your response to Analysis Question 5 in Activity 31. This activity has provided you with more evidence about the erosion of cliffs. Where would you expect to see more erosion, at Green Hill or at Seaside Cliff? Be sure to explain your evidence.
6. What did all the designs for reducing erosion on a shoreline have in common? Explain how they reduce erosion at a cliff and a beach.
7. What are some of the advantages and disadvantages of building a structure to protect a cliff or beach?

EXTENSION

Design and conduct an investigation of the model cliff that compares the erosion in an area that has high and powerful waves to the erosion in a calmer area with less powerful waves.

33 Earth Processes and Boomtown's Coast

READING

Although a beach is not one of the possible building sites, Boomtown is a coastal community and the beach is important to the area. The Town Beach is a landform that is directly related to the three possible sites. Rain and sediments run down Green Hill to the Rolling River. The river then transports the water and sediments to the ocean at the Delta Wetlands, where they become a part of the beach. Likewise, eroded material from Seaside Cliff adds material to the beach.

Some geologists are interested by beaches because beaches are subject to repeated weathering, erosion, and deposition. Beaches are always changing because they are a part of a larger, dynamic system of earth processes.

CHALLENGE

How is a beach part of a coastal system?

A river meets the ocean at this beach.

READING

Beach Formation

There are many kinds of beaches, with different shapes, types of sand, and waves of various sizes. The appearance of a beach depends on many factors, such as the wave energy of the ocean, the sediment supply from the river, the earth material in the area, the tides and the seasons, and the weather. Of these factors, the most important ones are the amount of sediment moved to the coast by the river and the amount of wave energy hitting the shore.

Beaches are most commonly found near the mouth of a river where sediments are deposited. A beach will form when the amount of sediment supplied by the river is in balance with the erosion energy of the ocean waves. In other words, a beach has equal and opposite forces: the constructive force of sediment deposition is roughly the same as the destructive force of the waves eroding the sediments.

Listen as your teacher reads aloud.

Stop when you see this yellow pencil and close your book.

Write down the main ideas you just heard.

A Naturally Changing Coastline

When the sediment supply from the river is much more than the ocean waves can erode, a delta will form. This happens at a coastline when the constructive force of deposition dominates over the destructive force of erosion. Deltas are typically formed on coastlines with large rivers. In fact, almost every major river builds a delta at its mouth. If the delta continues to form, it will extend the beach, or coastline, towards the ocean.

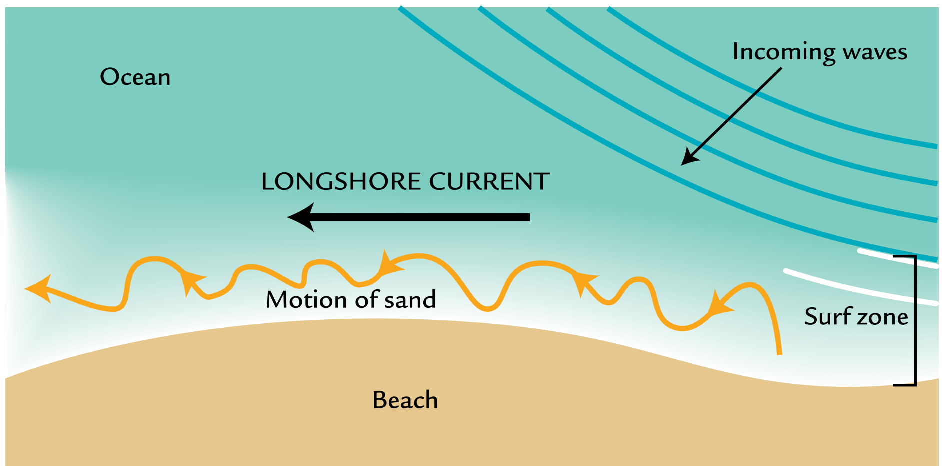
When the force of the ocean waves is much greater than the amount of sediment deposited by the river, the destructive force of erosion dominates the force of deposition. The result is a coastline that erodes and retreats inland. A beach can be washed away in this situation, or a cliff can form from any nearby high land. When a shore or coast is actively eroded, the effect can be dramatic because of the large force of ocean waves.

Longshore Current

Every time an ocean wave hits the beach, it picks up millions of sand grains and moves them. Sand is continually moved off shore and then back again. But sand doesn't just move in and out from the beach. Because waves hit the shoreline at an angle, sand is pushed across the shore as well as in and out. The **longshore current**, which is a result of waves hitting the beach at an angle, is a stream of water in the ocean that runs parallel to the shore and moves sand across the face of the beach. (See Figure 1 on the next page.) The longshore current lengthens a beach by transporting sand and sediments away from the mouth of a river.

When humans build near the beach, there can be a large environmental impact because of the high activity of the earth processes there. One problem that is created when buildings, bridges, or harbors are placed on the shore is the interruption of the longshore current. When water in the longshore current travels around a structure, it slows down, causing sand and sediments to settle out of the water. This results in excessive deposition of sand near the structure.

FIGURE 1:
LONGSHORE CURRENT



Managing Earth Processes

One way to protect the beach from the problem of unwanted deposition is to dig up the sand and move it to another location. Dredging is often successful, but it's a lot of work. It can also expose contaminated sediments, and can make the land less stable. A **jetty**—a rock structure built perpendicular to the shore—can help avoid the problem of unwanted deposition by collecting the sand on one side of it before it reaches the structure. Jetties are often used in harbors to prevent the harbor from filling in with sediment. (See Figure 2 on the next page.) Although a jetty will increase deposition on the upstream side of the jetty, the other side of the barrier will erode and narrow the beach there.

Another common problem associated with building on the shore is erosion caused by the force of ocean waves, which may make the land beneath the buildings unstable. One way to slow down this erosion is to reduce the energy of the waves. A **breakwater**—a rock structure that is built parallel to the shore—may slow erosion by reducing the wave energy that hits the shore. (See Figure 3.) However, the breakwater also slows down the longshore current, so that sediments in the longshore current are deposited in between the breakwater and the beach.

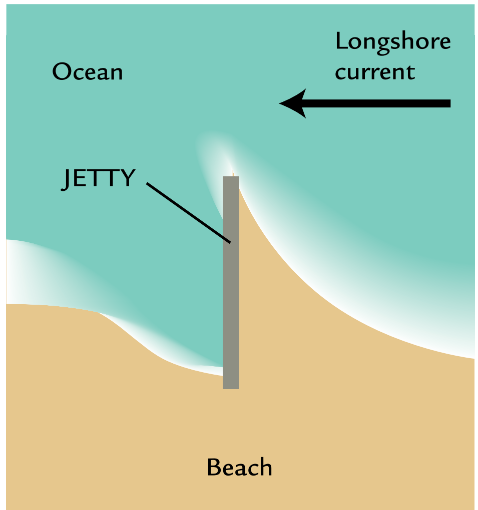


FIGURE 2: JETTY

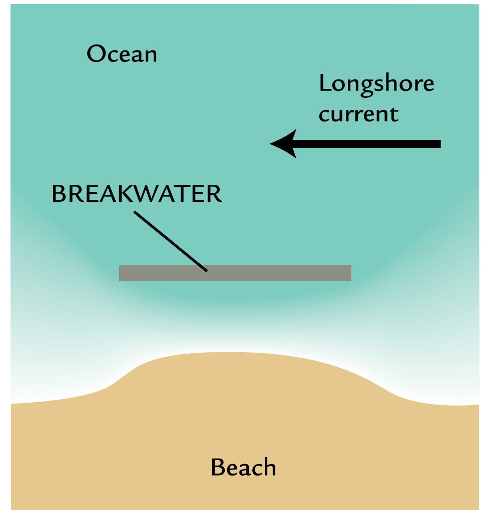


FIGURE 3: BREAKWATER

Sometimes piles of rock (called *riprap*) or **seawalls** are built right up against the cliff or shoreline. Ocean waves hit the structure instead of the cliff, reducing the wave energy and the amount of erosion. The erosion around the seawall, however, is often increased because waves are redirected there.

Dredging and building jetties, breakwaters, and seawalls are only some of the ways communities attempt to protect their coastlines. All of these approaches are effective, but have undesirable consequences. These structures can be effective for a while, but the protection is temporary. Eventually, the waves and longshore current will destroy any attempts to hold back the sea.

ANALYSIS

1. Describe how each of the landforms below contribute sediments to the Town Beach in Boomtown.
   - **a.** Seaside Cliff
   - **b.** Delta Wetlands
   - **c.** Green Hills
   - **d.** Rolling River

2. Look at the topographical maps of Boomtown over the last 100 years on Student Sheet 26.1, "Maps of Boomtown 100 Years Ago," Student Sheet 26.2, "Maps of Boomtown 20 Years Ago," and Student Sheet 26.3, "Maps of Boomtown Today." At the Delta Wetlands, is the constructive force of deposition greater, less than, or equal to the destructive force of erosion? Explain your answer using evidence from the maps.

3. Prepare a concept map for beaches and coastal systems. Be sure to use the following terms:

coastal system	beach	dredging
erosion	delta	jetty
deposition	cliff	breakwater
balanced	hill	seawall
longshore current	river	

4. Choose a method that helps control either erosion or deposition on the coastline. For the method you choose, describe both an advantage and a disadvantage of its use.

EXTENSION

Visit the *Issues and Earth Science* page on the SEPUP website for more information and dramatic photographs of beach and cliff erosion.

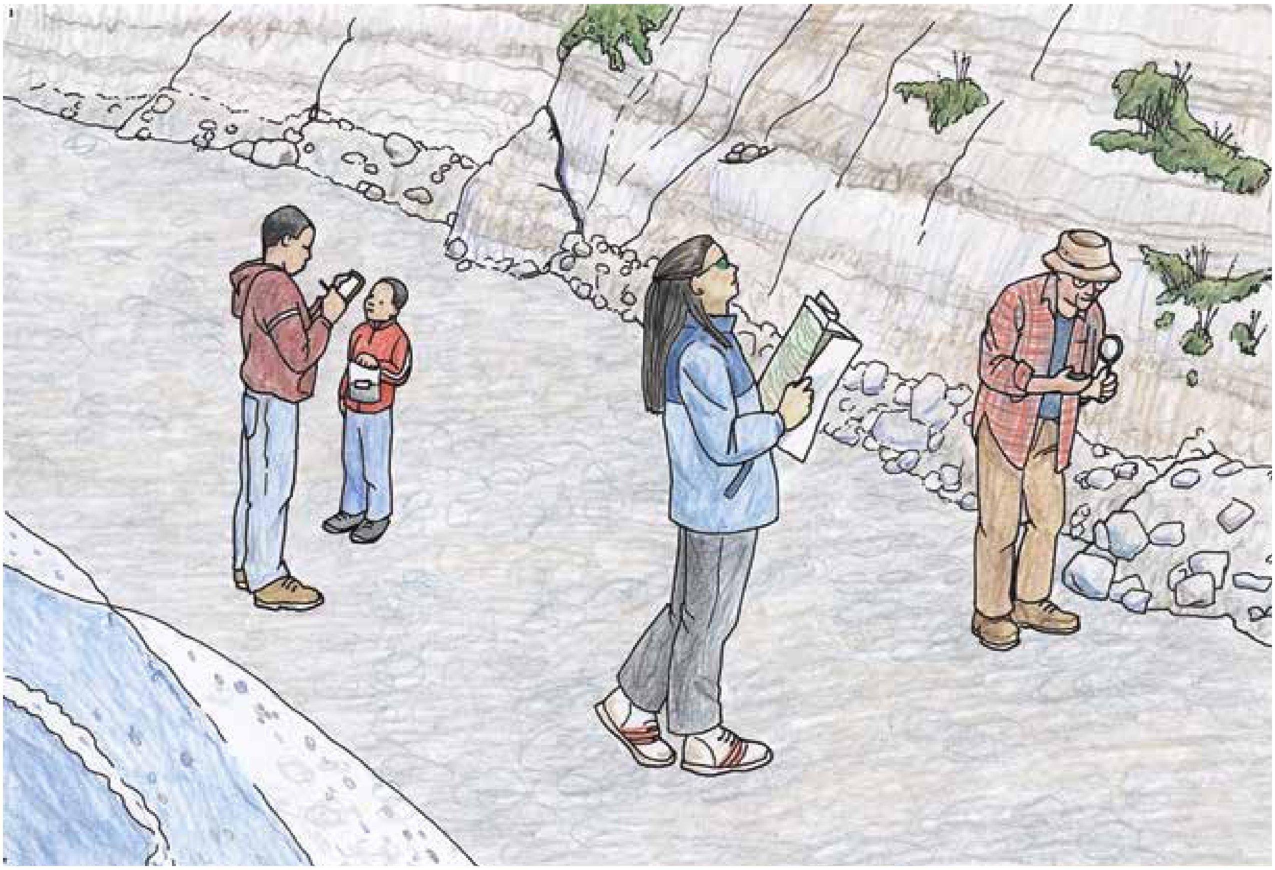
Preparing the Geologist's Report

In Boomtown, all the land that is best for building has already been developed. The only options are to build on Green Hill, the Delta Wetlands, or the top of Seaside Cliff.

To help decide where to build new housing, the Boomtown City Council has asked local experts to visit the three possible building sites and report on their findings. In this activity, you will help prepare the Geologist's Report. The City Council will discuss your report at their next meeting.

CHALLENGE

What is the geology of the three building sites?



MATERIALS

For each student

1 **Student Sheet 34.1, "Evidence for the Geologist's Report"**

Student Sheets, observations, and notes from previous activities

PROCEDURE

1. Read the Geologist's Report on Green Hill on the next page.
2. With your group, review the report by identifying the following information:
   - the description and location of the landform
   - the role of earth processes in the area
   - the topographical changes and land stability over time
   - the potential geological problems for construction
3. To prepare for writing your own report, do each of the following steps with your group members.
   a. Gather information about the geology at the Delta Wetlands and/or Seaside Cliff. Use what you have learned from other activities in the unit.
   b. Complete Student Sheet 34.1, "Evidence for the Geologist's Report," by filling in the columns for your location(s). As an example, the Green Hill column is filled in already.

ANALYSIS

1. Prepare for the City Council meeting by writing a report stating what you know about the geology of the site(s) you investigated in Procedure Step 3.

   In your report, include a summary of the relevant information on Student Sheet 34.1. An example of a report for Green Hill is on the next page.

Geologist's Report: Green Hill

Green Hill is a 150-meter-high hill located next to the Rolling River in the western part of Boomtown. The land is steep on the west and south sides of the hill but it has a gentler slope on the east and north side. The east and south sides are covered with roads and homes. Green Hill is made up of loose, soft soil.

Erosion is the main earth process that affects this landform. The hill is eroded by the rainfall that runs down it. Eventually the sediments removed from Green Hill are carried down the Rolling River and deposited in the Delta Wetlands. Since the hill is at a higher elevation, there is little risk of flood on Green Hill.

The topographical maps of Boomtown show that the hill has been stable over the last 100 years, except for the area with houses. On that slope of the hill, there has been erosion in the twenty years since the houses and roads were built. The erosion may have been caused when the land was dug up to build the houses.

The biggest potential geological problem at Green Hill is erosion due to more building. Although the hill is eroded by rain instead of powerful ocean waves, the composition of the hill is less resistant to erosion than other places in Boomtown, so it may become a problem in the future.

35 Building in Boomtown

It is time for the Boomtown City Council meeting to decide where to build the new housing. Participants will discuss the ecology and needs of the Boomtown community at each site. You will play the role of a builder, and present your plans for one of the building sites to the City Council for approval.

CHALLENGE

Where should Boomtown build its new apartments and houses?

MATERIALS

For each group of four students

1 **poster board**

assorted colored poster pens

For each student

1 **completed set of Geologist's Reports from Activity 34**

1 **Student Sheet 35.1, "Discussion Web: Our Building Site"**

1 **Student Sheet 35.2, "Evidence from the City Council Meeting"**

PROCEDURE

1. Your teacher will assign your group one of the building sites. Your group will develop a building plan for this location.
2. Read all the reports for your location. The reports are found on the following pages.
3. With your group members, complete Student Sheet 35.1, "Discussion Web: Our Building Site." This will help you to identify the advantages and disadvantages of your location.

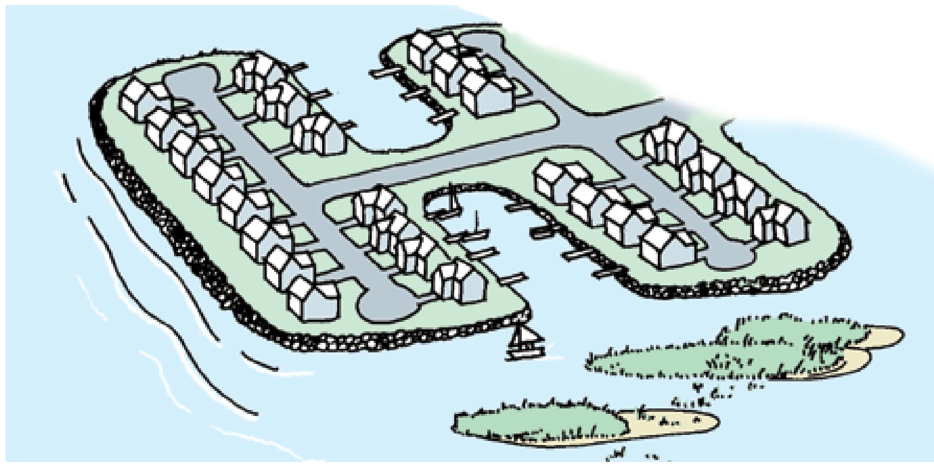
   Remember to listen to and consider the ideas of the other members of your group. If you disagree with others in your group, explain why you disagree.
4. Work with your group to prepare a presentation and poster that will describe your building plans. Be sure you present information from the geologist, engineer, ecologist, and City Council Member, as well as from the various activities in the unit. Your poster should include:
   - the advantages of your chosen building site, based on evidence from this activity and from earlier activities in this unit.
   - the main disadvantages or risks of your proposed building site.
   - how your plan will succeed despite the disadvantages of your building site.
5. Make your presentation to the class and listen to those of the other groups. As you listen to each presentation, record the information on Student Sheet 35.2, "Evidence from the City Council Meeting."

ANALYSIS

1. Where do you think Boomtown should build new housing—on Green Hill, the Delta Wetlands, or Seaside Cliff? Describe the evidence that you used to make your decision and how you weighed the advantages and disadvantages of each location.
2. **Reflection:** Look in your science notebook to see how you answered Question 3 in Activity 24, "Where Shall We Build?"
   a. Have you changed your mind since then?
   b. What new information did you use in making your decision this time?

Reports from the Field

Delta Wetlands



ENGINEER'S REPORT

The biggest challenge for building on wetlands is managing all the water. First, pumps are needed to remove the water from the marsh and dry the area. Next, soil will have to be brought in and added to the current, loose soil of the wetlands. This will make the ground solid and stable enough for building. However, once the wetlands are filled in and covered with buildings and roads, the water from heavy rains will no longer be absorbed by the wetlands. This means that the water can build up at the lower elevations and flood the area. A system of canals can be used to collect excess water from rains and help prevent floods. Walls can also be built to protect the buildings from water overflow or surges from the ocean during storms.

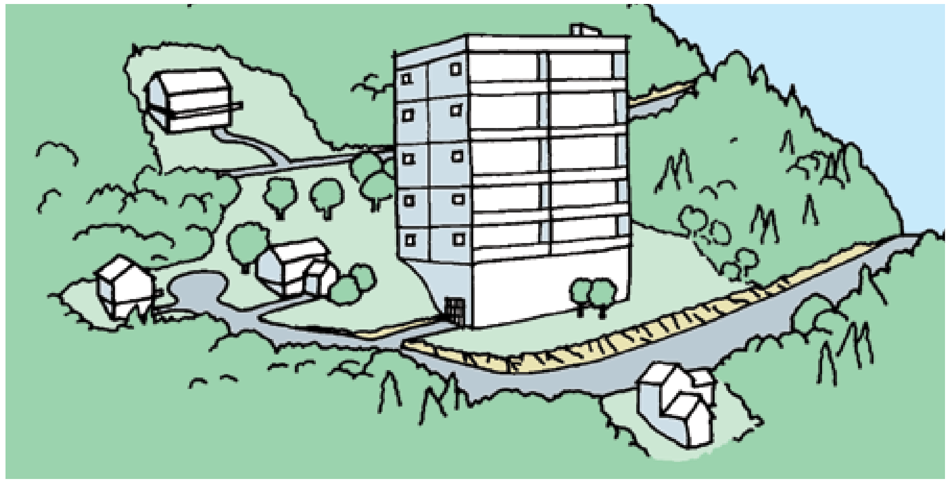
ECOLOGIST'S REPORT

Delta Wetlands is a unique habitat for shellfish, fish, and birds. These animals will no longer have a home if the wetlands are destroyed. The wetlands also help filter water before sending it to the ocean. If the sediments from the river are not deposited in the delta as nature intended, they will be carried directly to the ocean. Once there, the sediments could cloud the water near the beaches. This may lead to a loss of ocean fish and, as a result, a loss of the birds that eat the fish.

CITY COUNCIL REPORT

The city next to Boomtown filled in a wetland area 20 years ago and has not yet experienced any disasters, such as flooding. If Boomtown decides to fill in the wetlands, the plans must be evaluated by the Wetlands Protection Agency in order to determine the impact on the habitat. Their evaluation will take at least 12 months. It is likely that Boomtown will be required to preserve part of the wetlands.

Green Hill



ENGINEER'S REPORT

When we cut into the side of the hill to put up a building, it makes that part of the hill steeper and more likely to erode when it rains. When we cut down vegetation and cover the land with buildings and roads, the water runs off in channels down the hill because it can no longer sink into the soil. To fix this problem, drainage pipes can be built so that the water can flow down without eroding the hill. Then, the water in the drainage pipes can be directed to the Rolling River. We also can plant a lot of vegetation on the slopes, wherever there are no buildings, to help the hill become more resistant to erosion.

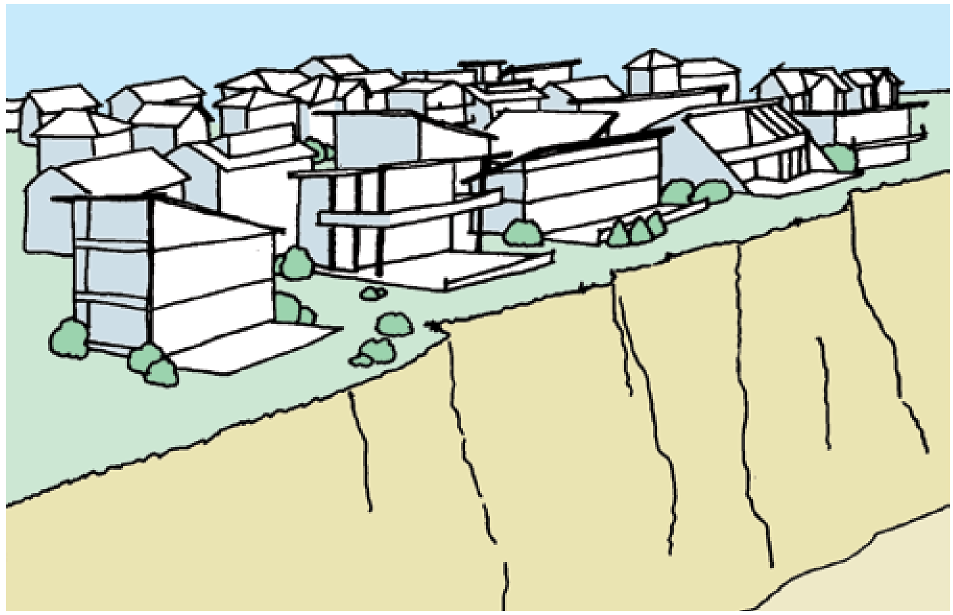
ECOLOGIST'S REPORT

Green Hill has an environment similar to that of other hills in the area. Where there are no houses and roads, the hill area is covered in thick forest. There are trees, grasses, and small bushes. Common wildlife on the hill includes deer, raccoons, rabbits, and foxes. Green Hill provides homes for these animals, as well as space for the animals to move between Pine Forest, Rolling River, and Riverside Forest. Building here will not only directly reduce the wildlife population by destroying their homes, but it will also stress the animals by preventing them from moving between areas with food and water.

CITY COUNCIL REPORT

People who already own houses on the hill are concerned about the new buildings. Some are upset that the habitat of the animals on the hill will be disturbed. Others think that large buildings will create bad traffic and congestion in the area. The Green Hill Neighborhood Organization is sending around a petition trying to block any new buildings on their hill. People in town are concerned that the water running off the hill could cause flooding or landslides that would affect the neighborhoods below the hill.

Seaside Cliff



ENGINEER'S REPORT

Structures built on cliffs suffer some of the same erosion problems due to heavy rain as do structures built on a hillside. Because of this, the problem is handled in a similar way—by improving drainage and planting vegetation that can absorb water. However, Seaside Cliff is also affected by the strong erosion force of the ocean waves that pound its base. This could cause the cliff to be undercut and, eventually, cause it to collapse. To prevent this, barriers should be placed at the bottom of the cliff to protect it from the waves. This could be in the form of retaining walls. Another way to slow down the erosion at the base of the cliff is to build a stone breakwater. This breakwater should be built in the water about 15 meters from the cliff. These additions will reduce the impact of the waves on the cliff and slow down the process of erosion.

ECOLOGIST'S REPORT

Seaside Cliff has some wildlife, although not as much as Green Hill. The cliff top is covered with vines, bushes, and a few small trees. The roots of these plants help to hold the soil in place. In order to build housing, these plants would have to be cleared, making the cliff erode more easily. Even if the vegetation is replanted after the building is finished, it will take a while for the plants to grow. In addition, there are also rabbits, gophers, deer, and other animals in the area. They would lose their homes because of the building.

CITY COUNCIL REPORT

Homes built on cliffs in other towns have been damaged when severe erosion causes the cliffs to collapse. Because of this, home insurance at Seaside Cliff will cost twice as much as in other areas of Boomtown. The buildings would have a great view of the ocean, though, and would be worth more than houses on the hillside. People from Boomtown have expressed concern that the houses will take away from the natural environment of the beach, since they will be so close to the water. The citizens of Boomtown are also worried that the seawalls or breakwaters will have negative effects on the beach and other places along the coast.

Plate Tectonics

D



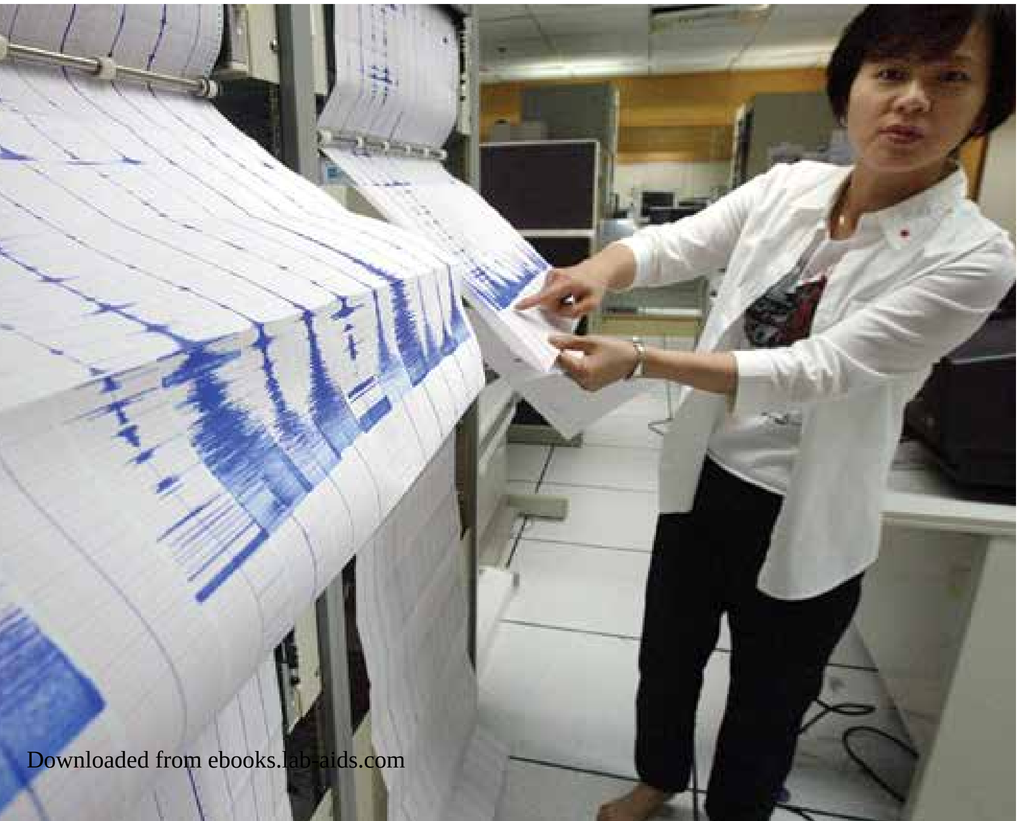




Plate Tectonics

Felix and his father were watching TV when they saw a news flash showing lava erupting from a volcano.

“Look at that!” said Felix. “It’s a huge fire!”

The reporter said that no one had predicted that the volcano would erupt. Then a scientist explained that the volcano was part of a mountain range that had been formed by volcanic eruptions that occurred over thousands of years.

Felix and his family lived near the base of Mount Adams. It was the biggest mountain around. He asked his father, “Is Mount Adams a volcano? Could it erupt like that?”

“I’m not sure,” answered his father. “We have a lot of mountains around here, but I’ve never heard of any of them erupting.”

“Yeah, but Mount St. Helens in Washington erupted when Aunt Pilar lived nearby,” thought Felix. “She told us they could see the ash from miles away. Maybe it could happen here.”

• • •

What happens when a volcano erupts? Is a volcanic eruption likely to occur where you live?

In this unit, you will investigate volcanoes and earthquakes. You will find out how mountains are formed. You will learn about changes to the earth’s surface that take place over very long periods of time.

36 Storing Nuclear Waste

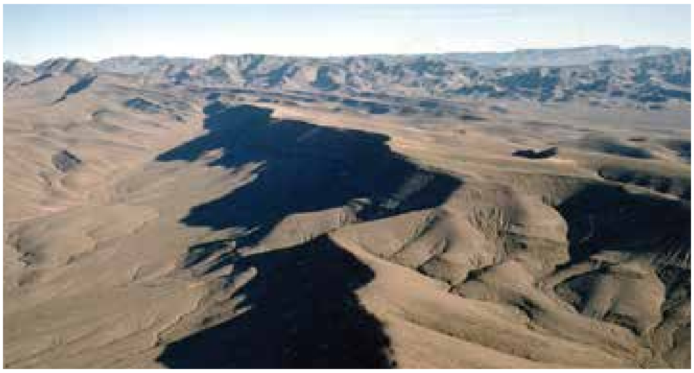
Each year the United States produces more than 60,000 tons of nuclear waste. Currently most of that waste is stored at the sites, such as nuclear power plants, where it is produced. The danger in storing nuclear waste is the possibility of it being released into the air or nearby bodies of water if the waste containers were to leak. People who inhale or ingest radioactive material are at increased risk of developing radiation-related illnesses. The level of risk depends on the dose and length of exposure.

For more than 50 years, scientists have been considering better ways to store nuclear waste. They have proposed sending it into space, placing it in the ocean floor, and burying it on a remote island. But all of those options pose problems—both known and unknown. Most experts now think that the safest solution is to store the waste in special containers placed in deep underground rooms.

In the early 1980s, the U.S. government reviewed several possible underground storage sites. In 1987, they chose Yucca (YUK-uh) Mountain in Nevada, and the Department of Energy prepared to build the storage site. However, in 2011, they withdrew their application for the site. The example of Yucca Mountain highlights the scientific and social issues involved in choosing a site for storing nuclear waste.

In January 2012, the Commission on America's Nuclear Future, appointed by President Barack Obama, released a report on the management of nuclear waste. It recommended that one or more deep disposal sites should be developed.

Yucca Mountain is 6.5 to10 km wide (4 to 6 miles) and 40 km long (25 mi). At its highest point, it is 457 m (1,500 ft) high. The entire Yucca Mountain area is about 384 km^2 *(260 mi*^{2}*).*



CHALLENGE

What are the advantages and disadvantages of storing nuclear waste in Yucca Mountain?

MATERIALS

For each student

1 **Student Sheet 36.1, "Analyzing Evidence: Yucca Mountain"**

1 **Student Sheet 36.2, "Discussion Web: Yucca Mountain"**

PROCEDURE

1. With your group, read the background information about nuclear waste on the following pages. Have each person read one section aloud.

2. **a.** With your group, read aloud each statement on Student Sheet 36.1, "Analyzing Evidence: Yucca Mountain."

   b. Discuss each statement with your group.

   c. Record on Student Sheet 36.1, "Analyzing Evidence: Yucca Mountain," whether you believe the statement is based on scientific reasons or on social or political concerns.

   d. Record whether the statement provides an argument for (+) or against (–) Yucca Mountain as a place for storing nuclear waste.

   When discussing your ideas, remember to listen to and consider the ideas of other members of your group. If you disagree, explain why.

3. Use Student Sheet 36.2, "Discussion Web: Yucca Mountain," to sort the evidence. Note: Do not copy the statements directly.

   a. In the "Yes" column, explain how a particular piece of evidence supports storing nuclear waste at Yucca Mountain.

   b. In the "No" column, explain how a particular piece of evidence does not support storing nuclear waste at Yucca Mountain.

Background Information about Nuclear Waste

WHAT IS NUCLEAR WASTE?

NUCLEAR WASTE IS the leftover radioactive material produced by nuclear power plants, nuclear research, nuclear medical treatments, and other nuclear technology. Radioactive materials release a type of energy that can't be seen, felt, or heard, but can damage living cells and cause diseases, such as cancer. Depending on the technology they are used for, such materials have high to low levels of radioactivity. Being exposed to highly radioactive materials for a short time or being exposed to low levels of radioactivity over long periods of time increases the risk of cancer and early death.


A nuclear power plant

Most nuclear waste comes from nuclear power plants and government defense projects. Most of it is in the form of highly radioactive solids made of metal, ceramic, or glass. Some of these solids will remain radioactive for a few years, while others are likely to be dangerous for at least 250,000 years.

HOW ARE PEOPLE PROTECTED FROM NUCLEAR WASTE?

There is no danger that nuclear waste will explode, but it does release radiation. It is usually stored in ways that protect people from its harmful effects and prevent it from leaking into the environment. A lot of nuclear waste is stored in containers made of lead, steel, and concrete, which shield people from the radiation. These containers are built to resist impact, high temperatures, and corrosive chemicals. It is possible that eventually water would damage these containers and cause them to leak. That is one reason why it is best to store nuclear waste containers in relatively dry areas. The most likely danger from nuclear waste is if it is accidentally released into the air or water, where it can spread throughout the environment and might be ingested or inhaled.

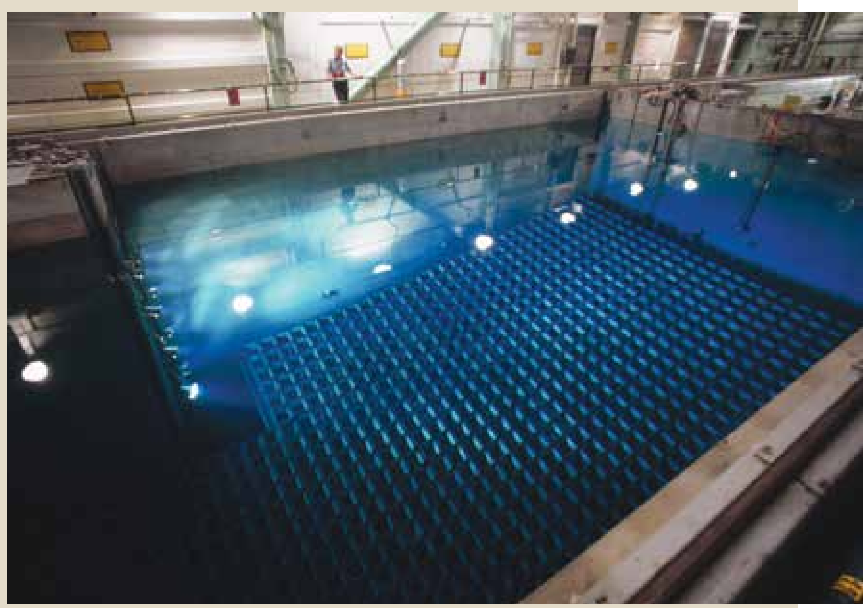
HOW MUCH WASTE COMES FROM NUCLEAR REACTORS?

About 20% of the electricity in the United States comes from its 104 nuclear power plants. Over the years, these power plants, which generate much of our electricity, have produced more than 65,000 metric tons of nuclear waste. If these power plants continue to operate to the end of their current licenses and no new nuclear power plants are built, the amount of nuclear waste to store will approach 150,000 metric tons by the year 2050. If more plants were built to help meet our electricity demands, this number would increase to as much as 200,000 metric tons.

WHERE IS NUCLEAR WASTE STORED NOW?

Nuclear waste is currently stored at 125 temporary sites in 39 states. These sites are located in cities, suburbs, and rural areas. More than half the U.S. population now lives within 121 km (75 mi) of stored nuclear waste. Some of the sites are in areas where earthquakes or hurricanes occur, some are near surface or groundwater sources that provide drinking water to communities, and some are near major cities.

When nuclear fuel is first removed from reactors, it is placed in deep pools of water. The water helps to cool the fuel and protect workers from radiation. About 50,000 metric tons of nuclear waste are currently stored in pools. At some power plants the cooled nuclear waste is transferred to dry storage. About 15,000 metric tons of nuclear waste are currently stored in dry containers above ground. Nuclear experts believe that it is possible to create places hundreds of meters below the earth's surface where up to 70,000 tons of nuclear waste can be safely stored for at least 10,000 years.



Nuclear power plants use radioactive fuel rods. When these rods can no longer be used to produce energy, they are first placed in pools of water to cool before being shipped to nuclear waste disposal sites.

ANALYSIS

1. What other information would you like to have before you make a decision about a proposed long-term nuclear waste site, such as Yucca Mountain? Be sure to explain how this information would be helpful.

2. Do you think that one or two sites deep in the ground would be better than the current situation? Explain by
   - **a.** stating your decision.
   - **b.** supporting your decision with as many pieces of evidence as you can.
   - **c.** discussing the trade-offs of your decision.

3. What role do you think each of the following should play in the selection of a long-term nuclear waste site?
   - **a.** Scientific evidence
   - **b.** Social or political concerns

4. **Reflection:** Would you agree to have nuclear waste stored near where you live? Why or why not?

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website for links to more information about the long-term storage of nuclear waste. How do these sites help answer your questions?

37 Volcanic Landforms

MODELING

Most people think of volcanoes as destructive. The high temperature of volcanic lava can burn almost everything in its path. Volcanoes also release large amounts of gas and ash that can cause other types of damage. But volcanoes can also be constructive because they form rocks that can eventually result in new landforms.

Millions of years ago, explosive volcanoes erupted in the Yucca Mountain area. These eruptions released ash and hot liquid rock called magma. As this material cooled, it formed the layers of rock that make up Yucca Mountain. Not all volcanic eruptions are the same. Some of the rock found in the Yucca Mountain area is from later volcanic eruptions. These eruptions were smaller and much less explosive. The force of an eruption is affected by the amount of gas in the magma.

CHALLENGE **How do volcanic eruptions vary?**

Some volcanic eruptions are explosive, while others release magma more slowly.

MATERIALS

For the class

1 sample of basalt rock
1 sample of pumice rock

For each group of four students

1 vial of baking soda
1 60-mL bottle of less gassy "magma" (red)
1 60-mL bottle of more gassy "magma" (colorless)
1 cup of water
1 plastic volcano model with base
1 clear, colorless plastic tube
1 rubber stopper
1 white plastic scoop
1 30-mL graduated cup
paper towels and/or a sponge

For each student

1 pair of safety goggles

SAFETY

Both types of "magma" contain dilute acid. Wear safety goggles and avoid direct contact with skin and eyes. Wash your hands after completing the activity.

PROCEDURE

Part A: Eruption of Less Gassy Magma

1. In your science notebook, make a table like the one below.

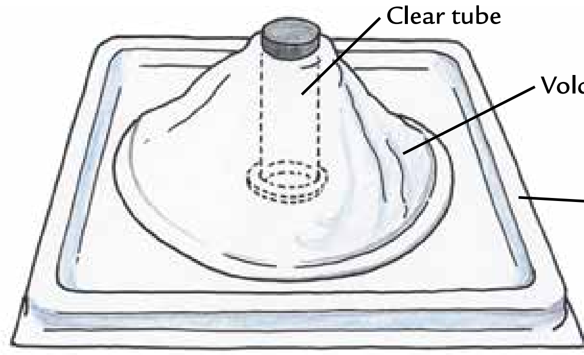
Observing Eruptions

Type of Eruption	Trial 1	Trial 2
Less gassy "magma"		
More gassy "magma"		

2. Work with your group to set up your volcano model as shown below by following these steps:

   a. Gently push the clear tube into the mouth of the white volcano cone.

   b. Set the base of the clear tube into the hole of the square plastic tray.



3. Place 1 scoopful of baking soda into the bottom of the volcano tube.
4. Use the graduated cup to measure and pour 5-mL of less gassy "magma" into the tube.
5. Without disturbing the model, observe it carefully for two minutes.
6. Record your observations in your science notebook.
7. Rinse your volcano model.
8. Then repeat Steps 3–7. Be sure to switch roles among your group members.

Part B: Eruption of More Gassy Magma

9. Use the graduated cup to measure and pour 2.5 mL of more gassy "magma" into the volcano tube.
10. Dip your finger into water and use it to moisten the bottom of the rubber stopper.
11. Dip the bottom of the stopper into the baking soda so that a thin layer of baking soda sticks to it.
12. Gently cap the volcano tube with the stopper. Try not to spill any baking soda and insert the stopper snugly into the tube.

13. Quickly turn the entire volcano model upside-down and then put it back on the table right-side up.

    Hint: Balance the volcano model on the palm of one hand. Use the other hand to hold the stopper and tube in place. Turn the model upside-down and right-side up, as shown below. Quickly set the model on the table right-side up.

14. Without disturbing the model, observe it carefully for two minutes.
15. Describe what you observe in your science notebook.
16. Rinse your volcano model.
17. Repeat Steps 9–16. Be sure to switch roles among your group members.
18. Your teacher will pass around two types of rock formed from cooling magma: basalt and pumice (PUM-is). Compare the two rocks. In your science notebook, record which rock is more likely to have been formed from: (a) less gassy magma and (b) more gassy magma. Explain your reasoning.

ANALYSIS

1. a. Describe the similarities and differences between the eruptions of less gassy and more gassy magma.

   b. Which type of magma produced a more explosive eruption?

2. Over time, there have been both very explosive and less explosive eruptions in the Yucca Mountain area. Which type(s) of volcanic rock might you find there? Explain your reasoning.

3. Imagine a volcano erupting many times over a period of years. Which of the following landforms is most likely a result of volcanic eruptions: a valley, a mountain, or a canyon? Explain.

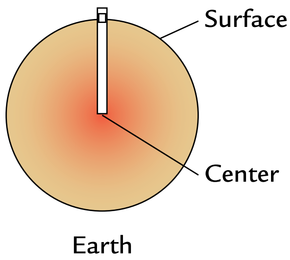
4. What were the strengths and weaknesses of the volcano model? **Hint:** Think about ways in which the model did or did not represent real volcanic eruptions.

38 Beneath the Earth's Surface

READING

When volcanoes erupt, magma is released. Where does this magma come from? To answer this question, it helps to know more about the earth.

Imagine taking a glass elevator to the center of the earth. What would you see?



CHALLENGE

What is beneath the earth's surface?

MATERIALS

For each pair of students

- 1 calculator
- colored pencils (optional)

For each student

- 1 Student Sheet 38.1, "Talking Drawing 1: Beneath the Earth's Surface"
- 1 Student Sheet 38.2, "Talking Drawing 2: Beneath the Earth's Surface"
- 1 metric ruler
- 1 compass (optional)

READING

Use Student Sheet 38.1, "Talking Drawing 1: Beneath the Earth's Surface," to help prepare you for the following reading.

On the Earth's Surface

A **volcano** is an opening in the earth from which magma and gas erupt. Gases within the magma build up enough pressure to force it upwards and eventually through gaps in the earth's surface, causing an eruption. Once magma has erupted onto the earth's surface, it is called **lava** (LAH-vuh). As it cools, the lava forms volcanic rock. Over time, volcanic rock and ash can result in a hill or mountain around the opening. This resulting landform is also called a volcano.

Volcanic eruptions are not all alike. Some eruptions are gentle, with lava slowly seeping from a vent. Other eruptions are violent, with lava, ash, and other materials being hurled hundreds of kilometers into the air. Differences in volcanic eruptions result in different volcanic mountain shapes, such as shield volcanoes, cinder cones, and composite volcanoes. You can see examples of each of these shapes in the photographs on the next page.

There is a lot of evidence of volcanic activity on earth. Many mountains have been formed from volcanoes that are now extinct or dormant. Yucca Mountain was formed from volcanic material exploding from a composite volcano that is now extinct. The Cascade Mountain Range that extends from British Columbia through Washington, Oregon, and Northern California, was mostly formed by volcanoes. Alaska's Aleutian Islands and all of Hawaii are volcanic formations.

Scientists who study volcanoes are known as volcanologists (vul-ka-NOL-o-jists). These volcanologists are measuring the temperature of an active volcano.

COMPARING VOLCANIC MOUNTAINS

a. ***Shield volcanoes,*** *such as Oregon's Mount Bachelor, shown here, usually form large, broad volcanoes. They release relatively fast-moving, less gassy lava, and tend to have less explosive eruptions than other types of volcanoes. People can often walk fairly close to these erupting volcanoes.*

b. The smallest and most common volcanoes are called ***cinder cones.*** *They are formed from explosive eruptions that shoot small pieces of magma and ash into the air. The magma then cools and hardens as it falls back to the earth, forming a cinder cone. In many cases, cinder cones form on the sides of a larger volcano. This photo shows a cinder cone on Mount Etna, in Italy.*

c. ***Composite volcanoes*** *have explosive eruptions as a result of more gassy magma. They are formed from layers of lava and ash. Composite volcanoes are also known as* ***stratovolcanoes.*** *This photo shows Mount St. Helens, Washington, a composite volcano, before its 1980 eruption.*

Inside the Earth

Early evidence about the inside of the earth came from volcanic eruptions. In the last hundred years, scientists have been learning more about the earth using technology and new methods for gathering evidence. For example, scientists have learned a lot from studying earthquakes. Earthquake waves move through different materials in different ways and at different speeds. In general, these waves move faster through more dense solids than they do through less dense solids. The waves move slowest through liquids. Scientists, such as the one shown below, measure the waves from a single earthquake at different places on the earth's surface. By analyzing and comparing the data from many earthquakes, they have been able to determine the state—solid, liquid, or gas—of the material inside the earth.

This geophysicist is using a GPS device to measure how much the land shifted after an earthquake.

Scientists now know that the rocks on the earth's surface are only a tiny fraction of what makes up the planet. Think of the earth as an egg. The thickness of the eggshell would represent the thickness of all the rocks at the surface. Beneath an eggshell there is egg white and yolk. What is beneath the rocks at the surface of the earth? Research indicates that the earth has three layers: a **crust**, a **mantle**, and a **core.** The core is made up of both a solid and a liquid layer, which are usually described separately as the **outer core** and the **inner core.** Information about each of these layers is summarized in the table on the next page.

Layers of the Earth

	Approximate depth below surface (km)	State	Material	Temperature (°C)
Crust	0–40 (average)	solid	many kinds of rocks	0–700
Mantle	40–2,800	upper part is solid, lower part is liquid	iron, magnesium, and silicon compounds	700–2800
Outer core	2,800–5,200	liquid	iron and nickel	2,800–5,200
Inner core	5,200–6,400	solid	iron and nickel	over 6,000

The magma that erupts from volcanoes often comes from the mantle. Magma rising from the mantle can collect in underground chambers in the earth's crust, building up pressure before exploding toward the surface. The mantle is almost 3,000 km thick, which is about the same as the distance from New York City to Denver, Colorado. The land from New York to Colorado is not always the same, and neither are all the parts of the mantle. The uppermost part of the mantle is more solid than the lower part. Because the upper mantle and the crust are both solid, geologists have a name for the combination of these two layers: **lithosphere** (LITH-o-sfeer). *Litho* means "stone" in Greek, and the lithosphere refers to the first 100 km below the earth's surface.

ANALYSIS

1. Which layer(s) of the earth is (or are):
   a. the hottest?
   b. at the earth's center?
   c. completely solid?

2. Copy the five words shown below.

   outer core　　upper mantle
   lithosphere　　solid
   crust

   a. Look for a relationship among the words. Cross out the word or phrase that does not belong.
   b. Circle the word or phrase that includes all the other words.
   c. Explain how the word or phrase you circled is related to the other words in the list.

Your teacher will give you Student Sheet 38.2, "Talking Drawing 2: Beneath the Earth's Surface." Use it and the information from the Reading to answer Questions 3 and 4.

3. Answer Parts a–h to create a scaled drawing of the earth's layers on Student Sheet 38.2. If you have time, you may want to color in the different layers.

a. How far is it to the center of the earth in kilometers (km)? Record this distance on Student Sheet 38.2.

b. Use a ruler to measure and record the distance from earth's surface to its center in centimeters (cm).

c. How many kilometers will a single centimeter represent? This is called a **scale.** Calculate and record your scale. **Hint**: You will need to divide the distance to the center of the earth in kilometers (km) by the scale.

d. Record the lowest depth of each earth layer in kilometers.

e Use your scale and a calculator to determine the scaled depth of each earth layer in centimeters.

f. Use a ruler to measure the depth of each layer, starting from the earth's surface. Draw a circle at each depth. **Hint:** After drawing the other layers, sketch the approximate location of the crust.

g. Label each layer with its name, state, and temperature.

h. Label the lithosphere. Be sure to record its actual depth in km.

4. At Yucca Mountain, nuclear waste will be stored at a depth of about 0.3 km (300 meters, or 1,000 feet).

a. In which layer of the earth will the waste be stored?

b. Place an "X" on that layer of your drawing on Student Sheet 38.2.

5. Compare your drawing on Student Sheet 38.1, "Talking Drawing 1: Beneath the Earth's Surface," with your drawing on Student Sheet 38.2. Describe the earth's interior and explain how your understanding of it has changed.

39 Earth Time

The earth is over 4 billion years old. But modern humans have been around for only hundreds of thousands of years, or 0.01% of earth's history. That's why paleontologists use fossil evidence, as well as the radioactive decay in rocks, to figure out when things happened. **Paleontologists** (pay-lee-un-TALL-oh-jists) are scientists who use evidence from rocks and fossils to understand when events occurred in the history of life.

Volcanoes are found in 18 states in the United States. Since 1900, volcanoes have erupted in Alaska, California, Hawaii, Oregon, and Washington. Volcanoes in other states have not erupted for thousands, hundreds of thousands, or even millions of years. All of these time periods are very long compared to the average human lifespan. Paleontologists usually refer to time periods of thousands, millions, and billions of years as **geological time**.

CHALLENGE

When did particular events in earth's history occur?

Argentinian paleontologist Rodolfo Coria prepares the fossilized vertebrae of a dinosaur.

MATERIALS

For each group of four students

1 set of 10 "Events on Earth" cards

1 Student Sheet 39.2, "Paleontology Student's Notes"

For each student

1 Student Sheet 39.1, "Ordering Events"

PROCEDURE

1. Imagine that your friend is studying to be a paleontologist. She asks you to help her list some events in the history of the earth in order. She's interested in organizing her ideas into the four time periods shown on Student Sheet 39.1, "Ordering Events."

2. With your group, carefully read the information on the front of each "Event on Earth" card.

3. With your group, place each event in order, from oldest to most recent. **Hint:** If you need help, read the clue on the back of the card. Some clues will help you put the events in order, while other clues will help you identify the time period in which an event occurred.

   Remember to listen to and consider the explanations and ideas of other members of your group. If you disagree with the others, explain why you disagree.

4. Discuss with your group during which time period you think each event occurred.

5. On Student Sheet 39.1, "Ordering Events," record the order of events that you have decided upon with your group. Be sure to place each event in the time period in which you think it occurred.

6. Your friend suddenly remembers that she wrote down the order of these events in her science notebook. Ask your teacher for a copy of Student Sheet 39.2, "Paleontology Student's Notes," for your group.

7. Use the information on Student Sheet 39.2 to rearrange the cards in the order scientists have determined from geologic evidence.

8. Record this revised order on Student Sheet 39.1.

ANALYSIS

1. How did your group's original order of events differ from that of paleontologists? Explain.

2. Would units of time such as minutes and hours be useful in measuring events in earth's history? Why or why not?

3. Some nuclear waste may be radioactive for 250,000 years. Would you consider this to be a long or short period in geological time? Explain your reasoning.

4. Your younger brother tells you about a television show he watched where humans ride dinosaurs instead of cars. He says he wishes he could go back to the time when people lived with dinosaurs. Based on what you learned in this activity, what do you tell him?

5. **Reflection:** How did placing these events in order yourself help you to understand the earth's history? **Hint:** Think about how your understanding of events in geological time has changed.

40 The Continent Puzzle

INVESTIGATION

Volcanoes occur all over the world. How likely is it that volcanic eruptions will occur at Yucca Mountain? To answer this question, it helps to study the past. You will find out more about the history of the earth in the next few activities.

In the early 1900s, Captain Robert Scott, who was from England, explored the continent of Antarctica. In his journal, he described finding plant fossils. These fossils were later identified as *Glossopteris* (gloss-OP-ter-iss), an extinct fern-like plant that grew on earth about 250 million years ago. *Glossopteris* grew in warm, wet areas, and could not have survived in an extremely cold place like Antarctica. How did the fossils of this plant end up in Antarctica?

CHALLENGE

What can rearranging the continents tell you about earth's history?

Captain Robert Scott's campsite in Antarctica.

MATERIALS

For each group of four students

1 **set of 7 "World Puzzle" pieces**

1 **Student Sheet 40.1, "Earth's Surface Through Geological Time"**

For each student

1 **completed Student Sheet 39.1, "Ordering Events"**

PROCEDURE

Part A: The World Puzzle

1. With your group, carefully examine the location of the world's continents on the map on the next page.
2. Record the names of the seven continents in your science notebook.
3. Compare each World Puzzle piece to the continents on the map. Put a star next to each continent in your list that is represented by a puzzle piece. Then record the name(s) of any additional pieces.
4. Work with your group to arrange your puzzle pieces in locations similar to the ones shown on the world map.
5. Look at the symbols on some of the pieces. The symbols represent types of fossils or rocks found in several locations. The key to these symbols is shown below.

	Key to Symbols on World Puzzle
	Glossopteris, an extinct fern-like plant that could grow to 3.7 meters (12 feet) in height
	Mesosaurus (MESS-oh-saw-rus), an extinct freshwater reptile about 0.5 meters (2 feet) in length
	Cynognathus (sy-nog-NAY-thus), an extinct land reptile about the size of a wolf
	Lystrosaurus (liss-tro-SAW-rus), an extinct land reptile about 1 meter (3 feet) long
	Mountain ranges that have similar rock layers

CONTINENTS OF THE WORLD

The country of India can be seen on the Asian continent, in orange.

6. Work with your group to try to place all of the puzzle pieces into a single shape. Work together to decide where each piece belongs.

   Remember to listen to and consider the explanations and ideas of the other members of your group. If you disagree with other members of your group, explain why you disagree.

7. In your science notebook, sketch an outline of the final shape of your completed puzzle. Then, draw and label the individual puzzle pieces within your outline.

8. Move the pieces back into positions similar to the location of the continents today. Then slowly move the pieces back together into the single shape.

9. Discuss with your group what this puzzle might tell you about the history of the earth.

Part B: The History of Earth's Surface

10. Ask your teacher for a copy of Student Sheet 40.1, "Earth's Surface Through Geological Time," for your group.

11. Discuss with your group what you think has happened to the land on the surface of the earth during geological time.

12. Compare the outline that you sketched in Step 7 with Student Sheet 40.1. Identify when in earth's history the continents were arranged in a similar way. Record this time period, and the name of the land at this time, next to your sketch.

ANALYSIS

1. Describe what has happened to the land on the surface of the earth over the past 425 million years.

2. There are seven continents and there were seven puzzle pieces. But not every puzzle piece represented a continent. Why do you think this is? Hint: Think about how you used the pieces to model changes on the earth's surface.

3. What types of evidence did the puzzle provide about change on the earth's surface?

4. a. Look at the information in the table below, "Approximate Time Period of Some Extinct Organisms." On Student Sheet 39.1, "Ordering Events," record when each of these organisms lived.

   b. Pangea began to break apart about 200–225 million years ago. Record this event on Student Sheet 39.1.

   c. Which of the extinct organisms listed in the table below lived on Pangea before it broke apart?

