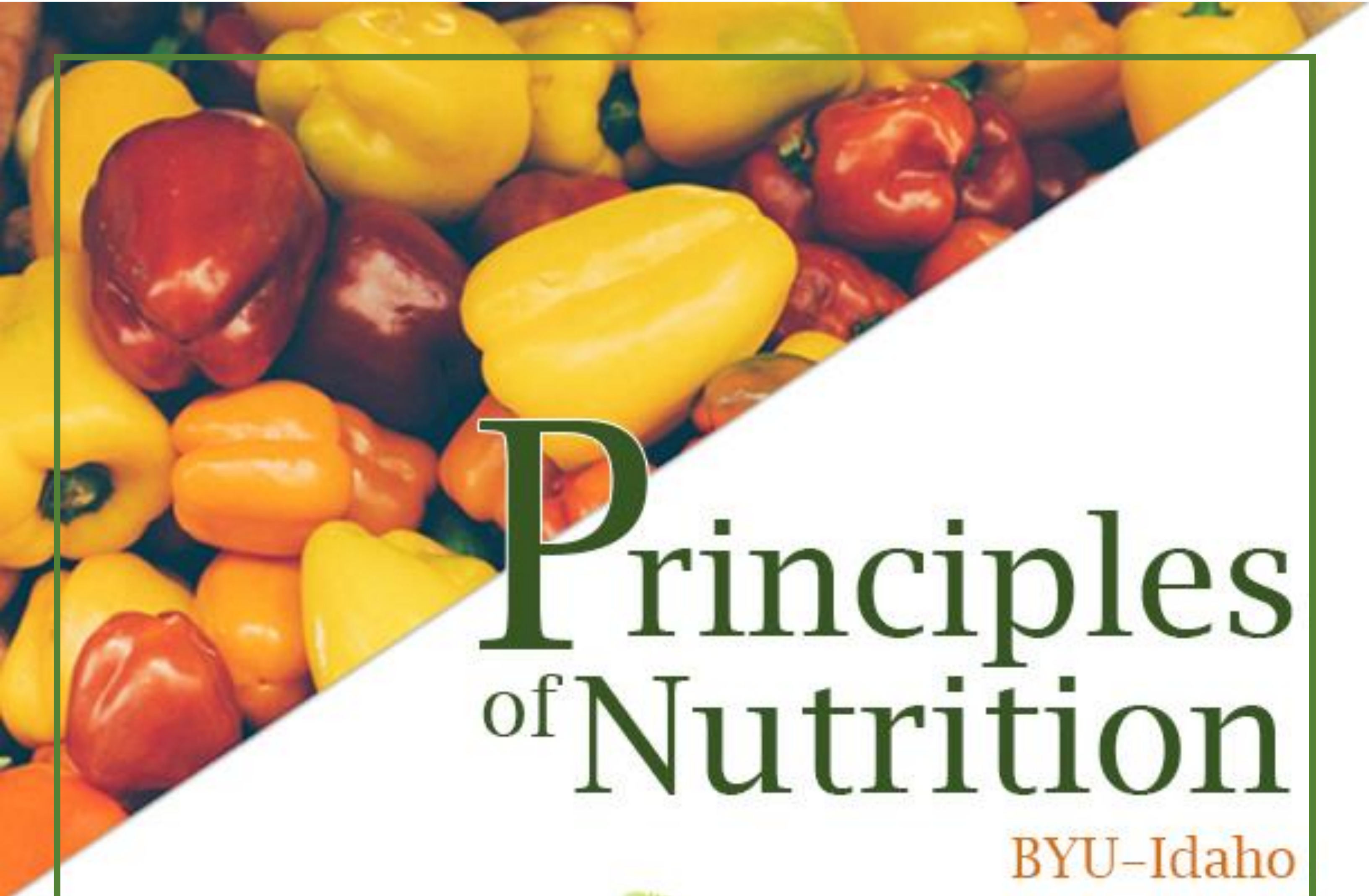


Principles of Nutrition

BYU–Idaho

About Principles of Nutrition

BYU-Idaho Edition – Revised 12/17/20

Principles of Nutrition was created at BYU-Idaho under the direction of the Nutrition faculty. It incorporates the best nutrition information known to science with principles taught in the Church of Jesus Christ of Latter-day Saints. Best efforts have been made to integrate the Gospel and science to help students make optimal nutrition choices.

Copyright

Additions to the text were made at BYU-Idaho and BYU-Provo, and from the sources noted in the reference section.

Contributions by

Jennie Oler Botkin, MS, RDN
Amanda Christensen, MS, RDN
Kathy Jo Cook, PhD, MPH, RDN
Jay Keller, MS, RDN, CSSD
Rachel England Wasden, BS
and the BYU-Idaho Curriculum Development group

Table of Contents

Chapter 1: Introduction to Nutrition Science

1.1 Nutrition Science

The importance of daily physical nourishment in the form of food and water was made clear to our first parents when they were introduced into the Garden of Eden.

> *Genesis 1:16 And the LORD God commanded the man, saying, of every tree of the garden thou mayest freely eat…*[1]

A significant amount of work was then required to maintain a food supply when Adam and Eve were cast out of the Garden of Eden.

> *Genesis 3: 17-19 …cursed is the ground for thy sake; in sorrow shalt thou eat of it all the days of thy life; Thorns also and thistles shall it bring forth to thee; and thou shalt eat the herb of the field; In the sweat of thy face shalt thou eat bread, till thou return unto the ground; for out of it wast thou taken: for dust thou art, and unto dust shalt thou return.*[1]

Adam and Eve in prayer

Since the time of Adam and Eve, our understanding of the importance of food and the effort that is necessary to produce or acquire it has not changed significantly. However, we have been blessed with additional light and understanding regarding the chemical composition of food, how the human body digests and absorbs the food, and how the components of food then maintain the body processes necessary for life. What we call **nutrition** today, is the sum of all these processes. The discipline of **nutrition science** is the investigation of how an organism is nourished, and also incorporates the study of how nourishment affects personal health, population health, and planetary health. Nutrition science includes a broad spectrum of disciplines such as biology, physiology, immunology, biochemistry, food science, agriculture, education, psychology, and sustainability.

The restored gospel teaches that there is an intimate link between body, mind, and spirit. In the Word of Wisdom, for example, the spiritual and physical are intertwined. When we follow the Lord's law of health for our bodies, we are also promised wisdom to our spirits and knowledge to our minds (see D&C 89:19–21)[2]. The spiritual and physical truly are linked.

Nutrition Science History

Historical records document the remarkable ability of early scientists to recognize a relationship between food components and disease states. As long ago as 1500 B.C., Egyptian records hint at a connection between a condition called night blindness and a component of the liver. In a collection of writings from the school of Hippocrates in 300 B.C., the author recommends the eating of "raw beef liver" soaked in honey to treat night blindness.[3] In the middle ages a Dutch physician wrote the following poem:

Who does not at night see right
Eats the liver of a goat
He will then see better at night [3]

Through careful observation and experimentation, these early scholars were able to identify a dietary treatment for night blindness correctly. The high vitamin A content of the liver was the active agent that cured the night blindness.

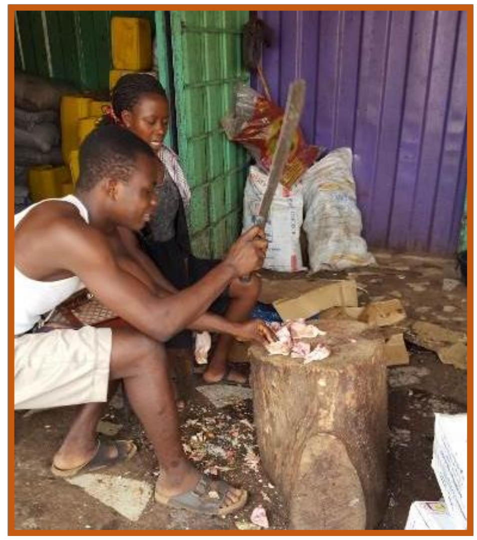
This process of discovery has continued into contemporary times. A disease called scurvy ravaged millions of sailors engaged in intercontinental travel up through the mid-1800's. The disease was characterized by weakness, apathy, bleeding gums, swollen legs, joint pain, skin bruising, impaired wound healing or even may result in death.

Bruising and skin hemorrhaging from scurvy

In the 1700's James Lind conducted experiments with citrus fruits on the British Royal Navy. His research indicated that scurvy could be prevented with this type of fruit. Lind is often credited for making the connection between citrus fruit and scurvy, but historically it seems that other health professionals had recognized this connection for hundreds of years before Lind conducted his studies.[4] In the 1930's a team of researchers identified the substance in citrus fruits that cures scurvy. It was named ascorbic acid (meaning without-scurvy acid) or vitamin C.[5-7] Similar historical stories are available for many of the essential nutrients we will discuss during this course.