Approximate Time Period of Some Extinct Organisms

Extinct Organism	Lived
Glossopteris (plant)	206–250 million years ago
Mesosaurus (reptile)	248–280 million years ago
Cynognathus (reptile)	230–245 million years ago
Lystrosaurus (reptile)	206–248 million years ago

EXTENSION

Go to the *Issues and Earth Science* page of the SEPUP website to link to animations showing the movement of continents over the last several million years. What do you notice?

41 Continental Drift

In 1915, a German scientist named Alfred Wegener (1880–1930) put together several kinds of evidence—including the location of fossils and rock layers on different continents—to come up with a new idea about the history of the continents. His idea was that the continents were once joined together to form a single large continent called Pangea. Over geological time, Pangea split apart and parts of it moved away to form today's continents. Today, this idea is called **continental** (kon-ti-NEN-tul) **drift.** "Drift" refers to the idea that the continents slowly moved away from each other, or *drifted* apart. In this activity, you will examine more evidence for this movement of continents.

CHALLENGE

What is the evidence that the continents have moved?

Fossilized Glossopteris *leaves*

MATERIALS

For each student

1 **Student Sheet 41.1, "Analyzing Evidence: Continental Drift"**

PROCEDURE

1. Carefully read Student Sheet 41.1, "Analyzing Evidence: Continental Drift."
2. Discuss with your group what is evidence and what is not evidence.

   Remember to listen to and consider the ideas of the other members of your group. If you disagree with others, explain why you disagree.
3. On Student Sheet 41.1, look at each statement carefully and then mark whether you think it is or is not evidence. Check "yes" if you think it is evidence, and "no" if you think it is not evidence.
4. Cross out each statement that you have decided was not evidence. You will no longer consider these statements.
5. On Student Sheet 41.1, mark whether you think each piece of evidence does or does not support the idea that continents have moved. Check "yes" if you think it supports it, and "no" if you think it does not.
6. With your group, discuss:
   a. whether you identified a statement as evidence or not.
   b. how each statement you checked as evidence either supports or contradicts the idea of continental movement.

ANALYSIS

1. On Student Sheet 41.1, you identified statements that provide evidence in support of continental movement. Explain *how* each of these statements supports the idea that continents have moved.
2. Look again at Student Sheet 41.1. Have people other than Wegener contributed to the evidence in support of continental movement? Explain.
3. Imagine that you have been asked to write an encyclopedia entry about the movement of the earth's continents. Write a paragraph about continental movement, describing the history of this idea and citing as many pieces of evidence as you can.

42 The Theory of Plate Tectonics

VIEW AND REFLECT

In Activity 40, “The Continent Puzzle,” you investigated the movement of continents. Today, geologists know that it’s not just the continents that move—it is the entire surface of the earth! The earth’s surface is broken into large sections called **plates.** These plates not only include the surface of the earth, but also extend down into the solid part of the upper mantle. This is one reason that geologists use the term “lithosphere.” The movement of these lithospheric plates is called **plate tectonics** (tek-TAWN-iks).

CHALLENGE

How did continental drift lead to the theory of plate tectonics?

MATERIALS

For each student

1 **Student Sheet 42.1, “Plate Tectonics Video”**

Divers examine an underwater volcanic vent.

PROCEDURE

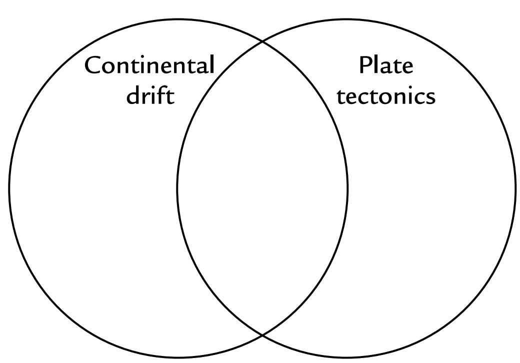
1. To prepare for watching the video, first read Analysis Questions 1–3.
2. Your teacher will provide you with Student Sheet 42.1, "Plate Tectonics Video." It will help you identify some of the important ideas presented in the video. Read the questions on Student Sheet 42.1.
3. Watch the video segments on continental drift and plate tectonics.
4. Answer as many questions on Student Sheet 42.1 as you can.
5. Watch the video segments again.
6. Complete Student Sheet 42.1.

ANALYSIS

1. Why were scientists surprised to find coal in the Arctic?
2. Think about what you learned from the video about where volcanoes are most likely to occur. Based on this information, do you think that the risk of a volcanic explosion at Yucca Mountain is high or low? Explain.
3. **a.** The idea of continental drift eventually led to the modern theory of plate tectonics. To help you remember similarities and differences between these two ideas, create a larger version of the Venn diagram shown below in your science notebook.

   b. Compare continental drift and plate tectonics by recording unique features of each idea in the circle with that label. **Hint:** Think about what you have learned about these ideas in the last few activities.

   c. Record features that are common to both these ideas in the space that overlaps.



43 Measuring Earthquakes

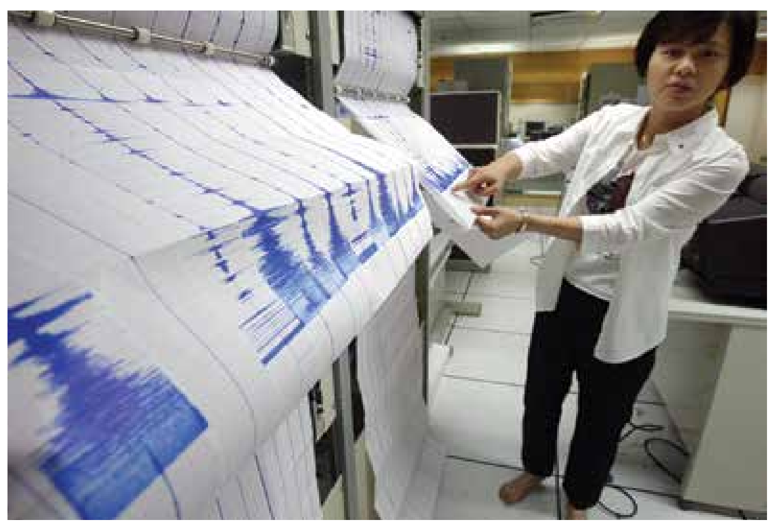
MODELING

The earth's plates continue to move. Today, the plate that includes North America is moving away from the plate that includes Europe at a rate of about two centimeters (cm) each year. Moving these huge plates takes lots of energy. Some of this energy causes large sections of underground rock to break and shift position, resulting in an earthquake.

Scientists measure the intensity of an earthquake using a tool known as a **seismograph** (SYZ-mo-graf). A seismograph contains a thin needle-like pen that records the movements detected within the earth on a roll of paper. The lines recorded on the paper are called a **seismogram.**

CHALLENGE

How can a seismograph be used to measure earthquakes?



During earthquakes, rocks shift along a crack that geologists call a fault. *The deep line shown in the middle of the picture on the left shows one of the best-known faults in the United States: the San Andreas Fault in California. Geologists have placed many seismographs along this fault. On the seismogram shown above, the large blue areas were recorded during an earthquake.*

MATERIALS

For each group of four students

1 **seismograph model**
1 **black marker**
4 **sheets of plain paper**
8 **toothpicks**

For each student

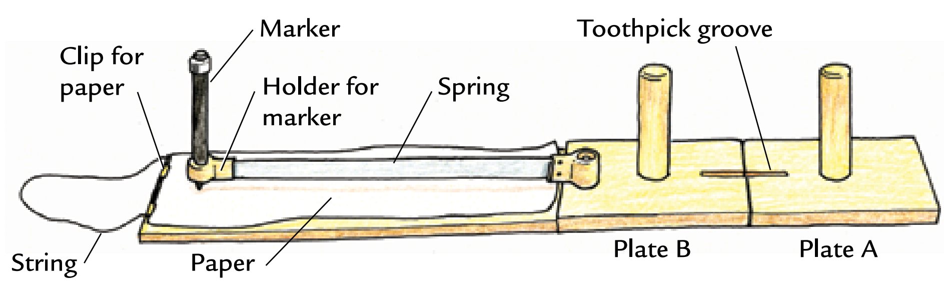
1 **pair of safety goggles**

SAFETY

Be aware of your surroundings when moving the different parts of the seismograph model. If you have long fingernails, hold the seismograph so that your nails point away from the hands of other group members.

PROCEDURE

1. Work with your group to set up the seismograph model as described in Steps a–d below.



a. Set up the model as shown in the drawing above.

b. Fold a sheet of plain paper in half, lengthwise. Slide the top of the folded sheet into the clips at the end of the paper tray.

c. Remove the cap from the marker and insert it point-down into the holder attached to the end of the spring on Plate B.

d. Check to see if the marker is positioned properly by gently pulling the spring sideways and then releasing it. The marker should leave a curved line on the paper.

2. Decide which person in your group will perform each of the following roles. During the activity, each person will have a chance to perform each role.

   - *Plate A Holder:* Hold the handle of Plate A and press down to keep it steady.
   - *Plate B Holder:* Push Plate B directly away from you, just hard enough so that Plate B slides past Plate A and the toothpick breaks. Don't start pushing until the Data Recorder tells you to start.
   - *Data Recorder:* Slowly pull the string to slide the paper tray away from Plate B (leaving a straight marker line on the paper). After the line is about 3–5 cm long (1–2 inches), tell the Plate B person to start pushing Plate B while you keep slowly pulling the paper tray. You should stop pulling the tray when you have almost reached the end of the paper.
   - *Observer:* Carefully observe the movement of each plate and the resulting seismogram.

3. Push the two plates together and place a toothpick into the groove formed by the two halves.

4. Simulate an earthquake along a plate boundary by completing your roles as described in Step 2.

5. As a group, discuss your observations of the seismograph model, the seismogram, and the force required to break the toothpick. Then record your observations for this trial in your science notebook.

6. Remove any toothpick pieces left in the groove of either Plate A or Plate B, and collect any toothpick pieces that may have fallen onto the table or the floor. Throw these pieces away at the end of the activity.

7. Remove the folded paper from the clip and turn it to the blank side. Insert the paper back into the clip with the blank side face up.

8. Keep the same roles and repeat Steps 3–6 one more time.

9. Now, replace the folded sheet of paper with a new sheet. Switch the roles among your group members and repeat Steps 3–8 until every member of your group has pushed Plate B two times.

10. Unfold the 4 sheets of paper so that all of the recorded data can be seen at the same time. Compare the 8 seismograms. Discuss your observations with your group.

ANALYSIS

1. What similarities and differences did you observe among your group's 8 seismograms?

2. **a.** What did each half of the seismograph model represent?

   b. What did the toothpick represent? (**Hint:** Reread the introduction to this activity.)

   c. When did an "earthquake" occur? It occurred when:

   - the Data Recorder began pulling the paper tray.
   - Plate B was first pushed.
   - the toothpick broke.

   d. What type of plate movement did you simulate?

   - plates colliding
   - plates sliding past each other
   - plates pulling apart

3. Describe what the seismogram looked like:

   a. when there was little or no movement.

   b. when the toothpick broke.

4. This activity modeled an earthquake occurring along a plate boundary. What do you think are the strengths and weaknesses of this model?

44 Mapping Plates

As you've learned, some of the earth's lithospheric plates are slowly sliding past each other, some plates are slowly colliding, and some plates are slowly moving apart. Both earthquakes and volcanoes occur more frequently along such plate boundaries.

CHALLENGE

How can you use earthquake and volcano data to map the earth's plates?

MATERIALS

For each student

- 1 **Student Sheet 44.1, "Anticipation Guide: Mapping Plates"**
- 1 **Student Sheet 44.2, "Plate Boundaries"**
- 1 **light-colored pencil (such as yellow)**
- 1 **dark marker (such as purple)**

The result of an earthquake

PROCEDURE

Use Student Sheet 44.1, "Anticipation Guide: Mapping Plates," to prepare you for the following activity.

1. Use a light-colored pencil to color in the continents on Student Sheet 44.2, "Plate Boundaries."
2. Use a dark-colored marker to trace the dashed plate boundary lines on Student Sheet 44.2.
3. The dark lines show the major plates. But if you look carefully, you will notice that the boundaries of the South American plate are missing!
4. To find the missing *eastern* boundary of the South American plate, plot the locations of the earthquakes and volcanoes listed in Table 1, below, on Student Sheet 44.2.

Table 1: Earthquakes and Volcanoes in the Atlantic Ocean

Name and Location	More Information	Location on Map
Earthquake in northern Atlantic Ocean	Occurred on 6/12/01; magnitude 5.4	13 J
Earthquake in northern Atlantic Ocean	Occurred on 4/14/02; magnitude 5.1	13 K
Earthquake in northern Atlantic Ocean	Occurred on 7/31/02; magnitude 5.4	14 K
Earthquake in the Atlantic Ocean	Occurred on 9/17/05; magnitude 4.8	15 L
Underwater volcano in southern Atlantic Ocean	Ship captain reported last known eruption in 1836	16 L
Earthquake in southern Atlantic Ocean	Occurred on 3/7/01; magnitude 6.0	16.5 L/M*
Ascension Island (volcano)	Summit of a stratovolcano; no recent eruptions	16 M
Earthquake in southern Atlantic Ocean	Occurred on 8/24/00; magnitude 5.5	16 O
Tristan da Cunha island volcano	Shield volcano; last known eruption in 2004	16 P
Bouvet Island (volcano)	Ice-covered shield volcano; may have last erupted in 50 B.C.	17 R

*Between 16 and 17, and between L and M

5. Complete this missing eastern boundary by using a dark-colored marker to draw a line connecting the earthquakes and volcanoes you have plotted. **Hint:** Work from top to bottom.

6. Now, to find the missing *western* boundary of the South American plate, plot the locations of earthquakes and volcanoes listed in Table 2, below, on Student Sheet 44.2.

Table 2: Earthquakes and Volcanoes in Central and South America

Name and Location	More Information	Location on Map
Nevado del Ruiz volcano, Colombia	Composite volcano; last major eruption in 1991	10 K
El Misti volcano, Peru	Composite volcano; last major eruption in 1874	9.5 M*
Earthquake in Atacama region, Chile	Occurred in 1922; magnitude 8.5	10.5 N**
Cerro Azul (Quizapu) volcano, Chile	Composite volcano; last major eruption in 1967	10 O
Earthquake near Valdivia, Chile	Occurred in 1960; magnitude 9.5	10 P
Villarrica volcano, Chile	Composite volcano; last major eruption in 2005	10 Q
Monte Burney volcano, Chile	Composite volcano; last major eruption in 1910	10 R

*Between 9 and 10
**Between 10 and 11

7. Complete this missing western boundary using a dark-colored marker to draw a line connecting the earthquakes and volcanoes you have plotted. **Hint:** Work from top to bottom and left to right.

8. Discuss with your partner how the shapes of the continents compare with the shapes of the plates.

9. Use Table 3, below, to help you label some of the plates with their proper names.

Table 3: Some Major Plates

Name of Plate	General Direction of Movement
African	northeast
Antarctic	southeast
Australian	northeast
Eurasian	east
Indian	northeast
North American	west
Pacific	northwest
South American	northwest

10. Use the information in Table 3 to draw an arrow on each of these plates showing the general direction of its movement.

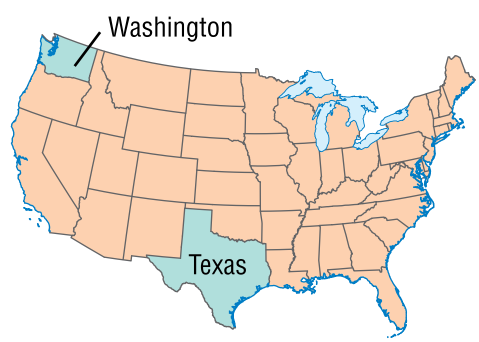
ANALYSIS

1. Are the sizes and shapes of the continents the same as the sizes and shapes of the plates? Support your answer with a specific example from Student Sheet 44.2.

2. Look again at Table 2, "Earthquakes and Volcanoes in Central and South America," on the previous page. In terms of geological time, would you consider these volcanoes and earthquakes to have occurred recently or a long time ago? Explain.

3. What is the relationship between earthquakes, volcanoes, and plate boundaries?

4. In Activity 36, "Storing Waste," you learned that Nevada has the fourth highest number of earthquakes per year in the U.S. Which state would you predict to have a higher risk of earthquakes: Washington or Texas? Why?



5. In Activity 40, "The Continent Puzzle," the country of India was a separate puzzle piece. Use the information on Student Sheet 44.2 to help you explain why.

EXTENSION

On Student Sheet 44.2, you labeled the name and direction of movement for eight major lithospheric plates. Visit the *Issues and Earth Science* page of the SEPUP website for links to sites that show both the name and direction of movement of the remaining plates. Use this information to label seven more plates on Student Sheet 44.2.

45 Understanding Plate Boundaries

READING

The map below shows the locations of earthquakes and volcanoes on the earth's surface. Today, many of the world's most active volcanoes are located around the edges of the Pacific Ocean, and are often referred to as the "Ring of Fire." You may notice that both volcanoes and earthquakes tend to be concentrated in particular areas. The theory of plate tectonics helps explain this pattern.

CHALLENGE

How does the theory of plate tectonics help to explain the locations of earthquakes, volcanoes, and mountain ranges?

MATERIALS

For each student

1 **completed Student Sheet 44.2, "Plate Boundaries"**
1 **Student Sheet 45.1, "Directed Reading Table: Understanding Plate Boundaries"**

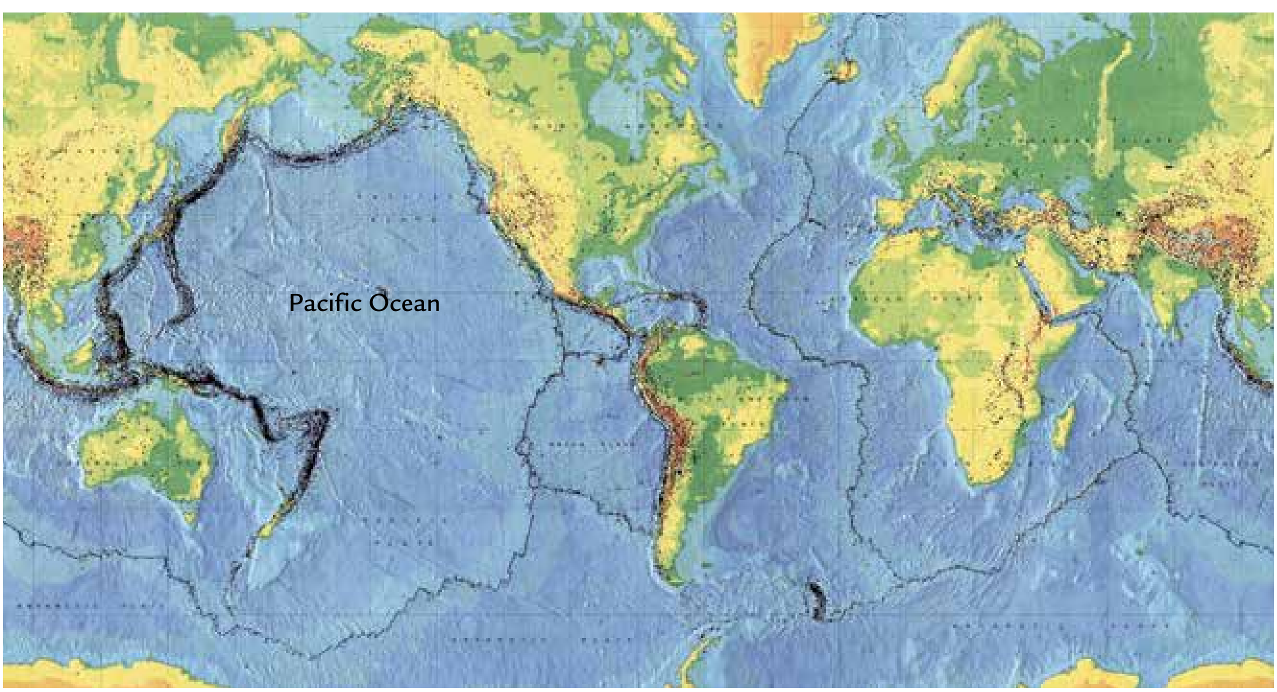


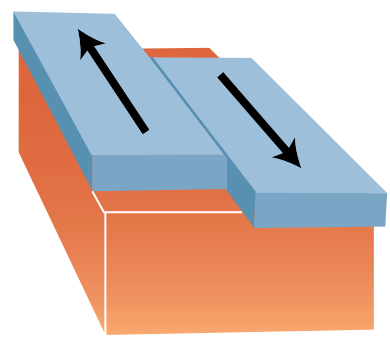
FIGURE 1: MAP OF RECENT EARTHQUAKES AND VOLCANOES ON EARTH
Black dots mark the locations of individual earthquakes and volcanoes.

READING

Use Student Sheet 45.1, "Directed Reading Table: Understanding Plate Boundaries," to guide you through the following reading.

Plate tectonics is the theory that the earth's lithosphere is broken into plates that are in constant motion. The edges of these plates may be sliding past each other, spreading apart, or colliding. Over geological time, important processes—such as the formation of mountain ranges, earthquakes, and volcanoes—take place along the boundaries where these plates meet.

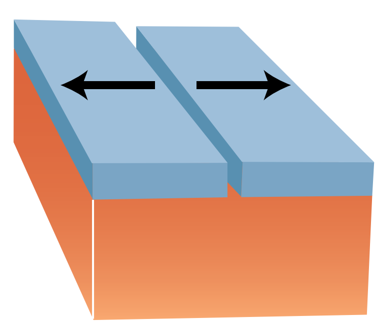
Sliding Plates



Geologists call the region where two plates are sliding past each other a **transform** boundary. Earthquakes are common along transform boundaries. There is a lot of pressure between the plates as they try to move past each other, and this pressure is only released when large pieces of rock along the boundary crack or shift their position. People can sometimes feel the vibrations caused by these movements and call them earthquakes.

In Activity 44, "Mapping Plates," you recorded the overall movement of several large plates. Each plate may have different types of boundaries along different parts of its edge. A transform boundary is located between a part of the Pacific plate and a part of the North American plate, along the western edge of California. This is an area known for its many earthquakes, as you can see in Figure 1, "Map of Recent Earthquakes and Volcanoes on Earth." On its eastern edge, the North American Plate has a divergent boundary.

Spreading Plates



The place where plates are spreading apart is called a **divergent** (dy-VER-junt) boundary. Volcanoes as well as earthquakes are common along divergent boundaries. As the plates pull apart, the lithosphere thins and molten magma from the earth's mantle erupts onto the surface, forming new lithosphere (See Figure 2, on the next page). Over time, the lava from these volcanoes can build

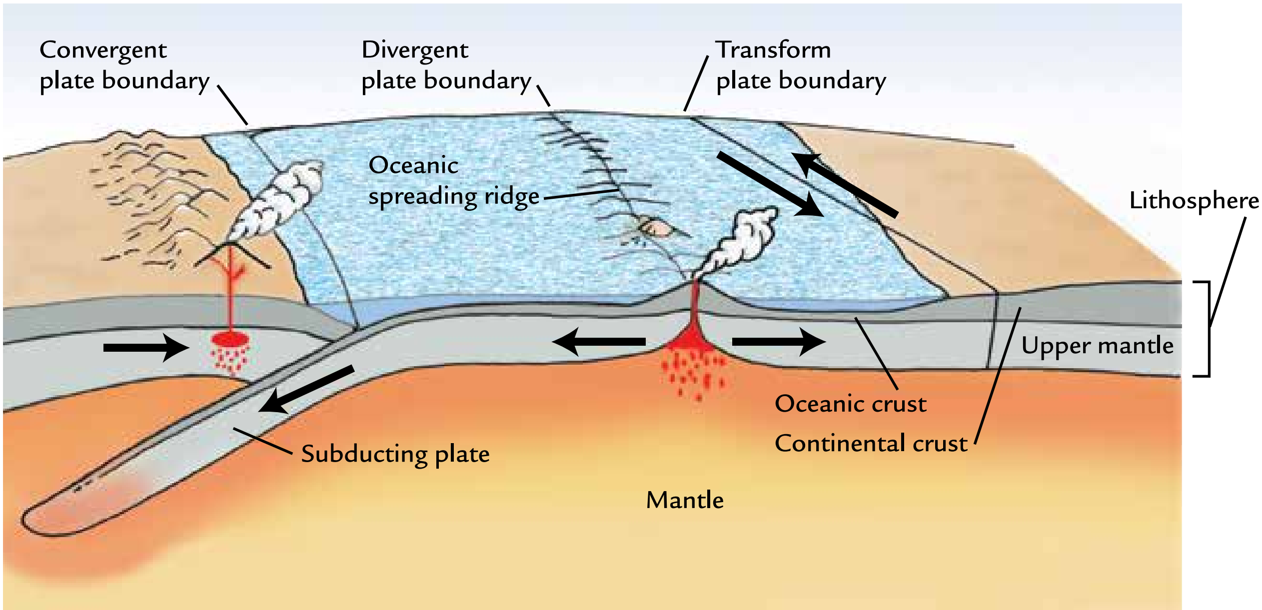


FIGURE 2:
TYPES OF PLATE
BOUNDARIES

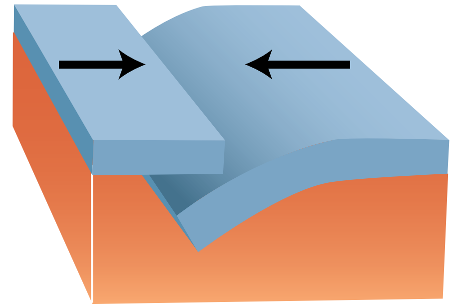
up and form volcanic mountains. You read about such mountains in Activity 38, "Beneath the Earth's Surface."

Sometimes, divergent boundaries are located under the ocean, and large underwater volcanic mountains can form. The plate boundaries seen along the middle of the Atlantic Ocean are an example of an underwater divergent boundary.

Colliding Plates

Colliding plates create **convergent** (kun-VER-junt) boundaries. What happens along a convergent boundary depends on the type of lithosphere at the edge of each of the colliding plates. The earth's lithosphere—which includes the crust and solid upper mantle—varies over the surface of the earth. This is partly due to differences in the thickness of the earth's crust. The crust that makes up the oceans is generally thinner than the crust that makes up the continents. Oceanic crust is usually about 10 kilometers (km) thick, while continental crust ranges from 20 to 80 km thick. For this reason, the lithosphere is about 100–150 km thick under the ocean, and up to 300 km thick at some continents. Despite being thinner, oceanic lithosphere is denser than continental lithosphere because its crust is made up of denser rocks, such as basalt.

When continental and oceanic lithosphere collide, the less dense continental lithosphere usually rides up over the oceanic lithosphere, which goes down into the mantle and is destroyed. (See Figure 2, above.)



The process of one plate moving below another plate is known as **subduction** (sub-DUK-shun). Both earthquakes and volcanoes are common along subduction zones. The volcanic mountains that you plotted along the western coast of South America in Activity 44, "Mapping Plates," are a result of the oceanic lithosphere of the Pacific plate being subducted below the continental lithosphere of the South American plate. The March, 2011 earthquake off the coast of Japan was also a result of the subduction of the oceanic Pacific plate beneath a continental plate. This is also happening in the Pacific northwest as the Juan de Fuca plate is moving under the North American plate. Subduction also occurs when two sections of oceanic lithosphere collide.

When two sections of continental lithosphere collide, the lithosphere tends to crumple and be pushed upward, forming mountains as well as causing earthquakes. The Himalayan mountains found along the northern border of India were formed when the Indian plate collided with the Eurasian plate. Several of the world's highest mountains, including Mount Everest, are part of the Himalayas and were formed from this collision.

Volcanoes and Plates

Most earthquakes and volcanoes occur along plate boundaries, but there are exceptions. For example, volcanoes formed each of the Hawaiian Islands. Lava from eruptions over hundreds of thousands of years built up the islands. Yet the Hawaiian Islands are located far from any plate boundaries. Hawaii, the "Big Island" at the southwestern end of the island chain, is the only one of those islands that still has an active volcano. A new island called Loihi has begun to form beneath the ocean southwest of the Big Island. But don't start making vacation plans to visit Loihi. Scientists predict it will rise above the ocean's surface in about one million years.

The explanation for the formation of the

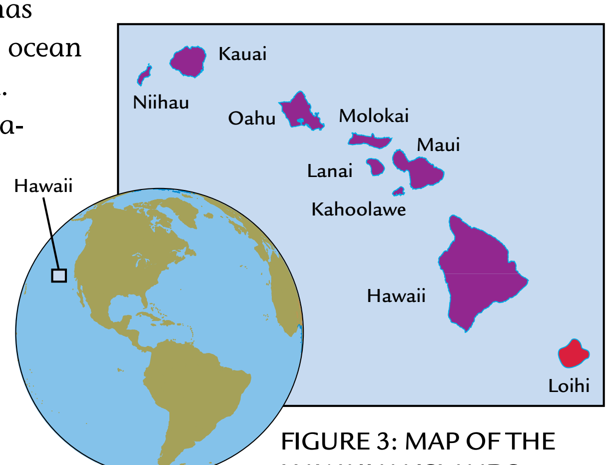


FIGURE 3: MAP OF THE HAWAIIAN ISLANDS

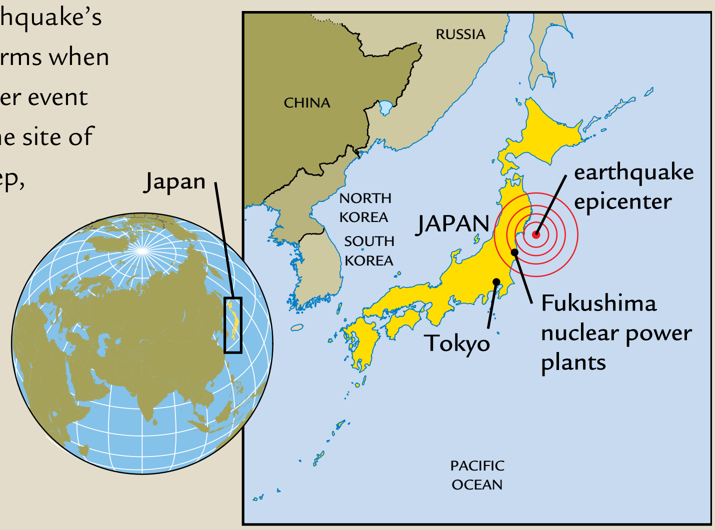
The 2011 Earthquake and Fukushima Nuclear Accident in Japan

ON MARCH 11, 2011, a huge earthquake rocked Japan. This earthquake had a magnitude of 9.0 and was centered 70 km (43 mi) off the coast of the largest Japanese island, Honshu. More than 15,000 people were killed, more than 5,000 were injured, and more than 330,000 structures, including buildings, roads, bridges, and railways, were destroyed. The cost of this earthquake is estimated at hundreds of billions of U.S. dollars.

Most of the deaths, injuries, and damage were caused by a tsunami, rather than the earthquake's shaking. A tsunami is a large wave that forms when an earthquake, volcano, landslide, or other event moves a very large amount of water. At the site of an earthquake where the water is very deep, the wave might be only a few inches high. But as the wave moves into shallower areas closer to shore, the very large amount of water forms a high wave. At its highest, the height of the wave from the Japanese earthquake reached nearly 38 m (125 ft).

The earthquake led to a serious accident at a nuclear power plant located in Fukushima, on Honshu. Three of the six nuclear reactors in the plant overheated when the cooling system failed. This caused a nuclear fuel meltdown and explosions. Several workers were killed, and more were exposed to radiation. Of concern to people outside the plant, radioactive material was released into the air and water. The long-term effects of radiation released to the environment by the accident are not yet known. The greatest fear is that exposure to radiation will lead to increased deaths from cancer.

Although nuclear waste does not explode, the accident in Japan has increased concern in the United States and elsewhere about all aspects of nuclear safety.



This damaged building at the Fukushima Daiichi nuclear power plant was photographed one year after the earthquake and tsunami.

Hawaiian island chain is still a subject of active research. One theory suggests that extremely hot material in a region called a hot spot rose to the surface from the deep mantle. According to this theory, movement of the Pacific plate carried each of the islands toward the northwest, away from the hot spot. Other ideas are based on the properties of plates. For example, volcanoes might form when thin or cracked areas of the lithosphere allow hot material from the upper mantle to break through.

ANALYSIS

1. Describe two ways in which the movement of lithospheric plates can result in the formation of mountains.

2. On Student Sheet 44.2, "Plate Boundaries," you drew the boundaries of large, lithospheric plates. Use information from this reading to identify and label:

   a. a transform boundary

   b. a divergent boundary

   c. a convergent boundary

3. Yucca Mountain is located close to H6 on Student Sheet 44.2. Which type of boundary is closest to it?

4. Of the three different types of rocks—igneous, metamorphic, and sedimentary—which type of rock would you expect to find along a divergent plate boundary? Explain.

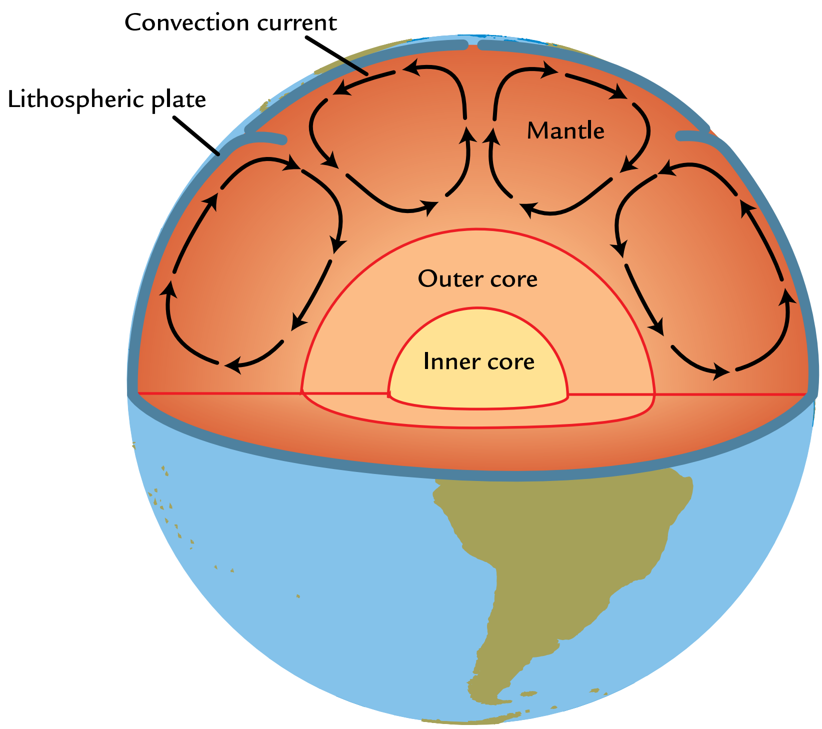
46 Convection Currents

Scientists don't know exactly what drives plate motion. One theory is that there are convection currents within the earth's mantle. **Convection** occurs when there is a temperature difference within a substance like magma, causing it to move in a circular pattern shown in the diagram below). This convection of the magma within the mantle is believed to cause plate movement. In this activity, you will investigate how differences in temperature can cause substances like magma to move.

CHALLENGE

How do differences in temperature cause a convection current?

MANTLE CONVECTION



MATERIALS

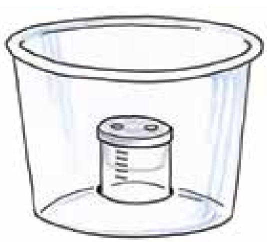
For the class

supply of warm water
supply of cold water

For each group of four students

- 2 9-oz. plastic cups
- 1 plastic syringe
- 1 plastic cup with circular depression
- 1 small vial with 2-holed cap
- 1 bottle of red food coloring
- paper towels and/or a sponge

PROCEDURE



CAPPED VIAL IN CUP

1. Fill two 9-oz. plastic cups, one with warm water and the other with cold water.
2. Snap the small vial (cap-side up) into the base of the plastic cup that has a circular depression, as shown at left.
3. Gently remove the cap and place 1 drop of food coloring into the bottom of the vial. Carefully and firmly re-cap the vial with the 2-holed cap.
4. Use the syringe to carefully fill the vial with about 5 mL of warm water. Gently tap the vial to remove any air bubbles.
5. Cover both of the holes in the 2-holed cap with two fingers and have one person in your group slowly add cold water to the set-up until it is almost full.
6. Remove your fingers and observe what happens from both the side and the top.
7. Record your observations as Trial 1 in your science notebook. Use arrows to sketch the movement of the colored water.
8. After a few minutes, carefully remove the vial from the cup. Describe the contents of the vial in your science notebook.
9. Empty and rinse the vial, the cap, and the cup.
10. Repeat Steps 3–9, but this time use *cold* water in Step 4 and *warm* water in Step 5. Record your observations as Trial 2.

ANALYSIS

1. **a.** Did both trials result in the movement of water? Why or why not? Discuss your ideas with your group.

   b. What do you think is necessary for a convection current to form?

2. Compare the results of your two trials. When warm and cold water are mixed, what happens:

   a. to the warm water?

   b. to the cold water?

3. Imagine that hotter magma is lying beneath an area of cooler magma deep in the mantle. What do you predict will happen? Be as specific as you can and explain your reasoning.

4. What do scientists believe causes plates to move?

47 Spreading Plates

The earth's plates move very slowly—even the fastest move less than 10 centimeters per year. But they have also been moving for millions of years. As a result, their motion has changed the surface of the earth. In this activity, you will further explore what happens to the earth's surface as two plates move apart from each other.

CHALLENGE

What happens when the earth's plates move apart over time?

The Red Sea was formed by spreading between the African and Arabian plates.

MATERIALS

For each pair of students

access to a computer

For each student

1 Student Sheet 47.1, "Spreading Plate Observations"

PROCEDURE

1. Set the direction for Plate 1 to move by clicking on the arrow pointing left (⟵).

   Note: You will explore the other directions in the next activity.

2. On Student Sheet 47.1, "Spreading Plate Observations," record the directions in which Plate 1 and Plate 2 will move.
3. Click on the SEE PLATES OVER TIME button at the bottom of the screen. You should now see a LEGEND on the bottom left of the screen. Read the legend so that you know what each symbol means.
4. Use the PICK TIME button to set the simulation to run for 10 years.
5. Click on the RUN button to begin the simulation and then carefully observe what happens.
6. Record your observations on Student Sheet 47.1.
7. Reset the screen by clicking on the RESET TIME button.
8. Repeat Steps 4–7, but run your simulation for 100 years.
9. Repeat Steps 4–7, but run your simulation for 1,000 years.
10. Repeat Steps 4–7, but run your simulation for 1 million years.
11. Repeat Steps 4–7, but run your simulation for 5 million years.
12. Repeat Steps 4–7, but run your simulation for 20 million years.

ANALYSIS

1. In the simulation, you saw water collect between the spreading plates: where does this water come from?

2. In the simulation, how many years passed before you observed major changes to the earth's surface?

3. There are seven continents on earth today. How many do you predict there will be:

   a. in 1,000 years? Explain.

   b. in 20 million years? Explain.

4. a. List at least three things that can happen as plates spread apart.

   b. Place these events in order by numbering them.

48 Other Types of Plate Motion

Plates can move in different directions. In the last activity, you explored what happens to the earth's surface as two plates move apart. Plates can also collide or slide past each other. Find out how these plate motions are similar to or different from spreading plates.

CHALLENGE

What happens as the earth's plates collide or slide past each other?

MATERIALS

For each pair of students

access to a computer

For each student

1 Student Sheet 48.1, "Other Plate Directions"

The movement of the earth's plates has changed the surface of the earth. The Himalayan mountains, right, were formed by the collision of two plates.

PROCEDURE

1. Choose a direction in which Plate 1 will move.

   Note: Do not repeat Activity 47, “Spreading Plates,” by selecting the arrow pointing left (⟵).

2. On Student Sheet 48.1, “Other Plate Directions,” circle the directions in which Plate 1 and Plate 2 will move and record the type of boundary (either convergent, divergent, or transform) that you are investigating.
3. Click on the SEE PLATES OVER TIME button. If you are investigating a convergent boundary, record the type of lithosphere (continental or oceanic) on the same line of Student Sheet 48.1 as the Type of Boundary.
4. Use the PICK TIME button to set the simulation to run for 20 million years.
5. Click on the RUN button and observe what happens. You may want to repeat the simulation or run it for different periods of time so that you can make better observations.
6. Record your observations on Student Sheet 48.1.
7. If you selected a convergent boundary, click on the button labeled WHAT IF TWO OCEANIC PLATES COLLIDE? and repeat Steps 4–6. If you did not select a convergent boundary, go on to Step 8.
8. Reset the simulation by clicking on the HOME button.
9. Repeat Steps 1–8, but select a new direction in which Plate 1 will move.

ANALYSIS

1. Why do the geological processes that occur at convergent boundaries vary?
2. In this activity, which type of boundary modeled:
   a. the formation of the Himalayan mountains?
   b. the formation of Greenland, a volcanic island country in the northern Atlantic Ocean?

3. In your science notebook, make a table like the one below. Identify the scientific term for each type of plate boundary and then place a ✔ to identify what is likely to happen at each type of plate boundary.

Comparing Plate Motion

Types of Plate Motion	Scientific Term for Boundary Type	Earthquakes	Volcanoes	Mountain Formation
Colliding				
Sliding				
Spreading				

4. Imagine that your parents ask you what you are learning in school. In your own words, explain:
   a. the theory of plate tectonics and
   b. how earthquakes, volcanoes, and mountain formation are related to plate tectonics.

   Be as specific as you can.

5. **Reflection:** Do you think the world's continents and oceans will look the same in the future as they do now? Why or why not?

EXTENSION

In this activity, you investigated the movement of plate boundaries in which the edges of the plate margin were straight. Find out what happens along a transform boundary when there is a bend in the plate. On the home page of the SEPUP Plate Motion computer simulation, click on the button that says EXTENSION: BENT PLATE BOUNDARIES. How do changes to the earth's surface at the bent transform boundary compare to the straight transform boundary you investigated in this activity?

49 Comparing Site Risk

In Activity 36, "Storing Waste," you learned about the nuclear waste problem. You also looked at evidence about Yucca Mountain, which has been considered as a possible site for storing nuclear waste. Based on current recommendations by experts, it is likely that the U. S. will search for other sites for deep storage of waste, either in addition to or instead of the Yucca Mountain site.

Imagine the year is 2030, and the United States is looking for a long-term storage sites. Use what you have learned in this unit to help you evaluate eight sites.

CHALLENGE

Which location would you recommend for further study as a possible site for storing nuclear waste?

MATERIALS

For each student

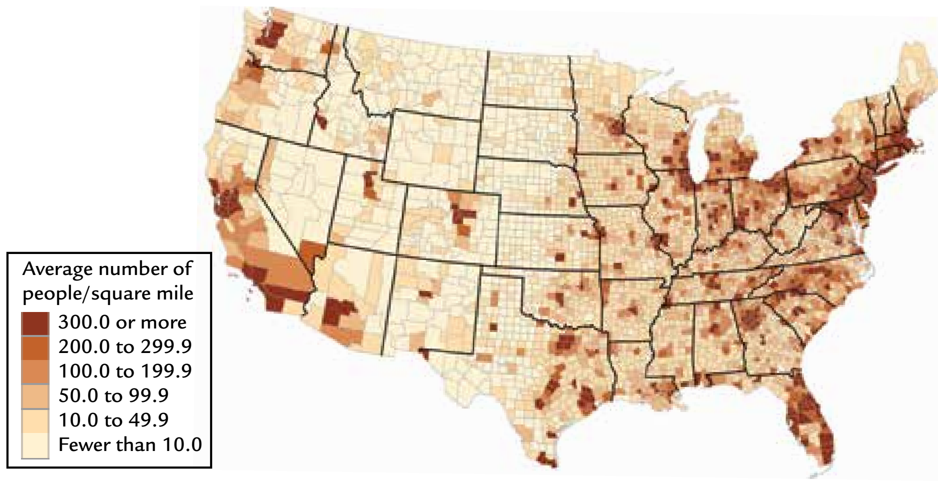
1 **Student Sheet 49.1, "Eight Proposed Waste Sites"**
1 **Student Sheet 49.2, "Discussion Web: Evaluating Site Risk"**
1 **Student Sheet 49.3, "Comparing Eight Proposed Sites"**

This chamber 700 meters below the surface near Carlsbad, New Mexico is part of a research project to study salt beds as a location for the storage of highly radioactive nuclear waste.

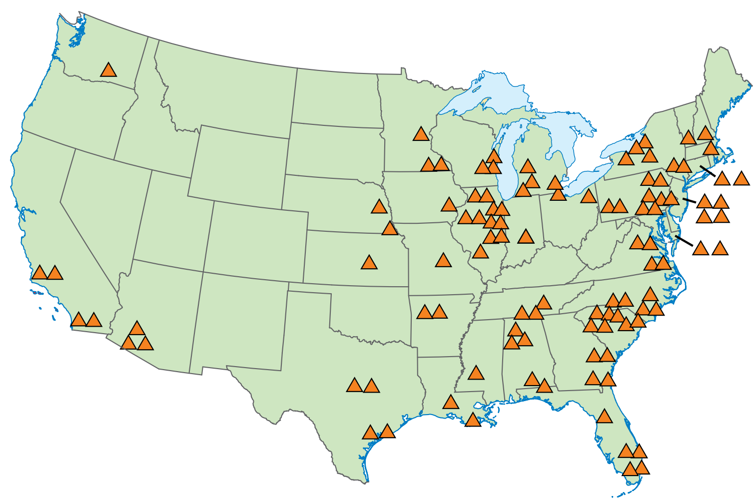
PROCEDURE

1. Work with your group of four to complete this activity. Remember to listen to and consider the ideas of the other members of your group. If you disagree with others in your group, explain why you disagree.
2. Examine Maps 1 and 2, on the following page. These maps show the population density and location of nuclear reactors around the United States. Discuss how this information might influence your choice of a site.
3. Examine Maps 3 and 4, and compare the risk of earthquakes and volcanoes in the United States. Discuss how this information might influence your choice of a site.
4. Examine Maps 5 and 6. Map 5 shows areas of stable granite. Map 6 shows where there are major sources of underground water. Discuss how this information might influence your choice of a site.
5. Your teacher will distribute Student Sheet 49.1, "Eight Proposed Waste Sites," and will assign your group to evaluate one of the sites.
6. Complete Student Sheet 49.2, "Discussion Web: Evaluating Site Risk," to sort the evidence about your site.
7. Present your group's analysis of your site to the class.
8. After each group has made a presentation, discuss with your group which two sites you recommend for further study.

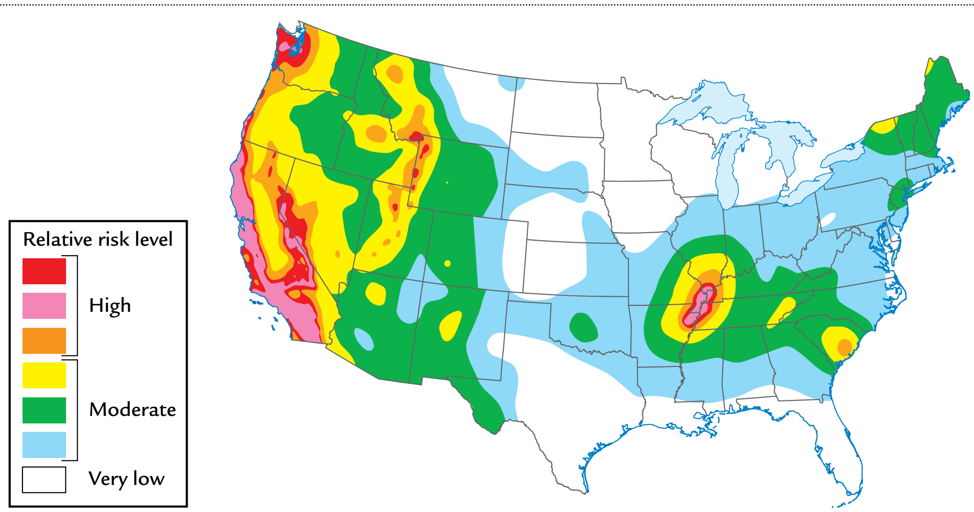
MAP 1:
POPULATION
DENSITY BY COUNTY



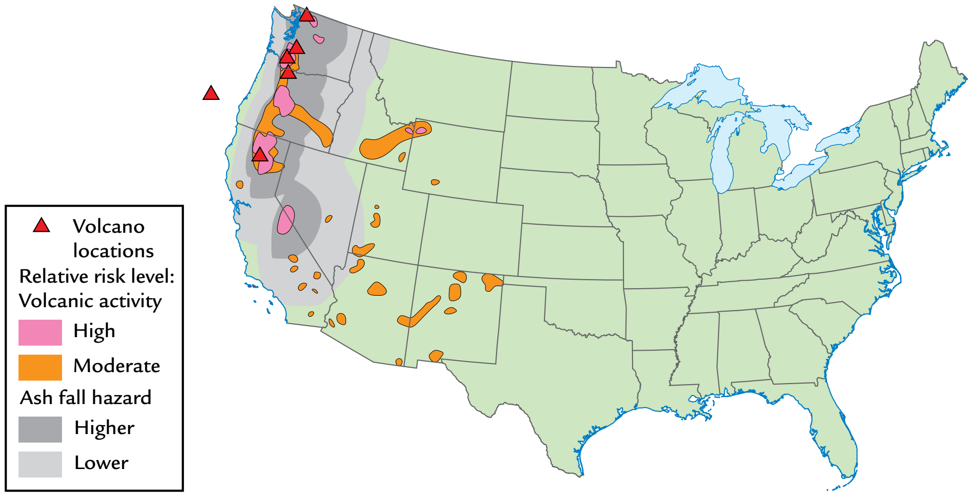
MAP 2:
U.S. LOCATIONS
OF NUCLEAR POWER
REACTORS



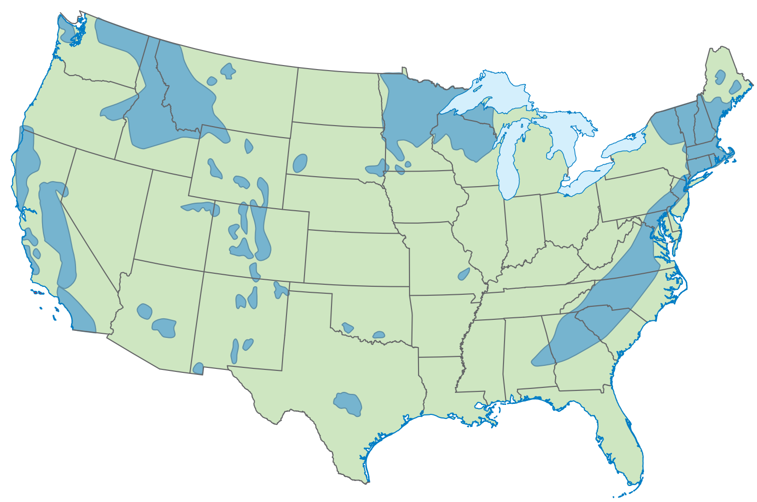
MAP 3:
U.S. EARTHQUAKE
HAZARDS



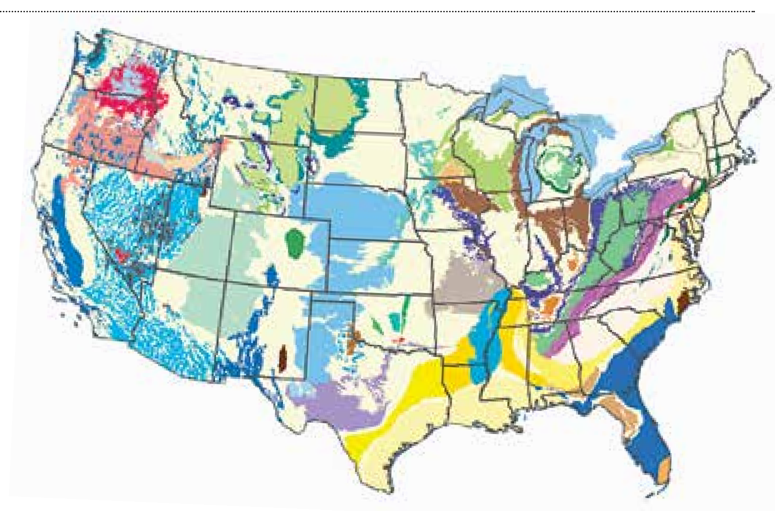
MAP 4:
U.S. VOLCANO
HAZARDS



MAP 5:
GRANITE OUTCROPS
IN THE U.S.



MAP 6:
U.S. AQUIFER MAP



ANALYSIS

1. What scientific evidence and risks should be considered when selecting a site for storing nuclear waste?

2. What role do you think people in the community should have when a site near them has been suggested for storing nuclear waste?

3. Would you select one of the eight sites, or would you suggest a different site?

    a. State the site you would choose.

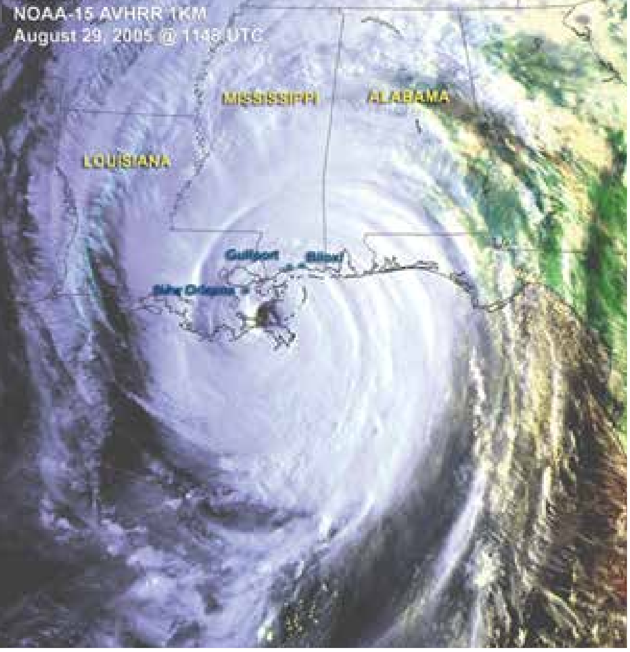
    b. Support your decision with as many pieces of evidence as you can.

    c. Discuss the trade-offs of your decision.

4. Reflection: Have your ideas about where to store nuclear waste changed during this unit? How?

Weather and Atmosphere

E


NOAA-15 AVHRR 1KM
August 29, 2005 @ 1148 UTC
MISSISSIPPI
ALABAMA
LOUISIANA
Gulfport
Biloxi

Weather and Atmosphere

Hey, how about a little one-on-one basketball after school today?" Scott asked Marquel as they walked to class.

“I’m up for it,” Marquel said. “But I don’t think this sun will last.”

”What do you mean?”

“This morning the meteorologist on Channel 5 predicted afternoon thunderstorms,” said Marquel.

Scott looked out the window. “Really? It’s sure sunny now.“

“Yeah, but she says it is going to change,” said Marquel, “and we’ve been having afternoon storms all week.”

“I know, I was just hoping that today would be different. Rain really puts a damper on practicing my 3-point shot,” said Scott.

“Do you remember last year being like this?” asked Marquel. “I don’t think it was so rainy. The weather was so good that we could practice every day.”

“I don’t remember,” said Scott. “But I do know that the next afternoon the sun is out I’ll see you on the courts.”

• • •

Weather affects what you wear, what you do every day, and even how you get from place to place. But do you know why it rains in some parts of the United States more than others? How would weather scientists describe the patterns of weather we experience each year? In this unit you will analyze weather, climate, and factors that affect weather and climate through the eyes of scientists who study the earth’s weather and atmosphere.

50 Weather Effects

Many people enjoy a warm sunny day or complain when it rains. But sometimes, bad weather can be more than an inconvenience. It can also pose a hazard. By knowing what the weather is likely to be, people can work to avoid such hazards.

CHALLENGE

How does weather influence daily life?

Weather can vary from day to day. How would you describe the weather in each picture?

MATERIALS

For each student

1 **Student Sheet 50.1, "Intra-act Discussion: Weather Effects"**

1 **Student Sheet 50.2, "Scientific Careers in Weather"**

PROCEDURE

1. Carefully read the story that starts on the next page.
2. Mark whether you agree or disagree with the statements on Student Sheet 50.1, "Intra-act Discussion: Weather Effects." Predict what you think other members of your group will say.
3. Discuss the statements with your group. Have each person share his or her opinion about each statement and explain why he or she agreed or disagreed.
4. Think about the different ways in which weather affected the students in the story. With your group, brainstorm about jobs that could be affected by severe or unexpected weather.
5. On Student Sheet 50.2, "Scientific Careers in Weather," review some of the knowledge about weather that is required by four scientific careers.
6. During this unit, you will learn what skills and knowledge are needed for each of these four careers. Decide which set of skills interests you the most by selecting one of the careers. Discuss your selection with the rest of your group.

BACK TO SCHOOL

It was the first day after Thanksgiving break. As Zoe walked down the hall, she saw her friends Sonia, Ray, and Luke.

"Hey Sonia, how was your break?" asked Zoe.

"Not bad," said Sonia. "We flew to my grandmother's house for a big family reunion. Everyone was waiting for us—my aunts, my uncles, and all of my cousins. We didn't get there until eight o'clock at night, and dinner was almost over."

"What happened?" asked Luke.

Sonia made a face as she replied, "That crazy snowstorm grounded our plane. The pilot said that it was too dangerous to fly. It must have been colder than 0 degrees Celsius (32 degrees Fahrenheit) because ice kept forming on the wings. The plane took off three hours late, after the storm was over."

"I remember," said Luke. "We had about 60 centimeters (24 inches) of snow on the ground after the storm ended. It was fun to walk around in the deep snow, but no one could drive anywhere, and most of the buses weren't running. I hated not being able to go to the movies."

"My vacation plans got messed up too," said Ray. "My uncle won one of those radio contests and took our whole family on a cruise. We were supposed to go to Puerto Rico, which is where my mother is from. The day after we left, a huge hurricane was moving through the Caribbean Sea. The ship went to Mexico to avoid the path of the hurricane."

"It's too bad you didn't make it to Puerto Rico," said Sonia.

Luke laughed. "Mexico still sounds pretty good. I'm surprised you're not more tan!"

"It was the weather," said Ray. "Even though the hurricane passed us by, it was rainy and windy in the whole area. Whenever it cleared up a bit and I went out on deck, I had to dump water from the deck chairs! The wind speed was about 40 kilometers per hour."

"That's equal to about 25 miles per hour. That doesn't sound very fast," remarked Zoe.

Ray replied, "The wind was strong enough to form some large waves and cause a lot of spray along the sides of the ship. Because it was such a large ship and it had a stabilizer, it didn't cause any rocking. So I guess it wasn't so bad."

"Did you have fun over break, Zoe?" asked Luke. "It was your birthday, wasn't it?"

"Yeah, I had a good time," Zoe replied. "It was pretty low-key. I saw a lot of relatives, and I did get some nice gifts. I'm still waiting for my big present, though. I asked my parents for a digital camera. They went to buy it, but the one that I want wasn't in the stores. The delivery trucks bringing the camera shipment were delayed because of floods. I won't get the camera until next week."

"I heard heavy rains caused flooding out west," Sonia added. "It rained several centimeters in less than 24 hours, and it'll take several days for all of the roads to be cleared."

Sonia sighed. "It sounds like the weather affected everyone's break."

"Yeah, it's one of the few things no one can do anything about," said Luke. "Next thing you know, they'll tell us to expect a tornado over winter break!"

ANALYSIS

1. How does weather affect your daily life? Provide at least two examples of situations when weather caused you to change your plans.

2. Use information from the activity to complete the following table.

Units Used to Measure Weather Data

	Metric Units	English Units
Temperature		
Rainfall		
Snowfall		
Wind Speed		

3. Locate your state on the three risk maps shown on the next page. These maps, produced by the U.S. Geological Survey, are based on the numbers of hurricanes, floods, and tornadoes that have occurred in each region. **Note:** These maps do not include the states of Alaska and Hawaii.

   What is the level of risk:

   a. of hurricanes in your state?

   b. of floods in your state?

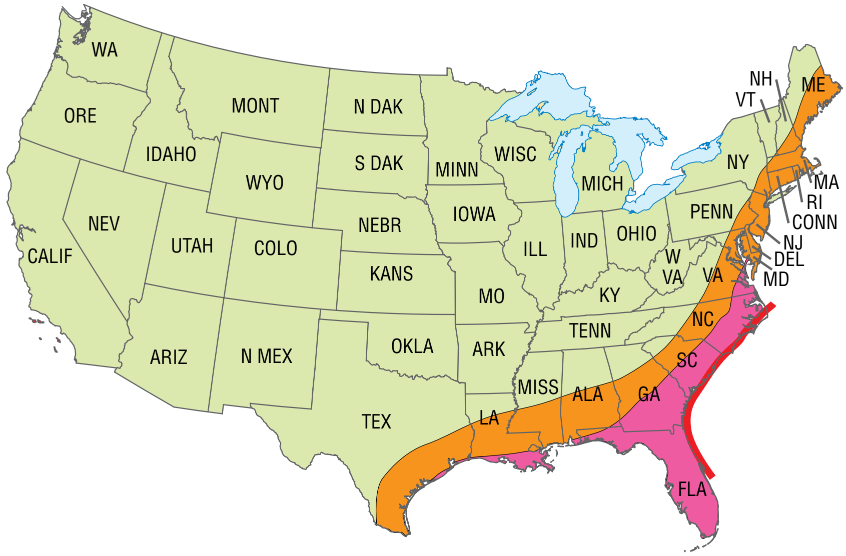
   c. of tornadoes in your state?

4. **Reflection:** What is the worst weather you have experienced? How did it affect you? Describe your experience.

UNITED STATES RISK MAPS

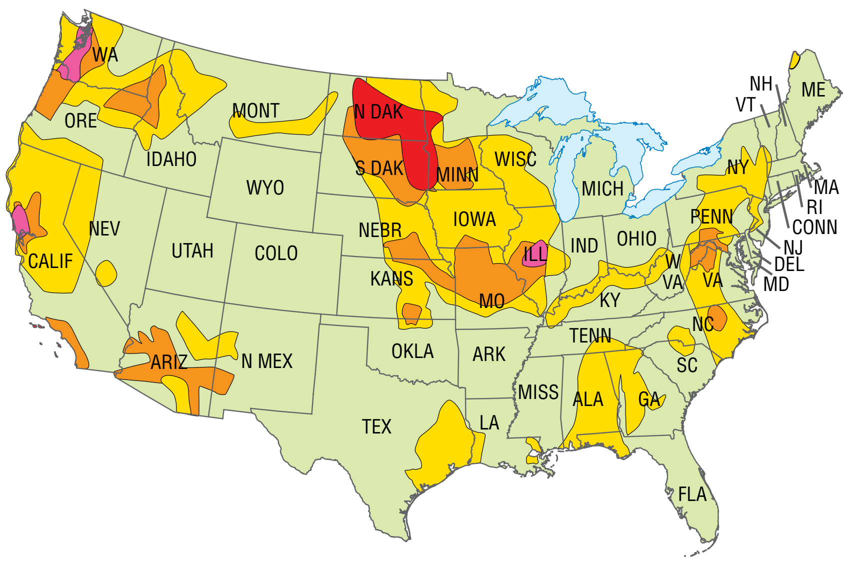
Hurricane Risk

Relative risk level
- Very high
- High
- Moderate



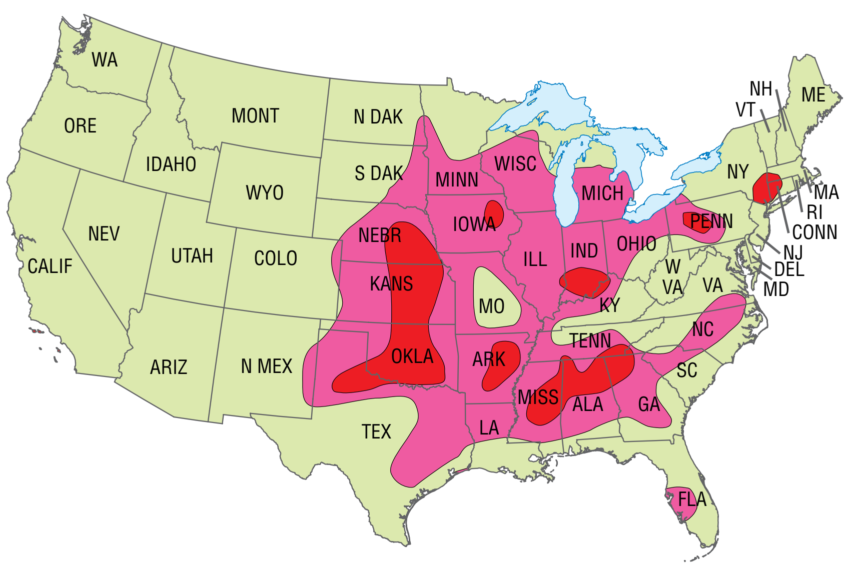
Flood Risk

Relative risk level
- Very high
- High
- Moderate
- Slight



Tornado Risk

Relative risk level
- Very high
- High



51 Investigating Local Weather

When people talk about weather, they often discuss temperature or rainfall. **Meteorologists** (mee-tee-ur-OL-o-jists) are scientists who study weather. When measuring and describing weather conditions, meteorologists may record data such as wind speed, air pressure, and **precipitation** (prih-sip-ih-TAY-shun). Precipitation is any form of water that falls to earth, including rain, snow, sleet, and hail. The amount of precipitation and other weather data can vary from hour to hour, day to day, and season to season. In this activity, you will investigate weather data for your area.

CHALLENGE

How is daily weather data different from monthly weather data?

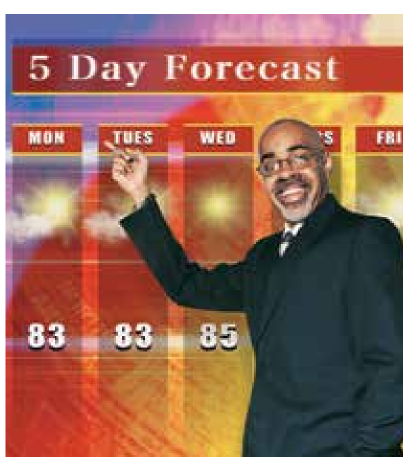
MATERIALS

For each student

access to an Internet site showing local weather (or local newspapers or television weather reports)

1 sheet of graph paper

You may have seen a meteorologist providing a weather forecast on television. Other meteorologists may collect data at weather stations, or work for the U.S. government or even an airline.



PROCEDURE

Part A: Investigating Daily Weather

1. In your science notebook, create a table like the one shown below.

Table 1: Daily Weather Data for ____________
(insert dates and location)

	Unit of Measurement	Day 1	Day 2	Day 3	Day 4	Day 5
Temperature						
Precipitation						
Air pressure						
Cloud cover						
Wind direction (Direction wind is coming from)						
Wind speed						

2. Use an Internet site (or the local newspaper or local television weather report) to record five days of local weather data.

- Be sure to notice the units of measurement they use and convert if necessary, so that your recorded data is consistent.
- Be sure you get data for days that have ended. Do not include weather predicted for the future.
- Abbreviations for wind direction include N for north, S for south, E for east and W for west. For example, NW would mean northwest.

Hint: You can go to the *Issues and Earth Science* page of the SEPUP website to link to weather websites.

3. Construct a second table to record mean and median temperature, precipitation, air pressure, and wind speed for the five-day period. You may also want to record the mode for cloud cover and wind direction. Title this table, "Table 2: Analysis of Five-Day Weather Data."

4. Complete Table 2 by calculating the means, medians, and modes of the data listed in Step 3. **Hint:** To see how to calculate these values, turn to page E-26 of Activity 54, "The Earth's Surface."

Part B: Investigating Seasonal Weather

5. Copy the table on the next page. Then use the Internet (or data provided by your teacher) to complete the table. Be sure to use the same units of measurement that you recorded in Tables 1 and 2.

   Hint: You can go to the *Issues and Earth Science* page of the SEPUP website to link to a site providing information about local weather.

6. Each person in your group will graph the Table 3 data set for one of the four weather conditions shown below. Decide who will graph which of the following data:
   - Maximum temperature
   - Minimum temperature
   - Precipitation
   - Wind speed

7. Use the data from Table 3 to construct a line graph of your data. Be sure to label your axes and to title your graph.

8. Share your graph with your group, and examine the graphs constructed by other group members.

9. Discuss the following questions with your group:
   - Which weather condition(s) appears to vary the most over the course of a year? Which weather condition(s) appears to vary the least?
   - What is the range of temperatures experienced in your area?
   - Which month(s) have the most precipitation? The least precipitation?
   - Which month(s) have the highest wind speed? The lowest wind speed?

Table 3: Monthly Weather Averages

	Maximum Temperature	Minimum Temperature	Precipi-tation	Cloud Cover	Wind Direction	Wind Speed
January						
February						
March						
April						
May						
June						
July						
August						
September						
October						
November						
December						

ANALYSIS

1. Recall what you did on each of the five days that you collected daily weather data, and compare it to your data in Table 1, "Daily Weather Data." Which aspect of the weather most affected your daily life? How did it affect you?

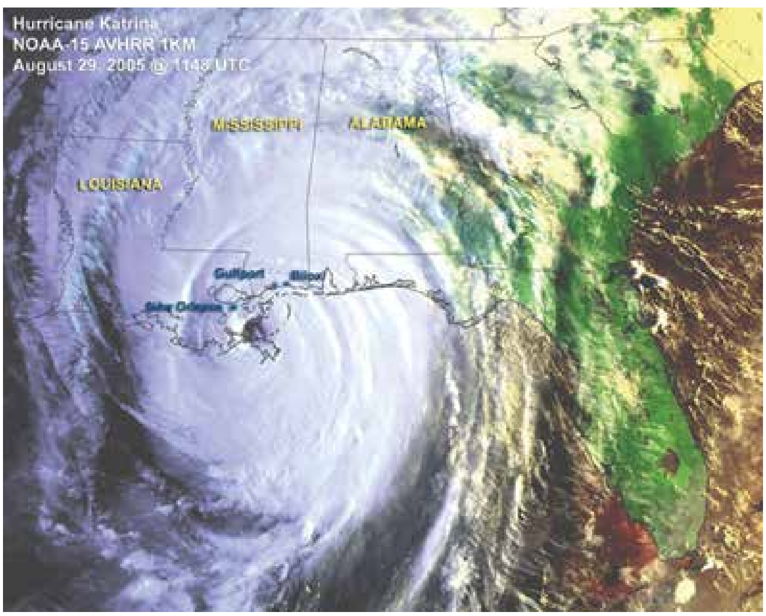
2. Imagine that you are a meteorologist for a local radio station. Use your data from Tables 1 and 2 to create a radio weather report that summarizes the weather over the five-day period.

3. In your experience, is your area's weather in a particular month, such as January, the same from year to year? Explain.

4. Which type of weather data—daily or monthly—do you think is more useful for describing weather? Explain your reasoning.

52 Local Weather History

Weather disasters, such as hurricanes, tornadoes, rain, snow, and ice storms, devastate communities, economies, and the environment.



In 2005, Hurricane Katrina struck along the coasts of Louisiana, Mississippi, and Alabama. Everyone living in the area, including 1 million people from the city of New Orleans, Louisiana, was asked to evacuate to a safer place.

In the spring of 2011, 25% of Joplin, Missouri was destroyed by a tornado. The tornado was 1.6 km (1 mi) wide. It caused 161 deaths and $2.2 billion in property damage.

How can you tell if a weather disaster is likely to happen where you live? Although weather affects people on the ground, a lot of weather occurs in the atmosphere. The scientists who study the atmosphere, from the surface of the earth to several hundred kilometers above, are known as **atmospheric** (at-muh-SFEER-ik) **scientists.** They may collect and analyze data about current and past conditions. Areas that have had more hurricanes, floods, or tornadoes in the past are considered more likely to have these events in the future. In this activity, you will find out more about the severe weather that has occurred in your area.

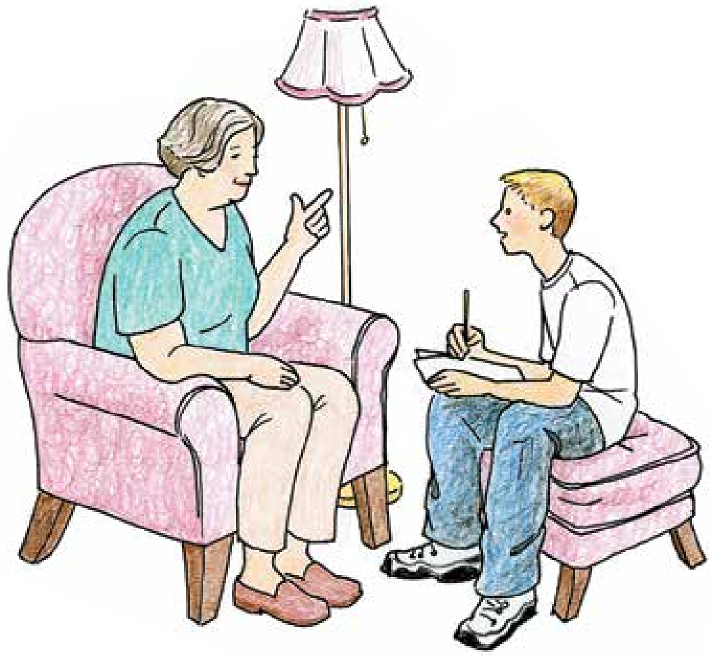
CHALLENGE

How are weather disasters different from everyday weather?

PROCEDURE

Part A: Designing the Survey

1. Work with your class to design a survey on weather disasters that have occurred in your area in the past 30 years. Begin by discussing the following questions with your class:
   - What would you like to know about weather disasters in your area?
   - How could people you know provide information about past weather disasters?
   - What questions could you ask to gather this information?
2. As a class, decide the following:
   a. What questions will you ask?
   To make your survey consistent, each student must ask the same set of questions.
   b. What kinds of responses are not relevant to your survey?
   Some people may have questions about your survey or may provide answers that are irrelevant. As a class, brainstorm possible survey responses that might cause problems, and discuss possible solutions.
   c. How will you compare or summarize the data that you gather?
   d. What population of people will you survey?
   Hint: Think about factors such as age or experience.
   e. How many people will you survey in total? How many people should each student survey? By what date?
3. Use the answers to each question in Step 2 to construct a class survey.



Part B: Conducting and Analyzing the Survey

4. Conduct your survey as decided in class.
5. Share your survey results with the rest of your class.
6. As a class, compare and summarize the results of your survey.

ANALYSIS

1. **a.** According to the class data, what type of weather disaster is most common in your area?

   b. When did such a disaster last occur?

   c. What can you do to prepare for such a disaster if it happens again?

2. Use your class data to create a bar graph of the number of times different types of weather disasters have occurred locally. Be sure to label your axes and to title your graph.

3. Look again at the risk maps on page E-9 of Activity 50, "Weather Effects." Did your class survey results support your local risk of hurricanes, floods, and tornadoes, as indicated by the maps?

4. Do you think that the survey was a reliable method for finding out what weather disasters have occurred in your area in the past 30 years? Why or why not?

5. **Reflection:** Which type of weather disaster are you most concerned about? Why?

53 Weather and Climate

The word **weather** is used to describe what's happening outside at a specific time and place, and it can change from day to day or even within a day. **Climate** (KLY-met) describes the average weather in a place over a fairly long period of time (usually at least 30 years). **Climatologists** (kly-muh-TOL-o-jists) are scientists who study the earth's climates. They use such factors as temperature and precipitation to describe different types of climate. For example, think about the climate of a desert as opposed to a tropical rainforest and how their temperatures and precipitation vary.

CHALLENGE

How do climates vary?

Climatologists study long-term weather trends, which may affect food-supply predictions, species survival, and human health. They may examine tree rings or collect sediments or ice cores (like the one pictured above) to find out more about the earth's past climates. Climatologists often use computer models to help them understand and predict climate changes.

MATERIALS

For each student

1 **Student Sheet 53.1, "Directed Reading Table: Weather and Climate"**

data from Table 3 of Activity 51, "Investigating Local Weather"

PROCEDURE

1. Examine Figure 1, "Map of Climates of North America," shown on the next page. It shows some of the different climates found in this part of the earth.

2. Examine the photos and descriptions of the different climate types shown in Figure 2, "Climate Descriptions," on the next two pages. On Student Sheet 53.1, "Directed Reading Table: Weather and Climate," summarize the information about the different types of climates.

3. Work with your partner to:

   a. Locate your state on Figure 1.

   b. Record the climate type for your area in your science notebook.

   c. Determine if your observations and experiences match this description of the climate for your area. In your science notebook, describe any similarities or differences between the climate description for your area and your own observations.

   d. Compare the climate description with your data from Table 3, "Monthly Weather Averages," of Activity 51, "Investigating Local Weather." In your science notebook, describe any similarities or differences between the climate description for your area and your seasonal weather averages. (Your seasonal weather averages will be the average for several months during the same season. For example, in the United States, the summer season is typically from June through August.)

(Procedure continues on page E-22)

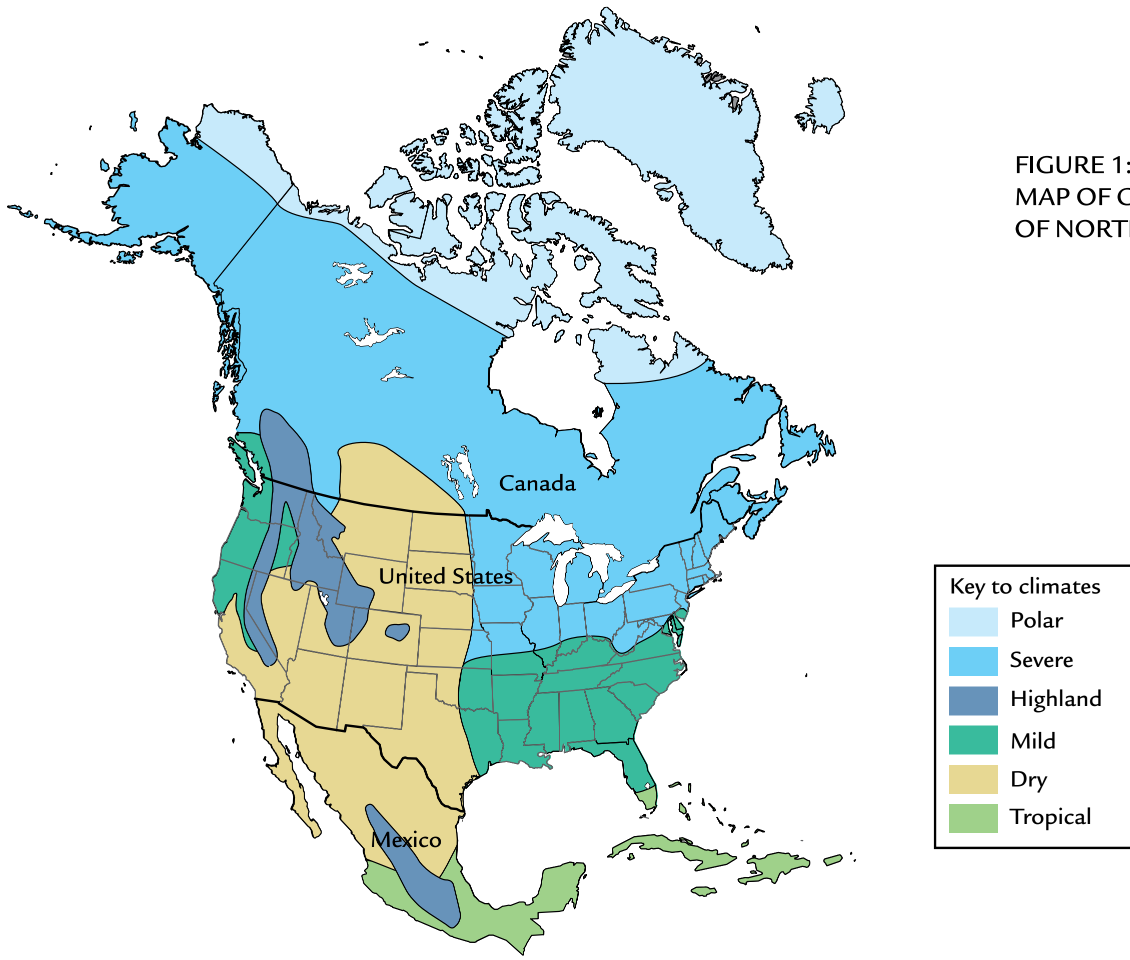


FIGURE 1:
MAP OF CLIMATES
OF NORTH AMERICA

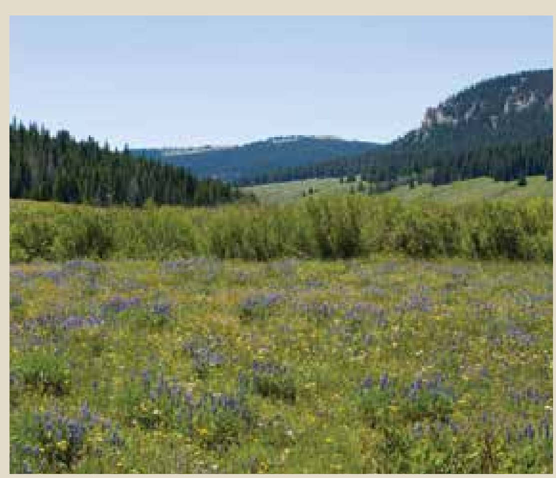
FIGURE 2:
CLIMATE DESCRIPTIONS

POLAR

- Extremely cold and long winters, with only 2–4 months having temperatures above freezing
- Cool summers, with temperatures less than 10°C (50°F)
- Dry year-round, with very little precipitation (usually falls as snow)

SEVERE

- Warm summers, with temperatures over 10°C (50°F)
- Very cold winters, with at least one month averaging less than –3°C (27°F)
- Amount of precipitation varies



HIGHLAND

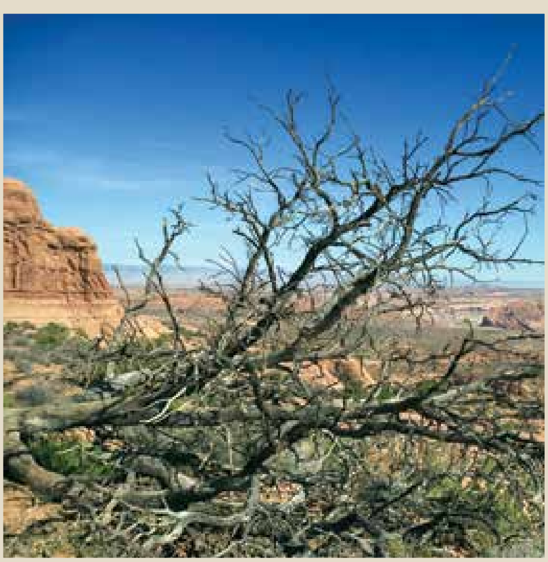
- Very high mountains, such as the Rocky Mountains in the western United States
- Cold to cool year-round, with temperatures between –18°C (–2°F) and 10°C (50°F)
- Amount of precipitation varies, usually falling as snow in winter

MILD

- Summers are warm or hot, with temperatures over 10°C (50°F)
- Winters are cool or cold, with temperatures below 18°C (64°F) but above –3°C (27°F)
- Moist climate, often with more precipitation in either the winter or summer

DRY

- Hot days and cool nights year-round
- Maximum summer temperatures usually over 31°C (88°F)
- Dry year-round, with very little precipitation



TROPICAL

- Hot year-round, with temperatures averaging over 18°C (64°F)
- Wet, with a total of more than 150 centimeters of rain in a year

4. Examine the three graphs on the next page. Each graph shows the average monthly temperature and precipitation for a specific place in the United States. In your science notebook, record which climate type you think each of the three places has and explain your reasoning.

5. Share and discuss your findings with the rest of your group. Remember to listen to and consider the ideas of other group members. If you disagree with someone's ideas, explain to the rest of the group why you disagree.

ANALYSIS

1. What are the most common climate types in the United States?

2. Compare your responses on Student Sheet 53.1 to Figure 1, "Map of Climates of North America." How do temperatures vary with latitude? Support your answer with evidence from this activity.

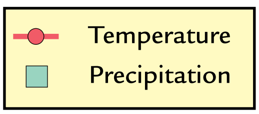
3. What is the relationship between weather and climate?

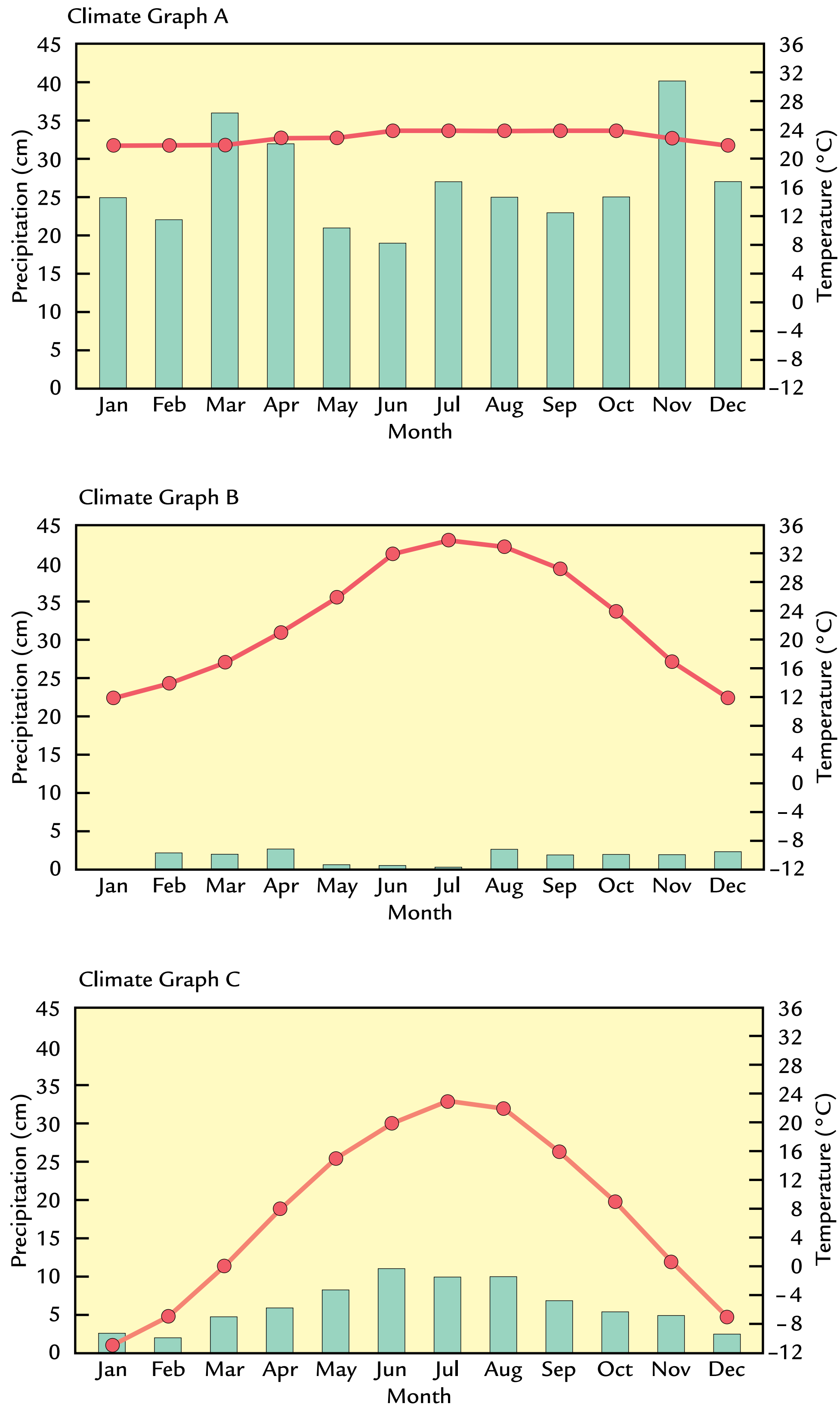
4. Could areas with different climates have the same weather? Explain.

EXTENSION

Graphs showing average temperature and precipitation for a particular area over a certain time period are known as *climographs* (KLY-moh-grafs). What does a climograph for your area look like? You can create your own climograph using the data from Table 3, "Monthly Weather Averages," of Activity 51, "Investigating Local Weather." First calculate the mean temperature for each month. Then use the temperature and precipitation data to create your own climograph.

FIGURE 3: CLIMATE GRAPHS SHOWING AVERAGE MONTHLY TEMPERATURES AND PRECIPITATION





54 The Earth's Surface

PROBLEM SOLVING

In the last activity, you considered some of the different climates that occur on land. But much of the earth's surface is water. **Hydrologists** (hi-DRAWL-o-jists) are scientists who study the distribution and movement of the earth's water. They have a lot of water to study! There are 326 quintillion (326,000,000,000,000,000,000) gallons of water on earth, which is equal to more than 1 sextillion (1,260,000,000,000,000,000,000) liters.

CHALLENGE

What percent of the earth's surface is water, and what percent is land?

Hydrologists who work for government agencies sometimes monitor the amount of water available in a particular area and how it is being used. Other hydrologists may work for private companies that specialize in water use or water chemistry. This hydrologist is testing for toxic chemicals.

MATERIALS

For each pair of students

1 calculator (optional)

For each student

1 Student Sheet 54.1, "World Map"

PROCEDURE

1. Copy and complete the following statement in your science notebook. Provide at least one reason to support your thinking.

   I think that the percentage of the earth's surface that is covered by water is closest to:

   25% (¼ or 0.25)   50% (½ or 0.50)   75% (¾ or 0.75)

2. Your teacher will give you a copy of Student Sheet 54.1, "World Map." With your partner, discuss how you will use it to determine the approximate percentages of water and land on the earth's surface. Briefly describe how you will make your estimate.

3. Calculate and record your estimate of the percentage of the earth that is covered by a) water and b) land.

4. Compare your estimates to those of the other half of your group. Discuss any major differences in your estimates.

5. Work with your group to label the following areas of land and water on Student Sheet 54.1:

Africa	Atlantic Ocean
Arctic Ocean	Asia
Caribbean Sea	Gulf of Mexico
Australia	Indian Ocean
Europe	Pacific Ocean
North America	Southern Ocean
South America	

6. Share your estimates from Step 3 with the class. Use the class data to calculate:

a. the mean
Hint: Calculate the **mean** by adding up all of the values and dividing by the total number of values.

b. the median
Hint: The **median** is the middle value after the data has been listed from smallest to largest OR largest to smallest. If the data has an even number of values, then the median is the average (mean) of the two middle values.

c. the mode
Hint: The **mode** is the value that appears most often.

7. Compare your initial thinking from Step 1 to the amount of water on the earth's surface that you calculated in Step 6a. Correct your statement (if necessary), and explain why your initial ideas were or were not correct.

ANALYSIS

1. Look at your class data from Step 6, and discuss:

a. Was your strategy a good way to estimate the percentage of the earth's surface covered by water? Why or why not?

b. How could you make a better estimate?

2. The water on the earth can be found in many places, including lakes, rivers, icebergs, oceans, and even underground. Based on your work in this activity, where do you think that most of the water on the earth can be found? Explain your reasoning.

EXTENSION

Use your response to Analysis Question 1b to revise your work from this activity. Calculate the percentages of water and land on the surface of the earth using your revised procedure. How does your revised data compare to your initial calculations? Which is more accurate? Why?

55 Heating Earth Surfaces

Many factors influence weather and the different kinds of climates on earth. You will investigate some of these factors in the next few activities. One important factor is how land and water interact with energy from the sun. How does the energy from the sun affect different earth surfaces such as land and water? Design an investigation to find out!

CHALLENGE

How can you design an experiment to investigate how the sun's energy heats different earth surfaces?

MATERIALS

For each group of four students

2 white plastic trays
2 clear plastic films
2 plastic-backed thermometers
1 30-mL graduated cup
1 spoon
1 metric ruler
1 watch with second hand
water
sand
sunlight (or a light source)

For each student

1 Student Sheet 55.1, "Anticipation Guide: Heating Earth Surfaces"
1 sheet of graph paper

PROCEDURE

Use Student Sheet 55.1, "Anticipation Guide: Heating Earth Surfaces," to prepare for the following activity.

1. Work with your group to design an experiment to find out:
   a. how different earth surfaces are heated by the sun's energy
   b. how the different surfaces then cool.

   When designing an experiment, think about the following questions:

   - What is the purpose of your experiment?
   - What materials do you need for the experiment?
   - How will you use these materials to investigate how different earth surfaces are heated and cooled? **Hint:** Think about how to keep everything the same except what you are testing.
   - What is your hypothesis? (What do you predict will happen?)
   - What data will you collect?
   - How will you record the data?
   - How will the data help you reach a conclusion?

2. Record your hypothesis and your planned experimental procedure in your science notebook. Be sure to decide what each person in your group will do.

3. Make a data table that has space for all the data you need to record. You will fill it in during your experiment.

4. Obtain your teacher's approval of your experiment.

5. Conduct your experiment and record your results.

ANALYSIS

1. a. Create a graph of the data you collected. Remember to label your axes, title your graph, and include a key.

   b. Summarize the trends that you see in your graph.

2. Copy the table below. Calculate the changes in temperature for each substance you tested, and fill in the table.

Temperature Changes

Tray containing	Change in Temperature During Heating	Change in Temperature During Cooling

3. What can you conclude about how land and water heat up and cool down? Support your answer with evidence from this activity.

EXTENSION

Design an experiment to further investigate how different surfaces on the earth are heated by the sun's energy and then cool. You may want to investigate if the amount of land or water or different types of soil affect heating and cooling. Use these or other questions to design and conduct your own investigation.

56 Ocean Temperatures

In Activity 53, “Weather and Climate,” you examined the range of temperatures found in North America and learned that different parts of the land on earth have different temperatures. But did you know that surface temperatures of the oceans also vary? Even if the ocean is several kilometers deep, the majority of the sun’s energy is absorbed at the surface (approximately the top 400 meters). Both hydrologists and climatologists study changes in ocean-surface temperatures to learn more about the movement of ocean water and its effect on climate.

CHALLENGE

How do ocean temperatures vary over the surface of the earth?

MATERIALS

For each group of four students

1 **set of colored pencils**

1 **calculator**

1 **set of Student Sheets 56.1a–d, "Mapping Mean Ocean Surface Temperatures"**

For each student

1 **completed Student Sheet 54.1, "World Map"**

PROCEDURE

1. Work with your group to complete a table like the one below. Record your results in your science notebook. **Hint:** To convert a temperature from Celsius to Fahrenheit, multiply it by 1.8 and then add 32.

Temperature Conversion

Temperature (°C)	Temperature (°F)
0	
5	
10	
15	
20	
25	
30	

2. Each person in your group will play the role of a climatologist studying the ocean temperatures on one part of the earth's surface. You may want to look at a completed copy of Student Sheet 54.1, "World Map," to help you identify different bodies of water. Decide who in your group will be the climatologist investigating water temperatures in and around the:

   a. northern Pacific Ocean and parts of the Arctic Ocean and Indian Ocean (Student Sheet 56.1a)

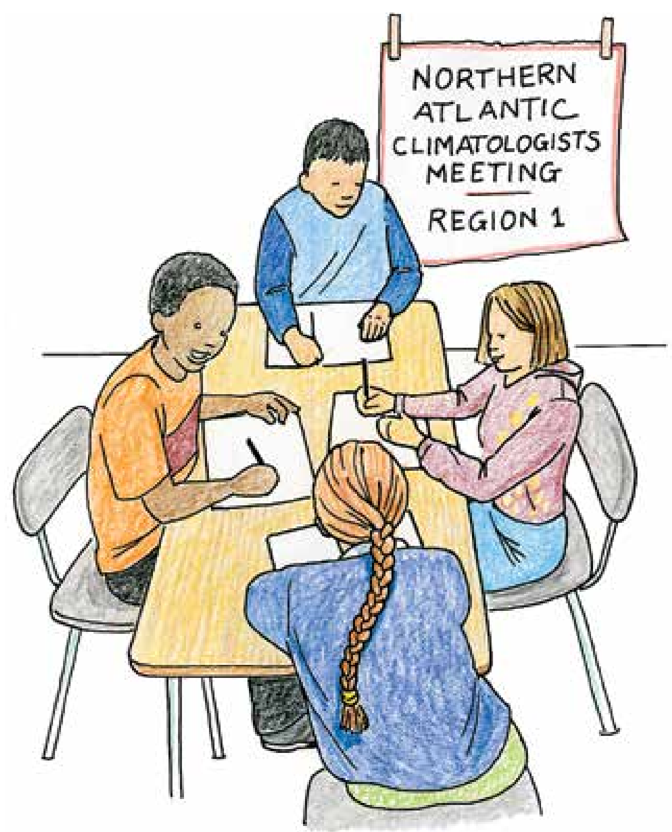
   b. northern Atlantic Ocean, Caribbean Sea, Gulf of Mexico, and part of the Arctic Ocean (Student Sheet 56.1b)

   c. southern Atlantic Ocean and parts of the southern Pacific Ocean and Southern Ocean (Student Sheet 56.1c)

   d. parts of the southern Pacific Ocean, Indian Ocean, and Southern Ocean (Student Sheet 56.1d)

3. Send each climatologist in your group to attend a "regional meeting" with the other groups' climatologists who are studying the same region.

4. At the regional meeting, examine the surface temperatures recorded on the section of ocean shown on your Student Sheet 56.1, "Mapping Mean Ocean Surface Temperatures." Fill in your map, using colored pencils and the Temperature Color Key.



5. At the regional meeting, discuss any patterns that you observe in your section of the map. You will present this information to your group. For example, you can discuss the temperature range, the relationship between temperatures and latitude, and any areas where high or low temperatures seem unusual.

6. Return to your original group and, one student at a time, present the patterns that you observed in your section of Student Sheet 56.1. Listen closely as other group members present their data.

7. Place the four sections of Student Sheet 56.1 together to form a single world map.

8. Discuss with your group any worldwide patterns that you observe in ocean temperatures.

   Hint: As you did in Step 5, you can discuss temperature range, relationships between temperatures and latitudes, and any areas of unusually high or low temperatures. Identify similarities and differences between individual sections of the map and the entire map.

ANALYSIS

1. What is the temperature range of mean ocean surface temperatures on the earth?

2. How do temperatures vary with latitude? Support your answer with evidence from this activity.

3. Compare your answer to Question 2 above with your answer to Analysis Question 2 of Activity 53, “Weather and Climate.” What similarities and differences do you notice?

4. Hurricanes start in areas where the ocean surface temperature is above 26.5˚C (80˚F). At what range of latitudes would you expect most hurricanes to begin? Explain.

57 Oceans and Climate

You have learned that the sun's energy heats the earth, including the earth's oceans. In this activity, you will find out how climate is influenced by ocean temperatures.

CHALLENGE

How do oceans affect climate?

MATERIALS

For each student

1 **Student Sheet 57.1, "Intra-act Discussion: Oceans and Climate"**

PROCEDURE


Benjamin Franklin

1. Assign one of the following roles to each person in your group.
   - *Benjamin Franklin, 18th century scientist, inventor, and statesman*
   - *Dr. Tansy Makya, climatologist*
   - *Bo Nye, student moderator of "Time Travel News"*
   - *Dr. Leena Reddy, hydrologist*
2. In your group, read the role-play aloud. As you read, think about what each character is saying.
3. Discuss how you think oceans affect climate.
4. Mark whether you agree or disagree with the statements on Student Sheet 57.1, "Intra-act Discussion: Ocean and Climate." Predict what you think other members of your group will say.
5. Discuss the statements with your group. Have each person share his or her opinion about each statement and explain why he or she agreed or disagreed.

MAPPING OCEAN CURRENTS

Bo Nye: In today's episode of "Time Travel News," we will focus on ocean currents and climate. Our guests include a scientist, inventor, and statesman from the 18th century, Mr. Benjamin Franklin. Joining him are Dr. Leena Reddy, a hydrologist, and Dr. Tansy Makya, a climatologist.

I have heard that there is a current in the Atlantic Ocean that is slowing down. Some scientists say that this may cause changes to the climate of Ireland. How can that be?

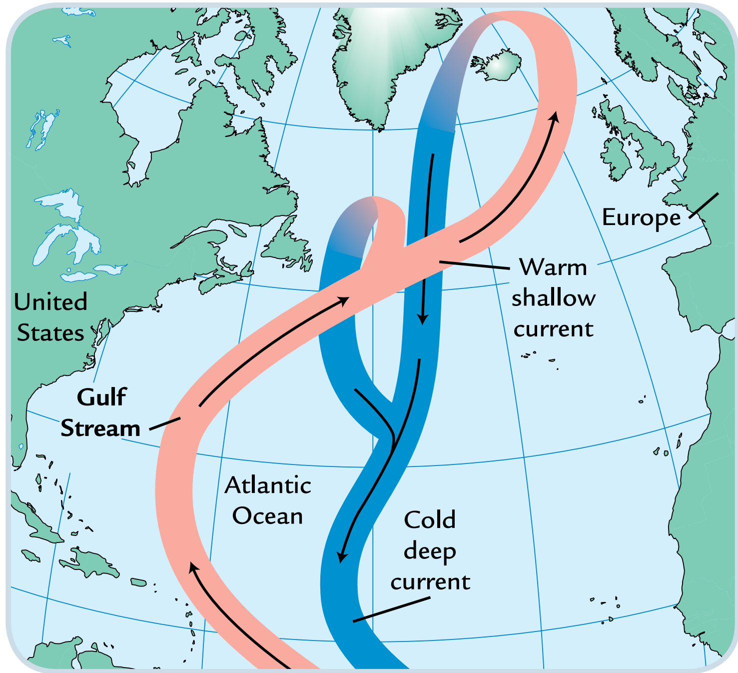
Dr. Leena Reddy: All around the world, there are regular movements of large amounts of ocean water called **currents** (KUR-unts). Some of these currents move warm water from one place to another, while other currents move cool water.

Bo: It sounds like you're talking about rivers, not oceans!

Dr. Reddy: Some people describe currents as rivers that run through the ocean. Like rivers, these currents vary in width and depth, but you can't see them the way that you see rivers that run through land. They may be 100 to 1,000 kilometers wide, and flow on the ocean's surface or a couple of kilometers below the surface.

Dr. Tansy Makya: One really important ocean current is called the Gulf Stream. It is one of the strongest ocean currents in the world. It flows on the surface of the northern Atlantic Ocean and carries warm water from the Gulf of Mexico to northwestern Europe.

OCEAN CURRENTS: THE NORTHERN ATLANTIC OCEAN



Dr. Reddy: The warm water begins to cool as it travels north and eventually sinks. It becomes part of a cold deepwater current that then flows south from the northern Atlantic toward the equator.

Dr. Makya: Measurements taken in 2005 show that this cold deepwater current appear to be slowing down. Ocean currents are like huge conveyor belts that move heat from one place to another. The slowing of one part of the belt may cause another part to slow down too.

Bo: Let me see if I understand this idea. If the cold deepwater current is slowing, that could slow down the Gulf Stream. And if the Gulf Stream slows down, less warm water will reach Ireland and northern Europe.

Dr. Reddy: Yes, but saying that this will lead to significant climate change in Ireland is an extreme prediction. There are no data showing that this will happen.

Bo: Mr. Franklin, you were one of the first people to chart the Gulf Stream. What do you think?

Benjamin Franklin: I'm afraid that I don't have enough information. In my day, we didn't have enough data to tell if ocean currents were speeding up, slowing down, or staying the same.

Bo: I still don't understand how ocean temperatures near Florida could result in a change in the climate of Ireland.

Dr. Reddy: The sun's energy heats both land and water. You probably know that water heats and cools more slowly than land. As a result, oceans retain a large amount of heat. Ocean currents move some of this heat around the earth.

Mr. Franklin: I was one of the first to propose that wind is a major cause of currents near the ocean's surface. But what causes the deepwater currents?

Dr. Reddy: When cold water near the North pole freezes to form ice, it leaves salt behind in the water that doesn't freeze. This water is denser than typical ocean water because it has a greater concentration of salt and is very cold. It sinks toward the ocean bottom, and then flows south. So differences in temperature and the amount of salt in the water drive deepwater currents.

Mr. Franklin: I see. Because they are denser, gravity makes those currents flow deeper in the oceans.

Dr. Makya: Wind blows some surface currents away from the equator toward the poles. A warm current like the Gulf Stream warms and moistens the air above it. The warm, moist air makes climates warmer and wetter than they would otherwise be.

Bo: Even to places that are far from the start of the current? Ireland is thousands of miles from where the Gulf Stream begins in the Gulf of Mexico.

Dr. Makya: Yes. Since the Gulf Stream carries warm water, it makes the climate of countries in northwestern Europe, like Ireland and England, warmer and wetter than other places of the same latitude.

Mr. Franklin: So you are saying that these countries have milder winters and warmer summers because of the Gulf Stream. If the Gulf Stream slowed down, less heat would be transferred, and both winters and summers in these places would be colder.

Dr. Makya: Exactly. The city of Tralee (TRAY-lee), Ireland has a mild climate because of the Gulf Stream. In January, it has an average temperature of 5˚C (41˚F). In comparison, Petropavlovsk (pet-ro-PAV-lofsk), a city of similar latitude in Russia, has a severe climate because it is cooled by a cold ocean surface current that comes down from the North Pole. It has an average January temperature of –8˚C (18˚F).

These two places are at similar latitudes, but have very different climates.

Dr. Reddy: You may have heard of El Niño (NEEN-yo). During El Niño years, the surface temperatures of the eastern Pacific Ocean become a few degrees warmer. This usually results in changes to local climates, like warmer air temperatures and more rain. It can also cause weather disasters, such as floods and droughts.

Bo: I never knew that oceans are so important to climate and weather!

Dr. Reddy: Ocean currents not only affect climate, they also affect businesses like shipping and fishing. Ocean engineers are always working on new and improved instruments to collect data about currents that make ocean navigation easier.

Mr. Franklin: When I was a postmaster in the mid 1700s, we would send letters to England by ship. It took about two weeks for them to reach England. But it would take three to four weeks for letters from England to reach an American port. One day, I received a letter from the head of the British postal service, asking why it took so much longer for mail to travel to the United States.

Bo: But didn't he already know about the Gulf Stream? I read that in the early 1500s, Juan Ponce De León of Spain explored the waters around Florida. He wrote about seeing ripples in the ocean moving faster than the surrounding water.

Dr. Makya: I understand that during Mr. Franklin's time, sailors familiar with the area knew approximately where the Gulf Stream flowed, but there were no accurate maps of the current.

Bo: So, Mr. Franklin, how did you investigate the Gulf Stream?

Mr. Franklin: In 1775, 1776, and 1783, I was on ships crossing the Atlantic. I took measurements of the water temperature, speed, and depth of the current two to four times a day by dropping a thermometer in the ocean. Then I recorded the temperatures on a map. I started to see a pattern of areas where the water was warmer and moving faster.

Dr. Reddy: Mr. Franklin's measurements were used to construct the first scientific map of the Gulf Stream.

Mr. Franklin: I also took daily air temperatures to help make maps of the Gulf Stream more detailed. Adding to my findings, fishermen and sailors told me about what they saw and experienced while sailing the Atlantic Ocean.

Dr. Makya: What did they tell you?

Mr. Franklin: The most fascinating stories they told were about catching huge fish originally from the Gulf of Mexico up north near North Carolina in the United States. They also described the color of the water in the Gulf Stream as more blue than the rest of the Atlantic Ocean.

Dr. Reddy: Today, new technology is used to measure ocean current temperatures more quickly and more often.

Bo: Are the measurements made with instruments on board ships?

Dr. Reddy: Some data are still collected that way. But most measurements are collected by instruments that scientists set afloat in the ocean. These instruments are dropped by boat or plane in specific places in different parts of oceans all over the earth.

Dr. Makya: Satellites pick up signals from these instruments and relay the data to scientists. With this data, we now have maps of temperature, speed, and salt content of different ocean currents. These maps can be updated every week or month.

Dr. Reddy: There are also instruments kept on board ships that link to satellites. People with smaller ocean-going boats sometimes buy these instruments so that they can download images of ocean currents to use for navigation.

Mr. Franklin: Amazing! Such accurate and up-to-date information must make sailing easier and safer.

Bo: I think so. How has this information changed people's understanding of ocean currents?

Dr. Reddy: Now we can see the details within large ocean currents. There may be smaller currents and different temperatures within a larger current as well, as you can see on this temperature map I brought.

Dr. Makya: We can also compare the speed, temperature and salt content of currents from year to year and tell, for example, if currents are slowing down.

Bo: So the information collected from these instruments shows that the climate of Ireland may change?

Dr. Makya: Not exactly. Temperature and water-speed measurements were collected in 1957, 1981, 1992, 1998, and 2004. In one study, scientists compared the five sets of data and concluded that the cold deepwater current flowing from the North Atlantic toward the equator has slowed down.

Bo: So that's why they're projecting that the climate will change in Ireland?

Dr. Makya: A slowing of the cold water current could result in the slowing of the Gulf Stream. This would mean less heat and a cooler climate for northern Europe.

Dr. Reddy: That's one way to interpret the data. Another interpretation is that the slowing of ocean currents is a part of a cycle that reverses itself every 100 years or so. If that is the case, the current may again speed up, and the climate of Ireland would not change so much.

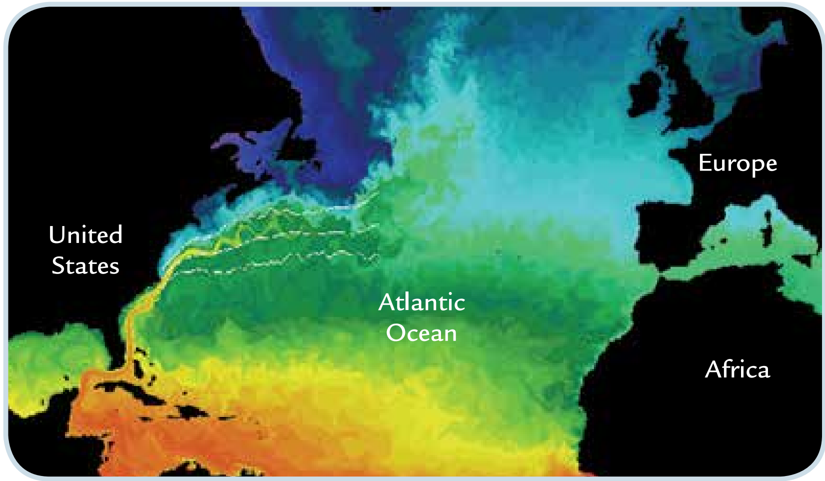
Mr. Franklin: It sounds like more data needs to be collected.

Bo: So it does. We'll have to keep an eye on the latest news. In the meantime, a big thank you to our guests. Join us next week for another episode of "Time Travel News."

Scientists prepare a buoy for release at sea. Instruments attached to buoys collect data about the earth's oceans.

SURFACE TEMPERATURES IN THE ATLANTIC OCEAN

Red areas represent warmer water temperatures.



ANALYSIS

1. What kinds of data do you think scientists need to collect to determine if the climate of Ireland is changing?

2. How do techniques used to map ocean currents today differ from those used in the late 1700s?

3. What is the relationship between oceans and climate?

4. Look at the map below. Describe the likely effect of the California Current on the climate of California.

The California Current is a cold water current that flows from north to south along the coast of California.

EXTENSION

Do you think you might be interested in a weather-related career? Go to the *Issues and Earth Science* page of the SEPUP website to find links to more information about careers in this field.

58 The Causes of Climate

READING

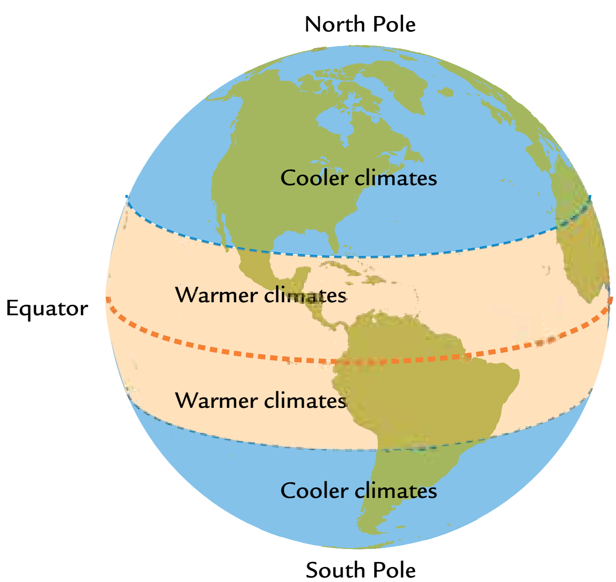
Climates are described by the same conditions used to describe weather, such as temperature, precipitation, and wind. You now know that oceans have an important effect on climate, but oceans are only one of the factors that influence climates. In this reading, you will find out what other factors cause places to have different climates.

CHALLENGE **Why do different parts of the world have different climates?**

READING

When reading, answer the Stopping to Think questions in your mind. They can help you find out whether you understand the main ideas.

You examined a map of climates in the United States in Activity 53, "Weather and Climate." You may have noticed that the southern part of Florida has a tropical climate, with warm temperatures and lots of rain year-round. The northern part of Florida has a mild climate with much cooler winters. Why does climate vary so much from place to place? Many factors influence climate. Some factors, like the energy from the sun, are global and affect climates on every part of the earth. Other factors, like landforms, affect local climates.



Energy from the Sun

The most important factor affecting the earth's climates is energy from the sun. The temperature of a place depends a lot on the sun's energy, because some parts of the earth's surface receive more intense sunlight than others.

Some of the earth's warmest climates are along the equator. In general, the areas around the equator receive more of the sun's energy, while the North and South Poles receive less. In Unit F, "The Earth in Space," you will learn why this is so. The result is that areas around the equator have warmer climates, and areas around the poles have colder climates, as you can see at left.