Importance of Nutrition

Without adequate nutrition, the human body does not function optimally, as illustrated in the case of vitamin C deficiency. Nutritional inadequacy can lead to disease and even death. Modern revelation also teaches us that the physical well-being of an individual is inseparably connected with their spiritual health. The biblical story of Daniel, Shadrach, Meshach, and Abed-Nego is an excellent example of the interconnection of dietary choices with physical, mental and spiritual health.[1,8]



Local man in an open market in Ghana, Africa chopping fresh chicken on an old stump with a machete.

Today, many countries have access to abundant food resources and severe deficiencies such as scurvy are not common. Regardless whether noticeable nutritional deficiencies are physically present or not, poor dietary choices affect the quality of life. Your ability to think clearly, communicate, hope, dream, serve, go to school, go to work, or any other personal development is tied to the quality of your food choices.

School Lunch in Ghana, Africa including traditional foods as well as French fries and chicken

1.2 Types of Malnutrition

The prefix "mal" means bad and when coupled with nutrition would imply "bad-nutrition." Therefore, collectively malnutrition could be represented with either **overnutrition** or **undernutrition**. Overnutrition occurs when there is an overconsumption of nutrients from food or supplementation to the point at which health is adversely affected.[9] Undernutrition occurs when there are insufficient nutrients and can cause stunted height in children, a wasted appearance (too thin compared to a person's height), or deficiency diseases.[9]

Although severe undernutrition is rare in developed countries, it is a leading cause of death of children in underdeveloped countries. Undernutrition is intricately linked with suppression of the immune system at multiple levels; consequently, undernourished children commonly die from severe diarrhea or pneumonia resulting from bacterial or viral infections. In 2020, the World Health Organization reported about 45% of deaths among children under 5 years of age are linked to malnutrition. The majority of these deaths occurred in low- and middle-income countries.[10]

Throughout human history, undernutrition has been a leading cause of death in many countries. Although undernutrition continues to be an issue worldwide, a noticeable number of underdeveloped countries are progressing economically, socially, and culturally. As a country becomes more urban or developed, access to education increases which allows for improved employment opportunities. As a result, income increases, but the time available to prepare traditional foods decreases.[11] Urbanization within developing countries yields a greater availability of food in the country. Access to a variety of foods results in a more Westernized diet which includes higher fat, sugar, meat, milk and overall calories than typically consumed in their traditional diet.[12]

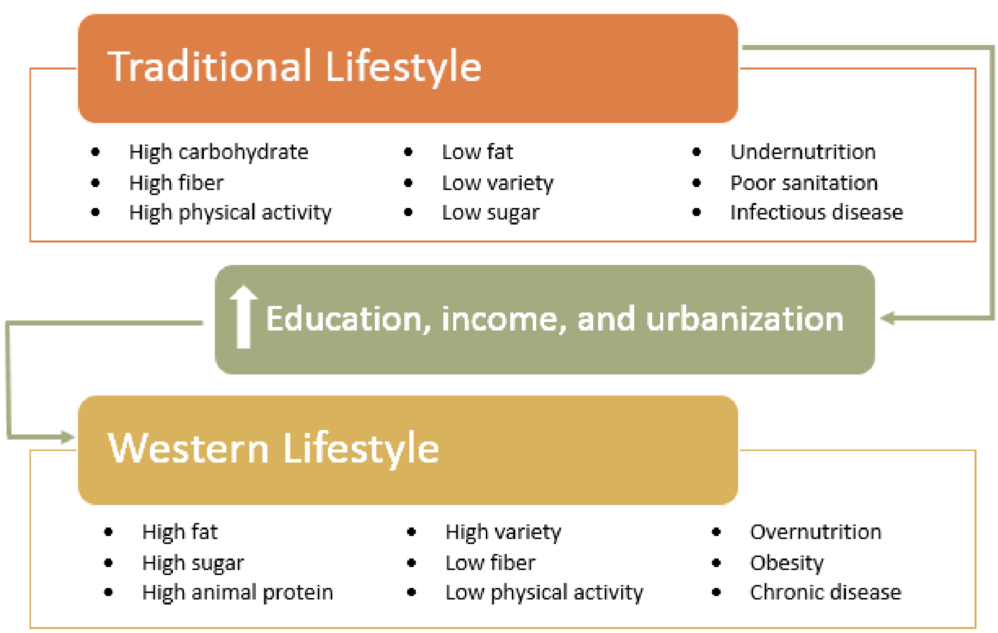


Figure 1: The nutrition transition from a traditional lifestyle to a Western lifestyle

This shift in diet composition is leading to the development of overnutrition in previously largely undernourished countries. Thus, countries that were mainly concerned about undernutrition and infectious disease are now also faced with the burden of chronic diseases caused by this transition in an industrial lifestyle and decreased physical activity (see Figure 1).[13] This coexistence of overnutrition and undernutrition in the same populations has led to the coining of a new phrase the **Double Burden of Malnutrition.**[14,15]

The urbanization of developing countries has some positive results, such as a decrease in infectious diseases and nutrient deficiencies, and an increase in lifespan. However, when a country does not recognize the risks of overnutrition, or correcting undernutrition past the point of being well nourished, the battle with chronic disease begins. This rapidly increasing double burden among developing countries emphasizes the importance of educating about risks of both undernutrition and overnutrition.[16,17]

Undernutrition and Deficiency Disease


Winter Quarters

Scurvy is an excellent example of the impact severe undernutrition can have on a person's life expectancy and quality of life. When identified, and if the proper resources are made available, this type of dietary deficiency is relatively easy to resolve. A good example of this occurred in early American history during the immigration of the Mormon pioneers. In the winter of 1846, as many as 600 immigrants died at Winter Quarters, largely from scurvy. In his travels as a missionary in England, George Albert Smith learned of the anti-scurvy properties of potatoes, when eaten with the skin on. Since potatoes could be stored and made available in the winter, he encouraged the pioneers to use the potatoes to prevent scurvy. George Albert was justly named the "Potato Saint" for his efforts.[18]

Today, when a nutrient deficiency is identified, our ability to preserve and store foods makes it possible to treat the problem any time of the year with whole foods, or through the administration of the correct supplement. Regardless of these technological advancements, the incidence of these types of deficiencies is still high in many areas of the world. For example, in 2005 the World Health Organization estimated that roughly 5.2 million children worldwide were affected by night blindness due to a vitamin A deficiency.[19] A severe deficiency of vitamin A can lead to keratomalacia (a deterioration of the lens of the eye due to low vitamin A levels).

An eye with keratomalacia

Even if a person's dietary intake was only marginally low in vitamins or minerals and there were no noticeable physical signs of a deficiency, there may still be vague symptoms that can impact quality of life. Health professionals often refer to this as a **sub-clinical deficiency** (inferring the absence of clear physical signs of the deficiency). An example would be an increased rate of infection with marginally low vitamin A intake. The paradox of this is that sub-clinical deficiency symptoms can occur in conjunction with over consumption of calories (another example of the "double burden").

Overnutrition and Chronic Disease

Overnutrition may manifest itself in several different forms. Excessive nutrient intake from supplementation or fortified foods may lead to toxicities of some of the vitamins and minerals. Despite how devastating these types of over consumption can be when they occur, the magnitude of the public health concern from this kind of excess hardly compares to the concern of the over consumption of calorie rich, nutrient poor food that is becoming common throughout the world. This type of "malnutrition" is a contributor to chronic diseases such as heart disease, type 2 diabetes, hypertension, and some cancers. Many of the health problems of modern society could be minimized by simply addressing poor diet choices.[20] Cancer and heart disease account for over 40% of the total deaths in the US (see Figure 2). Both diseases have a strong relationship to dietary habits.

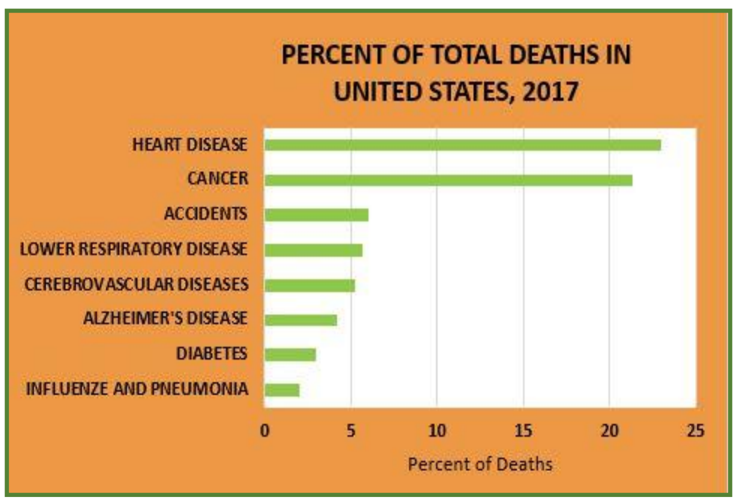


Figure 2: Percent of total deaths: data derived from the 2017 Final Vital Statistic Report provided by the Center for Disease Control (CDC)[20]

1.3 Food Components and Energy

Nutrients

A nutrient is a substance in food that is required by the body and provides either energy (calories), structure to the body, and/or regulates body processes. There are six classes of nutrients required for the body in order to maintain overall health and proper function. They are carbohydrates, lipids, proteins, water, vitamins, and minerals (see Figure 3).

Figure 3: The six classes of nutrients required for normal bodily functions

Essential Nutrients

The foods we eat contain many nutrients, or substances needed by the body to perform its basic functions. Not all nutrients found in food are considered **essential**. An essential nutrient cannot be made by the body or made in sufficient quantities and must be consumed in the diet to prevent deficiency. For example, cholesterol is very important structural and regulatory component of cell membranes. Our body needs cholesterol to operate properly, but because our liver can manufacture cholesterol from other food substances it is not an essential nutrient. In contrast humans cannot make ascorbic acid or vitamin C, so for humans and some other mammals it is an essential nutrient.

Most mammalian species do not require vitamin C to sustain life. They can make vitamin C from the sugar glucose. Humans along with higher primates, guinea pigs, and fruit bats lack the genetic material necessary to manufacture vitamin C.

Macronutrients

One way we classify nutrients is by the amount needed in the diet. Nutrients that are needed in large amounts are called **macronutrients**; this category includes water, carbohydrates, proteins and lipids (see Figure 4). The amounts needed by the body are typically measured in grams. Carbohydrates, proteins, and lipids are involved in regulatory, structural, and energy functions. For instance, carbohydrates' primary function is to provide energy to the body. The central nervous system and red blood cells are particularly dependent on carbohydrates for fuel. Another function of carbohydrate is at the cellular level. Cells use carbohydrates to communicate messages inside the cell or between cells. In this role, carbohydrates serve as a regulator.

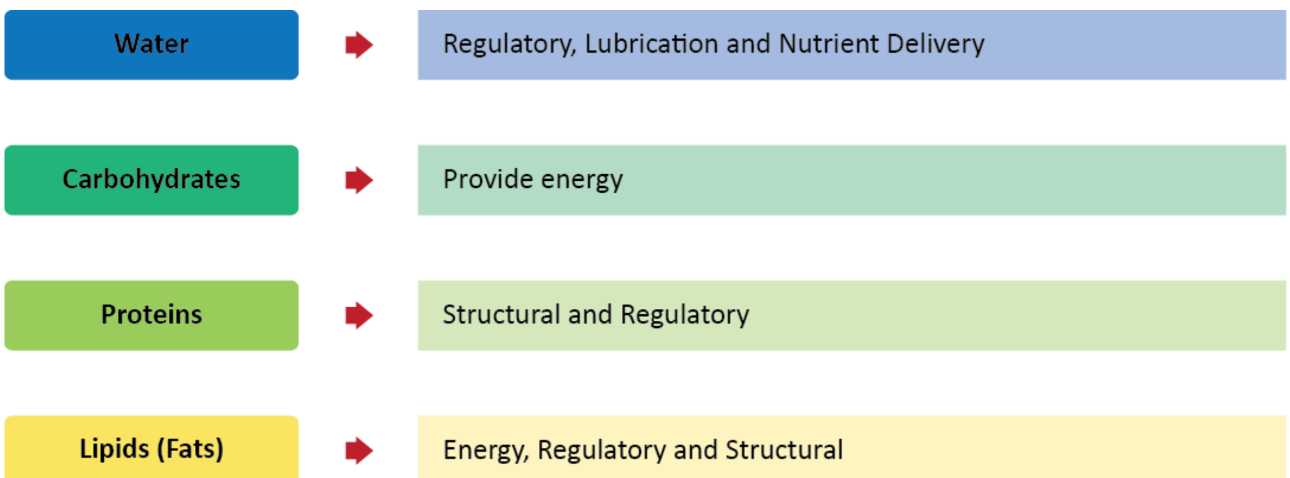


Figure 4: The macronutrients and their primary functions

Lipids have significant roles in all three areas. They are an excellent energy source, but also provide the primary structure for every cellular membrane in the body. A number of the hormones that regulate body processes are derived from lipids, such as vitamin D, estrogen, and testosterone. Protein can also be used for energy, but its primary role in the body is structural and regulatory. Most enzymes and some hormones (like insulin) are protein based, and both are regulators of body processes. Water does not provide energy (calories), but inadequate amounts will be lethal before any other nutrient. Its importance lies in its ability to help regulate body temperature, remove waste products, and provide the medium in which most of the body processes occur.

Micronutrients

Micronutrients are nutrients required by the body in lesser amounts but are still essential for carrying out bodily functions. Micronutrients include the vitamins and minerals (see Figure 5). The micronutrients specialize in regulating body processes. For example, the vitamins and minerals do not provide any energy (calories), but they help the body extract energy from carbohydrates, proteins, and fats. Several of the minerals also have a significant role in providing structure; bones are a good example. Just about all body processes that are essential for life require one or more of the vitamins and minerals to be present.

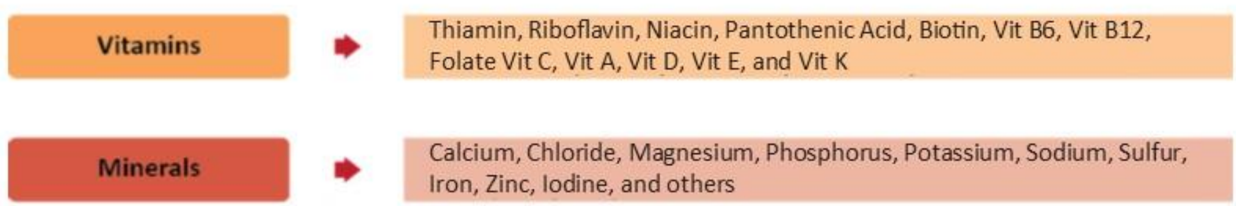


Figure 5: Micronutrient categories

Micronutrients are typically measured in milligram and microgram levels. To put macronutrients and micronutrients in perspective, let's compare a person's requirements for iron (a micronutrient) and carbohydrate (a macronutrient). A 20-year-old female would typically consume about 250 *grams* of carbohydrate per day. Her iron requirement is 18 *milligrams* per day. Although there is a difference between 250 and 18, it is vital to consider the units of measurement to appreciate the magnitude of the difference. A clearer perspective can be given by comparing these nutrients using the same measurement unit.

Carbohydrate (macronutrient) needed per day:	250,000 milligrams
Iron (micronutrient) needed per day:	18 milligrams

We can take that one more step. Some micronutrients are needed in even smaller quantities than iron. For instance, a 20-year-old female would only need about 10 micrograms of vitamin D a day.

A milligram is 1000 micrograms. So, if we put her need for carbohydrates, iron and vitamin D in the same units they would look like this:

Carbohydrate needed per day:	250,000,000	micrograms
Iron needed per day:	18,000	micrograms
Vitamin D needed per day:	10	micrograms

This comparison shows that a 20-year-old female would need 25,000,000 times more carbohydrate per day than she needs vitamin D.

Energy-Yielding Nutrients

The energy yielding nutrients include carbohydrates, lipids and proteins (see Figure 6). These can be metabolically processed into cellular energy. The energy from these macronutrients comes from their chemical bonds. When the bonds are broken, the energy released can be transformed into ATP (Adenosine Triphosphate). A unit of measurement for food energy is the calorie, which by definition (1 calorie) is the amount of energy that is needed to raise the temperature of 1 gram of water 1 degree centigrade. Food calories are typically listed in kilocalorie (also written as kcal or Calories with a capital "C") amounts. For instance, a fun size snickers bar has about 74 kilocalories or 74,000 calories (1 kilocalorie = 1 Calorie = 1000 calories).

Carbohydrates	4 Kcals/ gram
Proteins	4 Kcals/ gram
Lipids (Fats)	9 Kcals/ gram

***Alcohol** is not a nutrient but contains 7 kcals/ gram and needs to be considered in overall energy intake

Figure 6: Calorie content of the energy yielding nutrients

Estimating Energy

By knowing the calories contained in a gram of carbohydrate, protein, lipid and alcohol, total calories in a food product can be determined if the amount of energy yielding nutrients in the product is known.