STOPPING TO THINK 1

Imagine holding a tennis ball in front of a heat lamp for five minutes. What do you predict will happen to the temperature along the "equator" of the ball compared to the top and bottom?

The Role of Oceans

Another major factor influencing the earth's climates are oceans. This is because the water in the oceans holds a large amount of heat. Ocean currents transfer this heat from one part of the earth to another. Some surface currents move water as warm as 25˚C (77˚F), while other currents move water as cool as 10˚C (50˚F). Look carefully at the map on the next page, which shows both warm and cold currents on the ocean surface.

The temperature of ocean currents affects the temperature and moisture content of air. Warm surface currents heat and moisten the air above them. This warm, moist air is carried to different parts of the world, where it makes climates warmer and wetter. Cold surface currents cause air to become cooler, resulting in cooler climates.

The movement of ocean currents depends on heat from the sun. Without the energy from the sun, ocean currents would stop and climates all over the world would be very different.

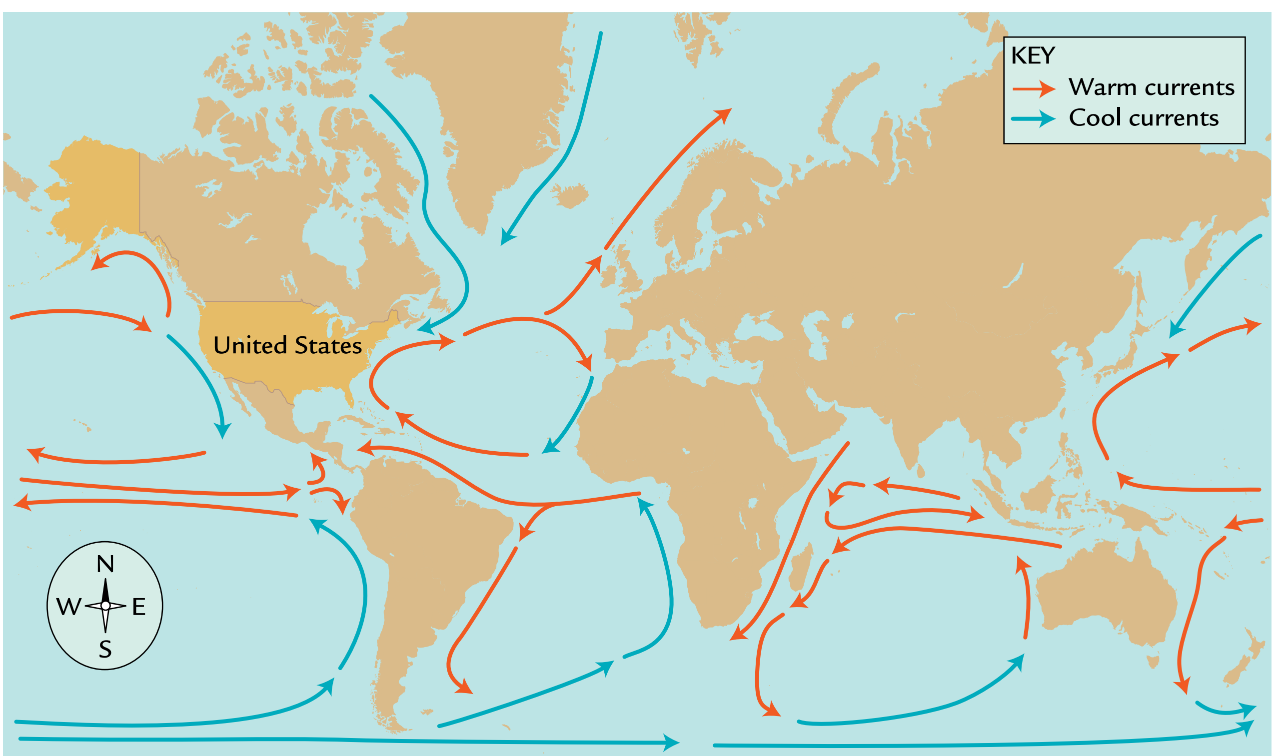
STOPPING TO THINK 2

a. Which coast of the United States is warmed by warm ocean currents? **Hint:** Look at the map below.

b. Which coast of the United States is cooled by cool ocean currents? **Hint:** Look at the map below.

c. Do you predict that the climate of southeastern states along the ocean (such as Georgia and North Carolina) would be warmer or cooler without ocean currents? Explain.

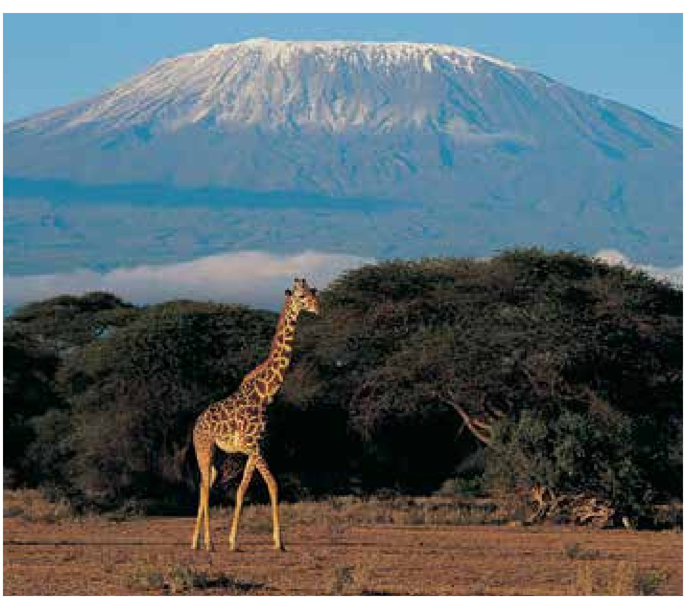
CURRENTS ON THE OCEAN'S SURFACE



Factors Affecting Local Climates

In Unit C, "Erosion and Deposition," you learned that the shape of the land and its closeness to water vary from place to place. Some features of local topography can affect climate. These include the presence of large bodies of water, the height of land above sea level, and large landforms such as mountains.

In Activity 55, "Heating Earth Surfaces," you investigated the differences between the heating and cooling of land and water. You observed that water heats and cools more slowly than land. The climates of land areas that are near large bodies of water are affected by this difference in heating and cooling. In general, land near a large body of water will have milder summer and winter temperatures than a similar area of land that is not near a large body of water.



The height of land above sea level is called its elevation, or *altitude*. The altitude of a place can affects its climate. Land at higher altitudes is usually colder than similar areas of land at lower altitudes. Tall mountains provide a good example of the effect of altitude on climate. Sometimes their peaks are covered in snow and are very cold while their bases, hundreds of meters below, are hot. For example, Africa's Mount Kilimanjaro (bottom left), is very close to the equator and has a tropical climate at its base and glaciers at its peak.

Landforms such as mountain ranges, hills, and valleys can also affect climate. When winds blow toward mountains, the air is pushed upward. As the air gains elevation, it cools and begins to release moisture that is in the air. This released moisture often forms clouds and then rain or snow. Because of this, the side of a mountain that is facing the most common wind direction is usually wetter, while the other side is usually drier.

STOPPING TO THINK 3

What three factors affect local climates? Which of these factors do you think affect your local climate?

Climate and weather are a result of complex interactions between the sun's energy, surfaces on the earth, and the atmosphere. Today, many scientists are concerned that human activities are also affecting climates worldwide. Because of the number of factors that influence climate, it is not easy to determine if one factor is causing more change than another. Climatologists and other scientists study earth's climates in order to answer such questions.

ANALYSIS

1. Which factors affecting climate were described in the reading in this activity?
2. Oceans can store large amounts of heat. How does this affect climate?
3. Imagine that the sun suddenly disappeared forever. What do you think would happen to the earth's climates? Explain.
4. **Reflection:** In this activity, you learned that many factors influence climate. If you were a climatologist, which factor would you most like to study? Why?

59 Water as a Solvent

Just like climate, ocean currents are affected by many factors. These factors include wind, water temperature, the shape of the ocean floor, and the rotation of the earth itself. Warm surface currents are driven primarily by wind. Deepwater currents are driven primarily by differences in density. Areas in the ocean where there is a lot of evaporation or areas near the poles where ice is forming have a higher **salinity** (suh-LIN-ih-tee), or amount of salt in the seawater. This makes the water denser, and it sinks. These cold currents travel deep beneath an ocean's surface and contribute to the interconnected global pattern of ocean currents. To better understand salinity, in this activity you will investigate how well solids dissolve in water compared to other liquids.

CHALLENGE

How well do different liquids dissolve the same solid?

In the Middle East, the Dead Sea is so salty that you can see areas of dried salt as well as water.

MATERIALS

For each group of four students

1 container of sodium chloride
1 container of calcium chloride
1 30-mL dropper bottle of water
1 60-mL dropper bottle of ethanol
1 60-mL dropper bottle of mineral oil
1 cup of water

For each pair of students

1 SEPUP tray
1 stir stick

For each student

1 pair of safety goggles

SAFETY NOTE

Wear safety eyewear, and do not touch the chemicals directly. Follow all classroom safety rules. Wash your hands when you finish the activity.

PROCEDURE

1. Carefully read the table below to review the different liquids and solids you will investigate in this activity.

Mixing Liquids and Solids

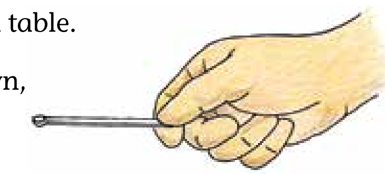
Cup	Liquid	Solid
1	15 drops of water	2 level scoops of sodium chloride
2	15 drops of ethanol	2 level scoops of sodium chloride
3	15 drops of mineral oil	2 level scoops of sodium chloride
4	None	2 level scoops of sodium chloride
5	15 drops of water	2 level scoops of calcium chloride
6	15 drops of ethanol	2 level scoops of calcium chloride
7	15 drops of mineral oil	2 level scoops of calcium chloride
8	None	2 level scoops of calcium chloride

2. Create a data table to record (a) your observations of the liquids in Cups 1–8 ,(b) your observations of each liquid and solid mixed together, and (c) the amount of solid dissolved in each liquid.

3. Work with your partner and use Table 1 to add the correct amounts of three different liquids to Cups 1–3 of your SEPUP tray.

4. Observe the color, transparency, and odor of each liquid, and record your observations of Cups 1–3 in your data table.

5. Use the scoop end of your stir stick, as shown, to add 2 level scoops of sodium chloride to Cups 1–4.



6. Stir the mixture in each cup for exactly one minute, making sure to rinse the stir stick before placing it in the next cup.

7. Compare the amount of solid remaining in the cup to the amount of solid in Cup 4. Estimate the amount of solid that dissolved (all, some, or none), and record your observations in your table.

8. Use Cups 5–8 to repeat Steps 3–7, but when you come to Step 5, use *calcium* chloride instead of *sodium* chloride.

ANALYSIS

1. A liquid that has a solid dissolved in it is called a **solvent** (SOL-vent). In this investigation:

   a. what are the solvents?

   b. in which solvent did the solids dissolve the most?

2. All water on earth contains some dissolved materials, usually salts. Ocean water is about 3.5% salt, with sodium chloride (table salt) being the most common dissolved salt. Calcium chloride is also found on the earth's surface. Would you expect to find calcium chloride in ocean water? Explain.

3. Water is sometimes called the universal solvent. Explain what you think this statement means. Support your answer with evidence from this activity.

4. Do you think most of the water on the earth is salt water or freshwater? Why?

EXTENSION

How good a solvent is water? Design an experiment to find out. Consider investigating how much of a particular solid can dissolve in water or test other solids to see if they dissolve in water. Then present your results to the class.

60 Changing States of Water

READING

Water is one of the most important natural resources. People need it for survival. Although the earth has a lot of water, it is not always in the right place or of the right quality for human use. Seawater, for example, has too much salt in it for people to drink. Hydrologists study how water moves around the earth so that they can help address people's need for water.

CHALLENGE

How does water change?

MATERIALS

For each group of four students

1 Student Sheet 60.1, "Instructions for Concept Map About Water"

1 sheet of chart paper

markers

READING

Work with your group to create a concept map that will help prepare you for this activity.

Water: Solid, Liquid, and Gas

Water can be found on the earth as a liquid, a solid, and a gas. Liquid water falls as rain or flows as a river. Sometimes water is frozen solid and falls to earth as snow, ice, or hail. When water is a gas, you cannot usually see it, but you can sometimes feel it.

When water is a gas, it is called **water vapor** (VAY-pur). If there is a lot of water vapor in the air, you may feel the air is damp or wet. **Humidity** (hew-MID-ih–tee) is the word meteorologists use to describe the amount of water vapor in the air. When it is very humid, there is a lot of water vapor in the air. It may take a long time for wet things to dry, and your skin may feel sticky and wet. Winds move water vapor from place to place.

Clouds and Climate

Sometimes, water moves in a form you see every day—clouds. The **clouds** that you see in the sky are large collections of water, usually in the form of tiny droplets of liquid and solid water. When these droplets become too heavy for air currents to hold them up, they fall down to earth as rain, snow, or hail.

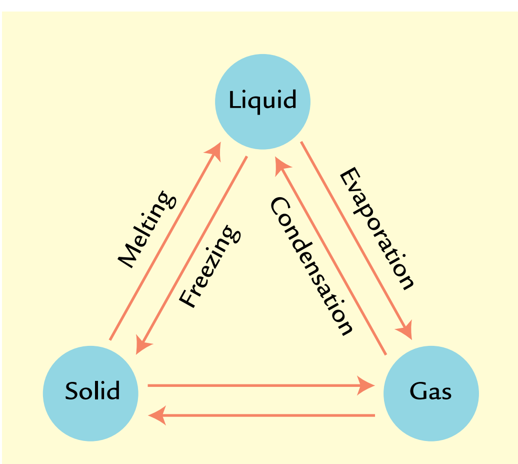
Like clouds, fog is also made up of tiny drops of water. If you have ever been in fog, you know what the inside of a cloud is like!

Clouds both cool and warm the earth. Clouds can reflect the sun's rays back into space, causing temperatures to be cooler. Sometimes they act as a blanket over the earth's atmosphere, keeping it warmer. Depending on the time of day and the type of clouds, the result can be either a warmer or cooler surface. Areas with heavy cloud cover tend to be cooler during the day and warmer at night than they would otherwise be.

Changing States of Water

Every second, somewhere on the earth water is changing its state and moving. Clouds, for example, are blown from one place to another, sometimes releasing rain that soaks into the ground. Because water changes state and moves around so much, it can sometimes seem like the earth has more or less water on it. This is not true. The amount of water on the earth stays the same.

Scientists have words to describe the different ways in which water can change from one state to another. Two familiar words used to describe water changing from one state to another are **melting** and **freezing.** Water melts when it goes from solid to liquid, and water freezes when it goes from liquid to solid.



Liquid water becomes water vapor through a process called **evaporation** (ee-VAP-oh-RAY-shun). If you have ever left a glass of water on a counter and come back to find that some of the water has "disappeared," you have seen evidence of evaporation. The water hasn't disappeared; it has changed state.

Water vapor can also turn back into a liquid through a process called **condensation** (CON-den-SAY-shun). If you have ever seen drops of water appear on the inside of a car window or the outside of a glass, you have seen condensation take place. Condensation often occurs high in the sky, when water vapor condenses into tiny water droplets and forms clouds.

The Water Cycle

Imagine water moving around the earth. Solid icebergs melt into liquid water that flows into the ocean. Water evaporates from the ocean into water vapor. Water vapor in the atmosphere condenses to form the tiny water droplets in clouds. Clouds release the water, and it falls back to earth as rain, snow, or hail. This movement of water from one state to another around earth is known as the water cycle.

Heat from the sun drives the water cycle. The sun's energy causes solid ice to melt into liquid water and liquid water to evaporate and become water vapor. Without the sun's energy, the water cycle would stop, and climates around the world would be very different. From evaporating the ocean water to melting snow, the sun plays an important role in the water cycle and the world's climates.

ANALYSIS

1. Copy the three lists of words below.

List 1	List 2	List 3
vapor	water	evaporation
liquid	solid	solid
solid	condensation	liquid
melting	vapor	vapor
water	liquid	water

   a. Look for a relationship among the words in each list. Cross out the word in each list that does not belong.

   b. Circle the word in each list that includes the others.

   c. Explain how the word you circled relates to the other words in the list.

2. The amount of water on the earth today is the same as it was 100 years ago. Use your knowledge from this activity to explain how this could be true.

EXTENSION

What are the types of clouds and what weather are they each associated with? Find out by going to the *Issues and Earth Science* page of the SEPUP website to link to this information.

61 Investigating Groundwater

Water can be found in many places: on the ground, in the air, and below the earth's surface. Precipitation that falls on land may run off into lakes, rivers, or oceans, but some of this water will go below the earth's surface, where it is called **groundwater.**

About 50% of the water used in homes in the United States comes from water sources on the earth's surface, such as lakes. The other 50% of the water used in homes comes from groundwater. Some people have wells that connect directly to groundwater, while others receive water piped in from wells operated by local water districts. Because groundwater is so important to so many people, some hydrologists specialize in the study of groundwater. In this activity, you will investigate how water interacts with different materials in the ground.

CHALLENGE

How does water interact with earth materials?

A hydrologist collects groundwater for analysis.

MATERIALS

For each group of four students

1 cup of gravel
1 cup of sand
1 cup of water
paper towels (or sponges)

For each pair of students

1 SEPUP tray
1 plastic spoon
1 syringe
1 30-mL graduated cup
2 clear plastic tubes with a hole in the middle of the closed end

PROCEDURE

1. In your science notebook, make a table like the one below.

Observing Water in Gravel and Sand

Tube Containing	Observations of Sample	Observations after Adding Water
gravel		
sand		

2. Examine the samples of gravel and sand. Complete the second column of your table by describing and sketching the size and shape of the particles of each material as best as you can.
3. You will investigate how water travels through these two materials. In your science notebook, predict through which material water will travel more quickly. Explain your reasoning.
4. Fill your graduated cup to the 30-mL mark with sand.

5. Pour the sand into one of the clear plastic tubes.

6. Fill your graduated cup to the 30-mL mark with gravel.

7. Pour the gravel into the other tube.

8. Fill the syringe with 13 mL (equal to 13 cc) of water.

9. Carefully add the water to the 30-mL graduated cup.

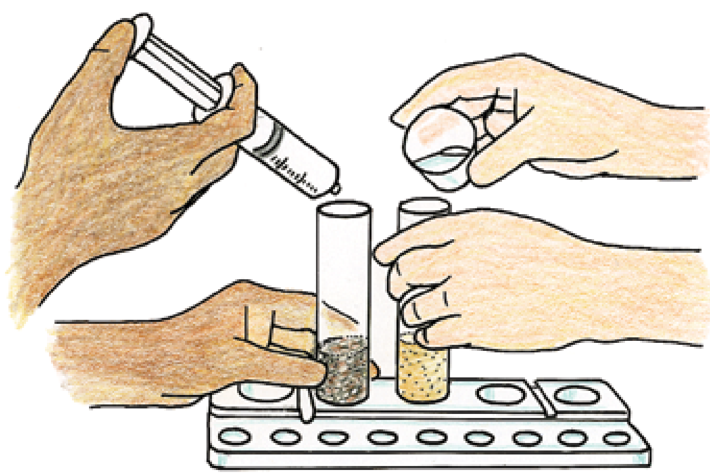
10. Fill the syringe with another 13 mL of water.

11. Place the tube of gravel with its open end up over large Cup B of the SEPUP tray. Place the tube of sand with its open end up over large Cup C.

    Note: Hold the tubes steady so that they are not accidentally knocked over.

12. You and your partner will need to add water to both tubes simultaneously as shown below. Before doing this, read the following directions:

    - Use the syringe to add 13 mL of water to the gravel by slowly squirting the water onto the inside wall of the tube of gravel.
    - Use the graduated cup to add 13 mL of water to the sand by slowly pouring the water into the tube of sand.



13. Record the time as you and your partner simultaneously add water to each tube.

14. Observe for five minutes what happens to the water in each tube.

15. Record your observations in your data table.

ANALYSIS

1. Through which material did water travel more quickly? How did this result compare with your initial prediction?

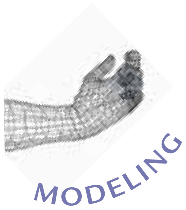
2. Explain how this activity helps provide evidence that the amount of water on earth stays the same.

3. Materials such as sand and gravel often contain small amounts of salts. Based on your work in Activity 59, "Water as a Solvent," what do you think happens as water travels through these materials?

EXTENSION

Where does your drinking water come from? Find out by going to the *Issues and Earth Science* page of the SEPUP website to find links to sites that provide local information. Or contact your local water district directly.

62 Traveling on the Water Cycle



Imagine taking all of the water at the earth's surface and pouring it into a single container. About 97% of it would be saltwater from the earth's oceans, seas, and salt lakes. The other 3% would be from all of the earth's freshwater, including water frozen in ice sheets, icebergs, groundwater, and water vapor in the air. The surface water in lakes, rivers and streams makes up only 0.03%!

H_2O is an abbreviation for a molecule of water. A molecule is the smallest size particle of water that there is. Imagine that you could follow a group of water molecules over time. Your observations of these molecules would start right here in your town.

CHALLENGE **How does water move from place to place?**

MATERIALS

For each pair of students

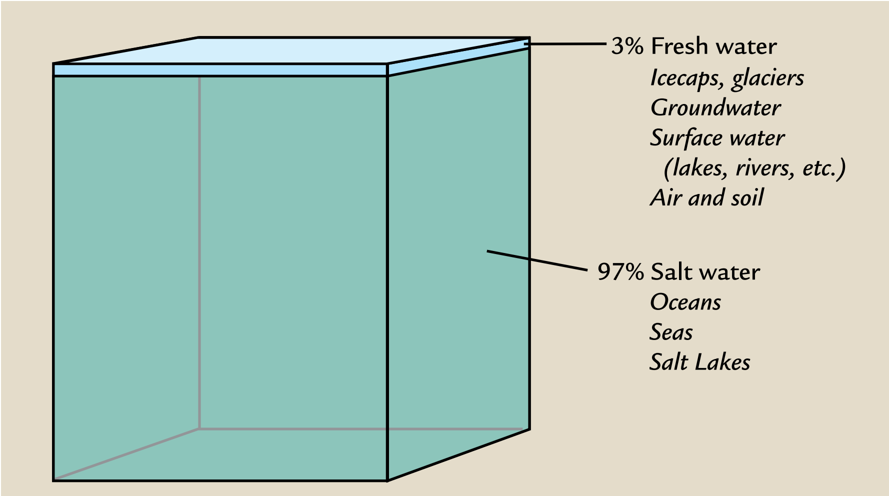
1 **set of six Water Cycle Cards**

1 **number cube**

For each student

1 **Student Sheet 62.1, "Anticipation Guide: Traveling on the Water Cycle"**

1 **Student Sheet 62.2, "My Water Cycle Story"**



PROCEDURE

Use Student Sheet 62.1, "Anticipation Guide: Traveling on the Water Cycle," to help prepare you for this activity.

1. With your partner, review the six Water Cycle cards.
2. Work with your partner to decide where your water adventure begins by selecting one of the Water Cycle cards as a starting place. Be sure to select a place that fits the location of your town. This is the card you will start with.
3. Record the title of the Water Cycle card on Student Sheet 62.2, "My Water Cycle Story."
4. With your partner, look at the Water Cycle card to see where your water molecules can be. Make a choice and record it on Student Sheet 62.2. In the third column, identify the state of your water (solid, liquid, or water vapor).
5. Roll the number cube. Look for the number you rolled on the Water Cycle card to find out where your water will go next.

   Note: Water can cycle back to the same place, so you may not use all six cards. When you get to one you have had before, choose a different form for your water.
6. Repeat Steps 3–5 for all the rows of Student Sheet 62.2. In the third column, identify the state of your water (solid, liquid, or water vapor) at each place in the story.

Which parts of the water cycle can you see in this photograph?

7. Each row of Student Sheet 62.2 is one part of the story of your water. Discuss with your partner:
   - Where in the world are your water molecules in each part of your story? Remember, your water first started in your town.
     Hint: If you are still having trouble, you may want to consult Student Sheet 62.3, "Story Ideas."
   - Describe what happened to your water molecules from one part of the story to the next. Be sure to explain exactly how your water changed.
     Hint: Did it move? If so, how? Or did something else happen, like a temperature change?
8. Based on your discussion, complete the last column of Student Sheet 62.2.

ANALYSIS

1. On Student Sheet 62.1, you recorded your initial ideas about the water cycle. To complete Student Sheet 62.1:
   a. Use the following words to identify where water can be found in the picture:

atmosphere	organisms	ocean
land	groundwater	precipitation

   b. Draw at least six arrows showing the movement of water from one place to another.

   c. Label places where each of the following is occurring:

condensation	evaporation
freezing	melting

   d. What changes did you have to make to your student sheet so that you could complete it?
2. The term "water cycle" is used to describe the movement of water on the earth. Do you think that your diagram on Student Sheet 62.1 is a good summary of the water cycle? Why or why not?
3. In this activity, you used cards and number cubes to model the water cycle. Do you think that this activity was a good model of the water cycle? Why or why not?
4. Expand your notes from Student Sheet 62.2 into a story that describes the journey of your water molecules. Your story should follow your water through at least five places. Be as creative and scientifically accurate as you can! Be sure to:
   - Describe or draw how your water molecules moved from one place to another.
   - Identify any changes in state (solid, liquid, gas) that occur.

63 Investigating Air

On a rainy day, you see lots of clouds and watch rain fall to the ground. On other days, the sun shines brightly onto the earth. During a hurricane or tornado, high winds can blow everything in their path from one place to another. All of this weather in happening in the air that surrounds the earth. Learn more about weather and climate by investigating air.

CHALLENGE **Can you provide evidence that air is a substance?**

MATERIALS

For each group of four students

1 **dropper bottle of BTB (bromthymol blue) indicator**

1 **cup of water**

For each pair of students

1 **plastic syringe**

1 **SEPUP tray**

1 **stir stick**

For each student

1 **pair of safety goggles**

1 **Student Sheet 63.1, "Anticipation Guide: Air"**

1 **Student Sheet 63.2, "Air Investigations"**

SAFETY NOTE

Wear safety eyewear, and do not touch the chemicals directly. Follow all classroom safety rules. Wash your hands when you finish the activity.

PROCEDURE

Use Student Sheet 63.1, "Anticipation Guide: Investigating Air," to help prepare you for this activity.

Part A: What is Air?

1. Observe the air around you. Record your observations on Student Sheet 63.2, "Air Investigations." **Hint:** Think about color and odor.

2. Fill a plastic syringe with 20 mL (equal to 20 cc) of air by pulling the plunger up slowly.

3. Keeping the tip of the syringe about one centimeter (cm) from the skin on your partner's arm, push the plunger all the way down. Your partner should record his or her observations on Student Sheet 63.2.

4. Fill the syringe with 20 mL of air by pulling the plunger back slowly. Hold your thumb tightly over the tip of the syringe and push the plunger all the way down, as shown at left.

5. Repeat Step 4, but this time lift your thumb off of the tip after pushing the plunger past 10 mL.

6. Record your observations on Student Sheet 63.2.

7. Switch roles with your partner, and repeat Steps 2–6.

Part B: Is Air Always the Same?

8. Place 3 drops of BTB into large Cups A, B, and C of a SEPUP tray.

9. Use the syringe to slowly add 5 mL of water to each cup. Use the stir stick to mix the solution.

10. Record the initial color of each solution on Student Sheet 63.2.

11. Fill the syringe with 20 mL of air, and place the tip of the syringe into the solution in Cup B. Slowly push the plunger all the way down. Remove the syringe from the solution.

12. Repeat Step 11 one more time.

13. Have your partner do Step 11 twice more.

14. Carefully remove the plunger from the syringe.

15. Hold the top opening of the syringe several centimeters from your mouth (as shown at left), and blow into it for 10 seconds, until you are sure that the syringe is filled with air coming from your lungs. Quickly put the plunger back into the top of the syringe. You should now have 20 mL of air from your lungs in the syringe.

16. Place the tip of the syringe into the solution in Cup C, and slowly push the plunger all the way down. Observe what happens.

17. Switch roles, and have your partner repeat Steps 14–16.

18. Repeat Steps 14–17 one more time each.

19. Record the final color of each solution on Student Sheet 63.2.

20. Share your results, and discuss Analysis Question 1 with the rest of your group.

ANALYSIS

1. Use your laboratory results to discuss the following questions:
   - **a.** How can you describe air?
   - **b.** Is air always the same?
   - **c.** Look again at Student Sheet 63.1. Would you change any of your answers? How?
2. Do your observations from Part A provide evidence that air is a substance? Why or why not?
3. Look at your results from Part B. Is the air that comes out of your lungs the same as your classroom air? Explain.
4. Is air a substance or is it just empty space? Support your answer with evidence from this investigation.

64 Earth's Atmosphere

You know the space around you as "air," and you may sometimes think of it as being empty. In fact, the air around you is a mixture of gases, including water vapor. Meteorologists call the air that surrounds the earth the **atmosphere**. To better predict weather and climate, scientists need to understand the atmosphere. You can find out what is in the earth's atmosphere by using a computer to simulate collecting air samples from different parts of it.

CHALLENGE

How does the earth's atmosphere vary?

This NASA aircraft can fly up to 20 km above the earth's surface. Atmospheric scientists have attached instruments to the bottom of the aircraft that can collect data on air temperature, water vapor, and air pollution.

MATERIALS

For each pair of students

1 **computer with Internet access**

1 **calculator**

For each student

1 **Student Sheet 64.1, "Data from Air Samples"**

PROCEDURE

1. Imagine releasing a balloon that can collect data about which gases are in the air, the air temperature, and the air pressure. Do you predict that the atmosphere would be the same at every altitude? Explain your ideas in your science notebook.

A researcher in Antarctica launches a weather balloon that carries a package of instruments to an altitude of around 25 kilometers.

2. On a computer, go to the *Issues and Earth Sciences* student page of the SEPUP website, and select the link under Activity 64, "Earth's Atmosphere."
   - On the left side of the screen, you should see a list of atmospheric layers and the distance of each layer from the earth's surface.
   - You will gather data from three different altitudes within each atmospheric layer.
3. Select an atmospheric layer to investigate by clicking on the name of that layer on the left side of your screen.
4. Read Student Sheet 64.1, "Data from Air Samples," carefully. Be sure you understand where to record the data for the atmospheric layer you selected. Then write the name of that layer on the top of the data table that shows the correct altitude.
5. Repeat Steps 3–4 until you have sampled the air at all of the altitudes above the earth's surface.
6. Observe any patterns in the atmospheric data that you have collected. As you look over the data on different layers of the atmosphere, consider what stays the same and what changes.

   Hint: Student Sheet 64.1 is set up so that the upper layers of the atmosphere are on the top and the lower layers are on the bottom.
7. Work with your partner to calculate the mean of each data set on Student Sheet 64.1.
8. In your science notebook, create a table to compare the mean data for the four layers of the atmosphere that you sampled. Be sure to create columns for each of the four gases that you sampled, the air temperature, and the air pressure. Label this table "Mean Atmospheric Values."
9. Discuss with your partner which data are the same for the different atmospheric layers and which data are different. Compare your data to the prediction that you made in Step 1, and revise your initial ideas as needed.

ANALYSIS

1. Which layer of the atmosphere has:
   a. the most water vapor?
   b. the lowest pressure?
2. What remains the same in different layers of the atmosphere?
3. Scientists have divided the earth's atmosphere into different layers. What property of the atmosphere do you think these divisions are based on?
4. You collected data on four layers of the atmosphere. The atmosphere merges into outer space in an extremely thin upper layer known as the **exosphere.** Which of the five layers of the atmosphere do people live in?

65 History of Earth's Atmosphere

INVESTIGATION

Today, the earth's atmosphere is a mixture of gases that includes nitrogen, oxygen, and water vapor. But the earth is more than 4.5 billion years old, and a lot of changes have happened in that time.

Atmospheric scientists and climatologists sometimes drill deep into the earth's surface to collect layers of ice and rock, as shown in the photo below. These layers provide information about what the earth's atmosphere was like hundreds of thousands of years ago.

CHALLENGE **Has the earth's atmosphere always been the same as it is today?**

MATERIALS

For each pair of students

1 set of eight Atmosphere Cards

PROCEDURE

1. With your partner, carefully read the information on each Atmosphere Card.
2. Work with your partner to place each card in order from oldest to most recent.
3. Compare how you ordered your cards with the way the other half of your group ordered them. Discuss similarities and differences in your arrangements.
4. With your group, work with one set of cards to place the cards in an order you all agree on, from oldest to most recent.

   Remember to listen to and consider the explanations and ideas of other members of your group. If you disagree with others, explain why you disagree.
5. In your science notebook, create a table like the one below, and record your final order for the Atmosphere Cards. Complete the table by writing down information about the gases in the atmosphere and important events during that time.

Earth's Atmosphere Through Time

Card	Gases Present in the Atmosphere (and percentage, if listed)	Important Date and Event

ANALYSIS

1. Look carefully at your completed table.
   a. How has the amount of carbon dioxide gas in the atmosphere changed over the earth's history?
   b. How has the amount of oxygen gas in the atmosphere changed over the earth's history?
2. What effect have living organisms (including people) had on the composition of the earth's atmosphere? Support your answer with examples from this activity.
3. **Reflection:** Do you think that the atmosphere will have different amounts of oxygen and carbon dioxide in the future? Explain your reasoning.

66 Atmosphere and Climate

Most of the earth's weather occurs in the **troposphere** (TROH-poh-sfeer). In Activity 58, "The Causes of Climate," you learned that the ocean has currents that move warm and cold water from one place to another. The troposphere has currents as well. Air currents move air from one place to another.

CHALLENGE

What role does the atmosphere play in weather and climate?

MATERIALS

For each student

- **1 completed Student Sheet 64.1, "Data from Air Samples"**
- **1 completed "Mean Atmospheric Values" data table from Activity 64, "Earth's Atmosphere"**

READING

Use the "Listen, Stop, and Write" strategy to help you with this reading. Listen as your teacher reads aloud. Whenever he or she stops reading, close your book. Write down the main ideas you just heard.

Earth's Atmosphere

The atmosphere is the layer of gases that surrounds the earth. The main gases are nitrogen (78%) and oxygen (21%), with the remaining 1% made up of other gases including carbon dioxide, water vapor, and argon. Atmospheric scientists divide the atmosphere into five layers based on temperature differences (see the table below). Compared to the radius of the earth (6,370 km), the atmosphere is a very thin 262–382 km.

Earth's Atmospheric Layers

Atmospheric Layer	Approximate height above earth's surface	What happens in this layer?
Exosphere	120 km+	The earth's atmosphere merges into space.
Thermosphere	80–120 km	The space shuttle orbits the earth.
Mesosphere	50–80 km	Meteors usually burn up.
Stratosphere	12–50 km	Ozone layer absorbs some of the sun's harmful ultraviolet radiation before it strikes the earth's surface.
Troposphere	0–12 km	Most weather occurs. Cruising altitude of most commercial aircraft.

Listen as your teacher reads aloud.

Stop when you see this yellow pencil and close your book.

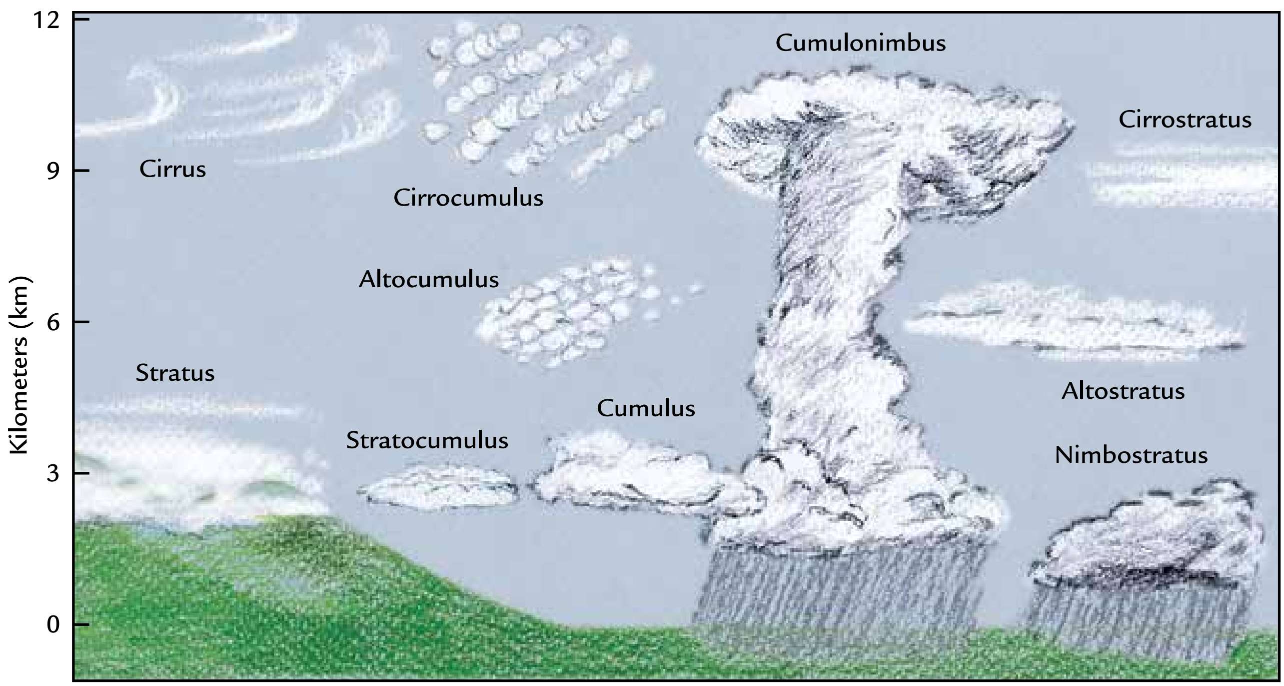
Write down the main ideas you just heard.

Atmosphere and Weather

Weather occurs in the troposphere. Air in the troposphere is heated from the ground up. The surface of the earth absorbs the sun's energy and heats up. The heated earth then heats up the air above it. Since some parts of the earth's surface heat up faster than others, this causes differences in air temperature and pressure, resulting in wind.

Wind is the horizontal movement of air. Air moves from areas of high pressure to areas of low pressure and can result in winds of different speeds. When there is very little or no difference between pressure in two neighboring regions, the air is calm and there is no wind. When there is a lot of difference in air pressure between two neighboring regions, strong winds can blow leaves off trees and push clouds across the sky. The fastest wind speed recorded to date is 513 km/hr (318 mi/hr) during a 1999 tornado in Oklahoma. In general, wind speeds tend to be higher in the daytime when there are greater differences in air temperature and pressure.

Heat is spread through the troposphere because air is slightly unstable. Unstable air can cause the moisture in the atmosphere to condense and clouds to form. On average, clouds cover 40–50% of the earth at any given time. Clouds and storms form when pockets of air rise and cool. They are carried through the atmosphere by wind. The more unstable the atmosphere is, the more likely you are to see clouds and more severe weather, such as storms.

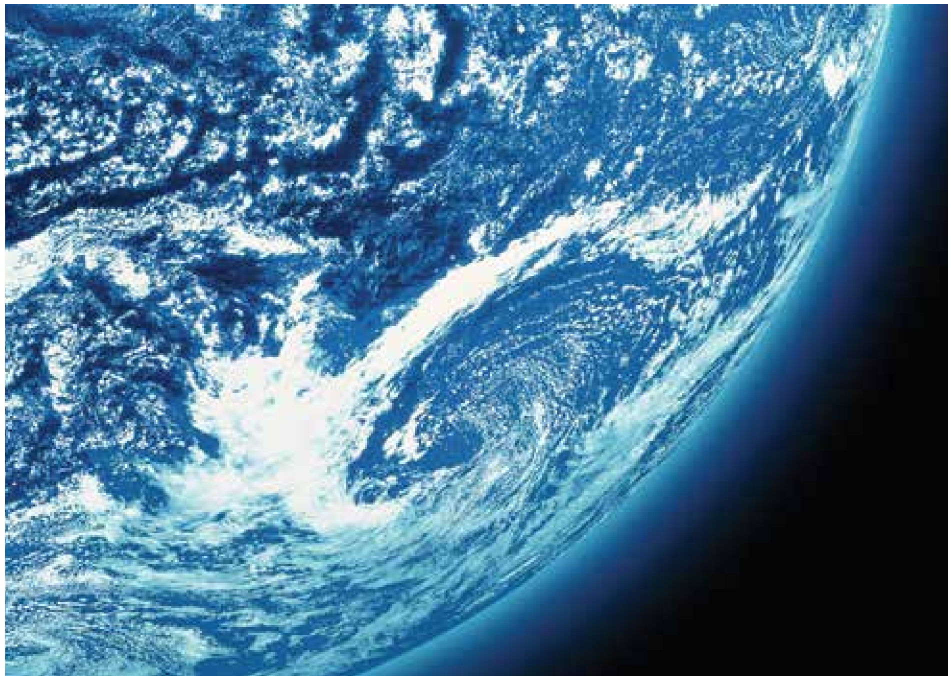


Clouds are described by their height in the atmosphere and their shape.

Atmosphere and Climate

The way the earth's atmosphere interacts with the sun's energy and the oceans helps determine the earth's average temperatures and its different climate zones. Air heated at the equator eventually moves north or south to other climates. Some of the sun's energy reflects off the earth's surface and would be lost to space if there were no atmosphere. By trapping some of the sun's energy, the atmosphere helps maintain the different climates on earth.

The constant movement of air in the earth's atmosphere also ensures a steady environment for living organisms. Almost all living organisms require gases found in the atmosphere for survival. The interaction between living organisms and the environment means that the earth's atmosphere supports life and that living organisms continue to produce gases that become part of the atmosphere.



Atmosphere and Global Climate Change

Substances in the earth's atmosphere help hold heat in the atmosphere, almost like a blanket around the earth. This is called the **greenhouse effect.** Respiration and volcanic eruptions add such greenhouse gases as water vapor and carbon dioxide (CO_2) to the atmosphere. The ability of these gases to hold heat near the earth is called the natural greenhouse effect. But human activities are changing the concentration of greenhouse gases, especially CO_2, in the atmosphere. The burning of fossil fuels, deforestation, agriculture, and industry have all added greenhouses gases. As a result of these human activities, CO_2 in the atmosphere has increased 33% since people started burning fossil fuels in the late 1700s. Evidence suggests that this increase will change climates around the world.

Scientists' predictions vary on how much the increased levels of greenhouse gases will change climates globally in the future. However, evidence suggests that certain effects are likely:

- Overall, earth will become warmer, although some areas might become cooler.
- Warmer temperatures will change the weather patterns. Some areas will receive more rain and snow, while others will receive less.
- Rising temperatures in the oceans will partially melt glaciers. As the temperature increases, ocean water will expand. These two changes will cause sea levels to rise.

- Warmer oceans will cause a change in sea-life habitats. Warmer water will kill some reefs and the fish that depend on them for survival. Other fish will find new habitats as ocean temperatures rise.
- Changing temperatures and rainfall patterns will affect crops, and new plants will grow in some regions.
- Weather events, such as hurricanes, tornadoes, and heat waves, will become more severe.

ANALYSIS

1. What is the relationship between the earth's atmosphere and its weather and climate?

2. As an atmospheric scientist, you are asked to write an encyclopedia entry about the atmosphere. Use your work from Activity 64, "Earth's Atmosphere," and your knowledge about the atmosphere from Activities 65 and 66 to write a paragraph explaining the atmosphere and its layers. Be sure to describe significant similarities and differences among the different layers.

3. Write a paragraph predicting what you think will happen to the area you live in as a result of global climate change. As you write your prediction, you might want to consider the following:
    - Are you close to a coastline where water levels may rise? What will the effect be?
    - Do you live in a farming community? How would changes in rainfall or temperatures affect the crops grown now?
    - Do you live in an area where people depend on snow in the mountains for their drinking water? What will happen if there is less snow due to global climate change?
    - Do you live in a low-lying area, possibly close to a river? What would happen if there were more rain?

4. **Reflection:** In the past three activities, you have learned a lot about the earth's atmosphere. If you were an atmospheric scientist, what aspect of the earth's atmosphere would you most like to study? Why?

EXTENSION

Your teacher may post some of your predictions on the discussion board on the *Issues and Earth Science* page of the SEPUP website. Be sure to check that page of the SEPUP website to see what students in other parts of the country have predicted.

67 Measuring Wind Speed and Direction

Moving air is called wind. During hurricanes, winds can reach over 248 kilometers per hour (155 miles per hour). A tornado can have winds as fast as 512 kilometers per hour (318 miles per hour). The instruments pictured on this page are used to measure wind. Wind *speed* is measured by an **anemometer** (an-uh-MOM-ih-ter). Wind *direction* is measured by a **wind vane.**

CHALLENGE

How will you design instruments to measure wind speed and wind direction?

MATERIALS

For each group of four students

1 stopwatch
1 compass
wooden sticks
thumbtacks
large index cards
paper clips
popsicle sticks
large tongue depressors
plastic straws
small and large paper cups
small and large plastic cups
modeling clay
sand
1 pair of scissors
1 stapler
glue
markers
tape

For each student

1 Student Sheet 67.1, "The Design Process"

Part A: Creating a Design

1. Your group will make a wind vane and an anemometer. Decide which two members of your group will work on which instrument.
2. Review the list of materials that will be available to you. Discuss with your partner how you would like to build your instrument.
3. After you and your partner decide on a design, each of you should draw and label the parts of your design on your copy of Student Sheet 67.1, "The Design Process."

4. Exchange student sheets with the other pair in your group and review their design.

5. Work with your partner to provide feedback by identifying at least one strength of their design and one recommendation for improvement. Write your feedback on both their student sheets.

6. Exchange student sheets, and review the comments made by the rest of your group. Work with your partner to make any needed changes to your design, and record these on Student Sheet 67.1.

7. On Student Sheet 67.1, write a step-by-step procedure that explains how to use your instrument to measure the wind.

Part B: Constructing Your Instrument

8. Build your instrument according to the design you sketched on Student Sheet 67.1.

9. Test your instrument by measuring wind (either outdoors or using a fan indoors).

10. Evaluate your instrument. If something did not operate according to plan or could be improved, record this on Student Sheet 67.1.

Part C: Redesign and Refine

11. Based on your observations in Steps 9 and 10, discuss with your partner ways to redesign or improve your instrument.

12. Make any needed changes to your instrument.

13. Test your instrument again, and record on Student Sheet 67.1 any factors that did not go as planned.

14. Continue redesigning and refining your instrument until the deadline your teacher has set.

Part D: Collecting Wind Data

15. Follow your teacher's instructions, and then take your instrument outside. Take three separate wind measurements with your instrument. Record your data on Student Sheet 67.1.

ANALYSIS

1. Evaluate your group's two instruments by completing the following table.

Instrument Evaluation

Instrument	Strengths	Weaknesses
Wind Vane		
Anemometer		

2. What do the more successful wind-measurement instruments have in common?

3. You designed and tested your anemometer and wind vane at school. Imagine using them on a ship, as Francis Beaufort did.

   a. What factors might be different on a ship than at school?

   b. Describe how you would adjust the design of your instruments so that they would work well on a ship.

68 Worldwide Wind

In Activity 58, “The Causes of Climate,” you read about many different factors that influence global climate, including the sun’s energy and ocean currents. In many places, the wind blows from one direction more than from any other. This direction is called the **prevailing wind**, and the pattern of prevailing winds also influences global climates.

CHALLENGE

What is the pattern of prevailing winds on different parts of the earth?

MATERIALS

For each pair of students

1 **computer with Internet access**

For each student

1 **Student Sheet 68.1, “My Wind Data”**

1 **Student Sheet 68.2, “Wind Currents on Earth”**

PROCEDURE

1. Your teacher will assign you and your partner to a city. Record the number for your assigned city in the space provided on Student Sheet 68.1, "My Wind Data."
2. On the Internet, go to the *Issues and Earth Sciences* student page of the SEPUP website, and select the link under Activity 68, "Worldwide Wind."
3. Click on the number for your city.
4. You should see a list of dates. These dates represent days in which a local middle school science teacher measured the direction of the wind in this city.
5. Select a date, and examine the direction from which the wind blew that day. Note that the arrow itself represents the wind.
6. On Student Sheet 68.1, "Wind Data," draw an arrow showing the direction of the wind on that day and label the arrow with the date.
7. Repeat Steps 5 and 6 until you have collected all of the wind data for your city. If two or more dates have the same wind direction, write the second (and third and more) date(s) under the first date for that arrow. Record days without wind at the bottom of Student Sheet 68.1.
8. Work with your partner to determine the most common wind direction in your city. This is the prevailing wind.
9. Share your data with your class. Report the number of the region containing your assigned city and the direction of your city's prevailing wind.
10. On Student Sheet 68.2, "Wind Currents on Earth," draw arrows showing the prevailing winds for each of the regions that the other groups investigated.

ANALYSIS

1. Look carefully at Student Sheet 68.2. Describe any overall pattern that you see.

2. Summarize global wind patterns by constructing a table to record the prevailing wind direction at different latitudes.

3. Look at the direction of the prevailing winds over North America. Based on the direction of the prevailing wind, would you expect weather systems over the United States to travel from east to west or west to east?

Latitude	Prevailing wind

69 Forecasting Weather

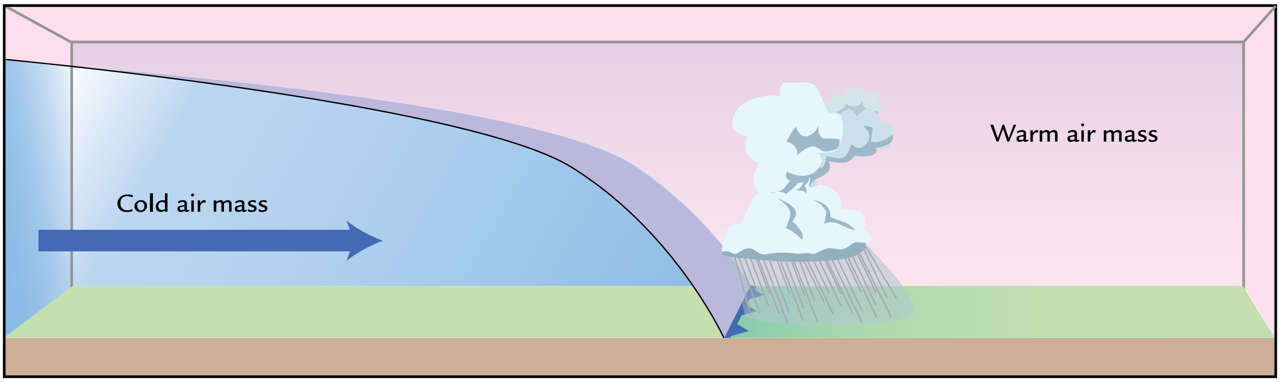
You have learned that meteorologists collect data about the earth's weather. They often use that data to construct weather maps. Meteorologists then use those maps to predict what the weather will be like in the next few hours, the next day, or for the next several days. This is known as a **weather forecast.**

When forecasting weather, meteorologists sometimes refer to **cold fronts,** which form when cold air moves in and replaces warm air. The cold air pushes the warm air up, forming high columns of clouds, as shown below. Cold fronts usually cause cooler temperatures. A **warm front** occurs when warm air moves in and replaces cooler air. Warm fronts bring in warmer temperatures. They also create cloudy conditions that usually last longer than the cloudy conditions produced by cold fronts.

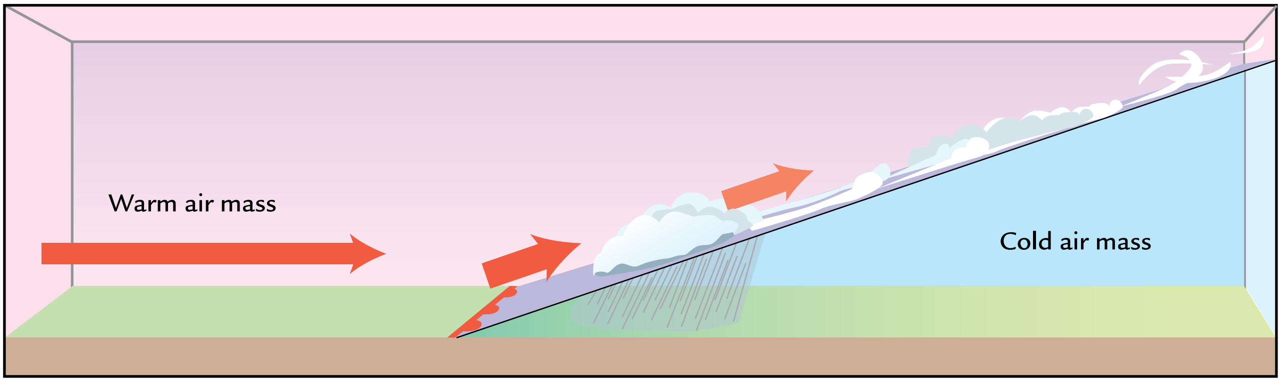
CHALLENGE

What information is found on a weather map? How can a weather map be used to forecast weather?

COLD FRONT



WARM FRONT



MATERIALS

For each student

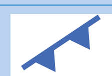
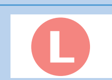
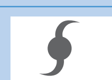
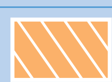
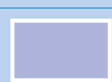
1 **Student Sheet 69.1, "Summarizing Weather Reports"**

1 **Student Sheet 69.2, "Map of Iowa"**

PROCEDURE

1. Work with your group to review the information in the table below, "Weather Map Symbols." Make sure that you are familiar with the different weather symbols and what they mean.

Weather Map Symbols

Weather	Symbol	Associated Weather
Precipitation		Rain, snow, fog, or other forms of precipitation
Cold front		Cooler temperatures, possible precipitation
Warm front		Warmer temperatures, possible precipitation
Low pressure		Cloudy skies, possible precipitation
High pressure		Clear skies
Hurricane		Damaging winds, rain, possible flooding
Tornado watch		Area where tornadoes may occur, possible severe thunderstorms
Tropical storm		Very strong winds and heavy rains

2. Your teacher will assign your group one of the weather maps for August 24–31 shown on pages 88-89.

3. Work with your partner to summarize the weather on this map. Identify:
   - weather fronts
   - precipitation
   - areas of high and low pressure
   - any unusual weather events, such as a tornado watch or a hurricane

   Be sure to discuss with your partner each type of weather and where in the country it is occurring. For example, if you were to begin to summarize the weather for August 24, you might say, "There is a cold front stretching from Arizona northeast up to Minnesota."

4. Work with your partner to write a weather report for your assigned day. You can do this by describing the weather that is associated with each weather symbol (see the table). As you summarize current weather conditions, make sure to describe:
   - weather fronts and possible changes in temperature
   - areas of precipitation
   - clear or cloudy skies due to changing pressure
   - any unusual weather events, such as a tornado watch or a hurricane

   In your science notebook, write your weather report in complete sentences and in the present tense, as if you were reporting the weather on television or the radio. For example, if you were to begin to summarize the weather on August 24, you could write, "The cold front stretching from the southwest up to Minnesota is causing cooler temperatures and may result in some precipitation."

5. Share your weather report with the other half of your group. Discuss similarities and differences in your weather reports, and make any needed changes.

6. Prepare one weather report to present to the class.

7. Read the statements on Student Sheet 69.1, "Summarizing Weather Reports." You will respond to these statements after listening to your classmates report on the weather for each of the eight days from August 24 to 31.

8. Have your group present its weather report and listen to other groups reports.

9. After listening to all eight weather reports, complete Student Sheet 69.1.

LOCATOR MAP FOR CLEVELAND, OHIO

10. Based on the weather reports you heard, forecast the weather for Cleveland, Ohio for September 1. Describe likely fronts, temperature changes, pressure changes, precipitation, and severe weather that may arrive.

    Hint: Look at the pattern of weather over the eight days. Use your knowledge of how weather moves across the United States to predict what type of weather is likely to occur in Cleveland.

ANALYSIS

1. a. Based on the patterns you observed in the weather maps, in what direction does weather generally travel across the United States?

   b. Think back to your work in the last activity. In what direction does the prevailing wind move across the United States?

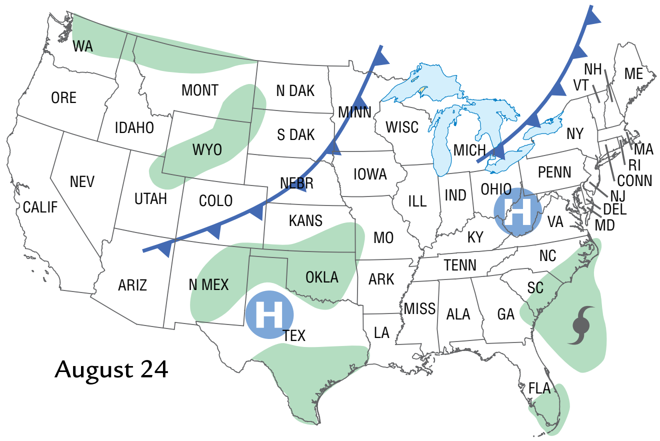
   c. How does the movement of the atmosphere globally affect weather locally?