For example, if a person knows that a peanut butter and jelly sandwich has:

60 grams of carbohydrate

14 grams of protein

32 grams of lipid

…then the total calories of that sandwich can be determined (see Table 1).

Energy yielding Nutrient	Total Grams	Calories/Gram	Total Calories
Carbohydrate	60	4	240 (60 x 4)
Protein	14	4	56 (14 x 4)
Lipid	32	9	288 (32 x 9)
		Total	584

Table 1: Determination of Calories when given grams of carbohydrate, protein, and fat

1.4 Phytochemicals and Nutrient Density

Phytochemicals

If an extraction process were available that would allow us to take a plate of food and remove all the essential nutrients (carbohydrates, proteins, lipids, vitamins, minerals, and water), reflect on what might be left on the plate when those were gone. Surprisingly there are quite a few substances in food that don't fit into any of those essential nutrient categories but are still suspected of providing health benefits if eaten. Most of these types of compounds are found in plant food such as fruits, vegetables, whole grains, nuts and seeds and are called **phytochemicals** (the prefix phyto- comes from the Greek word for plant).

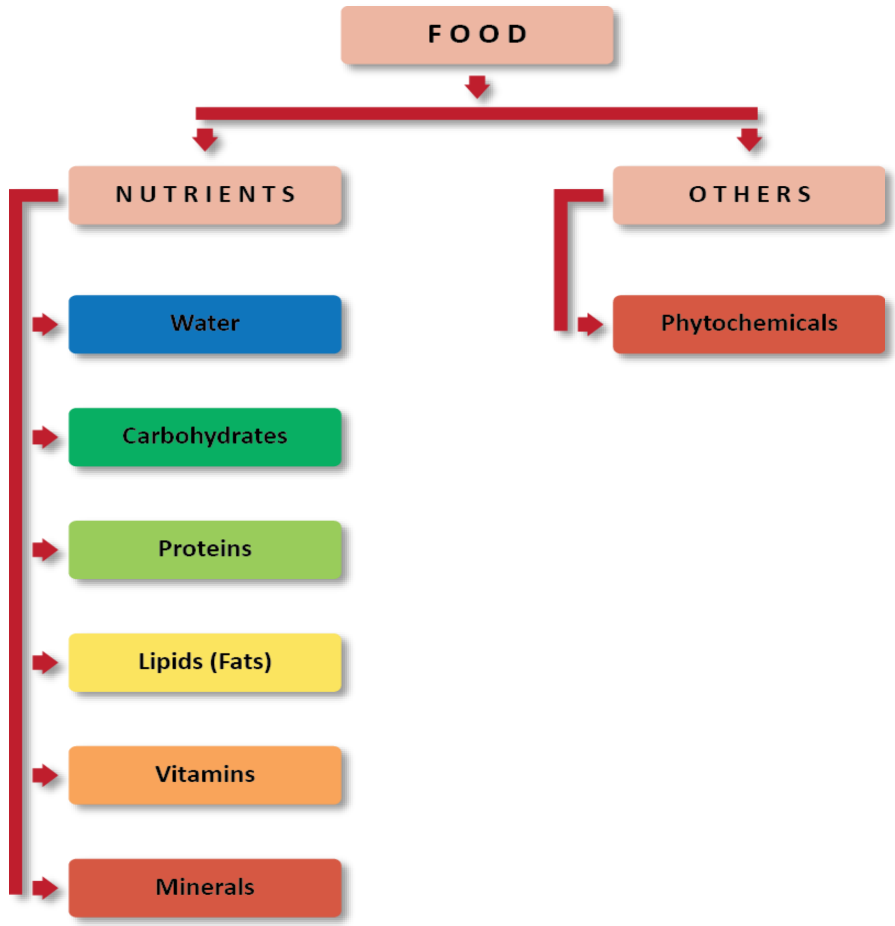


Figure 7: Where phytochemicals fit in food

They are not considered essential nutrients because there isn't a specific deficiency associated with not eating these compounds, but they may have a host of benefits when they are included in the diet. Many observational studies show a relationship between eating lots of fruits and vegetables and a reduction in many chronic diseases such as cardiovascular disease, cancer and neurodegenerative diseases like Alzheimer's.[21,22] It is suspected that the phytochemical content of these foods may be in part responsible for this observed relationship. Thousands of these compounds have been identified, and there are likely many more to be discovered. The presence of these compounds in foods is one of the key reasons eating whole foods is recommended and leaning on supplements as a makeup for poor dietary choices is discouraged. It is likely these compounds work together with other food components to produce their positive effect.[23] Trying to isolate all these compounds and put them in a supplement with the hopes of reaping all the benefits of food, is not remotely possible now, nor in the perceivable future. Some of the common phytochemical groupings and examples of their food sources are pointed out in Figure 8.

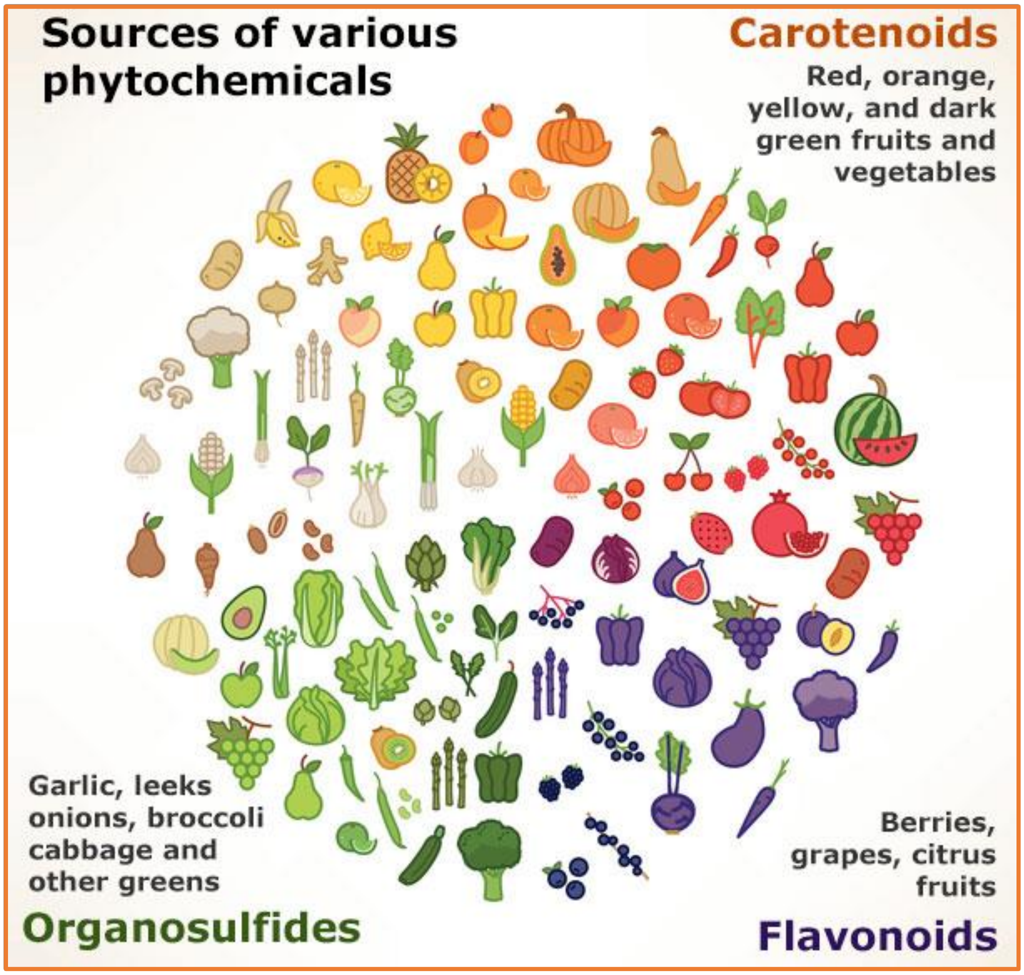


Figure 8: Some common phytochemicals found in whole foods

In an effort to point out the complexity of this topic, it is important to recognize only a few of the phytochemical groups have been highlighted here and within groupings are layers of subgrouping. For instance, the flavonoid group (highlighted in Figure 8) is a component of a larger group called the polyphenols. The polyphenol group contains the flavonoids, plus the phenolic acids, stilbenes, and lignans. Within the flavonoid group there are subcategories consisting of the flavonols, flavones, flavanols, isoflavones and proanthocyanidins. Each of these categories contains specific phytochemicals. For instance, quercetin, kaempferol and myricetin are phytochemicals that exist in the flavanols subcategory. Each phytochemical has specific foods that are particularly rich in that particular agent.[24] This is an exciting field and scientists are just beginning to understand the complexity of food and the possible biological benefits of its many components, particularly of those contained in fruits, vegetables, nuts, seeds and whole grains – the foods emphasized in the Word of Wisdom.[2] We have only just begun to delve into the nutritional implications of these compounds; medical properties are also being explored. (Reflect on Alma 46:40)[25]

Nutrient Density

One of the most significant concepts to understand in a person's pursuit of a healthy dietary intake is the principle of **nutrient density**. In the daily quest for nourishment, we have two primary objectives. First, to obtain adequate calories to fuel the day's activities. Second, to acquire all the other essential nutrients needed to maintain body function in sufficient amounts (the vitamins and minerals are of special emphasis in this discussion). The challenge in most developed countries is to obtain all the necessary vitamins and minerals without exceeding the calories needed to maintain a healthy weight. Foods that provide ample amounts of the vitamins and minerals and only modest amounts of calories would be considered "nutrient dense". For example, consider the comparison between a 150-Calorie serving of baked potato and French fries (see Figure 10). Both are potato products but when a comparison is made with select vitamins and minerals the baked potato is much more nutrient dense. In Figure 10, the higher the bar, the higher the amount of the selected nutrients provided in

150 Calories French Fries
(46 grams)

150 Calories Baked Potato
(155 grams)

150 Calories of a baked potato is far more filling than 150 Calories of fries

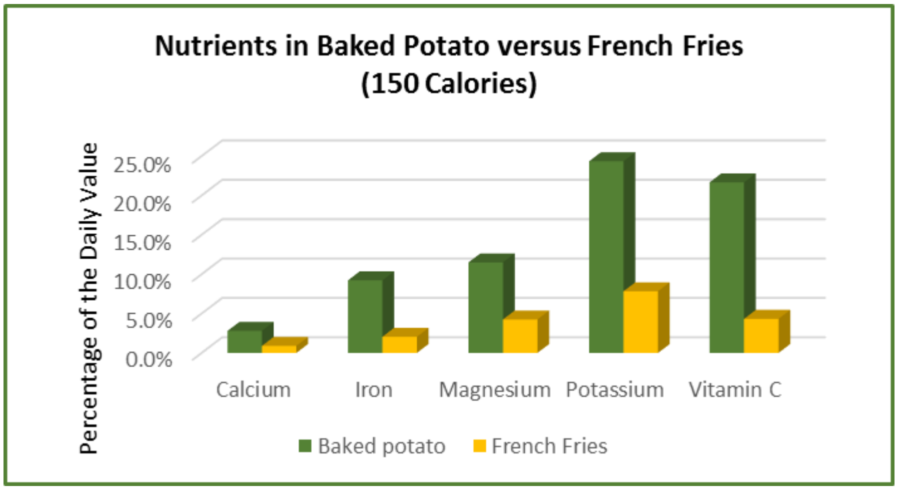


Figure 9: The amount of the selected nutrients provided in a 150-Calorie serving of a baked potato or French fries in relation to the Daily Value.

relation to recommended intake levels. Now compare Figure 9 with Figure 10. If you add about 75 Calories of butter to the potato (3/4 tablespoons), look what happens to the nutrient density. The potato is still better than a French fry, but the gap has closed quite a bit. When added to foods, purified fats (like butter) or added sugars reduce the nutrient density of the food by adding additional calories but little additional vitamins and minerals.

Someone might choose a different spread, topping, or sauce to maximize the amount of nutrients they get per calorie. This principle can also be applied towards simple daily choices such as the type of sauce you put on your pasta or the type of milk product you choose (Figures 11 and 12).

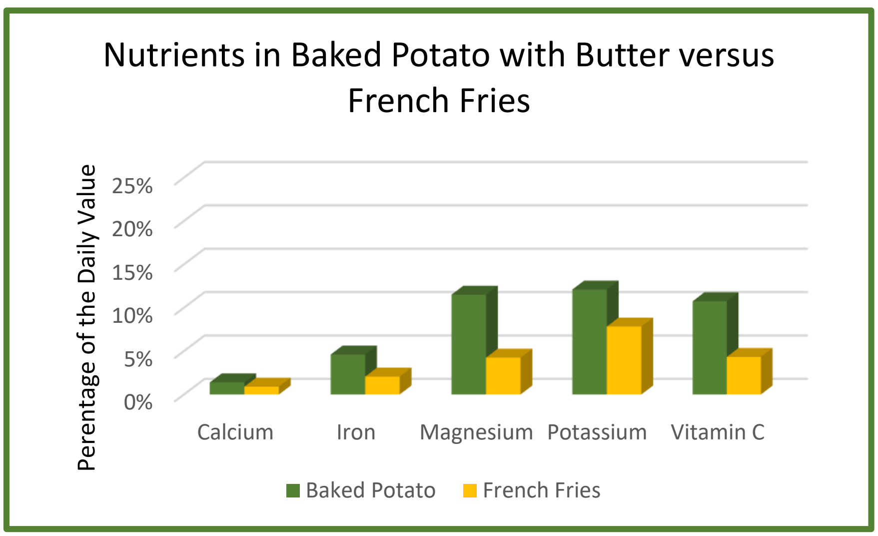


Figure 10: The amount of the selected nutrients provided in a 150 Calorie serving of a baked potato with butter and French fries in relation to the Daily Value.

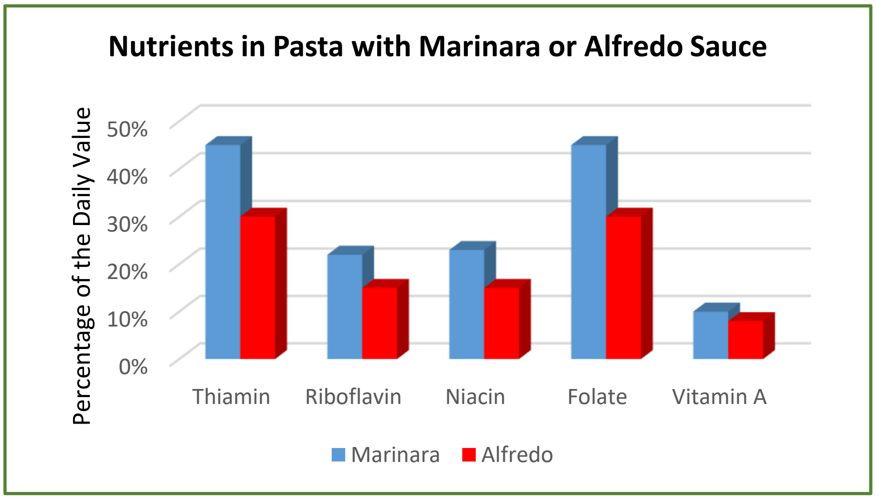


Figure 11: The amount of the selected nutrients provided in a 320 Calorie serving of a pasta with Alfredo or marinara in relation to the Daily Value.

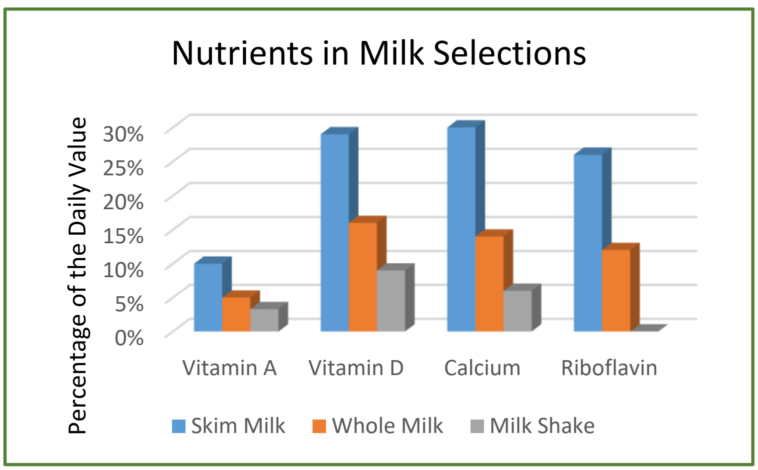


Figure 12: The amount of the selected nutrients provided in an 83 Calorie serving of milk products in relation to the Daily Value.

By focusing on the principle of nutrient density on a daily basis a person can be more successful at adequately nourishing the body at a caloric intake level that supports a healthy weight!