2. Below is weather data collected for Iowa on September 15. Your teacher will give you Student Sheet 69.2, "Map of Iowa." Use the information provided and your knowledge of weather maps to place the appropriate weather symbols on Student Sheet 69.2. Be sure to construct a key for your map.

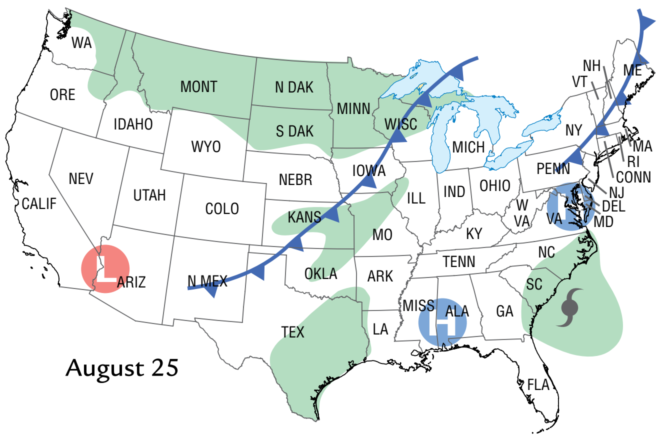
   - Warm front extending from Lincoln, Nebraska northeast to Mason City, Iowa
   - Rain all along the warm front
   - Low-pressure system in and around Des Moines, Iowa

3. **Reflection:** People often complain about the unreliability of weather forecasts. Why do you think meteorologists are sometimes wrong about what the weather will be like?

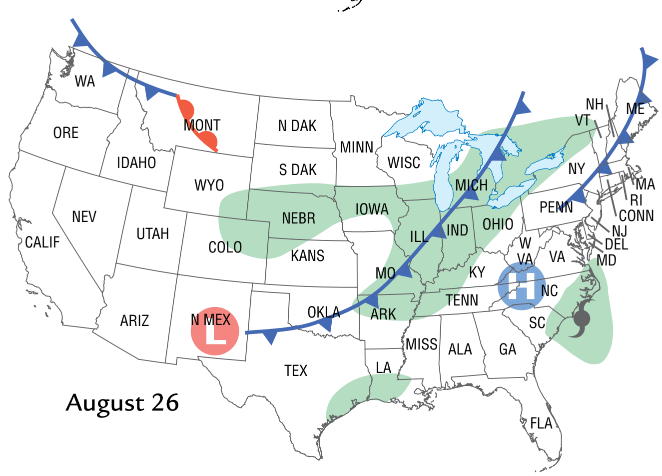
WEATHER MAPS: AUGUST 24 THROUGH AUGUST 31



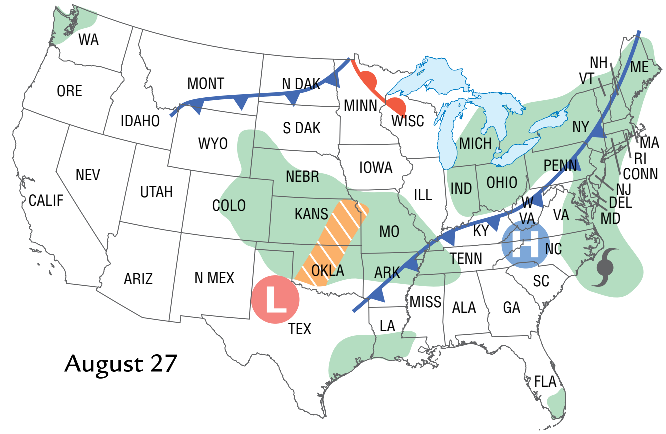
August 24



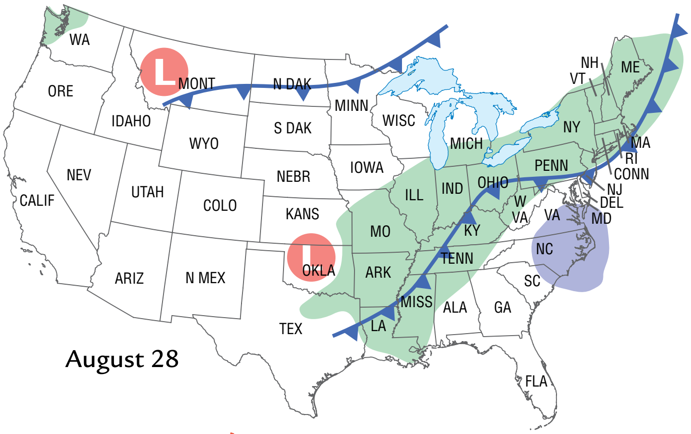
August 25



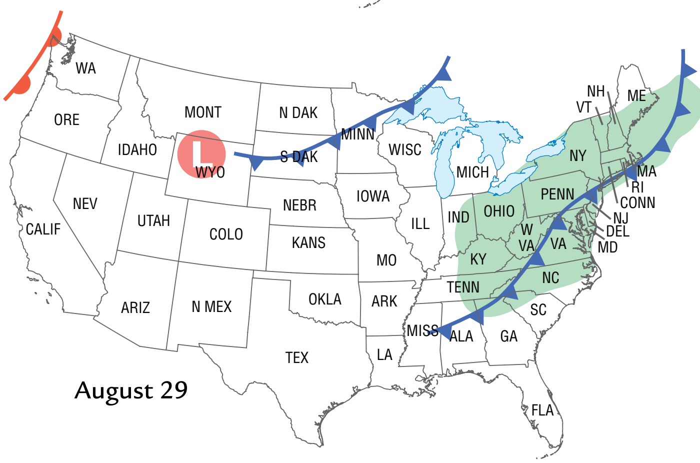
August 26



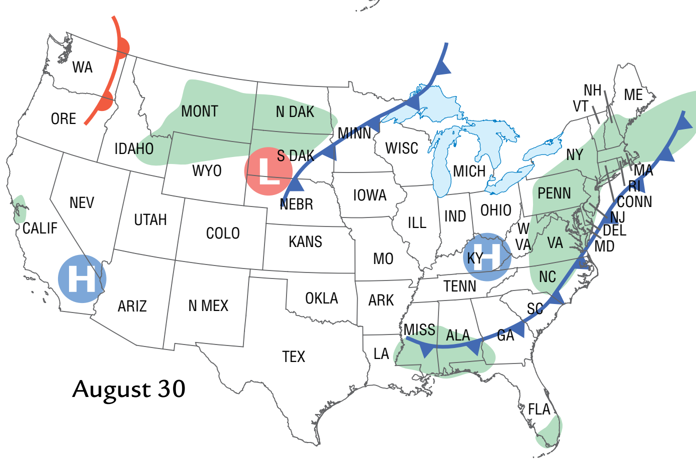
August 27



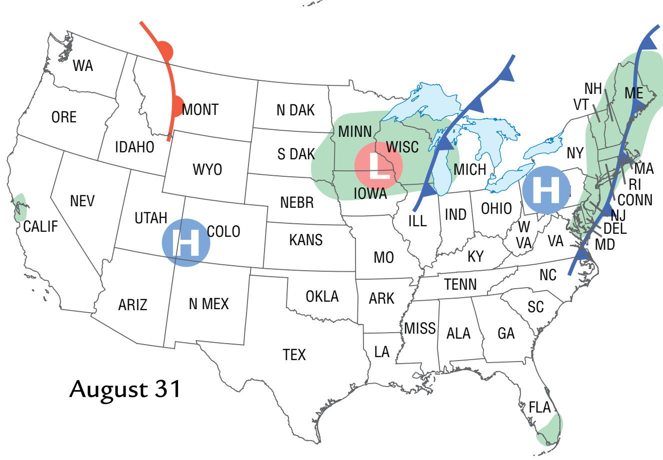
August 28



August 29



August 30



August 31

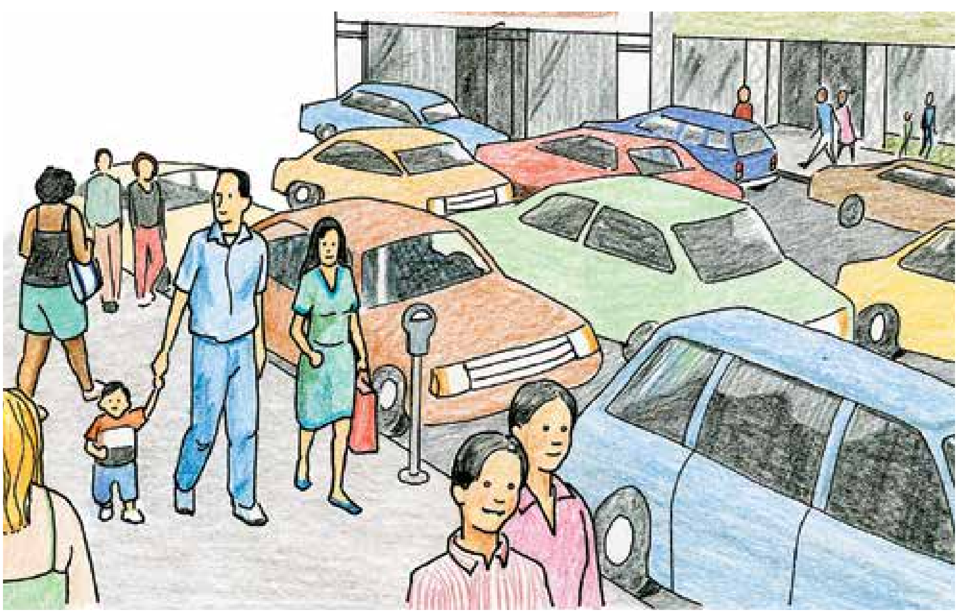
70 People and Weather

Over the course of this unit, you have learned about different aspects of earth's weather and atmosphere. Atmospheric scientists, climatologists, hydrologists, and meteorologists all study how the earth's weather, atmosphere, and climates work. Some of these scientists also study the interactions of humans with the earth's natural systems. In this activity, you will investigate the possible connection between the population of Sunbeam City and its weather and atmosphere.

Imagine living in Sunbeam City, a rapidly growing city that has experienced population growth partly because of its sunny weather and dry climate. The economy is growing and many people are happy with the city's growth, but some city planners are concerned. They worry that the increase in population might cause changes to the weather, atmosphere, and water availability of Sunbeam City.

CHALLENGE

Is the growth of Sunbeam City affecting its weather, atmosphere, and water availability?



MATERIALS

For each group of four students

1 **Student Sheet 70.1, "Atmospheric Scientist's Report"**

1 **Student Sheet 70.2, "Climatologist's Report"**

1 **Student Sheet 70.3, "Hydrologist's Report"**

1 **Student Sheet 70.4, "Meteorologist's Report"**

For each pair of students

1 **calculator**

For each student

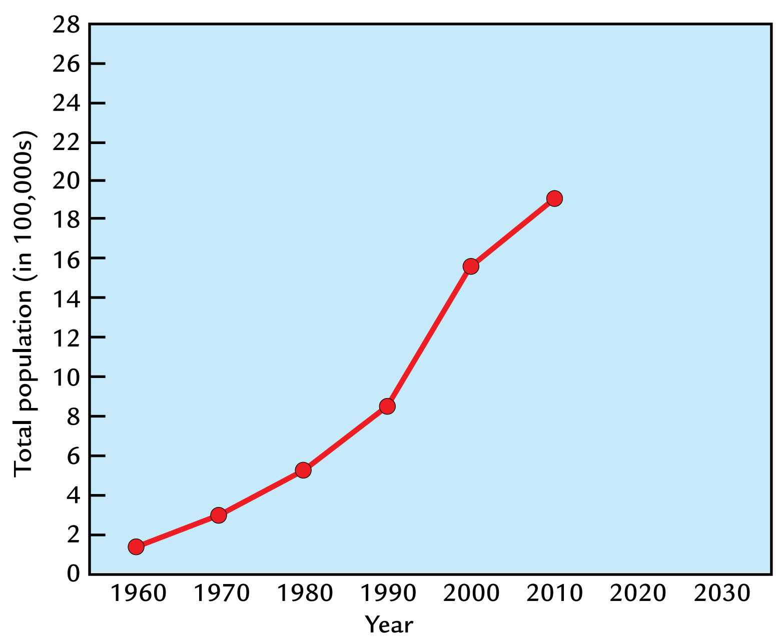
1 **Student Sheet 50.2, "Careers in Weather"**

1 **Student Sheet 70.5, "Intra-act Discussion: People and Weather"**

PROCEDURE

1. Look at the graph below. Discuss with your group how the population of the city has changed during the past 40 years, and what you think the size of the population will be in the years 2020 and 2030.

POPULATION OF SUNBEAM CITY



2. Each person in your group will role-play a scientist studying the weather and atmosphere of Sunbeam City. Decide which person in your group will be the:

- atmospheric scientist
- climatologist
- hydrologist
- meteorologist

3. Have each scientist from your group attend a "regional meeting" with other scientists who are studying the same data. At the meeting, you will receive one of the following student sheets:

- Student Sheet 70.1, "Atmospheric Scientist's Report"
- Student Sheet 70.2, "Climatologist's Report"
- Student Sheet 70.3, "Hydrologist's Report"
- Student Sheet 70.4, "Meteorologist's Report"

4. At the regional meeting, read the summary on pages 94–97 that is most relevant to your type of scientist. For example, students who are role-playing atmospheric scientists should read the "Summary of Atmospheric Pollutants in Sunbeam City" on page 94.

5. Work with the other scientists at the regional meeting, and use the information in the summary to complete your student sheet.

Remember to listen to and consider the ideas of other members of your group. If you disagree with someone, explain to the rest of the group why you disagree.

6. At the regional meeting, discuss the following questions with the other scientists. You will later present this information to your group.

- What patterns do you observe in your data?
- Do your data sets help explain why people would like to live in Sunbeam City? If so, how?
- Compare your data to the population changes in Sunbeam City shown in the graph on page E-91. Do your data sets indicate that the weather, atmosphere, or water availability of Sunbeam City has been affected by an increase in its population? If so, how?
- What will you tell scientists from other regions about your findings?

7. Return to your group. Present the data on your student sheet, pointing out any patterns that you observed in the data, and state your conclusions about the relationship between Sunbeam City's population growth and any changes in its local environment. Then listen as other group members present their data.

8. Work with your group to summarize the data by discussing the following questions:
   - Which data set(s) help(s) explain why people would like to live in Sunbeam City?
   - Which data set(s) show(s) that the weather, atmosphere, or water availability of Sunbeam City may have been affected by an increase in its population?

9. Mark whether you agree or disagree with the statements on Student Sheet 70.5, "Intra-act Discussion: People and Weather." Predict what you think other members of your group will say.

10. Discuss the statements with your group. Have each person share his or her opinion about each statement, and have them explain why he or she agreed or disagreed.

11. As a group, brainstorm all of the possible actions that the Sunbeam City planners could recommend to city residents to reduce the possible impact of people on the city's weather, atmosphere, and water availability.

12. Discuss the advantages and disadvantages of each option.

Summary of Atmospheric Pollutants in Sunbeam City

CARBON MONOXIDE is a colorless, odorless gas that forms during the incomplete burning of such fuels as gasoline, oil, and wood. In high concentrations it is poisonous to humans. More than half of the carbon monoxide released in the United States is from car exhaust. In cities, 85–95% of carbon monoxide in the air may come from car exhaust. In 2005, Sunbeam City's carbon monoxide releases were greater than the concentration limits set by the U.S. Environmental Protection Agency.

NITROGEN OXIDES are gases that form from the burning of fuels at high temperatures. Most of them are colorless and odorless, but one of them—nitrogen dioxide—is a brownish gas that can sometimes be seen in a smog layer above a city. These gases can form acid rain, ground-level ozone, and other chemicals that affect human health. More than half of the nitrogen oxides released in the U.S. are from car exhaust. Prevailing winds can blow nitrogen oxides over long distances.

SULFUR DIOXIDE is a colorless, odorless gas that dissolves easily in water. It can be harmful to animals and humans, especially those with asthma, other lung problems, or heart disease. It forms from the burning of sulfur-containing fuels such as coal. More than 65% of sulfur dioxide is released from power plants that produce electricity. Sulfur dioxide can be blown over long distances, affecting air quality far from its original release.

PARTICULATE MATTER refers to microscopic particles of solid and liquid chemicals, including metals, smoke, and even soil, that float in the air. The particles are small enough that people can inhale them into their lungs, sometimes causing health problems. Some particles are released into the air from human sources such as cars, power plants, and construction sites. Other particles are from natural sources and include dust and pollen. In 2005, the concentrations of particulate matter in Sunbeam City exceeded limits set by the U.S. Environmental Protection Agency.

Release of Air Pollutants in Sunbeam City

Air pollutant	2000 Release	2010 Release
Carbon monoxide	793,225	943,680
Nitrogen oxides	132,563	143,212
Sulfur dioxide	65,816	63,466
Particulate matter	123,458	234,650

Climate Summary for Sunbeam City

Sunbeam City is located in a flat valley in the western United States. The valley is bordered on the east and west by mountains ranging in height from 610 to 3,048 meters (2,000–10,000 feet) above the valley floor. The city itself is approximately 610 m (2,000 ft) above sea level. This altitude contributes to its cooler nighttime temperatures, which can be more than 15°C lower than daytime highs.

The prevailing winds, which are primarily from the south/southwest, can cause severe dust storms and sandstorms. Sunbeam City is 434 kilometers (270 miles) from the ocean, but the mountains block most of the precipitation that it might otherwise receive. Thunderstorms are rare, but can occur with the arrival of a low-pressure system. Summer thunderstorms can cause flash flooding. In general, the region has a desert-like climate with very little precipitation year-round.

Sunbeam City has warm temperatures and more than 300 days of sunshine per year. Skies are usually clear, without much cloud cover. In the summer, daytime temperatures exceed 38°C (100°F). During summer nights, temperatures drop into the low 20s°C (70°F). In the winter, daytime temperatures average about 16°C (60°F). During winter nights, temperatures can drop as low as 2°C (36°F).

Mean Monthly Temperature and Precipitation for Sunbeam City (1981–2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Temperature (°C)	9	12	16	20	25	30	34	33	28	21	14	9
Precipitation (cm)	4	9	1.0	0.4	0.3	0.2	1.0	1.0	0.6	0.7	0.9	1.3

Hydrological Summary of Sunbeam City

Historically, most of the water used in Sunbeam Valley came from groundwater. In 1980, the city passed a law that limited the amount of groundwater that could be removed each year. Today, Sunbeam City and the surrounding area get 10–15% of their water from groundwater and 85–90% of their water from Cross Country River. The river begins as snowmelt high in the mountains, which collects over hundreds of kilometers to form the river. The freshwater from the river is shared with seven nearby states.

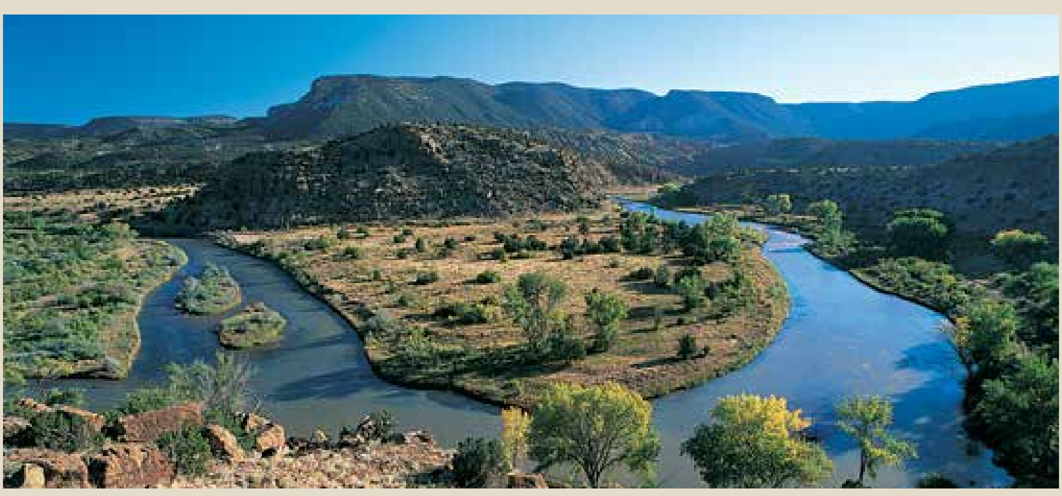
Sunbeam City is allowed to use 370 billion liters of water per year from the Cross Country River. The only way for Sunbeam City to get more water from Cross Country River is to regularly pay one of the other states for its share of the water.

About 65% of the water used by Sunbeam City each year is used by households. Each home uses an average 800,000 liters per year. About 60% of this water is for outdoor use, such as watering lawns.

The remaining 10–15% of water used by Sunbeam City is mostly from groundwater. It collects from the rain and the snow that melts into the ground from the mountains surrounding Sunbeam City. It can take thousands of years for the water to travel from the mountaintops to the groundwater basin in the center of the valley, with precipitation from the mountains replenishing the groundwater at a rate of about 49 billion liters per year.

Groundwater Use Since 1940

Year	Groundwater used (billions of liters per year)
1940	26
1950	43
1960	59
1970	110
1980	92
1990	76
2000	92
2010	83



Meteorological Summary for Sunbeam City

As the population of Sunbeam City grows, city planners and scientists wonder if it is becoming an "urban heat island." An urban heat island is a city or suburban area that experiences hotter temperatures than the surrounding rural areas. Heat islands can develop as cities grow and areas of natural vegetation are replaced by concrete sidewalks, roads, and buildings. Buildings and roadways absorb more of the sun's energy and can result in an increase in local surface and air temperatures. The U.S. Environmental Protection Agency reports that urban areas can be anywhere from 1° to 6°C warmer than surrounding rural areas.

The following temperature data sets were collected for Sunbeam City as well as the surrounding rural area to determine if the growth of the city is affecting its mean temperature.

Mean Monthly Temperature (°C) in Sunbeam City

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1961–1971	7	11	10	17	23	29	33	30	26	16	8.5	8
2001–2011	9	13	16	20	26	30	34	33	29	22	14	10

Mean Monthly Temperature (°C) in Rural Areas Outside Sunbeam City

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1961–1971	7.5	11	12	16	22	29	33	29	25	17	12	7
2001–2011	10	13	16	19	25	30	34	32	28	20	14	10

ANALYSIS

1. Would a weather map provide more evidence about a possible relationship between population growth and changes in the weather and atmosphere of Sunbeam City? Why or why not?

2. Based on the evidence in the scientists' reports, is there any possible relationship between population growth and the weather, atmosphere, or water availability of Sunbeam City? Support your answer with evidence from this unit.

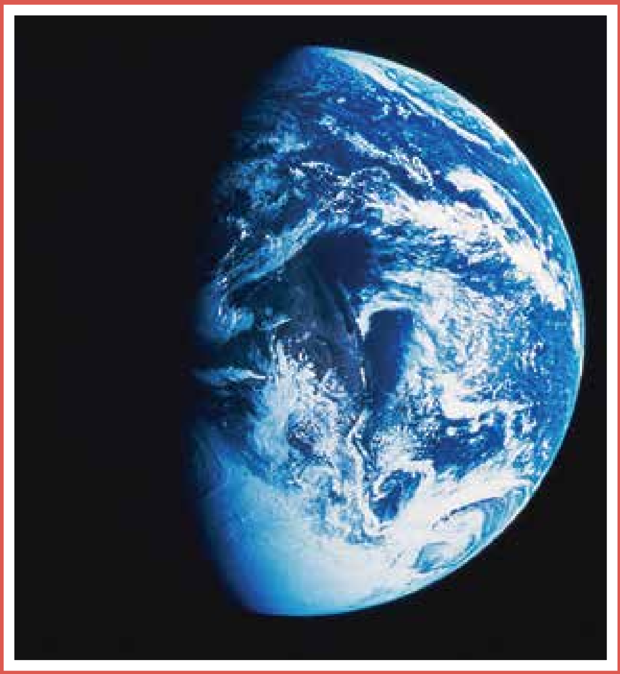
3. What do you think the people of Sunbeam City could do to reduce the possible effects of population growth on their weather, atmosphere, and water availability? Make a recommendation to Sunbeam City's residents, explaining what you think should be done and why. Be sure to support your recommendation with evidence and to identify the trade-offs.

4. In Activity 66, "Atmosphere and Climate," you read about global climate change and what the possible effects on the earth's climate could be.
   a. What do you think might be happening to Sunbeam City's climate?
   b. What do you predict will happen to the climate of Sunbeam City in the future? Explain.
   c. How certain are you of your prediction? What would make you more certain?

5. **Reflection:** In this unit you learned a lot about weather-related careers and the kind of work that scientists in these careers do. Which of these careers is most interesting to you? What kinds of scientific questions or issues would you be most interested in investigating? Why?

EXTENSION

Find more information about the weather-related career of your choice. You may want to investigate the type of education, training, and salary associated with this career. Begin by going to the *Issues and Earth Science* page of the SEPUP website for career-related links.



The Earth in Space

F


WESTCLOX

The Earth in Space

Mia woke up suddenly one Monday morning in early March. “Oh no!” she thought. “It’s already light out. I must have forgotten to set my alarm clock.”

“Wake up, Sleepy,” Mia said to her sister. “And hurry up! We’re late!” She jumped out of bed and began searching in her closet for something to wear to school.

Just then the alarm clock went off. “You see? We’re not late,” said her sister. “It’s 7:00—the same time the alarm was set for last week.”

When Mia went down to breakfast, she told her mother how confused she was when she woke up and saw it was already light.

“I know,” said her mother, “It’s March now and I’m beginning to notice that the days are getting longer. Last Friday was the first day that it was still light when I got home from work.”

That reminded Mia of how gloomy it had felt when the days became shorter in the fall. When she had left school after practicing for the school play, it was already dark out.

“I’m glad there’s more daylight now. It’s so much easier to get up in the morning when it’s light out.”

• • •

Why do the daylight hours get shorter in the fall and then longer again in the spring? Does the amount of daylight explain why it is warmer in summer than in winter?

In this unit, you will investigate the cause of the day–night cycle, the year, and the seasons. You will also investigate changes in the phases of the Moon. You will relate these changes to the motions of Earth and the Moon in space and to the way people measure time.

71 Sunlight and Shadows

An important part of scientists' work is discussing and presenting their results and ideas to other scientists. It begins with informal discussions and eventually leads to formal presentations and written papers in scientific journals. When scientists present their work, other scientists review their ideas and comment on them. With this exchange, human knowledge moves forward—from discovering planets to curing diseases, and from exploring the past to thinking about the future.

In this activity, you will review the work of another scientist—a middle school student named Tyler. His class is studying the Earth, Sun, and Moon. Everyone in the class has to do a project, and Tyler's is on sunlight and shadows.

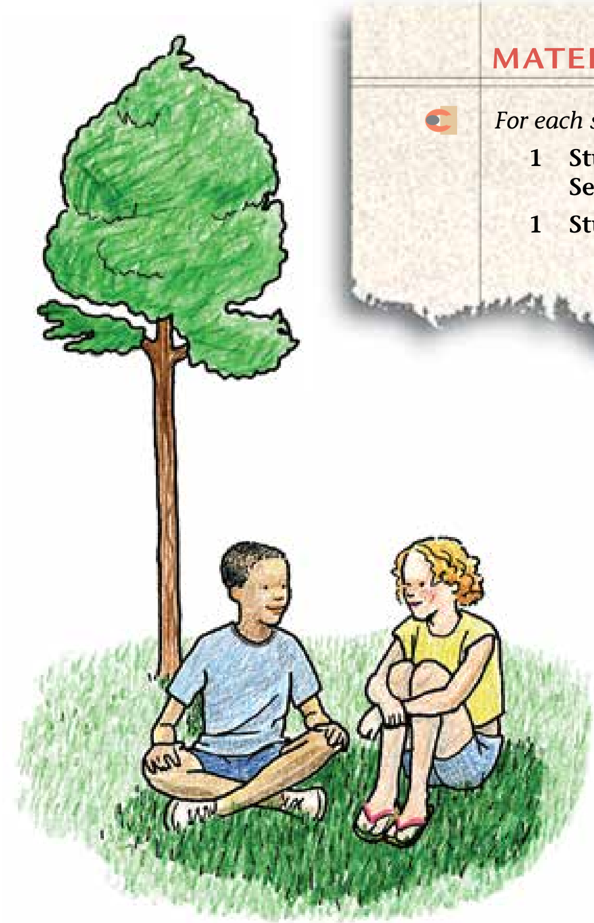
CHALLENGE **How can Tyler improve his investigation?**

MATERIALS

For each student

1 **Student Sheet 71.1a, "My Ideas About the Day, Year, Seasons, and Moon Phases: Before"**

1 **Student Sheet 79.1, "My Moon Observations"**



READING

Read Tyler's science notebook. When you come to the "Talking It Over" questions, stop and think about them. Then discuss them with your group.

Tyler's Science Notebook

MARCH 15

Yesterday was the first hot day this year. It gets hot much earlier here than it did when we lived in Chicago.

We had an early dismissal day, and Emily came home from school with me. She wanted to sit outside in the shade of the little tree in our backyard. We just planted the tree last year, so I didn't think there would be enough shade. But she was right; there was just enough room for both of us in the shade.

It was kind of annoying though. We had to keep moving to stay in the shady spot. I asked my science teacher why the shadow moved. She explained that it was a phenomenon—a simple or amazing event related to how the world and universe work. She suggested I investigate this question for my science project. I plan to start making observations this weekend.

TALKING IT OVER 1

a. Why do you think Tyler's shady spot keeps moving?

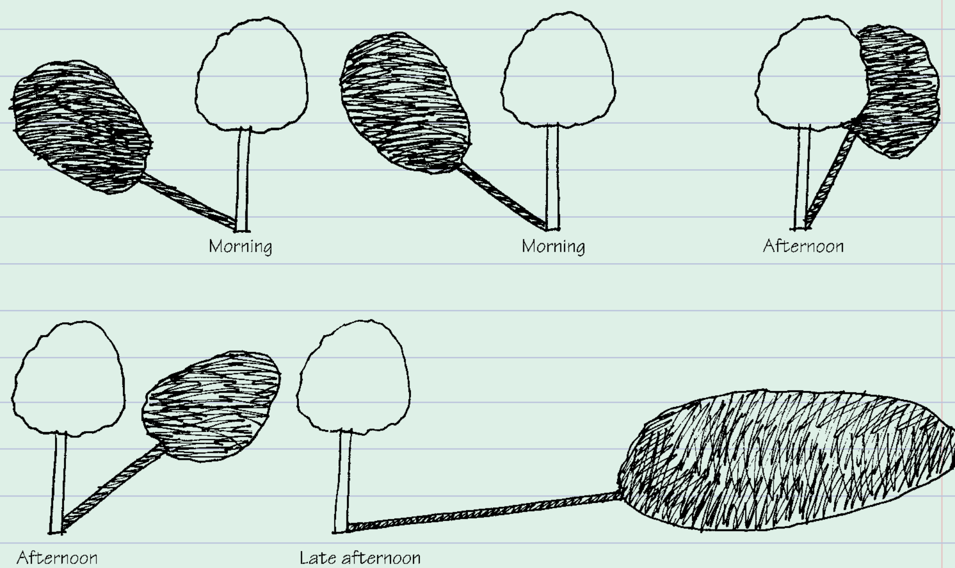
b. During a single day have you ever noticed a change in position of:

- your shadow?
- the shade from a tree or other object?

MARCH 18

PROCEDURE: Today I began collecting data about the shadow from the tree. I decided to check which way the tree's shadow was moving twice in the morning and three times in the afternoon.

RESULTS: Here are pictures of my results.

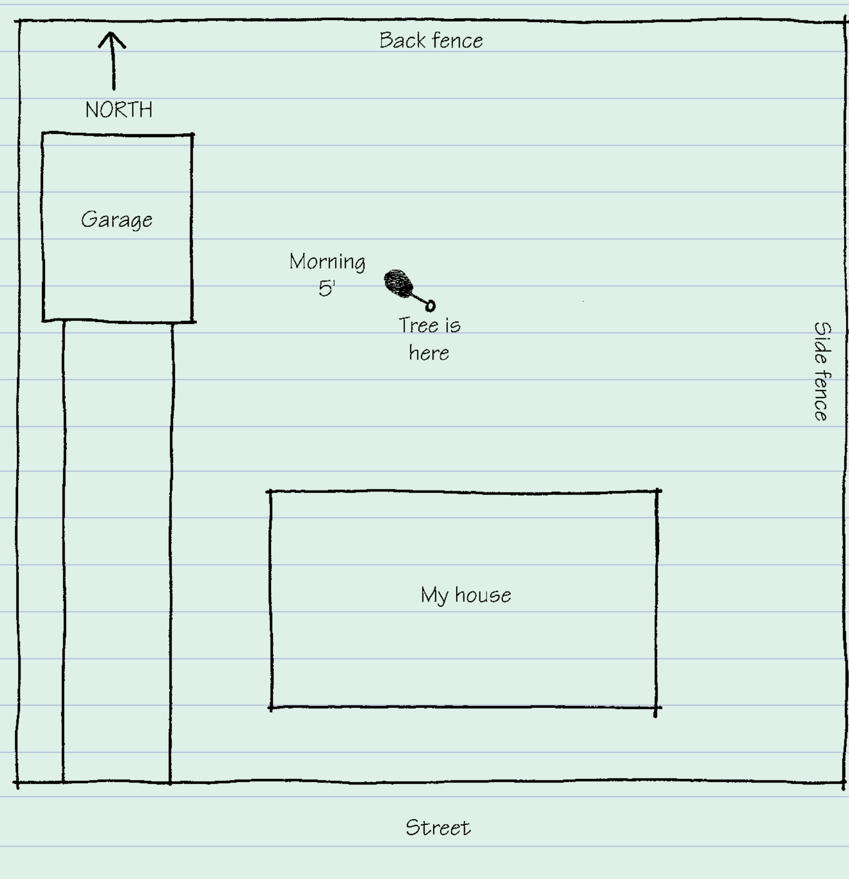


CONCLUSION: I saw that the tree's shadow moved from left to right across our backyard. I also observed that it changed in size. As it got later in the afternoon, the shadow from the tree became much longer. Tomorrow I am going to measure the shadow.

MARCH 19

PROCEDURE: Today I will measure the length of the tree's shadow and note its direction in the morning, at noon, and in the afternoon.

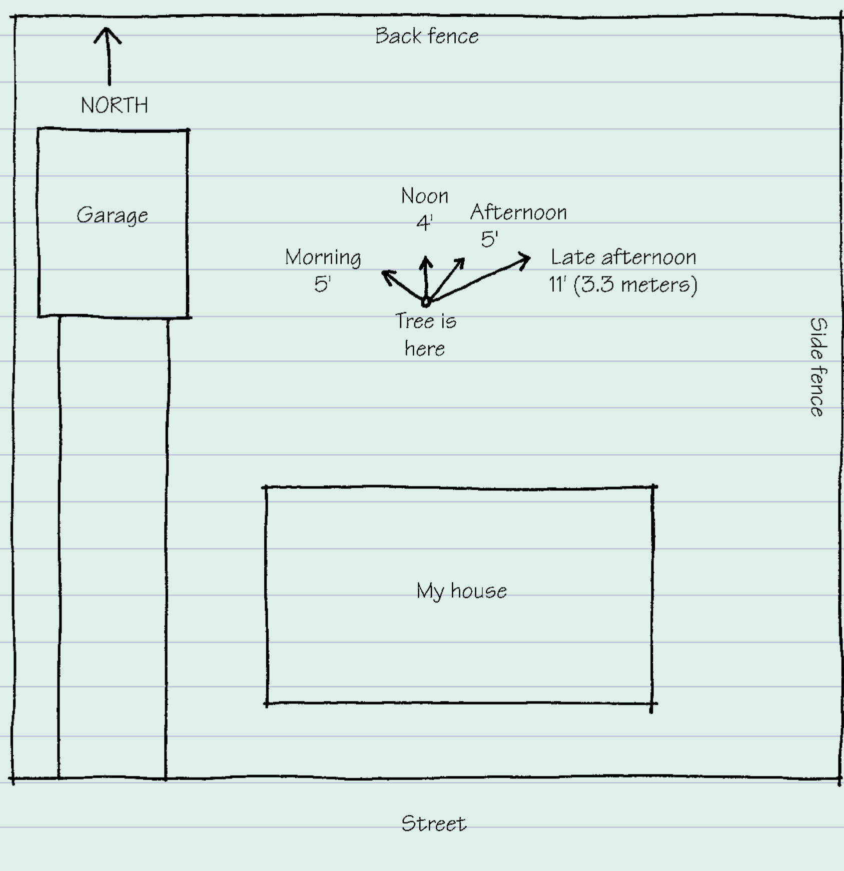
First Observation:



MARCH 19, CONTINUED

At first I just drew a picture and measured the shadow length in feet. Later I remembered that scientists use meters. To make it easier to see, I used an arrow to show the tree's length and direction. I also added my observations of the weather, because the wind and clouds made it hard to measure the shadow at noon. I decided to put all these observations in a table so I could compare the data.

RESULTS: My results are shown below and on the next page.



SHADOW OBSERVATIONS

Time	Shadow Direction	Shadow Length (feet)	Shadow Length (meters)	Observations
Mid-morning		5 feet		
Noon		4 feet		A little windy and cloudy, so shadow came and went.
Early afternoon	I noticed the shadow was moving. This morning it pointed toward the garage on the left side of our back-yard, but now it's pointing toward the back fence and a little to the right.	5 feet		No clouds, no wind, very hot.
Late afternoon	The shadow has moved again and points toward the fence to the right of our backyard.	11 feet	3.3 m	No clouds. No wind. Sun is almost behind the tall trees.
6:00 p.m.				No shadow. It was getting dark and chilly because the Sun just set.

SUMMARY: The length of the shadow really does change during the day. It gets especially long in the afternoon.

TALKING IT OVER 2

a. Based on the data he collected, how could Tyler improve his summary of his results?

b. How could Tyler improve his data collection?

ANALYSIS

1. **a.** What do you think is causing the changes in the *direction* of the shadow from Tyler's tree from early to late in the day?

   b. What do you think is causing the changes in the *length* of the shadow from Tyler's tree from early to late in the day?

2. What data would you collect to test your ideas?

3. Do you think Tyler's measurements would be the same if he made them at the same times of day the next month? Explain why or why not.

4. **Reflection:** In hot weather Tyler likes to sit in his favorite shady spot under his tree. How does the Sun affect you each day?

72 Measuring Shadows, Measuring Time

INVESTIGATION

In the last activity, you read Tyler's science notebook and suggested how he could improve his investigation. In this activity, you will have a chance to plan and conduct your own investigation of the shadows cast by the Sun.

Instead of investigating the shadow a tree casts, you will investigate the shadow of a stick. Your investigation should be reproducible (ree-pro-DEW-si-bul). That means that another scientist could follow your procedure to do the same investigation and obtain similar results. This is common in science. Scientists read each other's work and attempt to repeat and extend their findings and conclusions.

Your investigation should also provide enough observations and measurements, or data, to be convincing.

CHALLENGE **How can you improve Tyler's investigation?**

MATERIALS

For each group of four students

1 **compass**

For each pair of students

1 **sun stick**
1 **sun stick base**
1 **ruler**
1 **sheet of white plastic**
1 **binder clip**

PROCEDURE

1. Insert the sun stick into the base.
2. Using Tyler's approach, design a better investigation to answer the questions: How do the position and length of a shadow change during the day? What causes these changes?

   When designing your investigation, think about these questions:

   - What is the purpose of your investigation?
   - How will you describe and conduct your investigation so that it will be reproducible—so that someone else can repeat it and get the same results?
   - What materials will you need to conduct your investigation?
   - Where is the best place to put your sun stick?
   - What observations and measurements will you make?
   - How will you record your data?
   - How will you use your data to make a conclusion?
3. Discuss your investigation design with your group to come up with the best possible combined approach. Record your group's plan in your science notebook.
4. Get your teacher's approval of your investigation.
5. Conduct your investigation, and record your results.

ANALYSIS

1. What changes did you observe in the shadow at several different times on the same day?
2. Why do you think the shadow moved during the day?
3. What observations did you make that support your answer to Question 2?
4. Why do you think the length of the shadow changed during the day?
5. What observations did you make that support your answer to Question 4?
6. How did your observations compare to Tyler's observations?
7. Explain how you could use your sun stick to tell time.

EXTENSION

Conduct an investigation of the shadows from the Sun over a period of a month. Repeat your shadow measurements at the same time of day and in the same location at least once a week for three or four weeks. Record your data and conclusions in your science notebook.

73 A Day on Earth

The Sun shines on every planet, but the time from one sunrise to the next—one full day–night cycle—is different for each planet. On Earth, one full day–night cycle lasts 24 hours, one complete day. On average, each day on Earth has about 12 hours in light and 12 hours in darkness. On Mercury, a day–night cycle lasts about 4,223 hours, or nearly 176 Earth days! On Jupiter, one full day–night cycle takes less than 10 Earth hours.

Have you ever wondered why night and day happen here on Earth, or anywhere else?

As Tyler took his last measurement, he began to wonder what caused the day–night cycle. When he asked a friend, she said that the Sun just turns dark at night. This didn't seem right to Tyler, but he wasn't sure.

CHALLENGE

What causes the day–night cycle?

MATERIALS

For each pair of students

1 Student Sheet 73.3, "Possible Explanations: A Day On Earth"

For each student

1 Student Sheet 73.1, "Talking Drawing 1: A Day On Earth"

1 Student Sheet 73.2, "Talking Drawing 2: A Day On Earth"

This ancient Greek bowl shows Helios, the Greek god of the Sun, travelling across the sky in his chariot. This is how the Greeks explained the day-night cycle.

PROCEDURE

1. What do you think causes the day–night cycle on Earth? Take a moment to think about this.
2. Create a drawing and add words to describe your ideas on Student Sheet 73.1, "Talking Drawing 1: A Day On Earth." Save your drawing for later in the activity.
3. Read the explanations of the causes for day and night on Student Sheet 73.3, "Possible Explanations: A Day On Earth."
4. Choose the explanation(s) that are closest to your ideas about how night and day happen. You may select more than one explanation. Place a check mark next to the one(s) that you think are closest to your ideas. Explain to your partner why you chose that explanation(s).
5. With your partner, re-read the explanations carefully. Next to each explanation in the table, record any observation that supports or contradicts the explanation.
6. Watch your teacher's demonstration of how the Earth and Sun look from outer space during a 24-hour day–night cycle on Earth.
7. Circle the explanation from the table that is the same as the model you watched.

ANALYSIS

1. What causes daylight and night on Earth? Create another drawing and description of your ideas on Student Sheet 73.2, "Talking Drawing 2: A Day On Earth."

2. Compare and contrast your work on Student Sheets 73.1 and 73.2.
   - **a.** What is the same? What is different?
   - **b.** What did you learn?
   - **c.** What are you unsure about?
   - **d.** What else would you like to know?

3. Think about what you observed and learned from this activity and Activity 72, "Measuring Shadows, Measuring Time."
   - **a.** How does the Sun's position in the sky change from early morning to late afternoon?
   - **b.** What is the reason for these changes?

4. Jupiter's day–night cycle is 10 hours long. What does this tell you about Jupiter's rotation around its axis?

5. **Reflection:** If you were to try to live on another planet, do you think it would be important to go to a planet with a similar length of day as Earth's? Why or why not?

74 As Earth Rotates

READING

Although the changing position of the Sun throughout the day makes it look like the Sun is moving, you now know that it is really Earth that moves. The rotation of Earth around its axis causes the 24-hour cycle of day and night.

CHALLENGE

What effect does the rotation of Earth have on the way people measure time?

MATERIALS

For each student

1 **Student Sheet 74.1, "Anticipation Guide: As Earth Rotates"**

1 **Student Sheet 71.1b, "My Ideas About the Day, Year, Seasons, and Moon Phases: After"**

This photograph taken from space shows the light and dark sides of Earth and the Moon.

READING

Use Student Sheet 74.1, "Anticipation Guide: As Earth Rotates," to help prepare you for this reading.

One Day–Night Cycle is One Complete Rotation of Earth

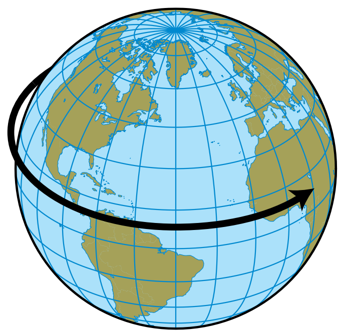


FIGURE 1:
EARTH'S ROTATION

The globe rotates counter-clockwise when viewed from above the Northern Hemisphere.

Every 24 hours, Earth **rotates**, or turns around its axis. The **axis** is an imaginary line through the center of Earth, from the North Pole to the South Pole. One complete turn of Earth is called a **rotation** (row-TAY-shun). You can simulate this movement by slowly spinning a globe on its stand. If you look down onto the North Pole at the top of the globe, you should spin the Earth counterclockwise, as shown in Figure 1 at left.

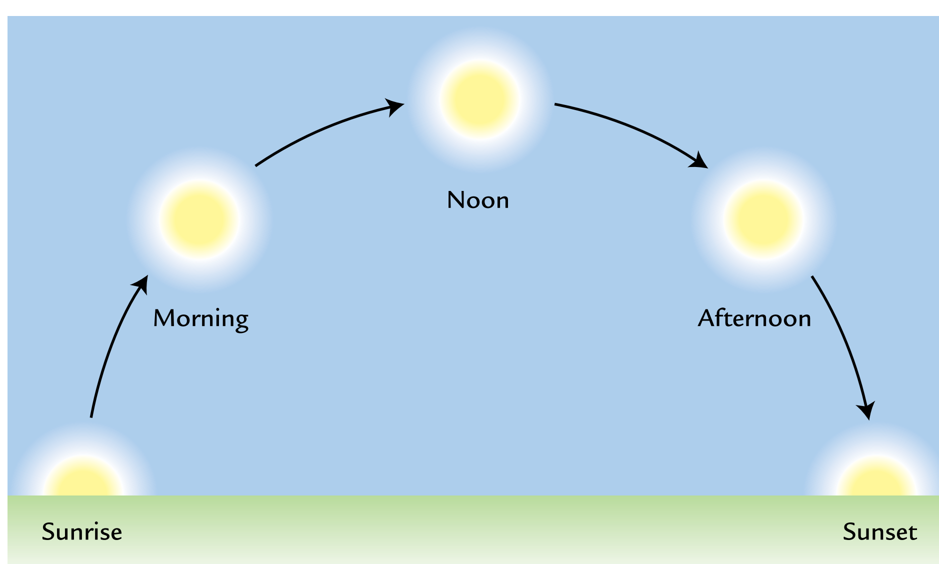
At sunrise where you live, you see the Sun coming up on the eastern horizon as your region of Earth rotates into the light from the Sun. Then the Sun appears to move across the sky from east to west, until it sets. Figure 2 below shows approximately where the Sun appears in the sky during a typical day in most of the United States in early spring and early fall. In spring and fall, day and night are about equal in length, at 12 hours each.

Using the Sun to Make a Clock

You observed that the shadow from your sun stick moved in the same direction as the hands on a clock, or "clockwise." You may not have realized it, but your sun stick observations are a lot like methods people used to measure time long ago.

FIGURE 2:
THE SUN'S POSITION IN THE SKY

If you face south on a spring day, you will see the Sun in different positions at different times of the day.



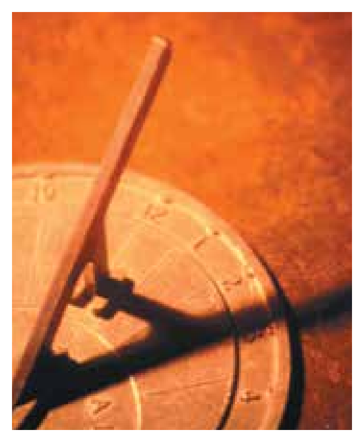
Researchers think that ancient peoples in Africa and the Middle East put sticks into the ground and scratched marks in the ground to track the movement of the shadow cast by the stick. This would have shown the passage of time during the day—that's just what a clock does.

Eventually, people began to build structures for keeping time. As early as 5,000 years ago, the Egyptians built tall stone towers called obelisks. Some people think they used the obelisks' shadows to show the time of day. Sometime after that, sundials were invented, probably in many places by different cultures. Although we can't say for sure who first invented sundials, the earliest known sundial was found in Egypt and was made about 3,500 years ago.

Like sun sticks, sundials use shadows to indicate the time, as shown in Figure 3. Each sundial has an upright piece that casts a shadow on a disc marked with the hours of the day. The shadow from a stick or on a sundial is shortest at noon, when the Sun is at its highest point in the sky. The direction of the sundial shadow changes just as your sun stick shadow does. In the Northern Hemisphere, the shadow moves across a sundial from morning to night. The clockwise movement of the shadow is no coincidence: inventors arranged the hands and hours on clocks to imitate the movement of the shadow and the hour marks on a sundial. Sundials are no longer used to keep time, but you might see them in special places in gardens and parks.

FIGURE 3:
EXAMPLES OF SUNDIALS

The shadow cast onto each of these sundials indicates the time.



Earth's Rotation and Time Zones

Every day in the United States, the Sun shines first on East Coast cities such as New York and Miami. It takes about three more hours for Earth to rotate enough to move West Coast cities like Seattle and Los Angeles into the sunlight. That's why sunrise on the East Coast is about three hours earlier than sunrise on the West Coast.

Until the mid-1800s, cities and towns kept their own time. For each of them noon was the exact time when the Sun reached its highest point in the sky. This meant that when the clocks in one town read exactly 12:00, the clocks in a town 50 miles to the east might have read 12:03. As train travel became common, these time differences began to confuse everyone. With each town using its own local time, scheduling arrival and departure times was very complicated. And the train engineers and conductors had to keep resetting their watches to the correct local time. Something had to be done to standardize the time of day.

First, each railroad company used its own standard time for its train schedules. That meant its time didn't match local times or times for other railroads' trains. Passengers kept missing their trains, and trains crashed into each other, too. The answer to this problem was time zones. A **time zone** is an area of the world where all clocks are set to the same time. The maps in Figure 4 on the next page show the time zones for the whole world and a close-up view of the U.S. time zones. Earth is divided into 24 major time zones, because it takes 24 hours for Earth to make a complete rotation around its axis. In 1883, all the railroads divided the United States into four time zones to make a single system of standard time that was known for many years as "railroad time." When it is noon everywhere in the Eastern Time Zone, it is only 9 a.m. everywhere in the Pacific Time Zone. It's even earlier in most of Alaska and Hawaii and midnight in some parts of Asia.

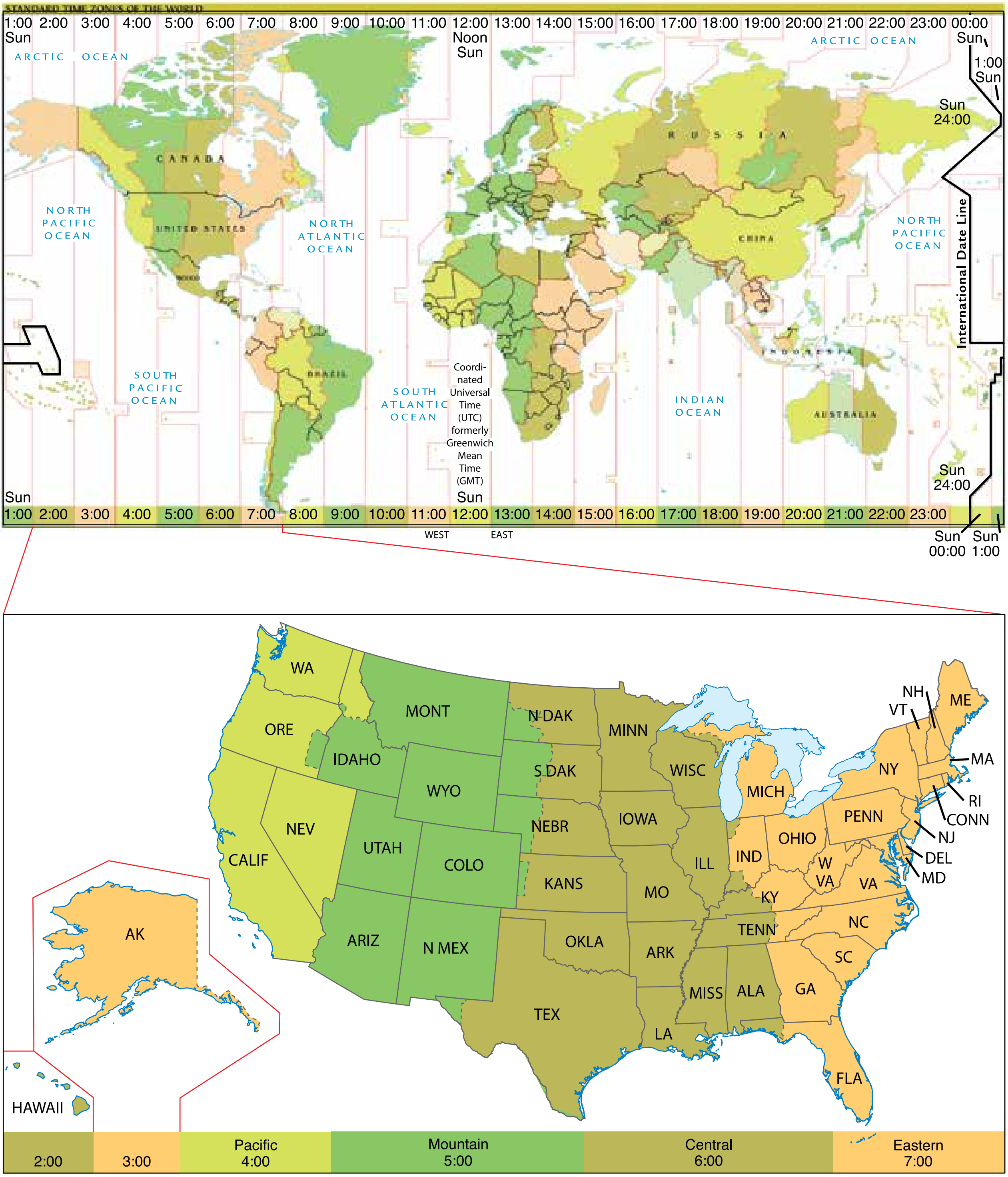


FIGURE 4: TIME ZONE MAPS

The map at the top shows time zones of the world. The map below it shows those of the United States.

ANALYSIS

1. In the United States, in what direction does the shadow from a stick or sundial point at each of the following times:
   a. at noon?
   b. in the morning?
   c. in the afternoon?
2. How does a sundial show the time?
3. Why is the world divided into time zones?
4. Why weren't time zones created until the late 1800s?
5. When it is 5 p.m. in the Eastern Time Zone, what time is it in the Mountain Time Zone?
6. **Reflection:** How have your ideas about the cause of Earth's day–night cycle changed since you began this unit?

EXTENSION

Go to the *Issues and Earth Science* page of the SEPUP website for links to information about ancient structures used to mark the movement of the Sun during the day and for instructions on how to make your own sundial.

75 Sunlight and Seasons

INVESTIGATION

June 15 was the last day of school. Tyler invited Emily to his house to listen to music. Since the temperature was almost 90°F, they got cold drinks and went outside to sit in the shade and listen there. But Tyler was surprised to find that the shady spot was much smaller than he expected it to be at that time of day.

You have investigated changes in the position of the Sun from early in the day to later in the day. Now you will investigate changes in the Sun's position in the sky over a year. This will help you explain why the shady spot from Tyler's tree is smaller in June than it was earlier in the year.

CHALLENGE

What do you observe about the length of daylight and the position of the Sun in the sky during the course of a year?

MATERIALS

For each pair of students

1 protractor
1 pair of scissors
tape
2 black pens or pencils
2 colored pens or pencils (both the same color)
1 Student Sheet 75a, "Graph of Daylight Length and Sun Angle vs. Month (2005)"
1 Student Sheet 75b, "Graph of Daylight Length and Sun Angle vs. Month (2006)"

For each student

1 completed Student Sheet 71.1a, "My Ideas About the Day, Year, Seasons, and Moon Phases: Before"

PROCEDURE

1. Review the data in Tables 1 and 2 on the next page. It is typical of data that would be collected in the United States.
2. Record in your science notebook the pattern you observe for each of the following (be sure to include a detailed description of your observations):
   a. time of sunrise
   b. time of sunset
   c. length of daylight
   d. the highest angle of the Sun in the sky
3. Record in your science notebook any relationships you see among the patterns you described for Step 2.
4. Working as partners, one person should use Student Sheet 75a to prepare a scatterplot of daylight length and the Sun's highest angle vs. month for 2005 based on the data in Table 1. The other should use Student Sheet 75b to prepare a similar scatterplot for 2006, based on the data in Table 2. Agree on which color to use to plot daylight length and which to use to plot the Sun's highest angle.
5. When you complete your graph, cut it at the line indicated on your Student Sheet and tape it to your partner's graph.
6. Draw a curve to smoothly connect the points on your graph.

Table 1: Daylight Hours and Sun Angle (2005)				
Month*	Time of Sunrise (a.m.)	Time of Sunset (p.m.)	Daylight (hours)	Sun's Highest Angle
January	7:20	5:19	10.0	32°
February	6:50	5:54	11.1	41°
March	6:09	6:21	12.2	52°
April	5:24	6:50	13.4	64°
May	4:53	7:17	14.4	72°
June	4:46	7:34	14.8	75°
July	5:02	7:26	14.4	73°
August	5:28	6:53	13.4	64°
September	5:55	6:06	12.2	53°
October	6:23	5:22	11.0	42°
November	6:56	4:52	10.0	32°
December	7:21	4:52	9.5	29°

*21st day of month

Table 2: Daylight Hours and Sun Angle (2006)				
Month*	Time of Sunrise (a.m.)	Time of Sunset (p.m.)	Daylight (hours)	Sun's Highest Angle
January	7:19	5:19	10.0	32°
February	6:50	5:54	11.1	41°
March	6:09	6:21	12.2	52°
April	5:24	6:51	13.4	64°
May	4:53	7:17	14.4	72°
June	4:46	7:34	14.8	75°
July	5:03	7:26	14.4	73°
August	5:28	6:53	13.4	64°
September	5:55	6:06	12.2	53°
October	6:23	5:22	11.0	42°
November	6:56	4:49	10.0	32°
December	7:21	4:52	9.5	29°

*21st day of month

7. Label each curve.
8. Record in your science notebook the pattern you see now that you have graphed the data.
9. Discuss with your partner what you think will happen over the next year.

ANALYSIS

1. Based on your graph, what do think was the length of daylight for each of the following days?
    a. March 6
    b. July 6
    c. November 6
2. When are the daylight hours:
    a. shortest?
    b. longest?
    c. about equal to the length of the night (12 hours)?
3. When is the Sun:
    a. lowest in the sky?
    b. highest in the sky?
4. What is the relationship between the length of daylight and the Sun's angle?
5. How do the Sun's position in the sky and the length of daylight relate to the seasons of the year?
6. In June, why was the shadow of Tyler's tree shorter than he expected?
7. What do you think will happen to the shadow from Tyler's tree in the fall?

EXTENSION

1. Explain how you could use a sun stick to tell the month of the year.
2. Go to the *Issues and Earth Science* page of the SEPUP website to investigate ways ancient civilizations used shadows from the Sun to indicate the passage of the seasons.

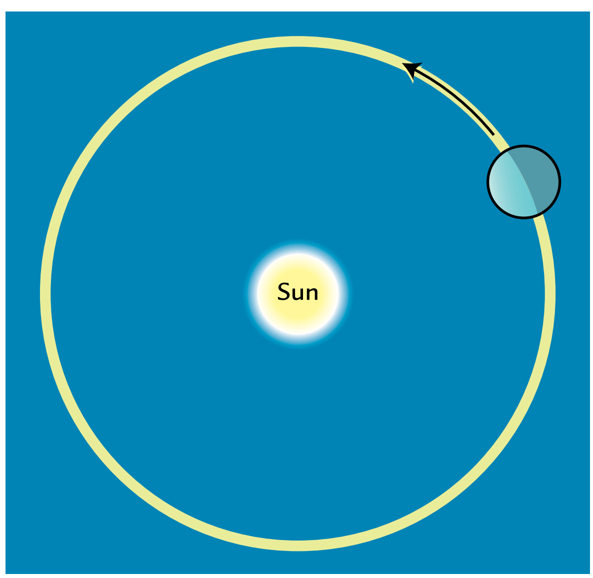
76 A Year Viewed from Space

You have learned that Earth's 24-hour day–night cycle is caused by Earth's rotation around its axis. The year is another cycle caused by Earth's motion. A year is the amount of time it takes a planet to make one complete trip around the Sun. Scientists use the term **revolve** to describe the movement of a planet around the Sun. The path a planet follows around the Sun is called its **orbit.** One complete orbit around the Sun is called a **revolution** (rev-ah-LOO-shun). Earth's year is about $365\frac{1}{4}$ days long because Earth rotates a little more than 365 times in the same amount of time it takes for Earth to make one complete revolution around the Sun.

After school let out in June, it got hotter and hotter, and Tyler wondered why the seasons change each year. He thought it might have something to do with what he was noticing about the Sun's position and the length of daylight.

CHALLENGE

What causes the yearly cycle of the seasons on Earth?



Diagrams like this one of Earth in its orbit around the Sun are much too small to show sizes and distances to scale, but they can help show how Earth revolves in its orbit around the Sun.

MATERIALS

For each pair of students

1 **computer with access to the SEPUP Seasons Interactive Simulation**

For each student

1 **Student Sheet 76.1, "Earth's Year Viewed from Space: Top View"**

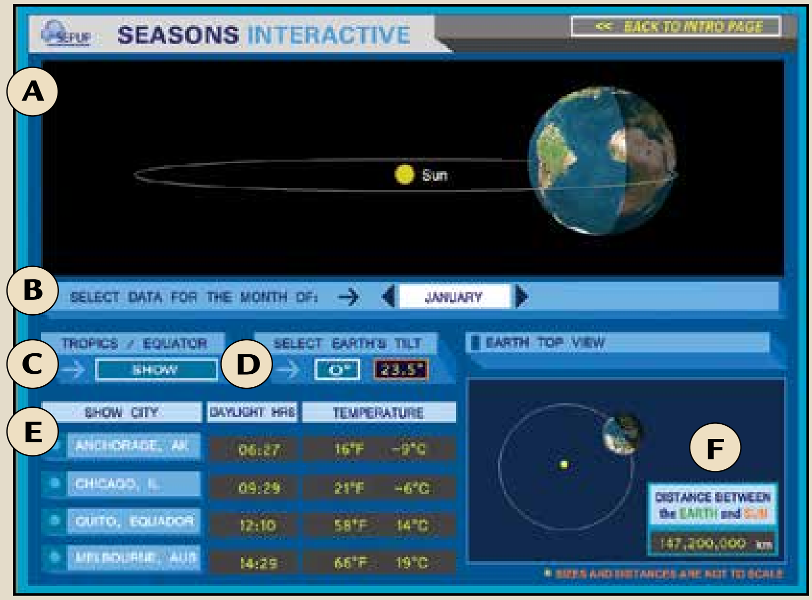
1 **Student Sheet 76.2, "Earth's Year Viewed from Space: Side View"**

1 **completed Student Sheet 71.1a, "My Ideas about the Day, Year, Seasons, and Moon Phases: Before"**

PROCEDURE

Part A: Analyzing Data on the Distance from Earth to the Sun

1. Open the Seasons Interactive Simulation and review the introduction. Find each of the following on the screen:
   - North America and the United States
   - the Northern Hemisphere
   - the equator
   - the Southern Hemisphere
2. Begin the simulation by clicking in the box on the upper right of the screen that says, CONTINUE TO INTERACTIVE. Find Earth and the Sun. Remember, the size of Earth and the Sun, and the distance between Earth and the Sun, are *not to scale.*
3. Use the diagram on the next page to find and set the following things on the screen:



A EARTH SIDE VIEW shows Earth and its orbit.

B MONTH SELECTOR: Use the arrows to move from month to month.

C TROPICS/EQUATOR selector: Make sure this is set to SHOW.

D SELECT EARTH'S TILT setting: Make sure this is set to 23.5°, the actual tilt of Earth.

E SHOW CITY buttons and columns for daylight hours and temperature: Try clicking on each of these to see what happens. Then turn them all off.

F EARTH TOP VIEW shows Earth from above the North Pole.

4. Look at the EARTH TOP VIEW. Notice how the distance from Earth to the Sun is displayed in millions of kilometers at the bottom right corner.
5. Set the month to December, the beginning of winter. Record the distance from Earth to the Sun in the appropriate space on Student Sheet 76.1, "Earth's Year Viewed from Space: Top View."
6. What do you think the distance from Earth to the Sun will be at the start of spring (March), of summer (June) and of fall (September)? Record your predictions in your science notebook.
7. Repeat Step 5 for March, June, and September to find out if your predictions are correct.

Part B: Analyzing Data on Earth's Tilt and the Seasons

8. Compare Student Sheet 76.2, "Earth's Year Viewed from Space: Side View" with the side view of the Sun and Earth at the top of your computer screen.

9. On the simulation, set the month for December, and click on the SHOW CITY button for Chicago.

10. Look at the top view and side view of Earth, and record each of the following on Student Sheet 76.2 for December in Chicago:

- the position of Earth and direction of its tilt
- the number of daylight hours
- the average temperature

11. Repeat Step 10 three more times: once for March, once for June, and once for September.

12. What do you think the number of daylight hours and average temperature for Chicago would be in December, March, June, and September if Earth were not tilted? Record your ideas in your science notebook.

13. Change the tilt to **0°**, and then describe what happens to daylight hours and temperature in Chicago as you change the months of the year and Earth revolves around the Sun.

14. Return the tilt to **23.5°**. Now investigate Melbourne, Australia. Notice that Melbourne is in the Southern Hemisphere. Explore its daylight hours and average temperature as you change the months. Record:

- its average daylight length in December and June
- its average temperature in December and June
- a description of the seasons in Melbourne, Australia and how they compare to seasons in Chicago

ANALYSIS

1. What motion of Earth causes the yearly cycle of the seasons?
2. Why does a year on Earth have $365\frac{1}{4}$ days?
3. In which month(s) is Earth:
   a. closest to the Sun?
   b. farthest from the Sun?
4. Based on what you have observed about the distance from Earth to the Sun, does the distance from Earth to the Sun determine the seasons? Explain the evidence for your answer.
5. In what month is the Northern Hemisphere most tilted *toward* the Sun?
6. In what month is the Northern Hemisphere most tilted *away* from the Sun?
7. Explain how the tilt of the Earth affects the seasons and daylight length.

EXTENSION

Graph the daylight length versus month for one of the cities presented in the simulation or for your city in the United States. Compare it to the graph you did in Activity 75, "Sunlight and Seasons." How are the graphs similar? How are they different?

77 Explaining the Seasons

In the last activity, you used a computer simulation to investigate why there are seasons on Earth. Like any model, the simulation has some strengths and weaknesses. It shows the orbit and tilt of Earth to help you understand the seasons. But it doesn't show the correct relationship between the size of the Earth and Sun or the distance between them. It also might give you the incorrect idea that Earth's tilt causes one hemisphere to be significantly nearer to the Sun. Let's take a closer look at the ways in which the tilt of Earth makes a difference.

CHALLENGE

Why does the tilt of Earth lead to different surface temperatures?

This globe, called the Unisphere, was built for the 1964 World's Fair in Queens, New York. Like most globes, it shows Earth's tilt.

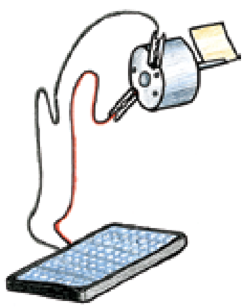
MATERIALS

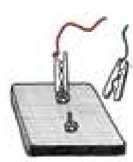
For each group of four students

1 **solar cell**

1 **electric motor with flag on axle**

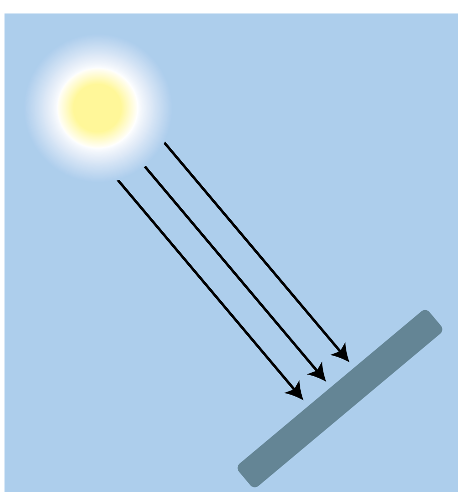
2 **wire leads with alligator clips (one red and one black)**



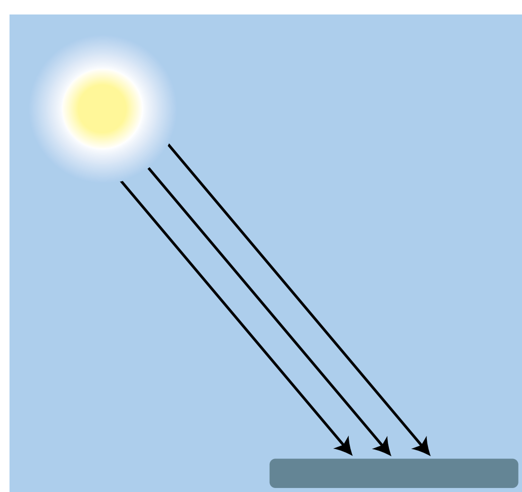


PROCEDURE

1. Work with your group to set up the solar cell. Use the diagrams at left as a guide.
2. Hold the solar cell so it directly faces the Sun, as shown in Position A below. Describe in your notebook what happens to the motor.
3. Gradually tilt the solar cell so that it still gets sunlight but does not directly face the Sun, as shown in Position B below. Describe in your notebook what happens to the speed of the motor.
4. Tilt the solar cell back to directly face the Sun. Keeping it directly facing the Sun, move it closer to and farther from the Sun. Describe what happens to the speed of the motor.



Position A



Position B

ANALYSIS

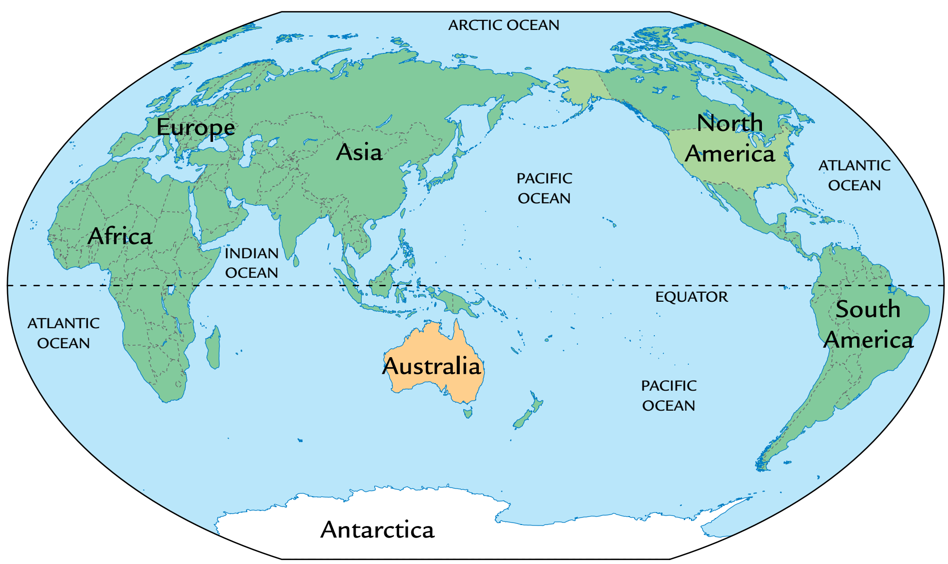
1. When your teacher tilted a portion of the globe directly into light from a flashlight, what happened to the light striking the globe?

2. When you tilted the solar cell from Position A to Position B, what effect did it have on the speed of the motor attached to the solar cell?

3. What does this tell you about the amount of the Sun's energy transferred to the solar cell in the two different positions? Be sure to give a complete explanation.

4. Why is the Northern Hemisphere warmer when it is tilted toward the Sun?

5. In Australia, it is summer in December and winter in July. Why is this?



6. Reflection: How did each of the following models help you understand how Earth's tilt causes the seasons?
   - the computer model
   - the globe and a flashlight
   - the solar cell and motor

78 The Earth on the Move

READING

It takes much longer for Earth to revolve around the Sun than to rotate on its axis. The period of time it takes for Earth to completely circle the Sun is called an Earth year—what we know simply as a year. During each year, the cycle of the seasons takes place.

Emily's cousin Charlotte from Australia came to visit her in June. One day, Emily took Charlotte to meet Tyler.

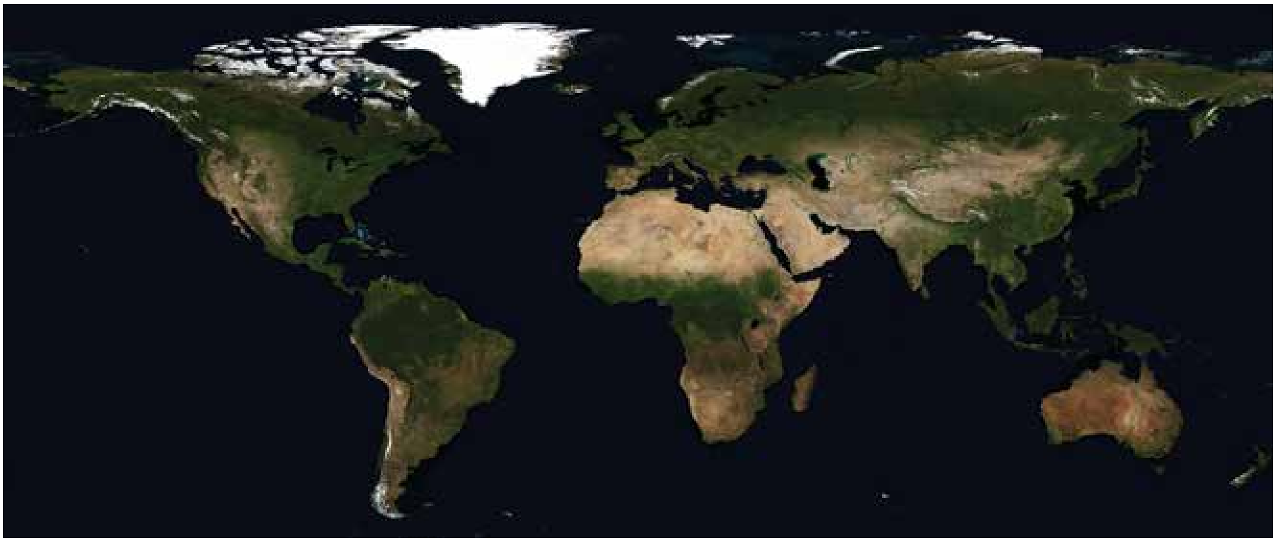
"This is so strange," Charlotte said. "At home, it's almost winter. Here it's hot and the flowers are blooming. I know it has something to do with the Northern and Southern Hemispheres, but I don't completely understand it."

Tyler went into his room and grabbed a globe. "Don't worry," he said, "Emily and I can explain."

CHALLENGE

How do the rotation and revolution of Earth explain the length of a year and the seasons?

A spiral rock marking is lit by the morning sun on the longest day of the year. Ancient Pueblo people may have made such carvings to mark the seasons.



Earth viewed from space in July. Compare the amount of snow in the Northern and Southern Hemispheres in this photo to the one on the next page.

MATERIALS

For each student

1 **Student Sheet 78.1, "Three-Level Reading Guide: The Earth on the Move"**

1 **completed Student Sheet 71.1a, "My Ideas About the Day, Year, Seasons, and Moon Phases: Before"**

1 **Student Sheet 71.1b, "My Ideas About the Day, Year, Seasons, and Moon Phases: After"**

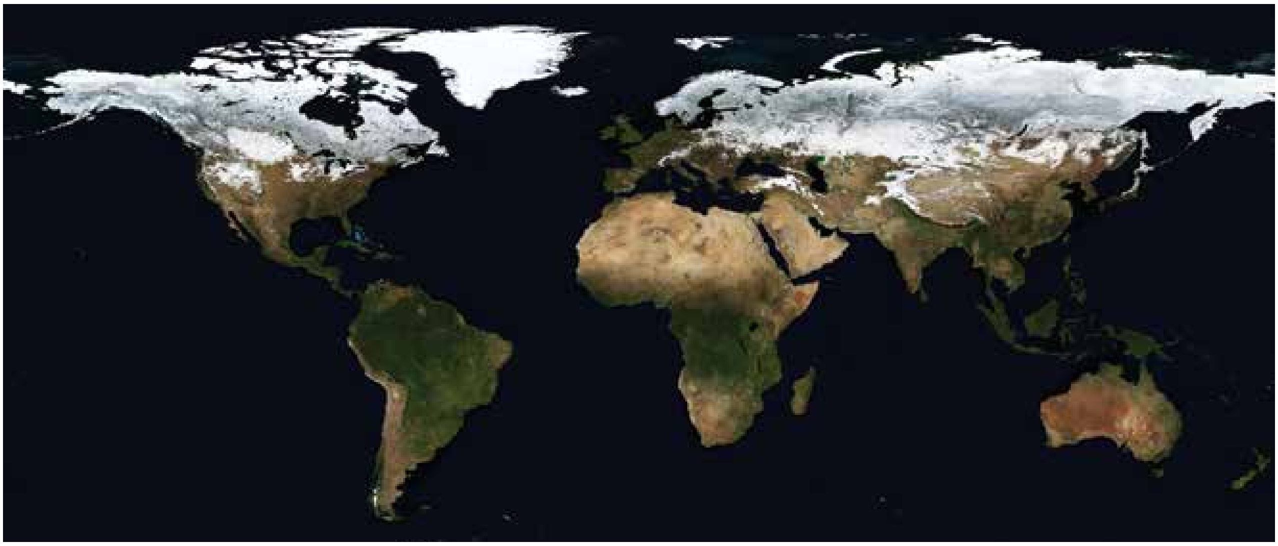
READING

Use Student Sheet 78.1, "Three-Level Reading Guide: The Earth on the Move" to guide you as you complete the following reading.

Earth's Year and the Seasons

As Earth orbits the Sun, the seasons change, but that does not mean Earth's orbiting causes the seasons. To understand seasons, you must consider both Earth's motion around the Sun and Earth's tilt.

Also, you might have thought that seasons are caused by changes in the distance between Earth and the Sun. This explanation could make sense because Earth's orbit is an ellipse, not a perfect circle—that means that sometimes Earth is closer to the Sun than at other times. However, you learned in the last activity that this idea doesn't fit the evidence that scientists have collected.



Earth viewed from space in January. Compare this with the photo on the facing page. Notice that there is more snow in North America, but less snow in the mountains of South America, where it is summer in January.

The computer simulation showed that Earth is about 6 million km closer to the Sun in December than it is in June, and yet Chicago has much warmer weather in June than in December. If closeness of Earth to the Sun explained the seasons, both the Northern and Southern hemispheres would have winter in June and July and summer in December and January!

If the seasons are not caused by changes in Earth's distance from the Sun, what does cause them? The computer simulation showed that the seasons are related to Earth's tilt. During the time of year when the Northern Hemisphere is tilted toward the Sun, the Northern Hemisphere, which includes the United States, experiences summer. The seasons in the Southern Hemisphere are opposite from the seasons in the Northern Hemisphere. This is because the Southern Hemisphere is tilted away from the Sun when the Northern Hemisphere is tilted toward the Sun, as shown in Figure 1 below. Australia and much of South America and Africa have winter from June through September, when the United States has summer!

FIGURE 1:
EARTH'S TILT

*This diagram shows that when one hemisphere is tilted toward the Sun, the other is tilted away from the Sun. (Size and distance are **not** to scale.)*

Earth's Tilt and the Light from the Sun

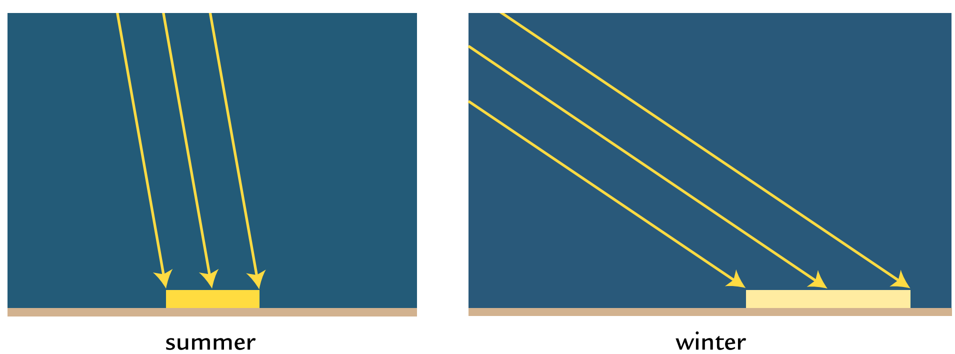
Why does Earth's tilt make such a difference? There are two reasons. The first reason is that the tilt puts part of Earth into the Sun's rays at a more direct angle than other parts.

When a part of Earth tilts toward the Sun, the Sun is higher in the sky and its rays hit that section of Earth at a higher angle. The higher the angle of the Sun's rays, the closer together they are when they hit Earth's surface. The closer together the rays are, the more effective they are at heating up the Earth. So, since the Northern Hemisphere is most tilted toward the Sun during June, that is when the United States experiences the beginning of summer. You observed the effect of sunlight striking a surface at a higher angle when you held your solar cell directly facing toward the Sun. The solar cell received more energy, which made the motor turn faster.

When you tilted the solar cell at an angle to the Sun's rays, it received less energy, which made the motor slow down. When you did this, you were modeling the change in the angle of the Sun's rays from summer to winter. Figure 2 below shows why the angle of the Sun's rays hitting Earth's surface in summer and winter affects the amount of energy hitting the surface.

FIGURE 2:
ANGLE OF SUNLIGHT AT EARTH'S SURFACE

When the sunlight strikes Earth's surface at a lower angle, as on the right, the Sun's energy is spread out more and is less effective in heating the Earth.



Earth's Tilt and Daylight Length

The second reason why the tilt makes such a difference is its effect on the length of daylight. Figure 3 on the following page shows how Earth's tilt causes longer summer days in the United States. More hours of daylight in summer allow more time for the Sun's rays to heat the Earth. The longest day and highest angle of sunlight occur around June 21. However, the warmest

FIGURE 3:
SEASONS AND
DAY LENGTH

*In the summer, Chicago's day is longer than its night because the Northern Hemisphere is tilted toward the Sun. (Sizes and distances are **not** to scale.)*

days usually come later in the summer because heat builds up over time. The opposite occurs in winter. The shortest days and lowest angle of sunlight occur around December 21. But it continues to get colder after that, as heat is gradually lost.

If Earth were not tilted, most places would have very little difference in average daily temperature over the year. You saw this in the computer simulation when you set Earth's tilt to "0°." But if Earth tilted even more, the difference in temperature and daylight hours between summer and winter would be more extreme.

Ancient Cultures and the Seasons

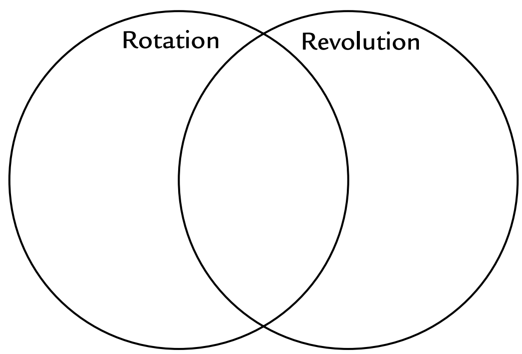
Ancient people knew the Sun and the seasons were important in their lives. For example, it was important for them to know when to plant crops. If they planted too early, a cold spell might kill the crops. If they planted too late, the plants might not have a long enough growing season. They needed to plant the seeds at just the right time of year so that the crops could grow during the long and sunny days of summer. Evidence gathered from ancient structures suggests that as long as 5,000 years ago, people made careful observations of the Sun's position and the shadows cast by the Sun. They used their observations to predict the seasons and know when to plant and harvest their crops. They also held celebrations at different times of the year, based on the Sun's position.

ANALYSIS

1. Rotation and revolution are both motions of the Earth.

   a. How does each of these motions help us mark time?

   b. In your science notebook, create a larger version of the Venn diagram shown below. Compare and contrast the rotation and the revolution of the Earth by recording the unique features of each phenomenon on the far side of each circle. Record common features of Earth's rotation and revolution in the space where the circles overlap. **Hint:** Think about what you have learned about these motions in the last few activities.



2. Prepare a labeled diagram that includes a caption that explains to Emily's cousin Charlotte how Earth's tilt and its revolution around the Sun cause each of the following:

   a. changes in the angle of sunlight hitting the Earth's surface

   b. the seasons in the Southern Hemisphere to be opposites of the seasons in the Northern Hemisphere

3. **Reflection:** Review your ideas about the seasons that you recorded on Student Sheet 71.1a, "My Ideas About the Day, Year, Seasons, and Phases of the Moon: Before." How have your ideas about the reasons for the seasons changed since you began this unit?

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website to research structures built by ancient cultures to indicate the position of the Sun and predict the seasons. You can also find links to animations that explain the seasons.

79 The Predictable Moon

FIELD STUDY

One sunny Saturday Emily was talking to Tyler on the telephone. As she looked out the window, she noticed the Moon in the sky.

"Hey Tyler," she said, "It's daytime and I can see the Moon, but I can see only part of it. Not that long ago, it was a full Moon and it was only out at night. I'm going to keep track of the Moon's phases for a while to see what will happen next."

As you made your observations of the Moon in the last few weeks, you probably noticed that the Moon seemed to change shape. The different shapes of the Moon visible from Earth are called the **phases** (FAY-zes) of the Moon. For example, when the Moon looks like a completely lighted circle, it is called the **full Moon.** When it is dark and not visible, it is called the **new Moon.**

The changing phases of the Moon have fascinated people for thousands of years. Before artificial lighting, a full Moon allowed people to see at night. Many cultures have used the Moon's changing phases for measuring time. People who lived near an ocean wanted to know about the Moon's cycle because it helped them predict the tides.

CHALLENGE **How can we predict changes in the Moon's appearance?**

MATERIALS

For each student

1 **Student Sheet 79.1, "My Moon Observations"**

1 **Student Sheet 79.2, "Emily's Moon Observations"**

Full moon rising over a lake shortly after sunset.

PROCEDURE

1. Review your data from your own observations of the Moon that you recorded on Student Sheet 79.1, "My Moon Observations."
2. Look for a pattern in the phases of the Moon. Record your ideas about the pattern in your science notebook.
3. Review Emily's data on Student Sheet 79.2, "Emily's Moon Observations."
4. Compare and contrast Emily's data with your data. Record in your science notebook the similarities and differences that you find.
5. In the circles on Student Sheet 79.2 for May 11, 22, and 28, draw the shape of the Moon you predict will be visible on those days.
6. Predict the date for the next full Moon for the June calendar on Student Sheet 79.2. Draw it on the calendar.
7. The phase when the Moon is not visible at any time of the day or night is called the new Moon. On Student Sheet 79.2, write the word "new" on the day(s) you predict the new Moon will occur.

ANALYSIS

1. Explain how you made your predictions for Procedure Steps 6 and 7.

2. In 2004, there was a full Moon on May 4. In 2005, there was a full Moon on May 23. Why doesn't the full Moon fall on the same day every year?

3. Predict the date of the next first quarter Moon for the June calendar on Student Sheet 79.2. Explain how you made your prediction.

4. Summarize the complete cycle of the Moon's phases in words and with a labeled diagram.

5. About how many days does a complete cycle of the Moon's phases take?

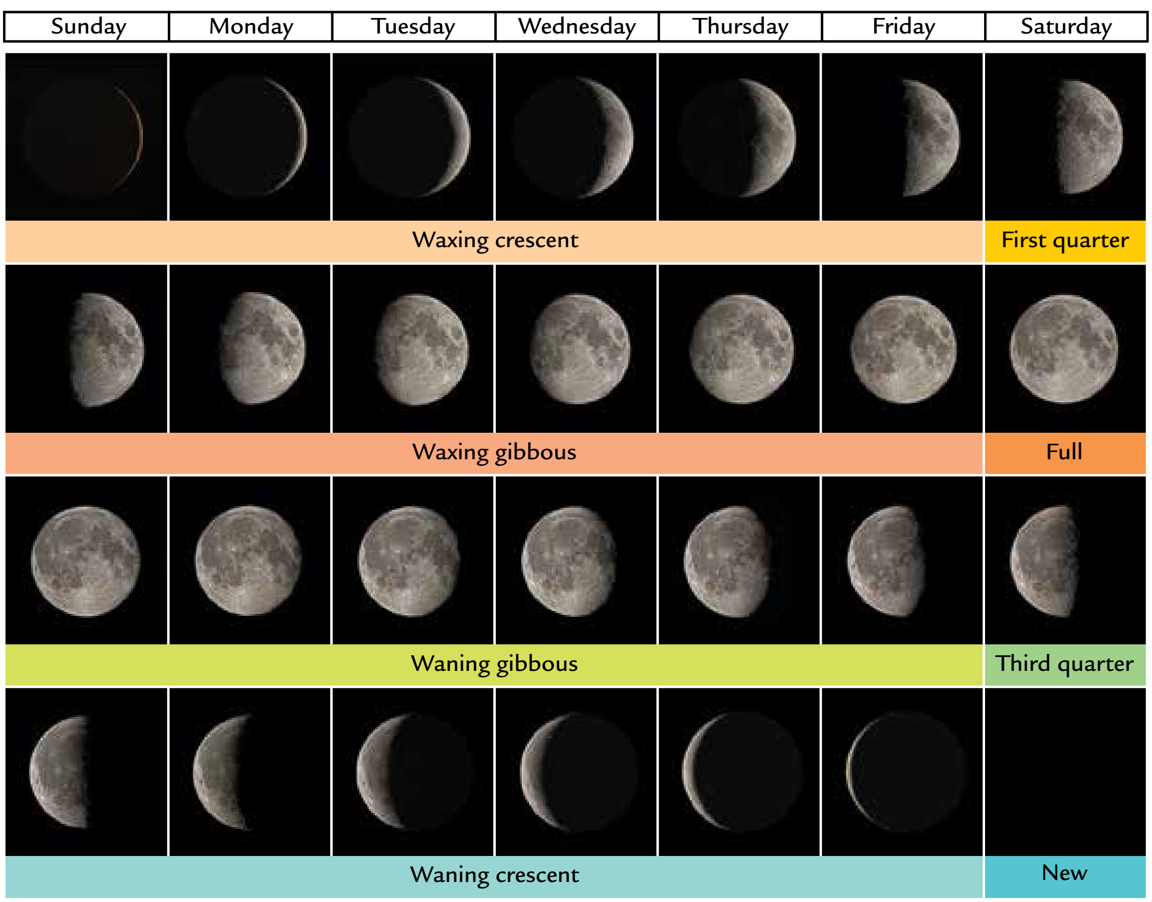
80 Explaining the Phases of the Moon

MODELING

In the last activity, you investigated the cycle of the Moon's phases. This is called the **lunar** (LOO-nur) **cycle.** To help you understand what causes the phases of the Moon, in this activity you will observe a model of the Sun, Earth, and Moon in space. Scientists build and use models to try to explain what they observe in nature. Often they find that the simplest models best explain what they see.

You will use a light to model the Sun, because the Sun produces its own light, and a ball to model the Moon, which does not produce light. Moonlight is actually sunlight that is reflected off the surface of the Moon! If the Moon produced light, it would always look like a full circle.

CHALLENGE **What causes the lunar cycle we observe from Earth?**



MATERIALS

For each pair of students

1 **Moon model: a white foam ball attached to a stick**

1 **light source**

For each student

1 **completed Student Sheet 71.1a, "My Ideas About the Day, Year, Seasons, and Moon Phases: Before"**

1 **Student Sheet 80.1, "Observations of Moon Model"**

PROCEDURE

Part A: Demonstration Model

1. Your teacher will do a demonstration with a ball that represents the Moon and a lightbulb that represents the Sun. You will represent a person looking at the sky from the Earth. Watch the demonstration and sketch your observations on Student Sheet 80.1, "Observations of Moon Model."
2. Answer Analysis Questions 1–3.

Part B: Students' Model

3. With your partner, use the Moon model to explore and understand the phases of the Moon.
4. Be sure to figure out why we sometimes see a crescent Moon, quarter Moon, or gibbous Moon. Draw sketches in your science notebook to show the position of the light, the white ball, and yourself when you see each of these three phases.
5. Answer Analysis Questions 4 and 5.

ANALYSIS

1. What fraction of the ball was always lit up by the lightbulb in the model shown by your teacher?
2. What fraction of the Moon is always lit up by the Sun?
3. Why can't you see the new Moon?
4. What motion causes the Moon to change phases?
5. What phase of the Moon is represented in each of the diagrams below?

   a. 

   b. 

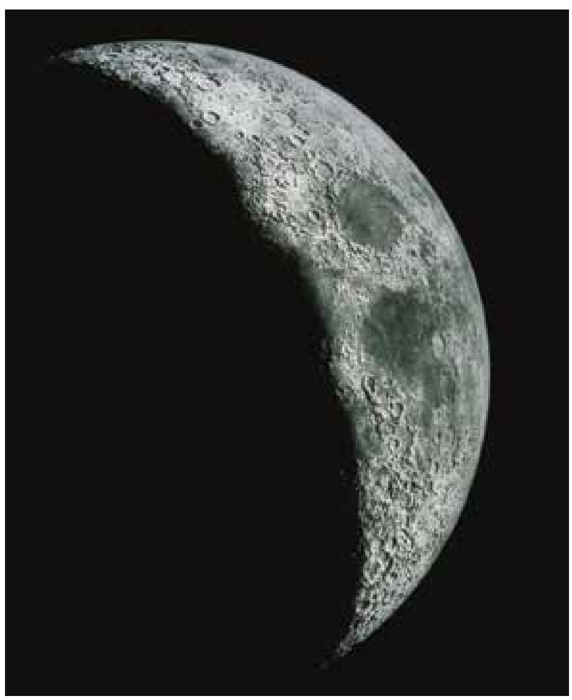
81 Moon Phase Simulator

Just as Earth revolves around the Sun, the Moon revolves around Earth. The seasons occur at different points in Earth's orbit around the Sun. The phases of the Moon occur at different points in the Moon's orbit around Earth.

Just as half of Earth is always lighted by the Sun and half is in darkness, half of the Moon is always lighted by the Sun and half is in darkness. In the last activity, you used a model to observe how the revolution of the Moon around Earth causes you to see different portions of the lighted half of the Moon. In this activity, you will use a computer simulation that provides a different model for understanding the phases of the Moon.

CHALLENGE

How does the Moon's revolution around Earth cause the Moon's phases?



MATERIALS

For each pair of students

1 **computer with access to the Moon Phase Simulation**

For each student

1 **Student Sheet 71.1b, "My Ideas About the Day, Year, Seasons, and Moon Phases: After"**

PROCEDURE

Part A: Exploring the Simulation

1. Open the Moon Phase Simulation on your computer.
2. Make sure your **POINT OF VIEW** is **TOP VIEW**. If it isn't, change it so that it is.
3. Identify the Sun, Earth, and Moon.
4. Click on **ANIMATE** and describe any changes that occur. Click on **STOP** to pause the motion.

Part B: Observing the Phases

5. Change the **POINT OF VIEW** to **BOTH VIEWS**. Make sure your **MOON PHASE** is **0.0**. If it isn't, change it by highlighting the number, typing in **0.0.**, and pressing **RETURN**.
6. Look carefully at the objects in the black box. Make a labeled sketch of them in your science notebook. Title your sketch with a) the moon phase number and b) the name of the phase.
7. Change the moon phase number to **0.25**, and press the **RETURN** key. Make a titled and labeled sketch as you did in Step 6.
8. Repeat Step 7 until you have made sketches for the phase numbers **0.5**, **0.75**, and **1.0**.
9. Click on **ANIMATE**, and describe what happens. Click on **STOP** to pause the motion.

ANALYSIS

1. In the simulation, what do the dark and light halves of Earth and the Moon represent?

2. Why are the lighter colored halves of the Moon and Earth always shown facing the Sun?

3. Compare your Part B sketches for **MOON PHASE 0.0** and **MOON PHASE 1.0**. Explain why these phases have different numbers but look the same.

4. Compare this computer model to the physical model your teacher showed you in Activity 80.

   a. What are the advantages and disadvantages of using the ball and light to represent the Moon and Sun?

   b. What are the advantages and disadvantages of the computer model?

5. Write a description and draw pictures that you could use to explain the reason for the phases of the Moon to a friend.

6. **Reflection:** How have your ideas about the reason for the phases of the Moon changed since you began this unit?

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website for links to information about eclipses of the Sun and Moon.

82 Tides and the Moon

INVESTIGATION

In August, Tyler went to visit his cousins who lived near the ocean in Tidal Town. After lunch on his second day there, his cousin Morgan took him to Sandy Beach. "Today is a great day for the beach," said Morgan. "The tide will be really low early this afternoon, so there will be a lot of room on the beach for us to play ball and run around."

At the beach, they spread out a blanket, played catch, and splashed around in the water. But in the late afternoon the tide began to come in, with the ocean covering up more and more of the beach. "Time to move our blanket way back," said Morgan. "High tide will be really high today."

"Do you know why the tides are extremely high and low today?" Tyler asked.

"I know it has something to do with the Moon," Morgan answered. "Right next to the tide information in the Tidal Town News are pictures of the Moon." That night they searched the Internet and found data on the Moon and tides for Sandy Beach. Then they started to look for a relationship between the tides and the Moon.

CHALLENGE

What is the relationship between the phase of the Moon and extreme tides?

Compare the water level at low and high tide in this bay in New Brunswick, Canada.

MATERIALS

For each student:

1 **Student Sheets 82.1a, b, and c, "Moon and Tide Calendar"**

PROCEDURE

1. Table 1 below shows the data about the Moon and tides that Tyler and Morgan found for the day when they went to Sandy Beach and for another day about a week earlier.

2. Record in your science notebook:

   a. How many high tides occur each day?

   b. How many low tides occur each day?

   c. Which day shows more extreme tides (higher high tides and lower low tides)?

Table 1: High and Low Tides for Two Days in August

Day	High Tide or Low Tide?	Tide Time	Height (feet)	Moon Phase
August 7	high	12:10 a.m.	2.6	quarter
	low	6:16 a.m.	0.5	
	high	12:18 p.m.	2.2	
	low	6:36 p.m.	0.2	
August 14	low	12:26 a.m.	–0.2	full
	high	7:02 a.m.	3.5	
	low	1:37 p.m.	–0.2	
	high	7:19 p.m.	2.3	

Tyler and Morgan realized that they had to look at the tide height and Moon phase for several months. They decided to look for the days with extreme tides and days with full Moons to see if they could find a connection. Their results are shown in Table 2 below.

Table 2: Moon and Tide Data for Five Months

Sets of Extreme Tides (EXT)	Full Moons (F)
May 2–5	May 18
May 18–21	June 16
June 1–2	July 15
June 14–16	August 14
July 1–2	September 13
July 13–17	
July 28–30	
August 13–15	
August 28–30	
September 12–15	

3. Transfer the information in Table 2 to your Student Sheet:

- Mark full Moon days with an "F."
- Mark when you think there will be new Moon days with an "N."
- Mark extreme tide days with an "EXT."

4. Record in your science notebook any patterns you see in the relationship between the tides and the Moon each month.

ANALYSIS

1. Use the information on your Student Sheet:
   a. to count the number of days between the full Moons and list them. **Hint:** You should list 4 numbers.
   b. to calculate the average number of days between full Moons.
   c. to use your average to predict the date of the next full Moon after the one on September 13.
2. Based on the data on your Student Sheet, how often do sets of extreme tides (both high and low) occur?
3. What is the connection between extreme tides and the phases of the Moon? Use the evidence from your calendar to support your answer.

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website to view an animation of the tides.

83 Marking Time

When Tyler got home from vacation, he called his friend Emily. "Hey, Emily," he said, "I just realized that the cycle of the Moon is pretty close to one month. Do you think that one month is based on the Moon's cycle?"

Emily thought that was reasonable, since the year and the day are based on the Earth's movement. "Makes sense to me," she replied. "Maybe it's no coincidence that the words 'month' and 'Moon' sound a lot alike!"

By doing some research in the library, Emily and Tyler found out that many calendars have been created at different times by different cultures.

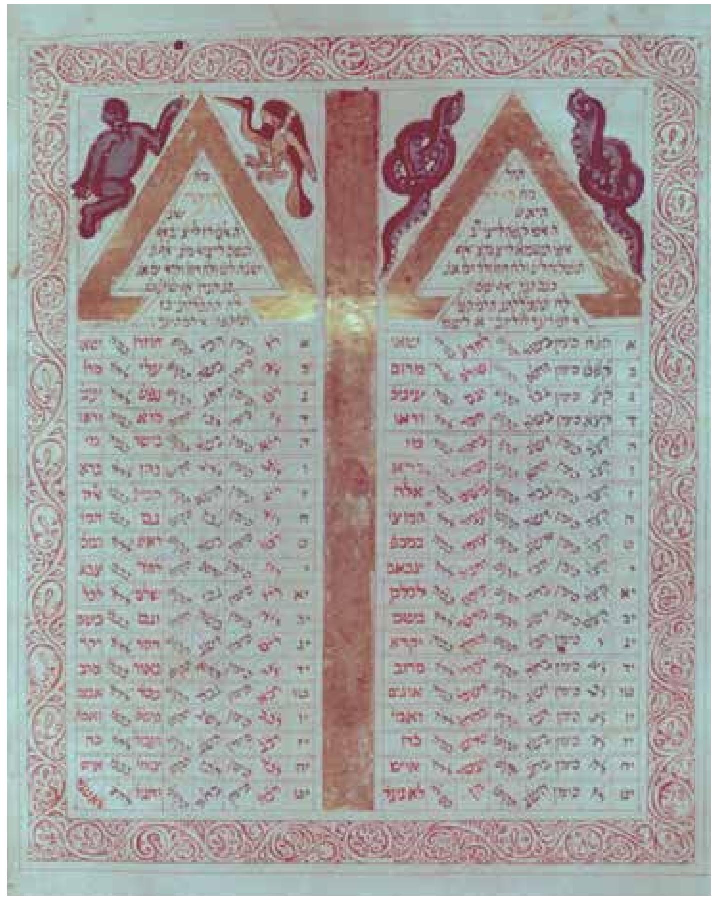
Some calendars have been closely linked to the changing light from the Sun, or the **solar** year. Others have been based on the Moon's cycle, or lunar cycle. Still others have been tied to both the Sun and Moon, and some are not related to either the Sun or the Moon. However, in each case, the calendar has met the needs of the society. You can see some examples on the next page.

CHALLENGE

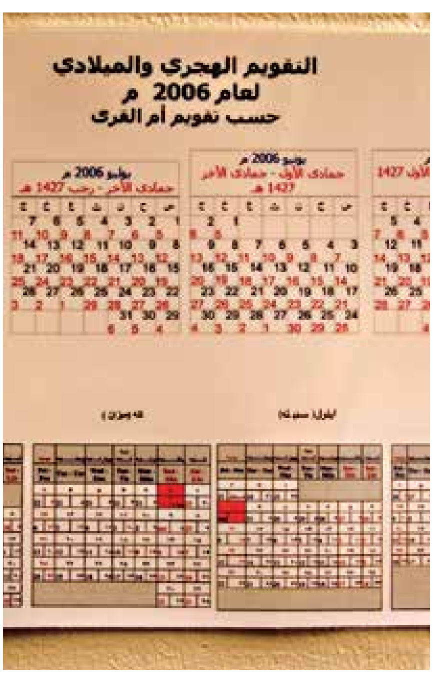
Why are there many different calendars?

CALENDARS USED BY DIFFERENT CULTURES

Chinese calendar



Jewish calendar



Islamic calendar

Aztec calendar

MATERIALS

For each student

1 **Student Sheet 83.1, "Calendar Advantages and Disadvantages"**

PROCEDURE

1. Review the proposals for three different calendars, A, B, and C on the following pages. Notice that each calendar shows the dates of the new Moon ●, the date of the shortest day of the year in the Northern Hemisphere (**W** for winter), and the date of the longest day of the year in the Northern Hemisphere (**S** for summer).
2. Use Student Sheet 83.1, "Calendar Advantages and Disadvantages," to prepare a list of the advantages and disadvantages of each calendar. Be sure to think about how the calendar fits with each of the following:
   - the cycle of the Moon's phases
   - the cycle of the year as Earth revolves around the Sun
   - the seasons
   - ease of use
3. Read "Place Descriptions" on page F-60.
4. Work with your group to answer Analysis Questions 1–3 for each place.
5. Be prepared to explain your answers for Analysis Question 3 to the class.
6. After the discussion of Analysis Question 3, complete the rest of the Analysis Questions as directed by your teacher.

Calendar Proposal A

We should have a calendar based on the Sun and the 365¼-day year. We will divide the year into 13 equal months of 4 weeks, or 28 days each. Every month in a year will start on a Sunday. Since 13 months times 28 days is only 364 days, we will add one day at the end for a New Year's Eve holiday. Every fourth year (leap year) the holiday will last for two days. These extra days will not be called by the usual day-of-the-week names. They will be New Year's Eve 1 and New Year's Eve 2.

Month 1

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 2

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 3

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 4

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 5

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 6

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 7

Su	M	Tu	W	Th	F	Sa
1	2	3	S	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 8

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 9

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 10

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 11

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 12

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28

Month 13

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	W	20	21
22	23	24	25	26	27	28

New Year's Eve 29

Leap Year New Year's Eve 30

● = New Moon S = Summer Solstice W = Winter Solstice

Calendar Proposal B

We should have a calendar based on the Moon's cycle to determine the length of each month and the Earth's revolution around the Sun to determine a year. Since the Moon's cycle is approximately 29.5 days, the months will alternate between 29 days and 30 days. Each year will have 12 (six 29-day and six 30-day) of these normal months. That will account for 354 out of 365¼ days. Every year will end with a 13th short month of 11 days (12 days in leap years) to fill out the year.

Month 1

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29						

Month 2

Su	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Month 3

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29			

Month 4

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Month 5

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

Month 6

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	S	26	27	28
29	30					

Month 7

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29				

Month 8

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Month 9

Su	M	Tu	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	

Month 10

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

Month 11

Su	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29					

Month 12

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Month 13

Su	M	Tu	W	Th	F	Sa
				W	2	3
4	5	6	7	8	9	10
11	[12] (leap year)					

● = New Moon   S = Summer Solstice   W = Winter Solstice

Calendar Proposal C

We should have a calendar based exactly on the cycle of the Moon. We can use a computer to predict the date of the new Moon each month for the coming year. The date of the new Moon will be the first of the month. The full Moon will always fall within one day of the 15th of the month. After 12 months, we will start a new year. Each year will be about 354 days long.

Month 1

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29						

Month 2

Su	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Month 3

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

Month 4

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29			

Month 5

Su	M	Tu	W	Th	F	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23/30	24	25	26	27	28	29

Month 6

Su	M	Tu	W	Th	F	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	S	27
28	29					

Month 7

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Month 8

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29		

Month 9

Su	M	Tu	W	Th	F	Sa
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	

Month 10

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Month 11

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29				

Month 12

Su	M	Tu	W	Th	F	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	W			

● = New Moon S = Summer Solstice W = Winter Solstice

Place descriptions

Tropicala is an island near the Equator. There are no noticeable seasons—it is warm and breezy all year. The people who live in Tropicala get their food from three sources. They pick fruits and greens from many kinds of plants that grow wild on the island all year. They gather oysters and clams that are easy to find only when the tide is extremely low. There aren't many animals on the island, but there is one animal that can be hunted when it searches for food at night. Moonlit nights are best for hunting, as bright torches or other lights scare the animals.

Storm Island has a cool and windy climate, with severe rainstorms every winter. The island has two main areas that the residents call East End and West End. Most people live on the rocky East End and have farms on West End, where the soil is excellent for growing crops. The growing season is short on Storm Island, so the residents grow cool weather crops, such as potatoes, carrots, and lettuce. They have to be careful to plant after the last frost of spring and harvest before the first frost of fall. Extremely high tides are a problem, because they flood the lowland that connects East End and West End.

Riverland is in the desert near a large river. The climate is very hot and dry all year. The river's floodplain is the only fertile land for growing crops. The crops are planted when all danger of flooding has passed in the late fall and harvested before flooding begins in the early summer. It is very important for the residents of Riverland to predict when the flooding will begin each fall and to know when the danger of flooding has passed in the spring.

ANALYSIS

1. How do the lives of people in each place depend on the yearly cycle of the seasons?

2. How do the lives of people in each place depend on the lunar cycle?

3. For each place:

   a. State which calendar (or calendars) would be most helpful for the people who live there.

   b. Give your reasons for your decision.

4. Look at the "Proposed International Calendar" on the following page.

   a. Is this calendar based more on the cycle of the Moon or on the cycle of the Sun?

   b. Discuss with your group the convenience of this calendar for the people of the world in terms of:

   - the cycle of the year and the seasons
   - the cycle of the Moon's phases
   - international business and trade
   - cultural factors, such as holidays and celebrations
   - ease of use

5. Based on your discussion, would you recommend that the world switch to this calendar or continue with the calendars already in use? Write a letter to a government official, such as one of your United States senators to express your recommendation. Discuss your reasons for and the trade-offs of your recommendation.

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website to investigate calendars used by other cultures.

PROPOSED INTERNATIONAL CALENDAR

Month 1

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Month 2

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Month 3

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Month 4

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Month 5

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Month 6

Su	M	Tu	W	Th	F	Sa	
				1	2	3	
4	5	6	7	8	9	10	
11	12	13	14	15	16	17	
18	19	20	S	22	23	24	
25	26	27	28	29	30	31	32 Extra Day (Leap Year Day)

Month 7

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Month 8

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Month 9

Su	M	Tu	W	Th	F	Sa
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Month 10

Su	M	Tu	W	Th	F	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

Month 11

Su	M	Tu	W	Th	F	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

Month 12

Su	M	Tu	W	Th	F	Sa	
				1	2	3	
4	5	6	7	8	9	10	
11	12	13	14	15	16	17	
18	19	20	21	W	23	24	
25	26	27	28	29	30	31	32 (New Year's Eve Day)

● = New Moon   S = Summer Solstice   W = Winter Solstice

GUIDELINES FOR INTERNATIONAL CALENDAR

- Each year will be based on 4 equal business quarters. Each quarter will have exactly 91 days divided into 13 weeks, or 3 months.
- The first, second, and third months in a quarter will have 30, 30, and 31 days respectively.
- Each year will begin on Sunday, January 1.
- Each quarter begins on Sunday and ends on Saturday.
- The calendar stays in step with the Sun by ending the year with a 365th day following December 31 each year. This additional day, December 32, is called New Year's Eve Day, (not Sunday or any of the other usual days of the week). New Year's Eve Day is a worldwide holiday.
- In leap years, an extra day is added at the end of June, following June 31. It will be June 32, and it will be called Extra Day (not Sunday or any of the other usual days of the week). Leap Year Day will also be a worldwide holiday.

84 Planets in Motion

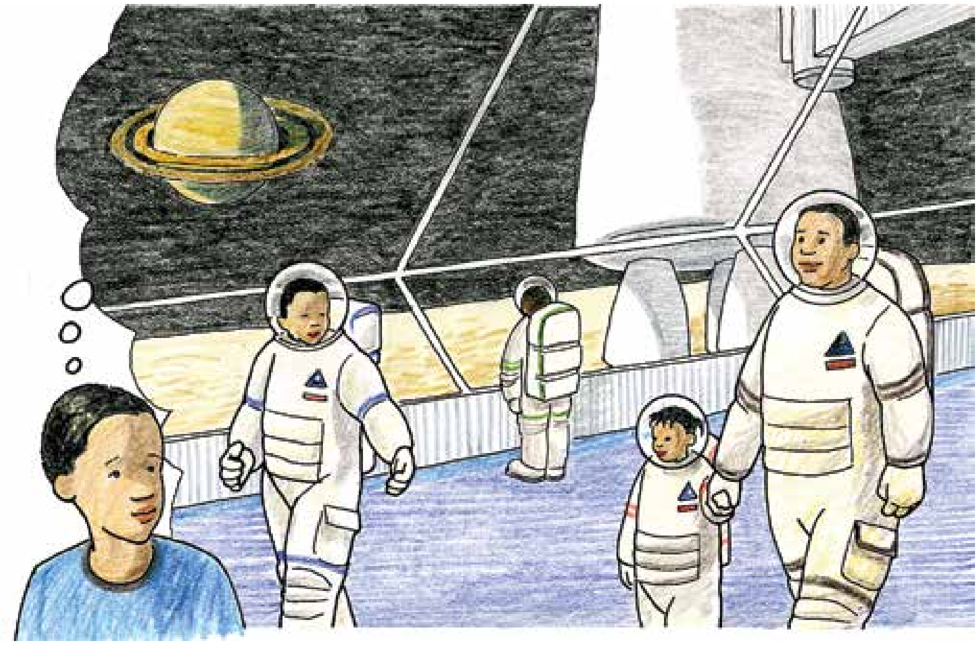
INVESTIGATION

Every planet rotates on its axis and revolves around a star. However, the time it takes for each planet to rotate and revolve can be very different from the other planets' times. Some planets have a tilted axis, while others do not. These characteristics determine each planet's day length, year length, and seasons. In addition, some planets have no moons, while others have one or many moons, which may be larger or smaller than Earth's Moon.