1.5 Promoting Change

Choices, Accountability and Change

Eating empty calories is a choice

Nutrition experts would hope that when food choices are made, a consideration of the short- and long-term health impact would be included in the process. While that certainly plays a role, it is well recognized that it is not likely the primary stimulus behind food choices. When a group of college students was surveyed regarding how they make food choices, the top reasons governing their selections were principles such as time, availability, cost, taste or preference.[26]

Preferences of parents, family traditions, cultural influences, and religious affiliations likely influenced the types of food eaten as a child. Research has shown that our current eating pattern is likely to be similar to how we ate as children.[27] We may have learned certain foods are associated with happy times and others were used to soothe stress. While none of these are inherently bad reasons to choose certain foods, if left unbalanced without a basic understanding of the principles behind healthy food choices, they can establish patterns that could lead to significant long-term health problems. The challenge is how to identify food habits that may be detrimental, and then, how to change them.

Insect eating is common throughout the world. In many areas, it represents a food choice based on culture, availability, cost and nutrition.

Stages of Change

It is estimated we make over 200 food choices every day.[28] Some choices we make based on learned habits. Others we may make based on the situation and how we feel. A trip to the grocery store is filled with decisions to make. Aisle after aisle thousands of foods and products call out for attention. Advertisements, health claims, colorful packaging – we are bombarded with information that influences our choices.

This life is designed for us to make choices and learn from our choices. So how do you promote healthy eating in a way where one can act and not be acted upon? It is important to realize behavior change does not usually happen all at once. Instead, there are distinct phases that a person goes through while making a change. Each of these phases of change have different strategies that can effectively help a person move to the next phase. The Stages of Change model can be used to develop the appropriate strategies to help guide behavior change.

Figure 14: Stages of change and change strategies

The first stage in the Stages of Change model is **Precontemplation**.[29] This stage is where the person is either not aware of the needed change or is not interested in changing. In other words, they are comfortable where they are. Trying to tell a person how to make a dietary change when he is not aware of the need or not interested in the change is an example of "acting upon" the person and is often met with rebellion. Instead, an appropriate strategy would be to increase the individual's awareness that the change would be beneficial for them. This action can help move the person to the next stage.

In the **Contemplation** stage, the person weighs the possible benefits versus the barriers to making the change.[29] For instance, a person would consider the pros of eating healthier to reduce the risk for chronic diseases against the cons of having to change preferences for food before making a decision. Strategies that may help the person move to the next stage include helping the person identify the perceived barriers and misconceptions and discussing their concerns.

The next stage is **Preparation**, which involves making a plan to change within the next 30 days.[29] For instance, at this stage a person would plan to include more physical activity into their life by walking 30 minutes a day or plan to buy more fruits and vegetables and put them on the counter where they can be seen. A useful strategy to help a person at this stage is to suggest realistic goals and give practical suggestions.

The next stage is **Action**, which involves the person following their plans.[29] Beneficial strategies for this stage are to provide encouragement, support, and positive reinforcement. After six months of action, the person moves to the **Maintenance** stage where those actions may become part of one's lifestyle and habits.[29] Change doesn't happen all at once – it is a process that takes constant effort and dedication.

In a similar way, the Spirit works in us and knocks on the door, informing us of consequences to our current actions, inviting us to act, and supporting us along the way. Change and Agency are eternal principles. As the Lord states, "For the power is in them, wherein they are agents unto themselves."[32]

Chapter 2: Evaluating Nutrition Information

2.1 The Science of Nutrition

Brigham Young taught that members of the church search diligently after knowledge and that "there is no other people in existence more eager to see, hear, learn, and understand truth."[1] In our world today it has never been easier to find information. A quick internet search can result in millions of websites offering up new ideas and knowledge. Searching for *nutrition* information is no exception. The vast amount of available and often contradictory nutrition information can be overwhelming. Should you believe everything you read? Is all the information reliable? How can you tell?

Scientific Method

The study of nutrition is a science and just like the sciences of chemistry, biology, and physics, nutrition relies on the process of the **scientific method** to answer questions and generate theories. Scientists using the scientific method, as shown to the right, explore questions, suggest a **hypothesis** (a proposed solution to the question or problem), conduct experiments, draw conclusions, and develop **theories**, an explanation for an observed phenomenon. Although it may appear that the scientific method is a linear process, in reality science rarely concludes and is ongoing as it continues to be reanalyzed and revised.[2]

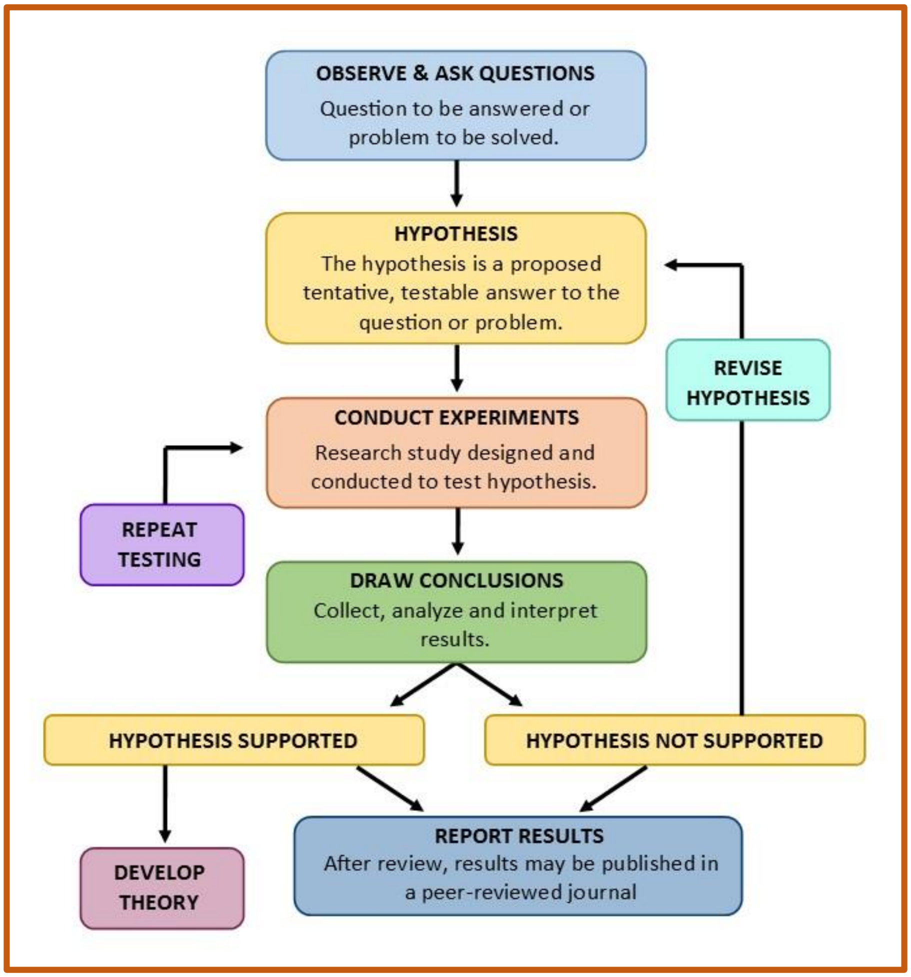


Figure 1: The scientific method

Once the researchers have finished their study and drawn conclusions, they submit their findings to be reviewed and critiqued by other nutrition investigators or peers. This is called a **peer review** and helps to validate the quality of the research before it is published in a peer-reviewed research journal.[3] It is after the article is published that news reporters may read and learn about the study findings and then communicate this to the public through the media.

Types of Scientific Research

There are many types of scientific research that can be used to test a particular hypothesis. The various types of studies include observational, experimental clinical trials, and laboratory research.

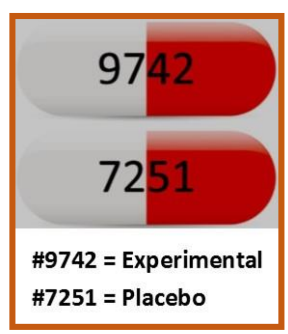
Observational Research

In **observational research,** characteristics of a group are observed and measured highlighting the relationship or correlation between variables; however, there is no intervention to influence the outcome. One type of observational research is **epidemiology** which investigates the frequency, distribution, and patterns of health events in a population.[4] These studies are often the front-line studies for public health and describe the occurrence and patterns of health events over time, revealing a **correlation** or relationship between two variables. The goal of an epidemiological study is to find factors associated with an increased risk for a health event, though these sometimes remain elusive.

Epidemiological studies are a cornerstone for examining and evaluating public health. Some of the advantages of these types of studies are that they can lead to the discovery of disease patterns and risk factors for diseases, and they can be used to predict future healthcare needs and provide information for the design of disease prevention strategies for entire populations. Some shortcomings of epidemiological studies are that investigators cannot control environments and lifestyles, a specific group of people studied may not be an accurate depiction of an entire population, and these types of scientific studies cannot directly determine **cause and effect,** or if one variable is the result of another variable.

Experimental Clinical Trials

In **experimental clinical trials,** variables are altered between at least two groups of people to determine causal (cause and effect) relationships. The **experimental group** receives a treatment (or intervention) and the **control group** receives a **placebo** (a fake or pretend treatment).



Example coding placebo versus treatment pills

The placebo will usually look and taste the same as the actual treatment. Although the placebo is different than the treatment, it may still affect how some of the participants feel even though the changes are not attributed to the placebo itself. This is called the **placebo effect** and seems to be caused by the individual person's strong belief or expectation that there will be a change, positive or negative.[5]

Blinding a study can help control or eliminate the placebo effect. The study is considered **single-blinded** if neither the subjects in the control nor the experimental group know who receives the treatment and who receives the placebo. The study is considered **double-blinded** if both the subjects and the researchers are unable to distinguish what group received which treatment until after the study is completed.

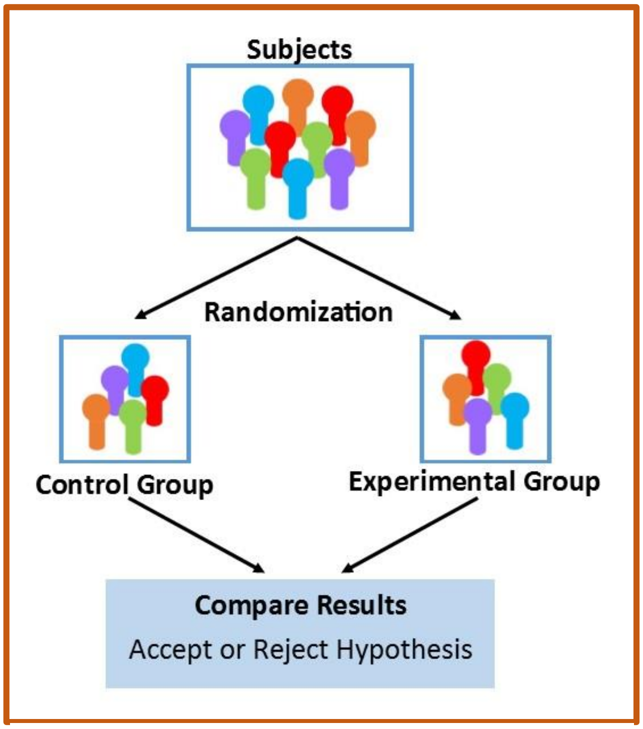


Figure 2: Experimental research

High quality experimental studies will include **randomization** in which subjects are assigned by chance to the control or experimental group. Neither the researchers nor the participants can choose which group a participant is assigned. Subjects will have an equal chance of ending up in either group. This is done to ensure that any possible confounding variables are likely to be evenly distributed between the control and the experimental group.

What are **confounding variables**? These are factors other than the one being tested that could influence the results of the study. For instance, in a study looking at diet, if one group of adults did less physical activity than the other, then it could be the amount of physical activity rather than the diet being tested that caused the differences in blood pressures among the groups.

Randomized double-blinded clinical trials are powerful tools to provide supporting evidence for a particular relationship and are considered the "gold standard" of scientific studies. The limitations of clinical trials are they are difficult to carry on for long periods of time, are costly, and require that participants remain compliant with the intervention. Furthermore, it is unethical to study certain interventions. For example, it would be unethical to advise one group of pregnant mothers to drink alcohol to determine the effects of alcohol intake on pregnancy outcome, because we know that alcohol consumption during pregnancy damages the developing fetus.

Laboratory Experiments

Other scientific studies used to provide supporting evidence for a hypothesis include laboratory studies conducted on animals or cells. An advantage of this type of study is that they typically do not cost as much as human studies and they require less time to conduct. Other advantages are that researchers have more control over the environment and the amount of confounding variables can be significantly reduced. Moreover, animal and cell studies provide a way to study relationships at the molecular level and are also helpful in determining the exact mechanism by which a specific nutrient causes a change in health. The disadvantage of these types of studies are that researchers are not working with humans or at least not the whole human, such as in cell studies, and thus the results may not be relevant. Nevertheless, well-conducted animal and cell studies that can be repeated by multiple researchers and obtain the same conclusion are definitely helpful in building the evidence to support a scientific hypothesis.

A lab mouse with test tubes

Evolving Science

Science is always moving forward, though sometimes slowly. One study is not enough to make a guideline or a recommendation or to cure a disease. Science is a stepwise process that builds on past evidence and finally culminates into a well-accepted conclusion or theory. Unfortunately, not all scientific conclusions are developed in the interest of human health and it is important to know where a scientific study was conducted and who provided the money. Indeed, just as in an air quality study paid for by a tobacco company diminishes its value in the minds of readers, so does one on red meat performed at a laboratory funded by a national beef organization.

2.2 Evaluating Strength of the Evidence from Scientific Studies

The use of the scientific method does not prove facts or absolute truths. Even the most widely-accepted scientific ideas or theories are provisional and may be revised based on new evidence. This does not mean that scientific theories or conclusions should not be trusted; however, it is important to evaluate the strength or reliability of the evidence being considered.

Reliable Information

What makes scientific evidence strong or reliable? How can you tell? Asking the following questions can help in determining the strength of the evidence.

1. Is the evidence quantifiable?

Quantifiable evidence means that the findings have been measured or calculated. The more quantifiable, the stronger or more reliable the evidence is considered. Identifying the research design or type of research used helps to determine if and how quantifiable the evidence is.

Anecdotal evidence or personal testimony is based on individual experience, opinion, or rumor. This type of evidence might be used as an observation in the first step of the scientific method, but it is considered weak evidence because it has not been fully measured and evaluated.

Observational evidence, such as epidemiology research, suggests associations and correlations. However, because these studies do not demonstrate cause and effect, their strength ranges from limited to moderate. They are considered moderate evidence if the study is well designed, includes large groups of people, and has consistent findings across multiple studies.

Experimental evidence tests an intervention or treatment and begins to determine cause and effect. This evidence is considered strong if the study is well-designed, includes large, randomized groups of people, controls the placebo effect, and has consistent results across multiple studies.

Although human experimental studies are ideal when studying human nutrition, laboratory studies, such as animal or cell experiments, may be used when there are cost, time, and ethical concerns. However, even the best designed animal studies are not as strong as human studies and results may not be applicable to a human population.

2. Is it the correct population?

Not all populations or groups of people used in studies are the same. It is important that a research study uses a population or group of people that represents the target population. This strengthens the study results. For example, if researchers are trying to determine the effects of vitamin D in pregnancy, using a group of non-pregnant men and women would not be appropriate. The size of a study population is also important to consider. Small sample sizes may not adequately reflect the population, weakening the overall strength of the evidence.

Type of Evidence	Strength of Evidence
Anecdotal, Opinion Poorly Designed Study Single Study Small studies	**Weak to Limited**
Well-designed Observational or Epidemiological Studies that have consistent results	**Moderate**
Well-designed, Large, Randomized, Double-blinded, Placebo-controlled Clinical Trials that have consistent results	**Strong**

Figure 3: Evaluating the strength of the evidence

3. Were there proper controls?

Controls or regulations help to eliminate unimportant, unconnected, or confounding factors that might otherwise affect the end result of an experiment. Studies that provide strong evidence use proper controls including a control group, randomization, and double blinding to reduce or eliminate the placebo effect.

4. Were the results interpreted accurately?

It is easy to assume that the results of a study are reliable or valid. However, sometimes researchers conducting the studies are driven by external factors such as receiving funding or getting published. As a result, the study may be biased or unreliable. Reliable studies that provide strong evidence use randomization, appropriate sample sizes, and avoid bias.[6] Also, results from a single study are not enough to develop a theory. Rather, evidence that is tried-and-true, having been tested multiple times with consistent results, is stronger than evidence from a single study.

2.3 Using Eyes of Discernment

Elder Mark Bassett of the Quorum of the Seventy explained, “In this modern age, we have come to expect that knowledge can and should be obtained immediately; when information is not easily known or accessible, it is often dismissed or mistrusted. Because of the abundance of information, some unwittingly give more credibility to available sources with an unknown origin".[7] In this age of information where instant internet access is just a click away, it is easy to be misled if you do not know how to evaluate and where to find reliable nutrition information.

Evaluating Nutrition in the Media

It is not uncommon to hear or read sensational headlines related to nutrition. Headlines are purposely dramatized to attract your attention, yet they can be misleading. Regardless of what type of media the headlines come from, you will want to carefully evaluate the information with discerning eyes.