Tyler was thinking about everything he had learned about the motions of Earth and the Moon and how they affect life on Earth. He started to daydream about what it would be like on another planet and realized that without Earth's day–night cycle and seasons, life would be very different. He began to imagine all sorts of strange planets . . .

CHALLENGE

What would the day length, year length, seasons, and tides be like on another planet?



MATERIALS

For each student

1 **Student Sheet 84.1, "Comparing Planets"**

PROCEDURE

1. Your teacher will assign you one of the planets in the table below. Assume that:
   - Your planet is like Earth in every way, except for the differences in the table.
   - Your planet orbits a star (sun) similar to Earth's Sun.
   - Your planet's moon, if it has one, is similar to Earth's Moon.
2. Work with your group to review the data for your planet in the table below. This shows ways that your planet may be different from Earth.

Data for Earth and 10 Imaginary Planets

	Planet Earth	A	B	C	D	E	F	G	H	I	J
Rotation Period (in Earth days)	1	10	0.5	1.12	2	3	– 0.8*	1.2	4	40	80
Revolution Period (in Earth days)	365.25	100	600	400	80	600	350	900	160	80	80
Axis tilt	23.5°	20°	5°	60°	15°	90°	20°	0°	3°	0°	15°
Number of Moons	1	1	0	1	1	0	1	1	0	1	1

* A negative sign means the planet rotates clockwise when viewed from its north pole, unlike Earth, which rotates counterclockwise.

3. Use the data to determine and record in your science notebook each of the following for your planet:
   - day length (complete day–night cycle) in hours (multiply days by 24)
   - average number of daytime and nighttime hours
   - year length in Earth days
   - year length in the planet's days (divide its revolution period by its rotation period and then subtract 1)
   - whether it has seasons and what they are like
   - whether the planet will have tides, and if yes:

     —will they be similar to, stronger than, or weaker than tides on Earth?

     —will there be extreme tides?
4. Describe in your science notebook what it would be like to live on the planet.
5. With your group, prepare a presentation to explain and model your planet's day, year, seasons, and tides to the class. Explain what it would be like to live on the planet. Your presentation must include a chart or poster.
6. View the other groups' presentations and record unusual features of each planet on Student Sheet 84.1, "Comparing Planets."

ANALYSIS

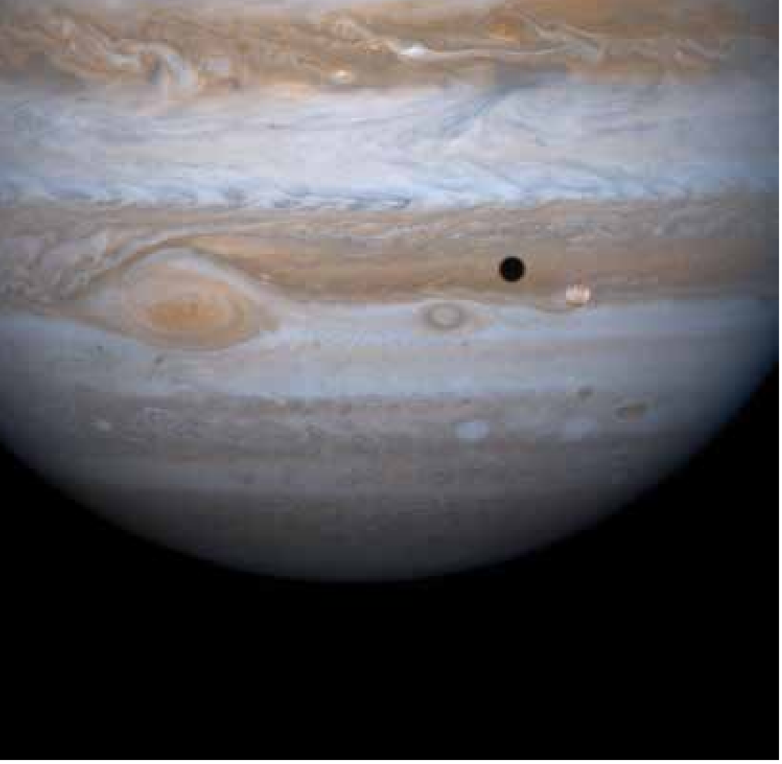
1. **a.** Create a concept map that includes each of the following 10 words:

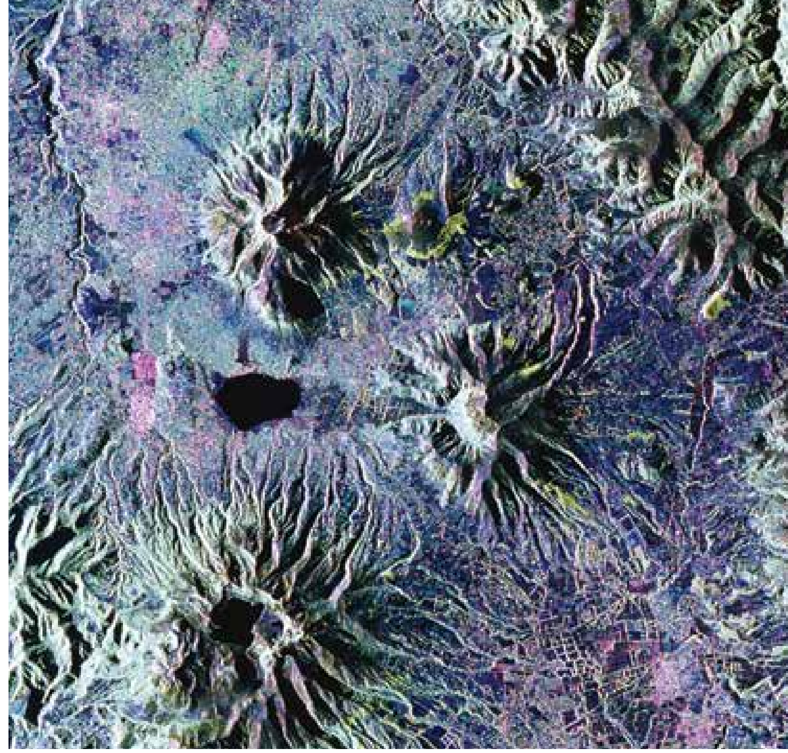
axis	rotate (or rotation)
day	seasons
Earth	Sun
Moon	year
orbit	
phase	

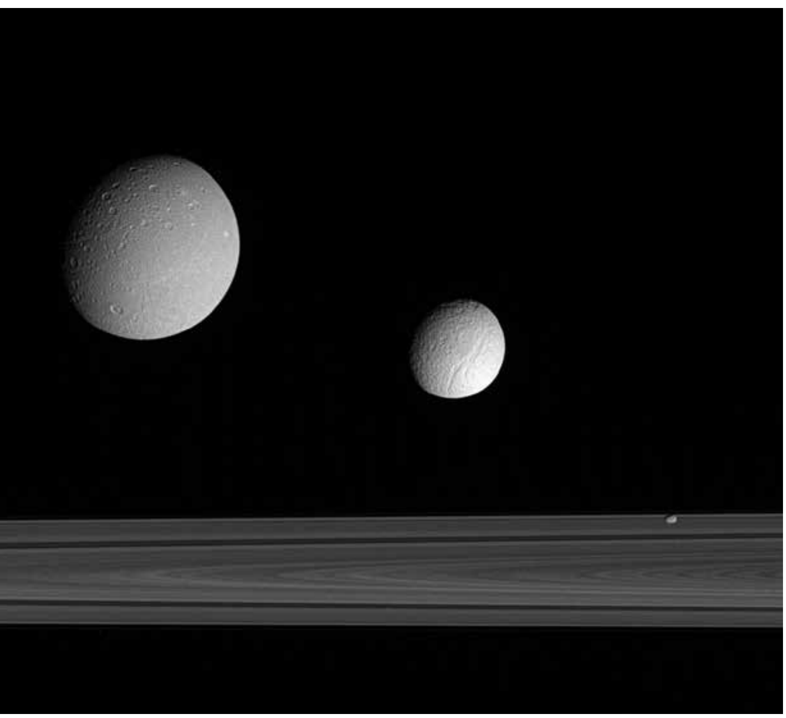
   b. Add at least four more words that relate to this unit to your concept map. Choose words that show important things that you have learned.

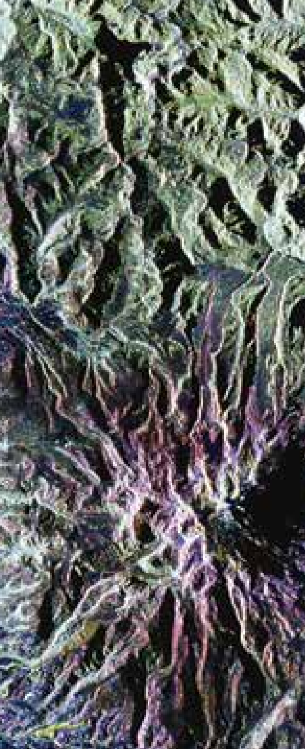
Exploring Space

G









Exploring Space

When Dean went over to Anya's house one day after school, he noticed a long cylinder on a stand in a corner of her back porch. "What's that?" he asked Anya.

"It's a telescope I built with my grandfather," she answered. "He was always going to the observatory, and finally he decided to build a telescope for himself. We put it together last summer."

"Wow," said Dean, "Can I look through it?"

Anya laughed. "Sure, but we might want to wait until it's dark. Maybe you can stay for dinner and do some stargazing with us."

Later, as they helped set up the telescope outside, Anya pointed to a small light in the sky and said, "See that bright spot next to the Moon? That's the planet Mars."

Dean asked, "How do you know it's a planet and not a star?"

"Well, it looks a little brighter," said Anya, "and it doesn't flicker or twinkle like a regular star. If you look carefully, you can see it's a slightly different color than the stars around it."

Then Anya aimed the telescope at Mars. "Come take a look, Dean. We'll be able to see a lot more with the telescope."

• • •

What kinds of objects are in outer space? Which ones can you see without a telescope? What can we learn about faraway objects with a telescope?

In this unit, you will investigate some objects in space. You will learn what size they are, and how far they are from Earth. You will learn about the ways people explore outer space—whether from Earth or from a spacecraft—and what space exploration may be like in the future.

85 History of Space Exploration

INVESTIGATION

People have always wanted to explore space. At first they just used their eyes, then telescopes, and then spacecraft and other tools. **Spacecraft** include rockets, satellites, probes, space capsules, space stations, and space shuttles. Some spacecraft have people aboard, but most do not. The first spacecraft, a satellite called Sputnik, was built and launched into orbit in 1957 by the Soviet Union. Since then, several nations and private businesses have put thousands of spacecraft of all kinds into orbit. The launches have cost billions of dollars, and while many have been successful, some have not. Some missions have even ended in disaster.

CHALLENGE **When did some of the great advances in space exploration occur?**

Soviet Union leaders stand in front of a model of Sputnik III.

An astronaut climbs down a lunar module.

Space Shuttle Atlantis takes flight.

Two modules of the International Space Station are put together during an astronaut's space walk.

A supply vehicle leaves the International Space Station.

MATERIALS

For each group of four students

1 set of 15 Space Exploration Date Cards

1 set of 15 Space Exploration Event Cards

For each student

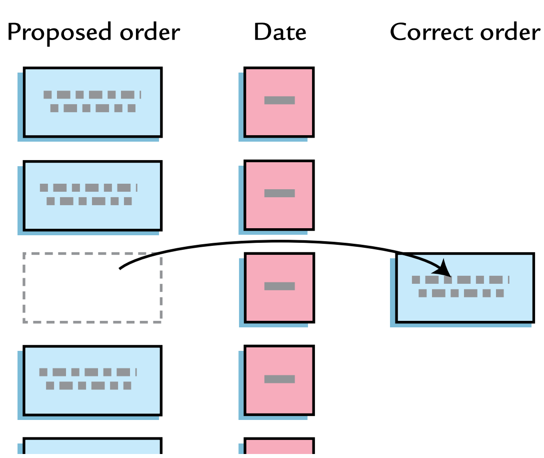
1 Student Sheet 85.1, "Anticipation Guide: History of Space Exploration"

1 Student Sheet 85.2, "Space Exploration Timeline"

PROCEDURE

Use Student Sheet 85.1, "Anticipation Guide: History of Space Exploration" to prepare for the following activity.

1. Place the Space Exploration Date Cards in order in a column, with the earliest year at the top and the most recent at the bottom.
2. Carefully read all 15 Space Exploration Event Cards.
3. Work with your group to put the Space Exploration Event Cards in the order in which the events occurred. Place each Event Card to the **left** of the Date Card showing the year in which you think the event occurred.
4. Using the letters and dates on the cards, write this order of events in your science notebook putting the most recent event at the top.
5. Your teacher will provide a clue to help you place one of the cards. Use this clue to move one of the Space Exploration Event Cards to the **right** of the Date Card, as shown in the diagram at left. Moving an Event Card to the right means it is next to the correct Date Card.



6. Re-order your Event Cards on the left of the Date Cards as necessary, based on the new information.
7. Repeat Steps 5 and 6 until you have moved as many Event Cards as possible to the right side of the Date Cards.

8. Compare your timeline to the one provided by your teacher. For any cards still on the left side of the Date Cards, move them to the right side of the correct Date Cards.

9. When all Events are in the correct order, copy all the Events onto Student Sheet 85.2, "Space Exploration Timeline."

ANALYSIS

1. Which of the Space Exploration Event Cards that did not have dates did you place:
   a. closest to the correct date?
      Explain how you made your decision.
   b. farthest from the correct date?
      Explain how you made your decision.

2. Why do you think many space exploration events occurred between 1960 and 1980?

3. **Reflection:** If you had to choose a place in space to explore, what would it be? Explain why you chose this place.

86 Observing Objects in Space

Space exploration has always been aided by the work of astronomers. An **astronomer** is a scientist who studies objects and events beyond the Earth's atmosphere, such as the composition or movement of stars and planets. A **star** is a huge ball of gas that gives off heat and light. A **planet,** which is smaller than a star, revolves around a star and reflects that star's light.

Although many objects in the night sky can be seen with the "naked eye," that is, without telescopes or binoculars, telescopes help astronomers make more detailed observations of space objects. For example, for a long time people thought they saw oceans and lakes on the Moon. Using telescopes, astronomers realized that these were fields of hardened volcanic lava.

CHALLENGE

What can you observe about objects in space?

PROCEDURE

1. Each photograph on the next page shows a space object as seen through a powerful telescope. In your science notebook, make a table like the one below.

2. Carefully examine the six space objects shown. Look for ways to tell the objects apart.

Observing Space Objects

Space Object Number	Observations	Category
1		
2		
3		
4		
5		
6		

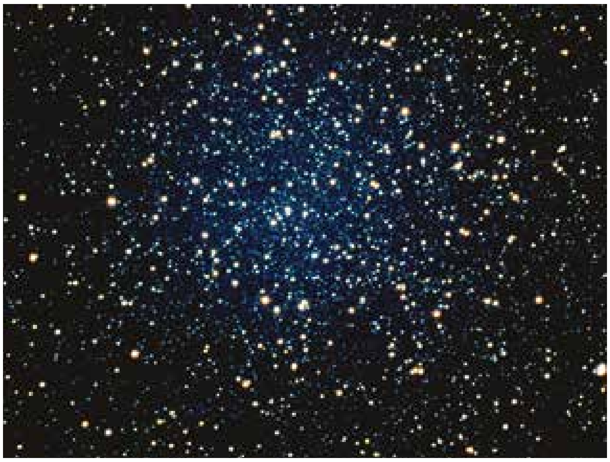
3. Discuss your observations with your partner, and then record them in the "Observations" column of your table. Leave the "Category" column blank for now.

4. Discuss your observations with the other pair in your group. Review the tables together, and add any new observations about the space objects.

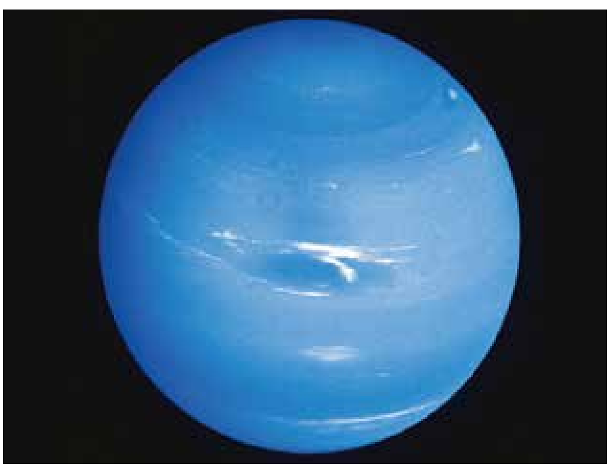
5. In your group of four, decide whether you think the space objects are planets, stars, or "other." Record your ideas in the "Category" column of the table.

6. Describe in your science notebook how you selected the category for each object in the photographs.

SPACE OBJECTS


1


2


3


4


5


6

ANALYSIS

1. Which objects were most difficult to categorize? Explain what made it difficult.

2. What other observations or information about the objects would help you identify them more easily?

3. What technological inventions have helped us describe and identify space objects?

EXTENSION

On a clear night take Student Sheet 86.1, "Night Sky Observations," a pencil, and a flashlight, and go outside. Find a place where you have a good view of the sky and you are as far away as possible from any lights. Look carefully at the sky, and find five bright, but different, objects. Use the information on the next page to guide your observations. Record your observations on your Student Sheet. Look at those same objects on five different nights and identify how they have changed.

Field Study of the Night Sky

The objects described below are visible with the "naked eye," and can usually be seen on a dark clear night.

STARS are the most common object we see in the night sky. The light from a star comes from so far away that it acts as a single ray of light. Stars seem to "twinkle" because the Earth's atmosphere refracts, or redirects, the ray of light. Stars appear to move together across the sky during the night.

PLANETS may be difficult to distinguish from stars. If an object in the sky looks similar to a star but doesn't twinkle as much, it is likely to be a planet. Planets appear as disks when magnified with binoculars or a telescope. Although much smaller than stars, they can appear larger because they are much closer to Earth.

EARTH'S MOON looks like the largest object in the night sky because it is the closest object to Earth. The phase of the Moon changes during the lunar cycle. Other planets have moons but they are too small or too distant to be seen without a telescope.

SATELLITES AND JETS move quickly across the night sky and often appear to blink regularly. Sometimes they can look very similar to each other. Most satellites take about 90 minutes to orbit the Earth, so if the object you are observing comes back along the same path in that time, it is probably a satellite.

METEORS are small, bright objects that speed across the sky for a few seconds and appear to leave a trail. Meteors are often mistakenly called "shooting stars" or "falling stars" but they are not stars at all. Meteors are pieces of rock that are falling through the atmosphere and usually burn up before they hit the ground. Meteors that reach Earth's surface are called meteorites.

GALAXIES are collections of billions of stars. When conditions make one or more of them visible, each galaxy appears as a fuzzy patch of sky. Only a few galaxies can be seen with the naked eye because most are too distant. Our galaxy, also known as the Milky Way Galaxy, is shaped like a disc. When we look out along the plane of the disk, we are looking toward billions of distant stars that appear as a hazy band of light.

87 Telescope Technology

The development of the telescope over the past 400 years has allowed astronomers to see more and more details in known space objects. It has also helped them discover objects that are smaller or farther away from Earth. In the early 1600s, telescopes helped astronomers better distinguish the objects they had already seen in the **Solar System.** The Solar System is the collection of space objects that includes the Sun, its planets, their moons, and other smaller objects. With every new telescope advancement, we have learned more about the regions beyond Earth and the Solar System.

CHALLENGE

How has the telescope helped astronomers see space objects?

MATERIALS

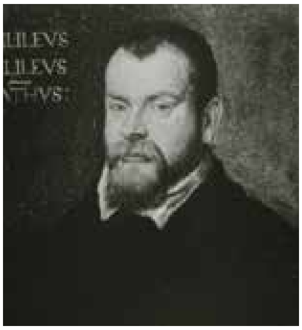
For each student

1 **Student Sheet 87.1, "Three-Level Reading Guide: Telescope Technology"**

This photo of a group of galaxies was taken by a camera aboard NASA's Hubble Space Telescope.

READING

Use Student Sheet 87.1, "Three-Level Reading Guide: Telescope Technology" to guide you as you complete the following reading.



A portrait of Galileo Galilei (1564–1642).

Galileo's Telescope

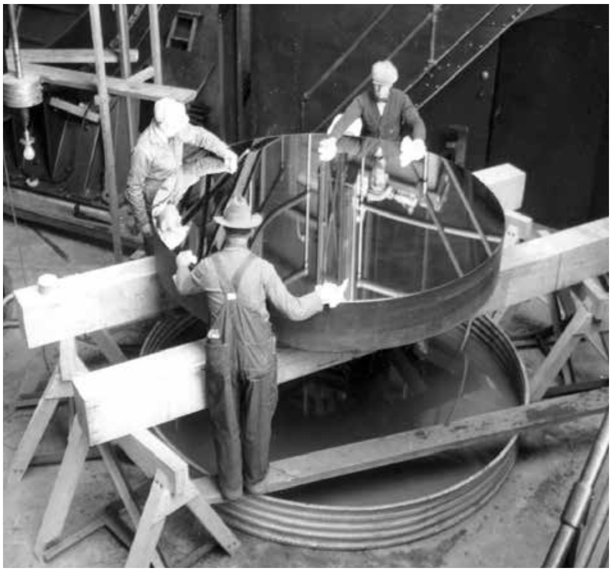
You may have heard that Galileo invented the telescope in the 1600s, but this is not true. In fact, many people made telescopes in the early 1600s to help ship captains find their way and see other ships at sea, but Galileo was the first to use a telescope to observe the sky. He improved it by increasing the strength of its magnifying lenses (the glass pieces that make objects appear larger). Using a telescope that had two one-inch-wide lenses he discovered that there were many moons orbiting Jupiter. This was a big leap forward for the science of astronomy. Another of the important observations Galileo made with his telescope showed that the Moon was not smooth as people thought, but its surface was rough and uneven.

Galileo's telescope with which he discovered four of Jupiter's moons.

George Hale at his desk in 1906.

Hale's Telescope

The power and quality of telescopes improved quickly, and by 1900, astronomers depended on them. Although their telescopes could show space objects hundreds of times bigger than could be seen with the naked eye, some twentieth century scientists wanted to look farther into space. George Ellery Hale was one of those scientists. An ambitious man, he built the now-famous Mount Wilson Observatory in Pasadena, California in 1904. Risking his reputation and a lot of money, in 1906 he ordered the making of a 100-inch telescope that would see far beyond the Solar System. Besides needing a new observatory and special machinery, his telescope would need the largest solid glass mirror ever made. Hale wasn't even sure if that could be done.



Engineers polish the glass of the 100-inch mirror before it is put in the telescope at the Mt. Wilson Observatory.

The project, from the very beginning, met problem after problem. The massive 4,100 kg (9,000 pound) mirror was made in France of wine-bottle glass. It took a year for the glassmakers to build the mold needed to form the mirror. When the mirror arrived in Pasadena in 1908, there were bubbles in the glass, which made it defective. Another mirror was built the next year, but it broke as it cooled. A third mirror was made, but it was too thin. Although some people said the first mirror was useless, Hale decided to use it anyway. That meant five years worth of grinding and polishing the glass before it could become part of the telescope. In the scientific community, doubts about Hale's effort grew as the years passed.

When the mirror was finally ready, it was very carefully trucked up the side of Mt. Wilson at 1 mph, with the help of 200 men. On November 1, 1917, 11 years after the project began, the 100-inch telescope was first aimed at Jupiter. Once the telescope was installed, it was clear that Hale's gamble had paid off. It showed stars as brilliant points of light. Hale's 100-inch telescope produced excellent results, and it remained the largest telescope in the world for 40 years. Using the 100-inch telescope and new methods for measuring distances, Hubble confirmed the existence of galaxies beyond the Milky Way. He also observed that all galaxies that he could detect were moving away from Earth and each other. This was the first evidence that the universe was expanding, a foundation of the modern theory of the origin of the universe.

Astronomer Edwin Hubble looks through the eyepiece of the 100-inch telescope.

Leavitt's Observations

Henrietta Leavitt created a way of measuring distances to stars that are very far away.

Meanwhile on the other side of the country, astronomers in Cambridge, Massachusetts were using other kinds of powerful telescopes to advance their science. One of these astronomers was Henrietta Leavitt, who, like Hubble, aimed a telescope beyond the Solar System. When Leavitt graduated from college in 1895, she went to work, first as a volunteer and then later as a paid staff member, at the Harvard College Observatory. Her work there was interrupted for several years by an illness that left her deaf.

When Leavitt went back to work in 1902, she was assigned the job of cataloging Cepheids (se-FEE-ids), which are stars that regularly brighten and dim. She observed more than 20 of these unusual stars using telescope photographs of stars outside of our galaxy. Several years before Hale's 100-inch telescope began working, Leavitt graphed her data and discovered a pattern. The Cepheids that appeared brightest took longer to cycle from bright to dim and then bright again. Her data allowed her to determine that a Cepheid's average brightness was related to its distance from Earth. She was able to find the distance to a nearby **galaxy**, a collection of billions of stars. To do this, she only needed to find a Cepheid star in that galaxy and then use it as a cosmic tape measure. This was a scientific breakthrough because until then no one had been able to estimate such large distances. Hubble used Leavitt's methods for measuring distances in his work on the movement of galaxies.

Leavitt's brilliant career was cut short when she died of cancer at age 53. Some scientists think that, had she lived, she might have received a Nobel Prize.

The Hubble Space Telescope has been orbiting Earth since 1990.

The Hubble Space Telescope

The 95-inch Hubble Space Telescope is named for Edwin Hubble because of his major contributions to the field of astronomy. The Hubble Space Telescope is currently orbiting Earth and looking deeper into space than any telescope has done before. It provides data and images of space objects that cannot be gathered from within Earth's atmosphere.

Although the Hubble Space Telescope has been successful, it has a major drawback: a telescope orbiting in space is difficult to repair. Since it was sent into orbit on a space shuttle in 1990, astronauts on shuttles have visited it several times to perform routine service and repairs.

ANALYSIS

1. How has the invention of the telescope helped scientists understand objects in the sky?

2. Choose at least two of the four scientists presented in the reading. Describe how they contributed to astronomy.

3. Carefully read the article below. Describe two lines of evidence that support the Big Bang model for the origin of the universe.

4. **Reflection:** If you had access to a powerful telescope, what space object would you want to observe? Explain.

The Big Bang Theory for the Origin of the Universe

The universe is everything in space—all matter and energy are part of it. Our Milky Way galaxy is just one of more than 125 billion known galaxies in the universe. A fundamental question in astronomy is: how did the universe form? In 1929, astronomer Edwin Hubble observed that all of the galaxies he could see were moving away from each other and from earth. Since then, astronomers have found extensive evidence that the universe is both expanding and cooling.

Over the next few decades, this and other evidence led scientists to conclude that the universe began with an event 13–14 billion years ago called the Big Bang. At the instant of the Big Bang there was only energy. At first, the universe was very hot, dense, and only a few millimeters across. The Big Bang was not really an explosion, as its name would suggest. Instead, it was an expansion and cooling that scattered energy, formed matter, and created space itself.

The Big Bang model for the origin of the universe predicts that all of space should contain remnants of the tremendous energy released by the Big Bang. In 1965, the scientists Arno Penzias and Robert Wilson detected a mysterious noise in a supersensitive antenna they were working with to detect radio waves at Bell Labs in New Jersey. The detector was picking up microwaves, which are near radio waves in frequency. Since this signal was evenly spread over the sky, it could not be coming from the Sun or the Milky Way galaxy. They concluded it came from throughout the universe. They and scientists at Princeton University realized that this radiation fit the predictions of the Big Bang. In 1978, Penzias and Wilson received the Nobel Prize for their discovery.

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website to investigate further the evidence for the Big Bang or the life and work of a famous astronomer.

88 Classifying Space Objects

INVESTIGATION

Many kinds of objects in the sky can be observed with the naked eye and with telescopes. In this activity you will further investigate objects in space, mostly those found in our own Solar System. Our Solar System, with its one star, is just one tiny part of our galaxy. Our galaxy is only one of billions of galaxies.

CHALLENGE

What types of objects are found in space?

MATERIALS

For each group of four students

1 set of 24 Space Object Data Cards

This galaxy made up of billions of stars forms a spiral shape.

PROCEDURE

1. Spread your Space Object Data Cards out on a table.
2. Read each card carefully, noting the similarities and differences among the objects.
3. With your group of four, classify the Space Objects into 5 to 10 groups that have similar features. Work together to agree on a classification system.
   - Listen to and consider explanations and ideas of other members of your team.
   - If you disagree with your team members about how to classify a space object, explain why you disagree.
4. In your science notebook, list the common features of each group of space objects. Then write down the numbers of the objects that belong to each group. Label your classification system, “Our Classification System.”
5. Discuss with the class your group’s classification system. Observe the similarities and differences between your system and the others.
6. Get a set of Classification Cards from your teacher. Each card represents a group of space objects as classified by astronomers. Based on the information described on the Classification Cards, place each Space Object Data Card under one of the Classification Card categories.
7. In your science notebook, list the common features of each category of space objects as described on the Classification Cards. Then list the objects that belong to each set. Label this classification system, “Astronomers’ Classification System.”
8. With your group, compare the two classification systems. Describe how the systems are:
   - similar
   - different
9. Record your group’s ideas in your science notebook.

ANALYSIS

1. How did your group classify the categories? Describe your system.

2. List the eight major categories described in the Astronomers' Classification System. For each classification, write down at least two of the major features of that category.

3. Carefully read the article below.

   a. Why was Pluto's classification changed?

   b. Do you agree with the changes made by the International Astronomical Union? Explain your choice using evidence from the article.

AUGUST 25, 2006

Pluto Demoted!

Prague, Czech Republic—Today the International Astronomical Union, a group of more than 9,000 astronomers around the world, voted to change the definition of a planet. Scientists met to settle the debate over the classification of Pluto and other solar system objects. The result of the vote is that Pluto, discovered in 1930 and designated our ninth planet, is no longer a planet. Pluto is round and orbits the Sun, as required by the definition. However, it does not qualify as a planet because the area around its orbit is not clear of other objects.

The new definition of a planet also settles the debate about Eris (formerly known as Xena), discovered in 2003. Eris is round and orbits the Sun. It is slightly larger in diameter and three times as far from the Sun as Pluto. The old definition said that a planet was any round object orbiting the Sun that is made of rock or gas and has a diameter equal to or larger than Pluto. If the old classification system were used consistently, Eris, Pluto, and another object named Ceres would all be planets.

The scientists were faced with a difficult choice. Either they had to add more planets to our solar system or they had to reclassify Pluto and similar objects. Currently there are dozens of objects like Pluto, Eris, and Ceres. Scientists predict that hundreds more will be discovered in the future.

The new classification system makes Pluto, Eris, and Ceres "dwarf planets," which is a new category. Objects that orbit the Sun but are not planets or dwarf planets are now called Small Solar System Bodies. Although the new definitions settled the debate about Eris, the new classification system is being criticized. Shortly after the vote was taken, 300 astronomers signed a statement saying they would not use the new definitions. They do not like that the new classification depends on how an object moves (namely, that the area around its orbit is clear of other objects) instead of on its properties. Furthermore, the definitions do not always work outside our Solar System.

89 Where in the Solar System Am I?

Planets have many features in common. For example, all planets are spherically shaped and each orbits a star. But each planet in our Solar System also has many other characteristics that make it different from the others.

Imagine that sometime in the future, people travel to all the planets in the Solar System. Imagine you are living in this time, and some of your friends are away on trips into outer space. You have received messages from your friends on other planets, but there is a problem with some of them. Four of your friends forgot to say what planet they are visiting.

CHALLENGE **What features make each planet unique?**

MATERIALS

For each student

1 **Student Sheet 89.1, "Planet Information"**

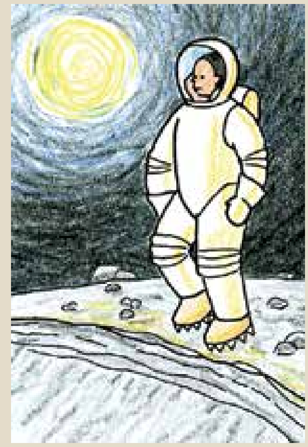
PROCEDURE

1. Read the four messages from space shown on the next page.
2. Choose one of the messages and carefully compare the descriptions in it with the information provided on Student Sheet 89.1, "Planet Information."
3. With your partner, decide which planet that message was sent from.
4. In your science notebook:
   - Record the name of the person who sent the message and the name of the planet he or she was visiting.
   - List the evidence in the message that helped you decide which planet the message came from.
5. Repeat Steps 2–4 for the other three messages.

ANALYSIS

1. Write a message from a planet in our Solar System other than the ones already used in the four messages presented in this activity. In your message describe several features that would help someone else identify the planet.

Interplanetary Message



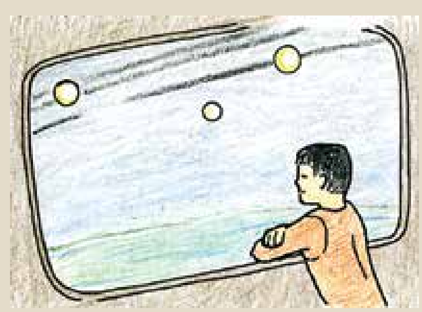
The temperature is so extreme here! During the day, the Sun looks huge and bright, and so it's very, very hot outside. When it is night, it gets really, really cold. Nighttime is always pitch black because there is no Moon. I guess it is kind of like living at the North or South Pole during summer or winter. There are no clouds, wind, or any kind of weather. Thank goodness we brought our own oxygen so we can breathe. I'm glad I brought my space hiking boots because there are lots of large craters, kind of like the Moon. I visited one yesterday that is the size of Texas!

Kayla

Interplanetary Message

I can't believe I finally got here! It took close to 10 years to make the trip. I'm glad to be here during this planet's summer, but it's still below –130°C. And, because the planet is tipped on its side, the Sun doesn't shine at all in winter, which lasts more than 7,500 Earth days. The Sun is shining now, but it's not very big, bright, or warm. I'm not sure how long I'll be here, because one year on this planet takes a lifetime, but it's weird because one day is so short.

Not having a solid surface to walk on is kind of tricky, so I spend most of my time on the spacecraft. They say there are a bunch of moons, but I've only seen five. I think the others must be pretty small. I can see some faint gray lines that go all the way across the sky. I'm not sure what they are—I'll have to keep looking.



Ronin

Interplanetary Message

There is so much iron here! The other day, I made the mistake of getting caught in a dust storm. The red dust coming off all the rocks completely blocked my view, and I was lost for a while. The day length is similar to back home, but even in the summer it is still cold. It's like Earth's South Pole in winter, but there is no snow. There is a lot of trash and equipment from previous explorations. It was quite a quick trip here, so I'll be home soon.

Len

P.S. I forgot to tell you that it's kind of spooky having more than one moon zipping across the sky.

Interplanetary Message

This place is so bizarre because it has no solid surface! It is a huge ball of gas, and our space hotel hovers above it. Going out for a walk is certainly not an option. We saw this place that has a huge red hurricane almost three times the size of Earth. It has 400 mph winds that have been blowing for centuries. That's over twice the speed of the winds from the strongest hurricanes on Earth. The atmosphere is constantly swirling and has a lot of hydrogen and helium.

Last night I saw four big moons, which are easy to see, and many little ones that I can't tell apart. It's easy to stay up all night long to watch them because a full night is only about 5 hours long. The daylight time is only 5 hours long, too, so a full day lasts only 10 hours. I can also see a few faint rings when I look out into the sky during the day.

Eva

90 Drawing the Solar System

MODELING

When you look into the night sky, most of the objects other than the Moon appear to be about the same size. They also look like they're all about the same distance from Earth. They are neither. Although early astronomers' observations gave people some idea of how big and how far away the planets are, it took the invention of telescopes, satellites, and rockets, to make accurate measurements.

In this activity, you will use a **scale**—a ratio between the actual size of an object and its size in a model—to turn scientific measurements into an accurate model showing the distances of the planets from the Sun.

CHALLENGE

How far away are other planets in the Solar System?

A model, such as this one of a skyscraper, helps people visualize something that is very large or small.

MATERIALS

For each student

1 **Student Sheet 90.1, "Talking Drawing 1: The Solar System"**

1 **Student Sheet 90.2, "Talking Drawing 2: Scaled Sun-to-Planet Distances"**

1 **ruler**

PROCEDURE

Use Student Sheet 90.1, "Talking Drawing 1: The Solar System" to prepare you for the following activity.

Part A: Distances in the Solar System

1. Using the data in Table 1 below and a scale of **1 cm = 200,000,000 km**, calculate the relative distances of the planets from the Sun.

   Hint: To calculate the distance in centimeters (cm), you will need to divide the planet's distance from the Sun in kilometers (km) by the scale.

Table 1: Planets' Distance from the Sun

Planet	Approximate Distance from the Sun (km)
Mercury	58,000,000
Venus	108,000,000
Earth	150,000,000
Mars	227,000,000
Jupiter	778,000,000
Saturn	1,429,000,000
Uranus	2,869,000,000
Neptune	4,505,000,000

2. Record the results of your calculations in the table on Student Sheet 90.2, "Scaled Sun-to-Planet Distances." Round your answers to the nearest 0.1 centimeter.

3. Using the information you just calculated, make a scaled drawing of the distances on Student Sheet 90.2. Measuring from the center of the Sun, draw an X on the line where each planet is located. Record the name of each planet next to its location on the line.

Part B: Diameters of the Planets in the Solar System

4. Look at the diameters of the planets shown in Table 2 below.

Table 1: Diameters of the Planets

Planet	Diameter (km)
Mercury	5,000
Venus	12,000
Earth	13,000
Mars	7,000
Jupiter	143,000
Saturn	120,500
Uranus	51,000
Neptune	49,500

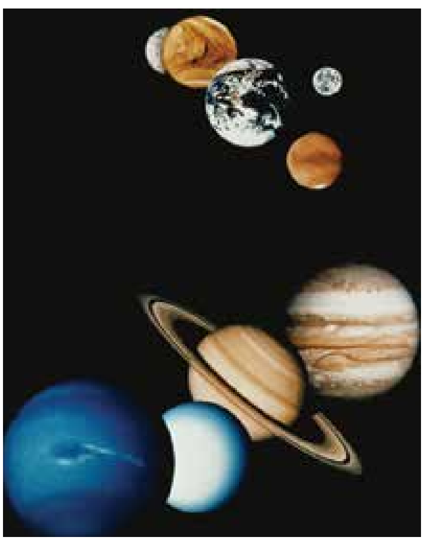
5. In your group, discuss the following questions about making a scale model of the planets' diameters.
   - Is the scale used in Part A (1 cm = 200,000,000 km) a useful scale for drawing the diameters of the planets? Explain why or why not.
   - The Sun has a diameter of 1,390,000 km. Is the scale used in Part A (1 cm = 200,000,000 km) a useful scale for drawing the diameter of the Sun? Explain why or why not.
   - Using a piece of regular notebook paper and a pencil, can you draw a picture that uses the same scale to accurately show the diameter of the Sun, the distances from the planets to the Sun, and the diameters of the planets?

6. Carefully examine each of the following models of the Solar System. With your group, discuss what is accurate and what is *not* accurate in each image. Record your ideas in your science notebook.

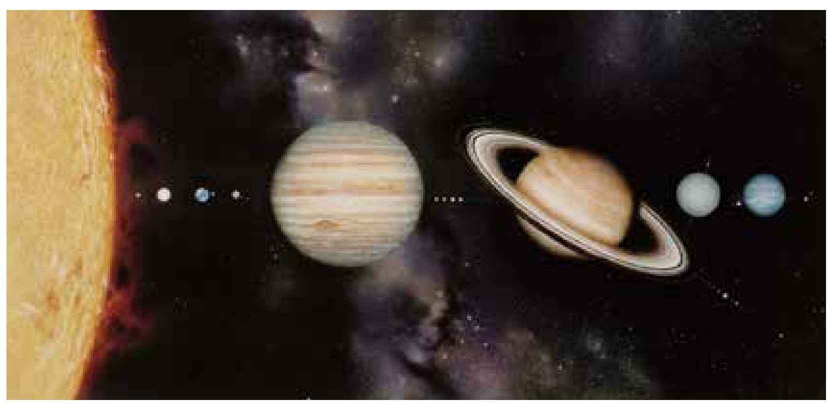
MODELS OF THE SOLAR SYSTEM

1

2



3



4

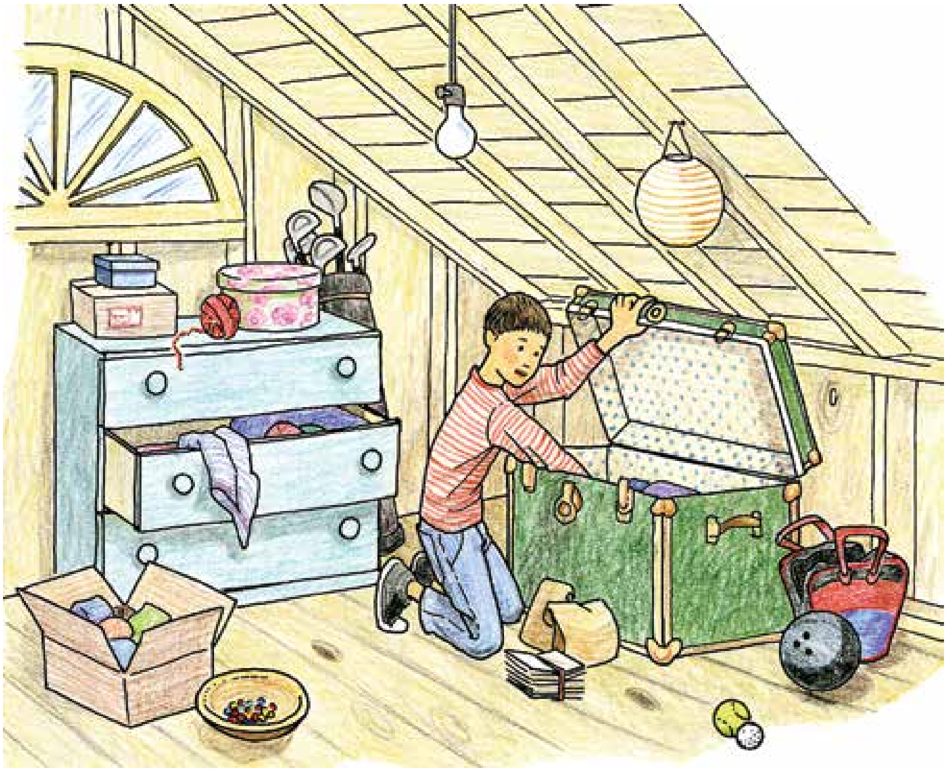
ANALYSIS

1. Astronomers often measure distances in the Solar System using a unit called the **astronomical unit** (AU). One AU is about 150,000,000 km—the mean distance between Earth and the Sun.
   a. Why do you think the AU is used to measure distance in the Solar System?
   b. Why do you think the AU is not used to measure distances on Earth?

2. What are the main advantage(s) and the main disadvantage(s) of drawing a picture of the Solar System on a piece of regular notebook paper?

91 How Big are the Planets?

In the previous activity, you drew a scaled diagram of the Sun-to-planet distances in the Solar System. On the same diagram, the scaled size of Earth would be much too small to see. We need to use a different scale when comparing the sizes of different planets.



CHALLENGE

How can you make a scale model showing the sizes of all of the planets?

MATERIALS

For each group of four students

9–10 **spherical objects of different sizes**

1 **ruler or meter stick**

For each student

1 **compass**

1 **Student Sheet 90.1, "Talking Drawing 1: The Solar System"**

1 **Student Sheet 90.2, "Talking Drawing 2: Scaled Sun-to-Planet Distances"**

1 **Student Sheet 91.1, "Talking Drawing 3: Scaled Sizes of the Planets"**

PROCEDURE

Part A: Determining a Scale

1. In your science notebook, make a table like the one below.

Diameter of the Planets

Planet	Actual Diameter of Planet (km)	Scaled Diameter of Planet (cm)	Diameter of Model Object (cm)
Mercury	5,000		
Venus	12,000		
Earth	13,000		
Mars	7,000		
Jupiter	143,000		
Saturn	120,500		
Uranus	51,000		
Neptune	49,500		

2. With your group, decide on a scale for the diameter of the planets. You will use this scale to find objects that represent the size of the planets. Complete Steps 2a–e to make the scale.

   a. Decide how many kilometers a single centimeter will represent. This is the scale.

   b. Convert the diameters of the smallest and largest planets using the scale. **Hint:** Divide the diameter in km by the scale in km to get the diameter in cm.

   c. If either of the scaled diameters is too big or too small for the ordinary spherical objects you have at school and at home, try creating another scale.

   d. Repeat Steps 2a–c until the group agrees that the scale for the size of the smallest and largest planets is reasonable.

   e. Record the scale in your science notebook.

3. Using the scale you made and the data in the table, calculate the scaled diameters of all the planets and record these in your table.

Part B: Making the Model

4. With your group, use your work from Part A to create an accurate model of the planets using round objects you find at home and school. Gather objects that will show the size of each planet compared to sizes of the other planets.

5. Measure the actual diameters of the objects and record them in your table.

ANALYSIS

1. How accurate is your model? Compare the scaled size of each planet to the size of the object you used to show it in your model.

2. The diameter of the Sun is about 1,390,000 km.

   a. Use your scale to convert this diameter to your model.

   b. What object could be used in the model to represent the Sun?

3. Complete Student Sheet 91.1, "Talking Drawing 3: Scaled Sizes of the Planets."
   a. Find a scale that allows you to accurately draw the smallest and largest planets on the paper.
   b. Record the scale on the Student Sheet.
   c. Convert all the diameters of the planets to the model, and record them in the table.
   d. Use a compass to draw the scaled planets as circles inside circles with all planet centers being Point C. To draw each planet, adjust the compass to one half the planet's diameter.
   e. Label each planet with its name and actual diameter.
4. Compare your drawing on Student Sheet 90.1, "Talking Drawing 1: The Solar System," with your drawings on Student Sheet 90.2, "Talking Drawing 2: Scaled Sun-to-Planet Distances," and Student Sheet 91.1, "Talking Drawing 3: Scaled Sizes of the Planets." Describe how your understanding of the Sun-to-planet distances and sizes of the planets has changed.

EXTENSION

With your class, make a physical model of the Solar System that shows both the Sun-to-planet distances and the sizes of the planets.

92 The Nearest Star: The Sun

READING

Without the energy we receive from the Sun, Earth would be a cold, dark, and lifeless place. The Sun provides energy for the growth of plants that support life on Earth and the energy that drives the winds, ocean currents, and the water cycle.

Since ancient times, people have recognized the importance of the Sun as a source of warmth and light. The Sun played a central role in the myths of nearly every ancient culture. People observed the Sun in the sky and used its changing positions to predict seasonal events, such as when to plant and harvest crops.

CHALLENGE **How is the Sun different from other objects in the Solar System?**

This 13th century temple in Konarak, Orissa, India is dedicated to the Sun God Surya.

READING

The Sun is a Star

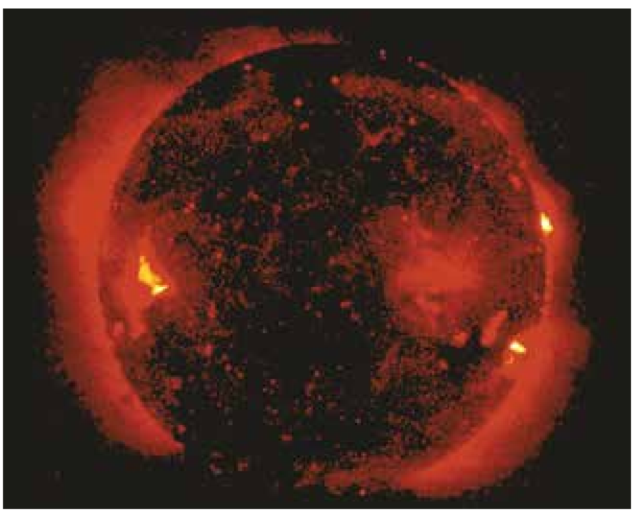
Listen *as your teacher reads aloud.*

Stop *when you see this yellow pencil and close your book.*

Write *down the main ideas you just heard.*

Among the many billions of stars in our galaxy, the Sun is average in size and temperature. When you look at the night sky with your naked eye from anywhere on Earth, you can see up to 8,000 stars. With a telescope you will see many more. Still others can only be detected with other technologies. These have also helped astronomers learn about the composition of the Sun.

The Sun's composition is very different than that of Earth or the other planets, except Jupiter. It is mostly hydrogen and helium mixed together in a high-temperature gas. It varies from 5,000° C at the surface to more than 10,000,000° C at the center. Dark spots on the surface of the Sun, called sunspots, are a little cooler than the rest of the surface.



The Sun is the star that is closest to Earth.

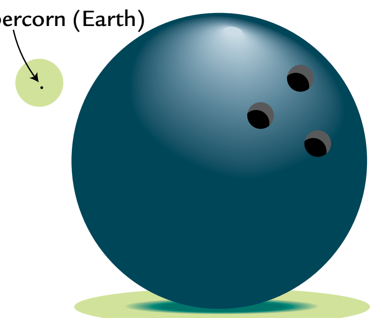
The Sun, like other stars, releases huge amounts of heat and light energy. This energy is produced by nuclear reactions at the Sun's center. A **nuclear reaction** involves a change in the nuclei (the center) of atoms. In the Sun, these nuclear reactions convert hydrogen to helium through a process known as nuclear fusion. In **nuclear fusion**, smaller atoms combine to form larger atoms. Nuclear fusion reactions release a very large amount of energy in comparison to other kinds of reactions. A hydrogen bomb, the most powerful type of nuclear bomb, uses nuclear fusion to produce more than enough energy to destroy an average sized city. Each second the Sun produces as much energy as millions of hydrogen bombs.

The Sun has been producing energy from fusion for 5 billion years. When the hydrogen in the Sun, its nuclear fuel, runs out, it will stop releasing heat and light. But this won't happen anytime soon. The Sun is only about halfway through its 10-billion-year-long life cycle.

How Far and How Big?

If the Sun is an average-sized star, why does it appear so much larger than other stars? Because, of course, it is much closer. To imagine how much closer, you have to think in terms of very large numbers. The Sun is about 150 million km away from Earth, but our next closest star is more than *40 million million* km away or more than 250,000 times farther away.

That the Sun is about 150 million km away means it's far enough that it takes eight minutes for light to travel from the Sun's surface to Earth. If you traveled to the Sun in a regular passenger jet, the trip would take about 20 years!



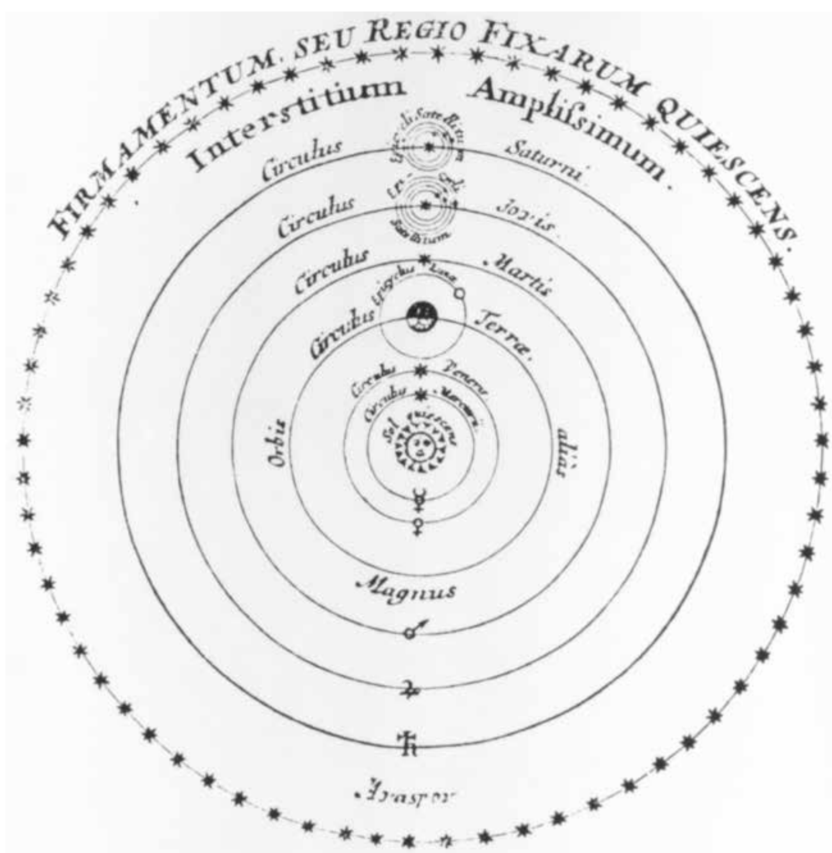
The size of the Sun is hard to grasp, because it is almost never shown to scale in diagrams. Its diameter is about 1,390,000 km, almost 110 times that of Earth. More than one million Earths could fit inside the Sun. Even Jupiter, the largest planet, is only one-tenth the size of the Sun. If you use a peppercorn to represent Earth as shown at left, the Sun would be about the size of a bowling ball. Using this scale, you would have to place these items about 25 meters (the length of most public swimming pools) apart to show the distance between them.

A researcher in Antarctica sets up a recorder that measures the duration of sunlight.

The Sun at the Center

Today, scientists accept that the Sun is at the center of the Solar System. But early scientists thought that the Sun and other planets orbited Earth. In about 260 BCE, a Greek astronomer and mathematician named Aristarchus may have been the first to argue that Earth orbits the Sun. Most people ignored his ideas for a very long time because other well-known scientists did not accept them. Then, in the 1500s, Polish astronomer Nicolaus Copernicus noticed that he could not explain all observations of planetary motion by using models with Earth at the center.

Copernicus realized that he could create a simpler model to explain the observations of planetary motion. In his model, shown below, you can see how it revived Aristarchus' idea that Earth and the other planets orbit the Sun. In the 1600s, the Italian astronomer Galileo used his telescope to make many observations that led him to support Copernicus' model. By 1700, most scientists agreed that the Sun was at the center of the Solar System. The model of the Solar System used today includes the planets circling the Sun, and also uses mathematical formulas to help predict the motion of the planets.



This drawing of Copernicus' model of the Solar System shows the Sun and the planets known at the time. It is written in Latin. Sol *means Sun and* Terra *means Earth.*

ANALYSIS

1. How would you explain to a fourth grader why the Sun looks so much bigger than other stars?

2. What is the source of the Sun's energy?

3. **a.** Is the following statement true or false?

   If you used an apple to represent the Sun, you would need to use a grape to represent Earth at the same scale.

   b. Explain your answer.

4. What characteristics of the Sun would make it a difficult place to explore or visit?

5. Why do you think it took a long time for people to accept that Earth and planets orbit the Sun?

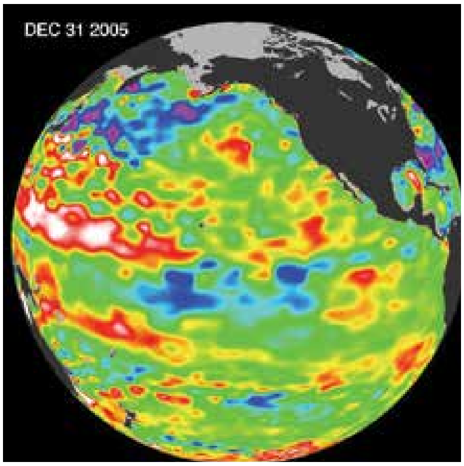
93 Picturing Without Seeing

No astronaut has ever been to the surface of another planet. In fact, no manufactured object has come within a thousand kilometers of most planets. Some of the planets are so covered with clouds or are so far away, that even the most powerful telescopes can't provide a very good view of them. Yet there are many images of the planets available. Scientists use different kinds of remote sensing methods to gather information about objects that we can't see or that are very distant. **Remote sensing** refers to any procedure that provides information about an object without us touching or directly observing the object.

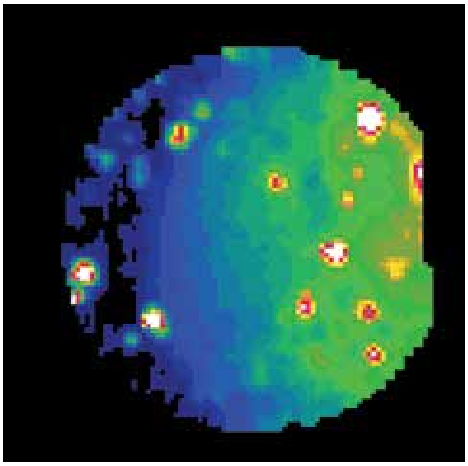
You and your fellow scientists are using a remote-sensing instrument to get information about the distance from a spacecraft to the surface of a planet. The measurements it takes from space are being sent back to Earth. You would like to use these measurements to make a picture of the surface of the planet.

CHALLENGE

How can you get a picture of a surface you can't see?



The remote sensing image above shows changes in the height of Earth's ocean. Purple means a drop in ocean height. Green is normal. Red means increased height.



This remote sensing image shows temperature on the surface of Io, Jupiter's largest moon. Red and white show hotter areas. Blue areas are colder. The red spots are volcanoes.

MATERIALS

For each group of four students

1 **Planet Surface Mystery Box**

2 **measuring probes**

7 **colored pencils or crayons:**
red, yellow, orange, green, blue, purple, and brown

For each student

1 **Student Sheet 93.1, "Class Data for the Planet Surface"**

1 **sheet of graph paper**

1 **ruler**

1 **Science Skills Student Sheet 4b, "Scatterplot and Line Graphing Checklist"**

PROCEDURE

Part A: Sensing the Surface

1. In your science notebook, make a table like the one below.

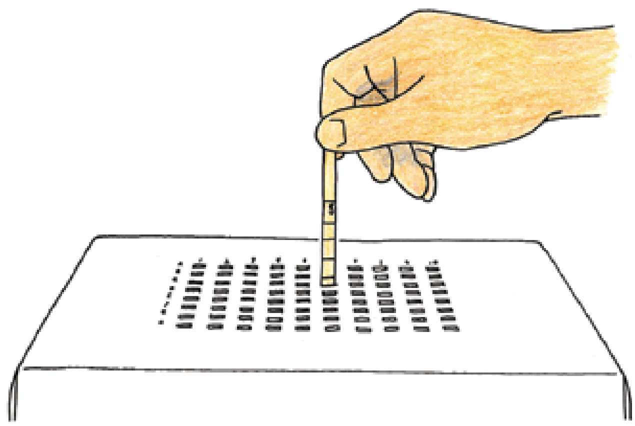
Surface Measurements
Row ____

Hole #	1	2	3	4	5	6	7	8	9	10
Depth measured										
Height of surface there										

2. Your teacher will assign your group one of the rows A–H of the box to investigate. Record the letter of the row in your table. One pair will measure Holes 1–5 in the row. The other pair will measure Holes 6–10 in the row.

3. At each hole, use the probe to measure the depth at that location. Round the measurement to the nearest 0.5 cm, and record it in your table.

   Hint: Make your measurement as soon as your probe touches the surface. Do not slide it farther into the box.



4. Calculate the height of the surface directly beneath each hole by subtracting the depth from the height of the box. Since the height of the box is 10 cm,

   10 cm − depth of hole = height of surface at that location

   Record the results in the bottom row of your table.

5. In your science notebook, use your data to make a line graph of what is inside the box. Label the graph, "Heights in Row ___," inserting the letter for the row you measured.

   Hint: On the horizontal axis, put the data for the hole number. On the vertical axis, put the data for the surface height beneath the hole.

6. In your group discuss the shape of the planet's surface. Describe your part of the surface of the planet based on your data. Record the description in your science notebook.

Part B: Sharing the Data

7. Share your data with the rest of the class. Record all the data on the top half of Student Sheet 93.1, "Class Data for the Planet Surface."

8. Use the key to complete the bottom half of Student Sheet 93.1. Color each square with the appropriate color for its height. In this way, your class data creates a false-color topographical map.

9. Using your false-color topographical map, describe the shape of the surface in the box. Record your ideas in your science notebook.

ANALYSIS

1. In a false-color topographical map, does it matter which color is used for each height?

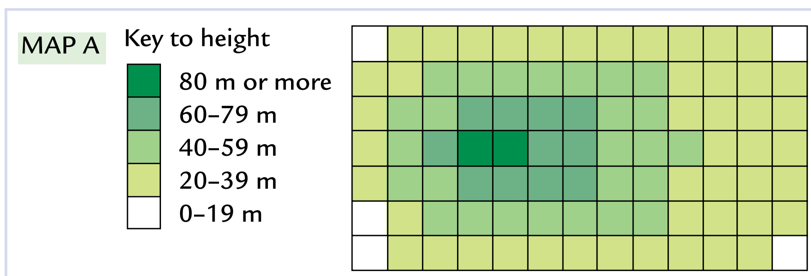
2. Compare the graph you made in Part A to the false-color topographical map you made in Part B. Did the additional data from your classmates change how you visualized the surface of the planet? Explain how.

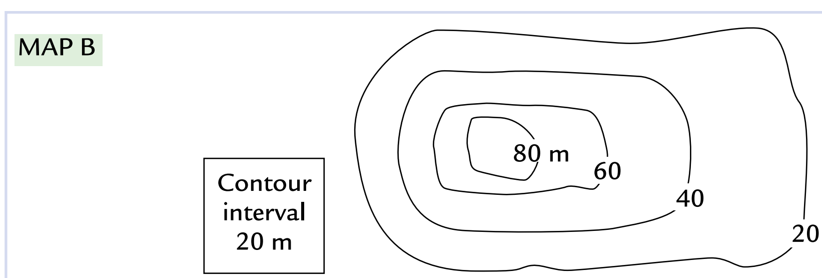
3. Look at the maps below. Both are maps of the same area. Map A is a false-color topographical map, and Map B is a lined topographical map.

   a. Describe the surface shown in the map.

   b. What are the advantages of the false-color topographical map?

   c. What are the advantages of the lined topographical map?





Remote Sensing

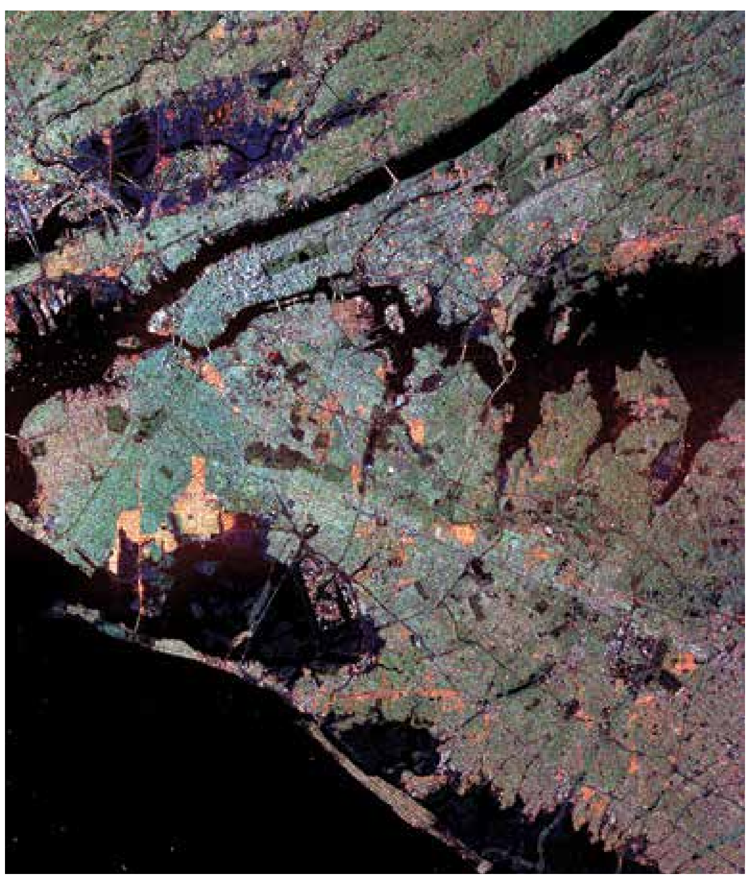
INVESTIGATION

Remote sensing is a way to measure things that are difficult to see or touch. Scientists may not use wooden probes like the one you used in the last activity, but they use similar methods. For example, one remote sensing method is radar, which uses radio waves to explore the surface of an object. The waves are sent toward a distant object, they bounce back, or reflect, from the object, and the roundtrip data is collected. Waves that take longer to return have traveled farther than those that returned sooner.

Waves also change when they are reflected from different materials, such as Earth's forests or rivers. Scientists have programmed computers to analyze the data from the reflected waves and make pictures, maps, and graphs. Because radar can be far away from the object, it is used to get information about hard-to-get-to places such as rain clouds and other planets.

CHALLENGE

What does remote sensing tell us about the surface of Earth and other planets?



This false color map of the New York metropolitan area was taken from a space shuttle using radar.

MATERIALS

For each group of four students

1 set of 4 remote sensing images of Earth
1 set of 4 remote sensing images of Mars
1 set of 4 remote sensing images of Venus

PROCEDURE

1. Look carefully at Image 1 for Earth, Mars, and Venus, and identify features that are common to all three planets.
2. In your science notebook, list the features that the three planets have in common. Label the list, "Common Features: Image 1."
3. Repeat Steps 1 and 2 for Images 2–4 for all three planets.
4. In your science notebook, make a table like the one below.

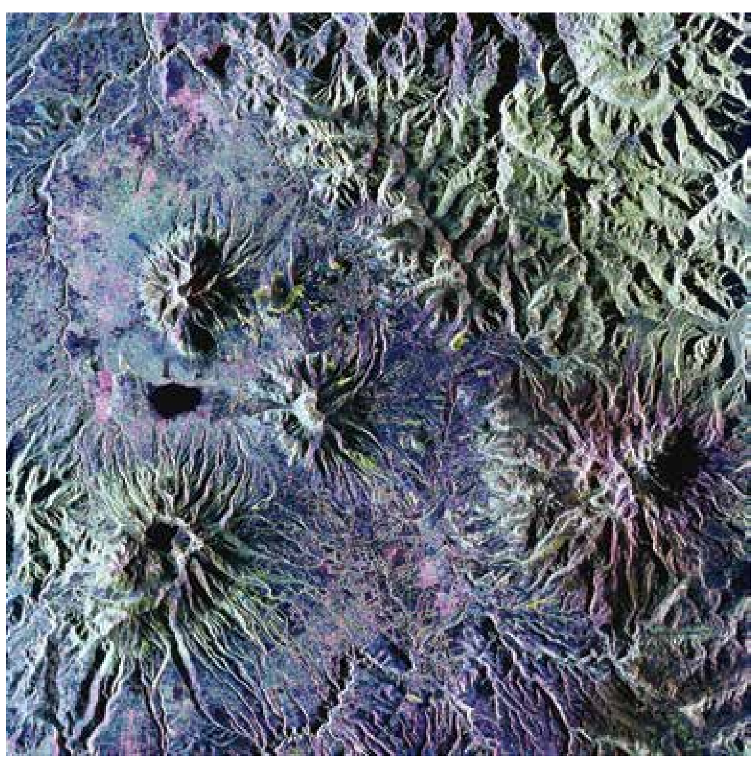
Unique Features of Planet Surfaces

	Image 1	Image 2	Image 3	Image 4
Earth				
Mars				
Venus				

5. Again look carefully at Image 1 for Earth, Mars, and Venus. This time try to find features that make each planet different from the other two. These are its *unique* features.
6. Record those unique features of the planets in your table.
7. Repeat Steps 5 and 6 for Images 2–4 for all three planets.

ANALYSIS

1. What information about the planets that was collected through remote sensing devices:
   a. is shown by these images?
   b. is *not* shown by these images?
2. In these images, how is the surface of Earth:
   a. similar to the other two planets?
   b. different from the other two planets?
3. Look at the image below, made by remote sensing. Can you tell from the surface features what planet it shows? Explain why or why not.
4. How could remote sensing be used to help prepare for a mission to another planet?



95 Universal Gravitation

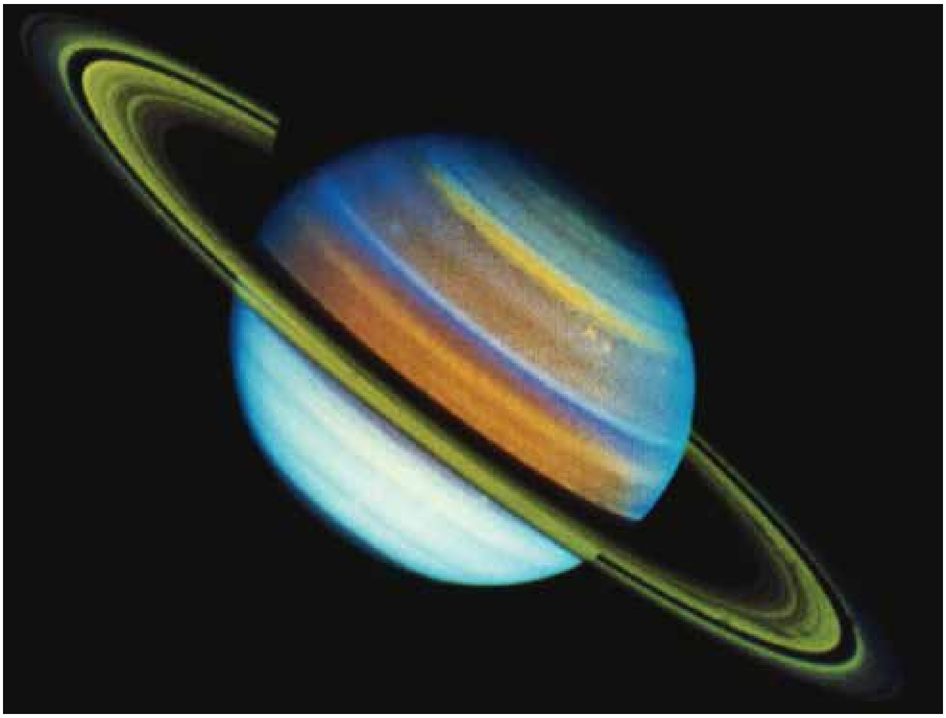
A **force** is any push or pull. The force due to gravity interests astronomers because it is most noticeable with big objects, like stars, and reaches over long distances, such as those between the planets. **Gravity** is a natural phenomenon that causes any two objects to be pulled together. Isaac Newton's inquiry into the effects of gravity led him to determine the universal law of gravitation, which relates the force of gravity to distance and **mass.** Mass is the measurement of the amount of matter or stuff that makes up an object.

Imagine that you are a scientist who has been receiving information from a spacecraft exploring Saturn's rings. The rings reach out from Saturn for 300,000 km and contain particles of ice and rock that range in size from as tiny as a sand grain to as big as a house. Your remote sensing device got information about some of the objects in one of the rings.

CHALLENGE

What determines the amount of gravitational force between objects?

Although they look solid from Earth, Saturn's rings are actually made up of a large number of small particles each in its own orbit.



MATERIALS

For each student

1 sheet of graph paper
1 ruler
1 Science Skills Student Sheet 4b, "Scatterplot and Line Graphing Checklist"

PROCEDURE

1. The table below shows the gravitational force between Saturn and some particles in Saturn's rings. All of the particles are the same distance, 180,000 km, from Saturn's center.

Table 1: Mass and Gravitational Force Data

Mass of Ring Particle (kg)	Gravitational Force between Saturn and Ring Particle (in 10,000 N)
2	23
3	35
4	47
5	58
6	70
7	82
8	93
9	105

2. Use the data in the table to make a graph of the relationship between mass and gravitational force. Label your graph "Gravitational Force and Mass."

   Hint: Put the data for mass on the horizontal axis and the data for gravitational force on the vertical axis.

3. Look at your graphed data, and record in your science notebook any relationship you notice.

4. The table below shows the gravitational force between Saturn and some ring particles that are at different distances from the planet. All of the particles have a mass of 1 kg.

Table 2: Distance and Gravitational Force Data

Distance of 1-kg Ring Particle from Center of Saturn (in 1,000 km)	Gravitational Force between Saturn and 1-kg Ring Particle (in 10,000 N)
100	38
120	26
130	22
150	17
180	12
200	9
220	8
250	6
280	5

5. Use the data on the table to make a graph of the relationship between distance and gravitational force. Label your graph "Gravitational Force and Distance."

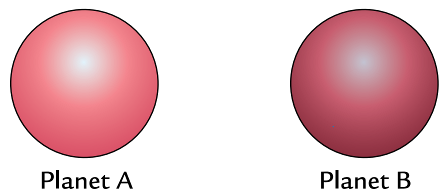
   Hint: Put the data for distance on the horizontal axis and the data for force on the vertical axis.

6. Look at your graphed data, and record in your science notebook any relationships you notice.

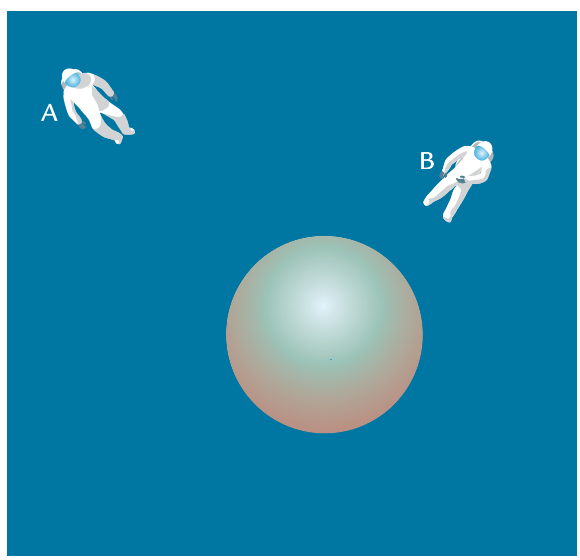
ANALYSIS

1. Compare your two graphs. Identify and explain any:
   a. similarities
   b. differences

2. Look at the pictures of the two planets below. Their diameters are the same, but Planet B has twice the mass of Planet A. Which one would you expect to have a stronger pull of gravity on its surface? Explain.



3. Look at the picture below of an astronaut at two different distances from a planet. In which position, A or B, would there be a stronger gravitational pull between the astronaut and the planet? Explain.



4. Your friend tells you that if you double the distance of a spacecraft from a planet, the gravitational pull is one half as strong. Do you think this is correct? Cite evidence from this investigation to support your position.

EXTENSION

Jupiter has about 300 times the mass of Earth. But gravity at its "surface" is only about three times the gravity on Earth's surface. Look at the Space Object Data Cards for Jupiter and Earth, shown below. Can you explain why the gravitational pull at Jupiter's "surface" is only about three times as much as Earth's?

Space Object 5 (Jupiter)

Shape: round

Orbits: the Sun

Composition: gaseous

Diameter: 143,000 km

Mass: 1,900,000,000,000,000,000,000,000,000 kg (1.9×10^{27} kg)

Other: Has rings

Space Object 11 (Earth)

Shape: round

Orbits: the Sun

Composition: rocky

Diameter: 12,800 km

Mass: 6,000,000,000,000,000,000,000,000 kg (6.0×10^{24} kg)

96 The Effects of Gravity

READING

The force of gravity holds us on Earth and helps objects in space stay in orbit. The planets in the Solar System could not continue to orbit the Sun without the force of gravity. Astronauts need to know a lot about gravity when they travel in space because they often orbit Earth. Those controlling the flight of any spacecraft must consider the effects of gravity from Earth and other planets on the spacecraft's course and safety.

CHALLENGE **How does gravity affect space travel?**

The pull of gravity between this astronaut and Earth keeps him in orbit.

MATERIALS

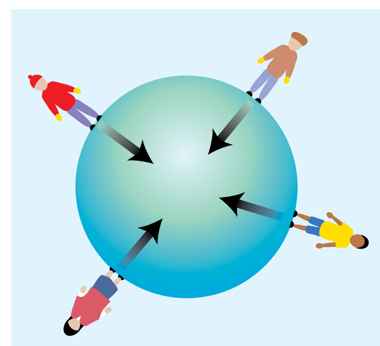
For each student

1 **Student Sheet 96.1, "Anticipation Guide: The Effects of Gravity"**

READING

Complete Student Sheet 96.1, "Anticipation Guide: Gravity" to help prepare for the following reading.

Direction of Gravity



Gravity is a force that pulls any two objects toward each other. You are familiar with gravity as the force that pulls things down toward Earth. But when considering Earth as a planet, which direction is "down"? Look at the diagram at right , which shows people standing on the surface of the Earth. "Down" is a different direction at different locations on the surface, but "down" is always the direction toward the center of Earth. Gravity always pulls the center of two objects toward each other.

STOPPING TO THINK 1

Argentina and Japan are on exactly opposite sides of the globe. Is "down" in Japan the same direction as "down" in Argentina? Explain.

Strength of Gravity—Mass and Distance

The strength of the force of gravity between two objects depends on the mass of the two objects and the distance between them.

All things with mass exert a gravitational pull on other objects with mass. The more mass an object has, the stronger it pulls. Earth is the most massive object near us, and so it has a strong attractive force. This is why things fall down toward Earth, specifically the center of Earth.

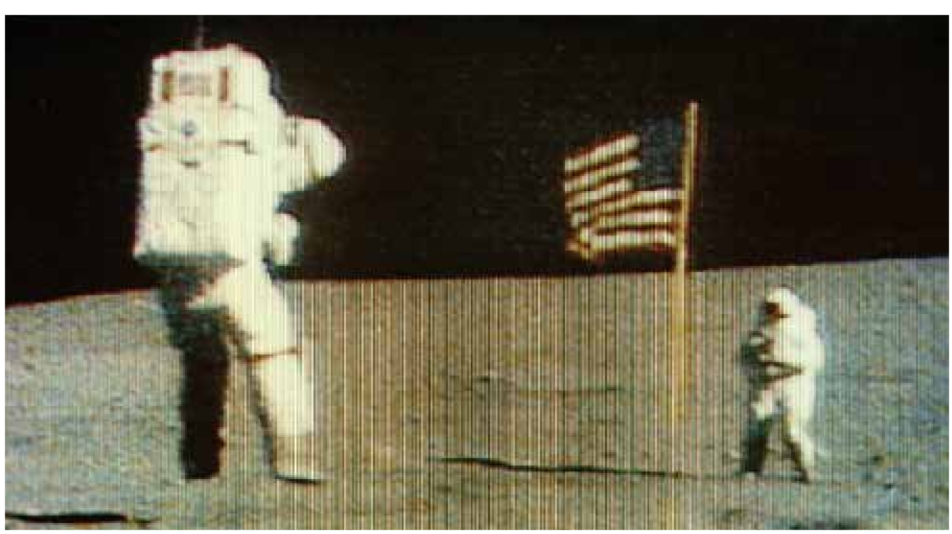
But, strange as it may sound, while Earth pulls on an object near it, the object also pulls Earth. When an object falls to the ground, even a paper clip, for example, Earth is pulled toward the falling object. This is because the falling object has mass, and any object with mass exerts a gravitational force on any other object. In the case of an object falling to Earth, however, the Earth moves much less than the object does, because Earth has so much more mass than the falling object.

The force of gravity near other planets is different than it is near Earth because each planet has a different mass. An object's **weight** on Earth is the pull of gravity between it and Earth. If the object is on another planet or moon, its weight is the force of gravity between it and the planet or moon. For example, Jupiter's gravitational pull is stronger than Earth's because Jupiter has more mass than Earth. A 10-kg rock on Earth would still have 10 kg of mass near Jupiter, but the rock's weight would be greater near Jupiter.

STOPPING TO THINK 2

Why do astronauts have the same mass on the Moon as they do on Earth, but weigh less on the Moon?

The reduced weight of this astronaut made him bounce when he walked on the Moon. In this television picture from a Moon landing, the astronaut jumped high as he saluted the flag.



Across a very long distance, gravity pulled these two galaxies toward each other.

When an object near Earth drops, it falls toward Earth instead of toward a more massive object, such as Jupiter or the Sun. This means the force of gravity must be determined by something more than mass. As you saw in the last activity, the farther away an object is from a planet, the weaker the gravitational force between them. The opposite is also true—the closer two objects are, the stronger the gravitational force between them. You may not have realized it, but you weigh slightly less when you are in an airplane flying high above Earth because you are farther from the center of Earth. A 150-pound person weighs about one-half pound less while flying in an airplane. Similarly, since the Sun is so far away, its gravitational pull on objects near Earth is not as strong as Earth's, even though it has much more mass than Earth.

Although the pull of an object's gravity decreases as you move farther away from it, gravity never entirely disappears. There is always a gravitational attraction between the centers of two objects, no matter how far apart they are. The long reach of gravity is an important consideration for space travel. When a spacecraft is launched, it only needs to use fuel until it gets so far away from Earth that Earth's gravity has very little effect on it. Beyond that point, it travels without using any fuel at all (except when it needs to slow down or turn). If it gets close enough to another planet, the Moon, or the Sun, the gravitational force between the two will increase and the spacecraft will be pulled toward that object.

STOPPING TO THINK 3

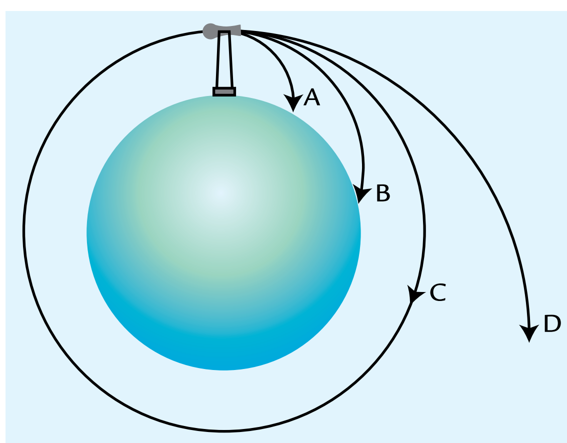
a. Would you expect to weigh more on an ocean beach or on top of a mountain? Explain.

b. Outside the Solar System is there any gravitational pull from the Sun?

Gravity and Orbiting Objects

Since Earth's gravity pulls everything down toward its center, why don't satellites and even the Moon come crashing down to Earth? Strange as it may seem, gravity helps satellites and the Moon stay in orbit around Earth.

Imagine throwing a ball as fast as you can. It might go 30 meters before it hits the ground. The ball curves as it falls because the force of gravity is pulling it down as it travels. Next, imagine that you have a cannon on the top of a tall tower as in the diagram below. Your cannonball might go quite a distance before it hits the ground (Path A). Now, imagine that you have a cannon that can fire a cannonball faster. It would travel much farther before falling to the ground (Path B). If you could keep firing cannonballs at higher and higher speeds, eventually one would go fast enough that it would "fall"all the way around Earth, but never hit the ground (Path C). An orbiting object is being pulled down by gravity, but it is going fast enough that it never actually hits the ground. If a satellite, or even the Moon, were not moving fast enough, it would begin to spiral back to Earth.



A & B: Speed too slow:
Satellite falls back to Earth because "orbit" is too small.

C: Speed just right:
Satellite stays in orbit around Earth.

D: Speed too fast:
Satellite goes beyond orbit and does not return.

When a spacecraft is launched, launch speed is very important. If the speed is too low, it will fall back to Earth like the cannonball in Path A. If the speed is just right, it will go into orbit. If the speed is greater than what is needed for the spacecraft to get into orbit, it can break away from Earth's gravity. This is how spacecraft are sent to the Moon, Mars, or farther.

STOPPING TO THINK 4

What is likely to happen to a rocket that takes off at a slow speed?

A shuttle is launched from the Kennedy Space Center, Cape Canaveral, Florida.

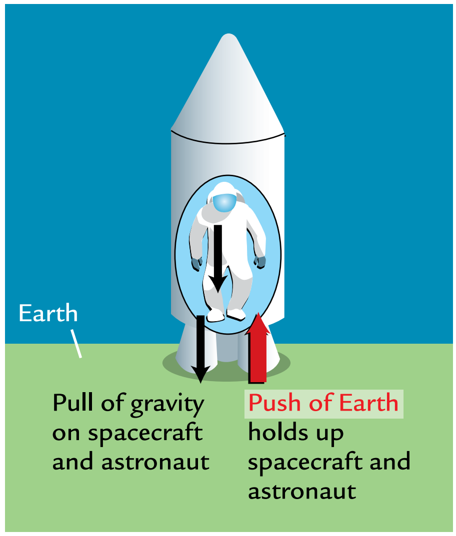
Weightlessness

Outside the Solar System, far away from the Sun and any planets, the pull of gravity is so small that a 150-pound person would not have any measurable weight at all. So far, no human has ever gone that far. Astronauts orbiting around Earth are too close to Earth to experience near-zero gravity. A 150-lb person weighs about 136 lbs while orbiting Earth. However, an astronaut may still feel "weightless" in an orbiting spacecraft. The reason astronauts "float" in space is not because they there is no force of gravity. Instead, they "float" because they are moving in an orbit. As they move along the path of the orbit, the spacecraft and the astronauts on board are constantly falling towards Earth due to the pull of gravity. This free falling makes astronauts appear to be floating.

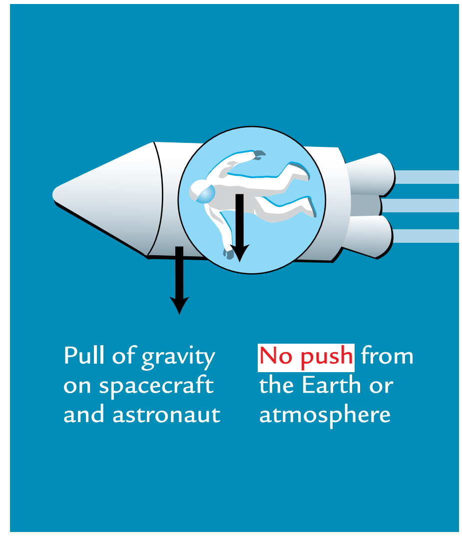
The astronauts' weightlessness is the same as you feel for a moment when you're on a rollercoaster and your car plunges down a steep slope. Both your body and the rollercoaster car are free-falling together, just like the astronaut in a spacecraft. You can experience "weightlessness" yourself if a gravitational force pulls on you but you are not held up by a surface, as shown at right.

STOPPING TO THINK 5

How is going over the top of a rollercoaster like experiencing "weight-lessness" in space?



On Earth's surface, the Earth pushes the spacecraft and astronaut up just as much as the gravitational force pulls them down.



In orbit, the Earth and its atmosphere are not pushing up. The spacecraft and astronaut fall freely and experience "weightlessness."

ANALYSIS

1. Choose one of the objects listed in the table to the right. Describe how astronauts' weights might change if they visited the object.

2. Your friend tells you that there is no gravity in the space shuttle, which orbits at 400 km (250 miles) above Earth. Do you agree or disagree? Explain.

3. What do you think would happen to a satellite in orbit if it suddenly stopped? Explain.

Object	Mass*
Mercury	0.055
Venus	0.86
Earth	1.00
Mars	0.11
Jupiter	318
Saturn	95
Uranus	14.5
Neptune	17.2
Sun	330,000
Moon	0.01

**relative to Earth*

97 Exploring Outer Space

The National Aeronautics and Space Administration (NASA) has a yearly budget of about $15 billion for space exploration. Although this is a lot of money, it is not enough to fund every project that NASA scientists propose. To help NASA administrators decide which exploration projects to fund, they sometimes listen to recommendations from a panel of space flight experts.

CHALLENGE **What types of space exploration should NASA fund?**

MATERIALS

For each student

1 **Student Sheet 97.1, "Intra-act Discussion: Exploring Outer Space"**

"There is nothing like take-off. It's terrifying, exhilarating, emotional. When the two rockets on either side ignite, you know you are going someplace! If you aren't scared, you don't understand what's about to happen." Sally Kristen Ride, the first American woman in space.

"When the images came down and we could see horizon all the way around, that was every bit as exhilarating as getting to the top of any mountain I've climbed on Earth." Chris Leger, Mars Rover engineer.

PROCEDURE

1. Assign one of the following roles to each person in your group.
   - *Greta Puzon, NASA Administrator*
   - *Kato Barr, astronaut*
   - *Wanda Keller, aerospace engineer*
   - *Dr. Owen Rowley, NASA medical doctor*
2. In your group, read the role-play aloud. As you read, think about what each character is saying.
3. Discuss which types of space exploration should take place in the future.
4. Mark whether you agree or disagree with the statements on Student Sheet 97.1, "Intra-act Discussion: Exploring Outer Space." Predict what you think other members of your group will say.
5. Discuss the statements with your group. Have each person share his or her opinion about each statement and explain why he or she agreed or disagreed.

EXPLORING OUTER SPACE

Greta: Good morning. I've asked you to come here today to talk to the public about NASA's future. The space shuttle program, which has been a large part of NASA for 30 years, ended in 2011. Now that private companies are developing spacecraft to take cargo and crews to the international space station, also known as ISS, NASA will focus on exploring our Solar System and beyond. I'd like each of you to discuss NASA's plans for the future and your own ideas about piloted and unpiloted space exploration. Before we begin, please introduce yourselves, and tell us a little about your background. Kato, will you begin?

Kato: Good morning. I am Kato Barr, an American astronaut. I have spent 184 days in the ISS. While in space, I conducted biology and physics experiments in a reduced-gravity environment. The ISS is a unique place to test technologies that will allow us to explore the Solar System and beyond. Astronauts have tested the automatic refueling of spacecraft, advanced life-support systems, and robotic devices.

Wanda: Hello. My name is Wanda Keller, and I am an aerospace engineer who specializes in space rover design. I design, build, and test robotic vehicles that will one day visit the surfaces of other planets.

Planet Earth as viewed from space.

Owen: And I am Owen Rowley, a medical doctor for NASA's astronaut program. I am part of a medical team that monitored the health of the astronauts on the shuttle from the beginning of their training, through their flights, and for some time after they returned safely to Earth. Currently I monitor the health of the six astronauts in the space station. Americans will continue to make up part of the ISS crew. In the United States' section of the station, we have a laboratory for scientific research.

Greta: Thank you for the introductions. Let's begin by discussing the role of piloted missions. Kato, as someone who has traveled in space, would you tell us about the most exciting part of that experience?

Kato: I would have to say that seeing the beautiful blue Earth from such a great distance was a tremendous personal experience. In terms of science, we learned a lot about the effects of being in space in a near-weightless environment. We learned, for example, how muscles lose mass and bones get weaker when they don't have to work against the same force of gravity we have on Earth.

Greta: Humans have orbited Earth and walked on the Moon. The space shuttles traveled up to about 350 miles above the surface of Earth, and astronauts flew in our lunar modules to the Moon, 239,000 miles from Earth. Wanda, do you think we will see a piloted space flight to somewhere farther—namely, another planet?

Wanda: I'm not sure how or when this will happen, although NASA and its partners are working on some of the technologies. Mars is the most likely planet for a piloted visit. But even when it is closest to Earth, Mars is almost 150 times farther away than the Moon. One NASA project is development of the Orion multi-purpose crew vehicle. This spacecraft is designed to take four astronauts on 21-day missions. But this is just a small step toward the nearly two years it would take to reach Mars, explore as much of it as we can, and return.

Owen: We have a lot more to learn before we are sure we can protect astronauts on a long mission, such as a trip to Mars. Without the protection of an atmosphere, astronauts are exposed to a tremendous amount of harmful radiation from the Sun. Solar shields on space suits and radiation-resistant materials block out only some of the radiation from the Sun. In addition, as Kato described, muscles and bones weaken. Even the heart, which is a muscle, gets weaker when it is not constantly working against the same force of gravity the Earth has. Exercise helps the astronauts minimize this effect, but, even so, on a long trip they lose strength.

Kato: Wanda and Owen are right that we cannot yet deliver and protect a crew on such a long mission. Another challenge of a long trip to a planet is sending enough supplies. Everything needed for the entire mission would have to be packed on board. This extra cargo weight demands that we have stronger and heavier rockets and more fuel to power them. This adds more risk and cost to the mission.

Greta: As NASA administrator, I have been working with a team as they begin the development of the space launch system, which we call SLS. This will be a heavy-lift launch vehicle that will allow humans to explore beyond Earth's orbit. We are hoping the SLS rocket will be capable of carrying the extra cargo.

Kato: Owen, were you saying before that you don't think piloted flights are worth the dangers they present to people?

Owen: No, I'm only saying that we have a lot of work to do to protect humans on longer missions. The work of scientists and engineers in space exploration has given us a tremendous amount of scientific information. Technology for the space program has led to improvements in such medical devices as pacemakers, ultrasound, and CT scanners. These tools have advanced the treatment of disease and have helped save many lives here on Earth.

Greta: Teams at NASA are working on technologies that we will need for human crews to explore our Solar System. They are developing solar-electric-propulsion systems, planning to develop refueling depots in orbit, and working to develop better protection from radiation and life-support systems for longer trips.

An American astronaut exercises on a treadmill using a bungee cord harness aboard the International Space Station.


A Japanese astronaut participates in a space suit fit check.

Kato: There is certainly more risk and cost involved when you send humans into space, but I can see the benefits.

Wanda: I'm not convinced we need to take those risks. Satellites and probes can travel greater distances for longer periods of time than astronauts can. And we are constantly improving the types of instruments that are placed on rovers, landers, and satellites to collect data.

Greta: But can instruments take the place of humans in conducting complicated experiments?

Wanda: Let me respond with two examples. The rovers on Mars used a robotic tool for sampling rocks. Scientists on Earth can make rovers drive up to a rock and extend the tool to drill into the surface. The rover then takes a picture and collects data about the inside of the rock, which is then sent to Earth for analysis. We also have a Mars science laboratory called Curiosity. It carries instruments for studying the surface of Mars.

Owen: Curiosity will also study radiation during the trip and on the surface of Mars. This will provide information necessary for planning piloted missions to Mars.

Kato: Unpiloted missions certainly make sense for exploring the outer planets and beyond. The Kepler mission is looking for star systems that might have a planet that can support life. Another mission carries telescopes that will search for black holes and other distant objects in space. Unpiloted missions allow us to gather information for many more years and from a much greater distance.

Greta: What types of missions would you like to see NASA conduct in the future?

Owen: I think it's important to develop technology that will allow us to travel farther and live in harsh environments that are unlike those on our own planet. I hope that someday spacecraft will carry humans to greater distances in space and also help us conduct more research on the human body. In this way, piloted space exploration helps both research on space and people here at home.

Kato: We have not landed on the Moon since 1972. I think we should again send missions to the Moon and build a complete space station there. This would allow astronaut crews to spend extended time in space and possibly use the Moon as a launching pad for explorations to other planets, like Mars. Other nations, such as China, are working toward sending crewed missions and building bases on the Moon and Mars. I think we should too.

Greta: Currently, NASA has a mission to study the Moon's gravitational field and learn about the structure of the Moon's interior. This information would be a first step in possibly putting a space station on the Moon.

Wanda: I still think NASA should focus on unpiloted missions. Piloted missions are simply not efficient or worth the risk. For less money and less development time, unpiloted spacecraft can perform important tests about the composition, gravity, and environment of the Moon and other planets.

Greta: I want to thank you for taking the time to come together to share your expertise. We know that NASA's future will include missions to better understand the Earth, the Solar System, and the universe. NASA wants to answer such questions as: Could Mars have ever supported life? What resources can we mine from the moon? What can we learn about the origin of the universe? Your work will help us figure out the best way to accomplish our goals.

In 2004, the Cassini spacecraft began orbiting Saturn and began taking measurements of Saturn and its moons.

New Planet Discovered Near Sun-like Star

On December 5, 2011, NASA announced that the Kepler mission confirmed its first discovery of a planet with features that suggest it could support life. The unpiloted Kepler spacecraft carries an instrument that is extremely sensitive to light. The new planet, called Kepler–22b, is in the center of its sun's "habitable zone." This zone is an area around a star with temperatures that would allow liquid water to exist on a planet's surface. Kepler–22b is about 2.4 times larger than Earth and 600 light-years away. This means that it takes 600 years for light from Kepler-22b's sun to reach Earth.

The Kepler mission was launched in March 2009, with the purpose of finding planets that could possibly support life. The Kepler mission has found evidence for more than 1,000 planets orbiting distant stars. Most of those planets are very large or at the very edge of the habitable zone, and are unlikely to support life. At least 10 of those planets are similar in size to Earth and orbit in the habitable zone of their sun. Follow-up investigations are needed to confirm all of these planets. In April 2012, NASA announced a plan to extend the Kepler mission into 2016.

ANALYSIS

1. Construct two tables in your science notebook like the ones below. Use the information presented in the role-play to complete the tables on the advantages and disadvantages of:
   a. unpiloted space exploration
   b. piloted space exploration

a. Unpiloted Space Exploration

Advantages	Disadvantages

b. Piloted Space Exploration

Advantages	Disadvantages

2. **Reflection:** If you had the opportunity, would you go on a mission into outer space? Explain why or why not.

EXTENSION

Visit the *Issues and Earth Science* page of the SEPUP website for links to information about what it would be like to travel into space as an astronaut. Describe the living conditions in a spacecraft. What does it take to become an astronaut?

98 Choosing a Mission

There has been a lot of debate about whether piloted spacecraft should return to the Moon or travel even farther to other planets. After nearly 50 years of spaceflight, the future of space exploration remains uncertain. Now that you know much more about the Solar System and space exploration, you are better able to make an informed decision about future space missions.

You and your classmates are participating in a National Government Council meeting to discuss this year's budget for space exploration. The government has set aside money to pay for one new space mission. As members of the Council, you have to decide which mission to fund.

CHALLENGE

What kinds of future space missions should we conduct?

MATERIALS

For each student

1 **Student Sheet 89.1, "Planet Information"**

1 **Student Sheet 98.1, "Comparing Four Space Missions"**

PROCEDURE

1. Read about four proposed space missions on the next page.
2. Review Student Sheet 89.1, "Planet Information."
3. Use Student Sheet 89.1, and anything else you have learned in this unit to evaluate the missions with your group. Discuss how you think the money should be spent by studying the following about each mission:
   - what scientists can learn on the mission
   - what makes the mission interesting
   - special challenges to the mission
4. Compare the missions by completing Student Sheet 98.1, "Comparing Four Space Missions." In the last column of the table, rank on a scale of 1 to 4 how much you support each mission, with 1 indicating the most support and 4 indicating the least support.
5. With your group of four students, come to an agreement about which mission the money should fund. Support your ideas with the information about the planets and the missions.
   - Remember to listen to and consider the ideas of other members of your group.
   - If you disagree with others in your group, explain why you disagree.
6. Present your recommendation to the class.

Mission Proposal A

Destination: Kuiper Belt

Type of mission: unpiloted

Estimated travel time (one way): 16 years

Unlike previous missions to the outer Solar System, the spacecraft for this one will carry a lander that will go to Pluto and take samples of the surface rocks. The spacecraft will also have the best remote sensing instruments possible. The instruments will send back information on all the planets the spacecraft passes along the way. The spacecraft will continue into the Kuiper Belt and visit other objects beyond Pluto. The data gathered could help us better understand what it is like at the edge of the Solar System.

Mission Proposal B

Destination: Mars

Type of mission: piloted

Estimated travel time (one way): 8 months

This mission is different than previous missions to Mars because it will be piloted. Mars is Earth's closest neighbor in the Solar System so it is reasonable for a piloted flight to get there. Mars is the most important place to visit because it has the possibility of having supported life. It may have had water in the past. The best way to find out as much as we can is to send people there and bring rock samples back to Earth.

Mission Proposal C

Destination: Titan, Saturn's largest moon

Type of mission: unpiloted

Estimated travel time (one way): 4 years

Titan has an atmosphere, and some people suspect it may even have water. The mission's rover will explore the surface of Titan and look for water. And since Titan orbits Saturn, the instruments on the lander will use remote sensing to provide detailed pictures and composition data of Saturn and its rings. As a "gas planet," Saturn doesn't have a solid surface. The pictures would help us know what a gas planet looks like up close.

Mission Proposal D

Destination: the Moon

Type of mission: piloted

Estimated travel time (one way): 2 days

The goal of this mission is to establish a base on the Moon. Before sending astronauts on a long mission to another planet, we need to make sure that they will be as safe as possible. The base on the Moon will allow us to test out new equipment in a lower-gravity situation. It will also let us learn more about the effects on the body of living in space for a long time. This will prepare us for piloted missions to farther places, and may provide a place for future colonization.

ANALYSIS

1. What other information do you wish you had known before making a final decision?

2. Write a letter to the National Government Council stating your recommendation for which of the four missions to fund. Convince the council with evidence you gathered in this activity and unit. Be sure to present the trade-offs of your recommendation.

EXTENSION

Space missions that are going on now are described on the NASA website. Research one of these current missions. Describe the goals of the mission, the spacecraft, measuring devices used, and what scientists are learning during the exploration.

Index

A **bold** page number identifies the page on which the term is defined.

A

B

C

D

E

G

H

I

J

K

L

M

N

O

P

T

U

V

W

Credits

Abbreviations: t (top), m (middle), b (bottom), l (left), r (right), c (center)

All illustrations by Seventeenth Street Studios / Valerie Winemiller.

Cover (front): volcano: Photodisc / Getty Images

"Problem Solving" icon photo: ©Thom Lang / Corbis
"Talking It Over" icon photo: ©Michael Keller / Corbis

UNIT A

Unit title (A1) Suzanne Paisley ©The Regents of the University of California; Unit opener (A2, A3): tl: Suzanne Paisley ©The Regents of the University of California; tr: Erwin Cole, USDA Natural Resources Conservation Service; mr: Jack K. Clark ©The Regents of the University of California; br: ©The Regents of the University of California; bl: Jack K. Clark ©The Regents of the University of California; A7 l, r: Jack K. Clark, ©The Regents of the University of California; A11 Jeff Vanuga, USDA, Natural Resources Conservation Service; A14 tl, tr, bl, br: Lab-Aids®, Inc.; A18 Lab- Aids®, Inc.; A19 t: Lab-Aids®, Inc., b: Jack K. Clark, ©The Regents of the University of California; A23 l: ©Lynn Betts, USDA Natural Resources Conservation Service; r: Suzanne Paisley ©The Regents of the University of California; A27 USDA Natural Resources Conservation Service; A29 tl: National Park Service; tr: Suzanne Paisley ©The Regents of the University of California; bl: Jack K. Clark, ©The Regents of the University of California; br: Peter Bowater / Photo Researchers, Inc.; A33 Resettlement Administration, Courtesy USDA; A34 tl, bl, br: Jack K. Clark, ©The Regents of the University of California; tr: Erwin Cole, USDA Natural Resources Conservation Service; A35 Resettlement Administration, Courtesy USDA; A37 Lab- Aids®, Inc.; A41 Ken Hammond, USDA Agricultural Research Service.

UNIT B

Unit title (B1) Courtesy of Ward's Natural Science; Unit opener (B2, B3): tl: Carnegie Institution of Washington, tr: National Park Service, mr: ©Marli Bryant Miller; br: ©Corbis; bl: Schenectady Museum; ml: ©United States Geological Survey; B4 Photodisc / Getty Images; B7 Robert Weldon, Courtesy of Aurora Gems, N.Y. from the Aurora Collection of Natural Color Diamonds; B11 diamond: Charles D. Winters / Photo Researchers, Inc.; calcite: Dorling Kindersley / Getty Images; glass: Photodisc / Getty Images; B15 tl: Alfred Pasieka / Photo Researchers, Inc.; tr: E. R. Degginger / Photo Researchers, Inc.; b: Lab-Aids®, Inc.; B17 all photos courtesy of Ward's Natural Science except orthoclase: United States Geological Survey; B20 Photodisc / Getty Images; B24: Courtesy of Ward's Natural Science; B30 bl: ©Stone Trust, Inc. / Earth Science World Image Bank; tr: ©Marli Bryant Miller; B32 ©Brian Law / Earth Science World Image Bank; B33 ©Corbis; B34 United States Geological Survey; B35 l: Rafael Macia / Photo Researchers, Inc. r: Photodisc / Getty Images; B41 t: National Park Service; b: Mark C. Burnett / Photo Researchers, Inc.; B47 Photodisc / Getty Images; B49 Schenectady Museum; B50 l: Courtesy of the Gemesis Corporation, r: Robert Weldon, Courtesy of Aurora Gems, N.Y. from the Aurora Collection of Natural Color Diamonds.

UNIT C

Unit title (C1) ©Oklahoma University / Earth Science World Image Bank; Unit opener (C2, C3) tl: Dr. Arthur Gibbs Sylvester; tr: ©AJ Mandolesi / Earth Science World Image Bank; br: ©Marli Bryant Miller; bl: Photodisc / Getty Images; C6 tl: United States Fish and Wildlife Service; tr: Photodisc / Getty Images; ml: ©Galen Rowel / Corbis; mr: ©Phil Schermeister / Corbis; bl: Graham Ewens / Photo Researchers, Inc.; br: Dr. Jeremy Burgess / Photo Researchers, Inc.; C8 United States Geological Survey; C11 Yellow Dog Productions / Getty Images; C18 ©Oklahoma University / Earth Science World Image Bank; C20 Connie Bransilver / Photo Researchers, Inc.; C22 l: National Park Service; r: ©Marli Bryant Miller; C23 James Steinberg / Photo Researchers, Inc.; C24 t: ©Paul Souders / Corbis; bl: John R. Foster / Photo Researchers, Inc.; br: Francesco Tomasinelli / Photo Researchers, Inc.; C25 Adapted from United States Geological Survey; C26 t: USDA Natural Resources Conservation Service; bl, br: ©Lynn Betts, USDA Natural Resources Conservation Service; C28 Adapted from National Oceanic and Atmospheric Administration; C31 ©Smiley N. Pool / Dallas Morning News / Corbis; C32 Georg Gerster / Photo Researchers, Inc.; C35 ©Marli Bryant Miller; C39 Dr. Arthur Gibbs Sylvester; inset: Dr. Robert M. Norris; C44 Grant Dixon / Getty Images.

UNIT D

Unit title (D1) R.E. Wallace / United States Geological Survey; Unit opener (D2, D3) tl: ©Bettmann / Corbis, tr: Image Science and Analysis Laboratory, NASA, Johnson Space Center; mr: C.E. Meyer/ United States Geological Survey; br: Photodisc / Getty Images; bl: ©Reuters / Corbis; B4 United States Department of Energy; D6 Corbis; D7 ©Tim Wright / Corbis; D9 l: J.D. Griggs / United States Geological Survey; r: United States Geological Survey; D15 Stephen and Donna O'Meara / Photo Researchers, Inc.; D16 t: W. E. Scott / United States Geological Survey; m: J. Lowenstern, United States Geological Survey; b: Donald A. Swanson / United States Geological Survey; D17 ©Roger Ressmeyer / Corbis; D20 ©Louie Psihoyos / Corbis; D21 ©Annie Griffiths Belt / Corbis; D23 ©Bettmann / Corbis; D27 Richard Paselk, Humboldt State University Natural History Museum; D29 Cousteau Society / Getty Images; D31 l: R.E. Wallace / United States Geological Survey; r: ©Reuters / Corbis; D35 C.E. Meyer / United States Geological Survey; D39 National Oceanic and Atmospheric Administration; D43 ©Tepco / Jana Press; D48 Image Science and Analysis Laboratory, NASA, Johnson Space Center; D51 ©Galen Rowell / Corbis; D54 Science Source; D56 Map 1: http://www.census.gov/prod/cen2010/briefs/c2010br-01.pdf, Figure 7; Map 2: based http://nrc.gov/reactors/operating/map-power-reactors.html; Map 3: based on http://pubs.usgs.gov/fs/2006/3016; D57 Map 4: based on http://pubs.usgs.gov/fs/2006/3014; Map 5: based on http://www.legalectric.org/f/2011/12/granite-report-sand2011-6203.pdf, page 20; Map 6: based on http://nationalatlas.gov/mapmaker?AppCmd=CUSTOM&LayerList=Aquifers&visCats=CAT-hydro.CAT-aquifers.

UNIT E

Unit title (E1) / Corbis; Unit Opener (E2,E3) tl: National Oceanic and Atmospheric Administration (NOAA); ml: Juan Silva / Photodisc / Getty Images; bl: Tom Tschida / NASA Dryden Flight Research Center Photo Collection; tr: Corbis; br: Corbis; E6 Image Source / Getty Images; E7 tl: Jim Reed / Digital Vision / Getty Images; bl: © Richard Carson / Reuters / Corbis; E10 bl: Digital Vision / Getty Images; br: Joe Raedle / Getty Images / Getty Images; E15: NOAA; E16 bl: David W. Hamilton / The Image Bank / Getty Images; br: Ian Waldie / Reportage / Getty Images; E18 British Antarctic Survey / Photo Researchers, Inc.; E20 bl: Robert Harding / Digital Vision / Getty Images; br: Philip Nealey / Photodisc / Getty Images; E21 tl: Photodisc / Getty Images; bl: Corbis; tr: Image Source / Getty Images; br: Corbis; E24 Viktor Drachev / AFP / Getty Images; E25 Noboru Komine / Photo Researchers, Inc.; E30 t: Corbis; b: Corbis; E35 Tom McHugh / Photo Researchers, Inc.; E38 t: Corbis; b: ©Gideon Mendel / Corbis; E40 Allen M. Shimada, NMFS / NOAA Corps Collection; E42 Martin Puddy / Stone / Getty Images; E45 t: Chad Ehlers / Stone / Getty Images; b: Digital Vision / Getty Images; E47 Richard Ashworth / Robert Harding World Imagery / Getty Images; E50 Captain Albert E. Theberge, NOAA, Corps (ret.) / NOAA / America’s Coastlines Collection; E51 Jim Reed / Photo Researchers, Inc.; E53 t: D. Robert Franz / Taxi / Getty Images; bl: Caroline Woodham / Photodisc / Getty Images; br: Juan Silva / Photodisc / Getty Images; E55 Stephen Ausmus / United States Department of Agriculture (USDA) / Agricultural Research Service (ARS); E60 Grant V. Faint / Photodisc / Getty Images; E62 Corbis; E66: Tom Tschida / NASA Dryden Flight research Center Photo Collection; E67 British Antarctic Survey / Photo Researchers, Inc.; E69 D.A. Peel / Photo Researchers, Inc.; E72 Digital Vision / Getty Images; E75 Science Photo Library / Photo Researchers, Inc.; E77 tl: Image Source / Getty Images; tr: Glowimages / Getty Images; bl: STR / AFP / Getty Images; br: Francoise Sauze / Photo Researchers, Inc.; E81 Photodisc / Getty Images; E95 Corbis; E96 Andrew Gunners / Digital Vision/Getty Images.

UNIT F

Unit title (F1) Photodisc / Getty Images; Unit opener (F2, F3) tl: Photodisc / Getty Images; tr: Photodisc; ml: Photodisc; bl: NASA / Photo Researchers, Inc.; br: Digital Vision; F15 ©Araldo de Luca / Corbis; F17 NASA / Photo Researchers, Inc.; F19 tl, bl: Frank Zullo / Photo Researchers, Inc.; tr: Jonnie Miles / Photodisc / Getty Images; br: Arthur S. Aubry / Photodisc / Getty Images; F32 ©Philip Gendreau / Bettmann / Corbis; F35 Troy Cline / NASA; F36 Reto Stöckli / NASA; F37 Reto Stöckli / NASA; F42 David Nunuk / Photo Researchers, Inc.; F44 Eckhard Slawik / Photo Researchers, Inc; F47 Photodisc / Getty Images; F50 r, l: Andrew J. Martinez / Photo Researchers, Inc.; F55 tl: ©Corbis Sygma; tr: ©B.N.F. / Corbis Sygma; bl: ©Cesar Vera / Latinvisions / Corbis; br: Macduff Everton / Getty Images; F60 t, m: National Park Service; b: Hisham F. Ibrahim / Photodisc / Getty Images.

UNIT G

Unit Title (G1) Photodisc / Getty Images; Unit opener (G2, G3) tl: Cassini Imaging Team, Cassini Project, NASA; tr: Photodisc / Getty Images; ml, mr: NASA; b: NASA / JPL-Caltech / Cornell; G4 tl: Keystone / Stringer / Getty Images; tr, bl, bc, br: NASA; G9 all: Photodisc / Getty Images; G12 NASA, ESA, and the Hubble SM4 ERO Team; G13 tl: SPL / Photo Researchers, Inc.; tr: Gianni Tortoli / Photo Researchers, Inc.; b: Courtesy of the Archives, California Institute of Technology; G14 t: Courtesy of the Archives, California Institute of Technology; b: Margaret Bourke-White / Time & Life Pictures / Getty Images; G15 t: Harvard College Observatory / Photo Researchers, Inc; b: NASA; G17 National Optical Astronomy Observatory/Association of Universities for Research in Astronomy/ National Science Foundation; G24 Spencer Grant / Photo Researchers, Inc.; G27 tl: ©Corbis; tr: Antonio M Rosario / The Image Bank / Getty Images; bl: Photodisc / Getty Images; br: Space Frontiers / Getty Images; G32 John Henry Claude Wilson / Robert Harding World Imagery / Getty Images; G33 Photodisc / Getty Images; G34 British Antarctic Survey / Photo Researchers, Inc.; G35 Dr. Jeremy Burgess / Photo Researchers, Inc.; G37 l: NASA / JPL Ocean Surface Topography Team; r: NASA / JPL / University of Arizona; G41 NASA / JPL; G43 Photodisc / Getty Images; G44 Photodisc / Getty Images; G49 Photodisc / Getty Images; G51 NASA; G52 NASA / The Hubble Heritage Team / STScI / AURA; G54 NASA; G56 l: Frederic Lewis / Getty Images; r: NASA / JPL; G58 Photodisc / Getty Images; G59 NASA; G60 NASA G61 NASA / JPL; G65 t: Dr. R. Albrecht, ESA / ESO Space Telescope European Coordinating Facility / NASA; b: Photodisc / Getty Images; G66 t: NASA, ESA and Erich Karkoschka (University of Arizona); b: Photodisc / Getty Images.