> *"New study shows that drinking milk leads to cancer."*
>
> *"Study reveals that two cups of soda per day can cause permanent damage to the brain."*

Examples of sensational headlines

The news organizations are sent hundreds of press releases or bulletins from different food and supplement companies, medical organizations, and journals about research being conducted. Their purpose in sending these announcements is to garner attention--hoping the news organization will report on this "breaking news". Are these press releases reliable? Is the media qualified to determine if a report is accurate? How can you tell? Listed below are ways that you can develop discerning eyes when reading or hearing nutritional news.

1. Look for dependable news organizations that seek out independent experts to comment on the findings and explain how they may relate to the public.
2. The scientific study under discussion should be referenced in the report and should be published in a peer-reviewed journal. Question studies that come from less trustworthy sources or those that are not published.
3. The methods used by the researcher(s) should be disclosed. Did the study last for three or thirty weeks? Were there ten or one hundred participants? What did the participants actually do? Did the researcher(s) observe the results themselves or did they rely on self-reports from program participants?
4. Who were the subjects of this study? Humans or animals? If human, are any traits/characteristics noted? You may realize you have more in common with certain program participants and can use that as a basis to gauge if the study applies to you.
5. Remember that one study does not substantiate a fact. One study neither proves nor disproves anything. Credible reports often disseminate new findings in the context of previous research. A single study on its own gives you very limited information, but if a body of literature supports a finding, it gives you more confidence in it.

6. Ask yourself, “Does this make sense?” Remember, if a headline professes a new remedy for a nutrition-related topic, it may well be a research-supported piece of news, but more often than not it is a sensational story designed to catch the attention of an unsuspecting consumer. Track down the original journal article to see if it really supports the conclusions being drawn in the news report.

Evaluating Internet Sources

The internet offers quick access to health and nutrition information and is an easy place to go when looking for answers. In fact, approximately 60% of U.S. adults have explored the internet for health information.[8] However, unlike peer-reviewed journals, no one examines the information posted on the internet before it is published. Some information is written by experts; however, much of the internet information created is authored by non-experts and may or may not be reliable. That means it is up to you to determine the quality and accuracy of the information found on the internet. Exploring questions such as “Who?”, “What?”, “When?”, “Where?” and “Why?” can assist you in evaluating the reliability of the information found on the internet.

WHO?	**WHO wrote/published the information on the site?** • Who is the author? • Does the author provide contact information? • What are the author’s credentials or qualifications? • Is the site created or sponsored by a reputable organization? • Who runs and pays the website?
WHAT?	**WHAT information and resources does the site provide?** • What is the site’s purpose: to persuade, inform, or entertain? • Is the information subjective (biased or opinionated), objective, or mixed? • Does the site provide thorough coverage of the topic? • Is the information well written? Are there misspellings or grammatical errors? • Does the site provide references?
WHEN?	**WHEN was the site created and last updated?** • Does the site indicate when it was first created and last updated?
WHERE?	**WHERE does the site come from or “live”?** • What is the extension in the URL (i.e. .com, .net, .edu, .gov, .org)? • What does the extension tell me about the source of the site? • Is there anything more current?
WHY?	**WHY should I use this site?** • Why is this information useful for my purpose? • Is the information verifiable, in-depth, and up-to-date? • Why is this page or site better than another? • Is the site trying to sell something?

Trustworthy Sources

With the vast array of information available it is helpful to know where you can turn for reputable and consistent nutrition information.

Finding a Nutrition Expert

New graduate

Who should you turn to for nutrition advice? Are all health professionals equal and qualified to provide nutrition help? You might be surprised to learn that many health professionals have minimal nutrition training. Only the **registered dietitian (RD) or registered dietitian nutritionist (RDN)** has the education and training established by the Accreditation Council for Education in Nutrition and Dietetics (ACEND). An RDN is trained in all areas of nutrition and will have finished a four-year degree in nutrition and dietetics from an accredited university, completed extensive supervised practice, and passed a rigorous national registration examination. Furthermore, about 50 percent of all RDNs hold at least a master's degree. This extensive education and training gives the RDN an advantage when providing sound nutrition advice.[9,10] Others may call themselves nutritionists, but will have taken few or no accredited courses and have no supervised practice experience. As a consumer, it is important to seek out qualified, trained individuals when seeking nutrition advice and information.

RDNs work with their patients and clients to provide individualized guidance to make healthy dietary changes that can prevent or treat diseases. They are required to participate in continuing education which helps to ensure they will remain current in this rapidly advancing field of nutrition and science. You will find RDNs working in a variety of settings including hospitals, long-term care facilities, other health care facilities, schools and universities, community and government agencies, businesses, professional athletic teams, food companies, and private practice.

Registered dietitian nutritionist working one-on-one with a client

Reputable Websites and Organizations

How about reputable internet sources? Websites with a web address ending in .gov (government agency), .edu (an educational institution) or .org (organization) are considered more reliable, credible sources. However, sites that end in .com (commercial) or .net (networks) should be explored with caution. The organizations and websites listed below can be consistently relied upon for accurate nutrition material that is updated regularly.

Reputable Websites	Sponsoring Organization	Website Link
Food and Nutrition Center	U.S. Department of Agriculture (USDA)	https://www.nal.usda.gov/fnic
healthfinder.gov	U.S. Department of Health and Human Services (HHS)	https://healthfinder.gov/
Nutrition.gov	USDA and HHS	http://www.nutrition.gov/
Centers for Disease Control and Prevention	Center for Disease Control and Prevention (CDC)	http://www.cdc.gov/
National Institute of Diabetes and Digestive and Kidney Diseases	U.S. Department of Health and Human Services (HHS)	https://www.niddk.nih.gov/
The Academy of Nutrition and Dietetics	The Academy of Nutrition and Dietetics (AND)	http://www.eatright.org/
Dietitians of Canada	Dietitians of Canada (DC)	http://www.dietitians.ca/
Health Canada	Health Canada	http://www.hc-sc.gc.ca/index-eng.php
American Heart Association	American Heart Association (AHA)	www.heart.org
American Cancer Society	American Cancer Society (ACS)	https://www.cancer.org

Table 1: Reputable nutrition websites and organizations

Federal Trade Commission

What do you do when you find an online scam? Do you keep it to yourself? Rather than ignoring something like this you may want to file a complaint with the **Federal Trade Commission (FTC)**. The FTC is the United States' consumer protection agency and can help to prevent fraud and scams. They investigate complaints about false or misleading advertising and provide the information to law enforcement agencies for follow-up.

Chapter 3: Assessing Nutrient Intake

Determining if dietary intake is adequate or not can be approached from two different points of view. The amount of the individual nutrients in a diet can be determined and compared to recommendations, or the overall types and amounts of the different food groups eaten can be quantified and assessed. Each of these approaches will be explained in this section of the material.

3.1 Food Databases and Food Labels

From time to time questions can arise regarding the specific nutrient content of foods. For instance, recently there has been an increased focus on making sure body Vitamin D levels are adequate, especially for people living at higher latitudes where the sun is not strong enough to initiate vitamin D production in the skin all year round. Many people also struggle with anemia, which can occur from low iron intakes or high iron losses. Either of these concerns might raise a person's interest in finding out food levels of these nutrients in some of their daily choices. Knowing how to use food databases and food labels can help answer these types of questions.

Food Databases

Food databases allow a user to look up nutrient content for most common foods. Typically, all that is required is to enter the name of the food in a search menu, and a list of foods that fit the description are displayed. Once you selected the most appropriate option the nutrient content of that food is displayed.

Mushrooms

For instance, let's say you are living in Northern Idaho and you are concerned about your Vitamin D levels in the winter. You have heard that mushrooms provide vitamin D and wonder how they compare to the levels in Vitamin D fortified milk (since you don't like milk very well, but love mushrooms). You wonder if eating 1 cup of cooked, sliced mushrooms will compare to drinking a glass of milk. A nutrient database is an excellent resource to find out the answer to a question such as this. You could enter a search for "mushrooms". Since there is a large variety of different types of mushrooms, you would then be prompted to select the specific type of mushroom you are interested in. When that is entered, the nutrient composition of a designated quantity of mushrooms will be displayed. You can repeat the process for milk and then compare vitamin D levels. Unfortunately, you will learn that the vitamin D content of mushrooms isn't nearly as good as Vitamin D fortified milk.

Not all food databases are the same. They will differ in a variety of ways such as the types of foods that are listed, and the number of nutrients that are reported for each food.

Food Labels

The **food label** does not provide a comprehensive list of nutrients in food like the food database, but can be a very useful tool if a person knows how to use it. In the United States, the Nutrition Labeling and Education Act (NLEA) passed in 1990 and came into effect in 1994. As a result, all packaged foods sold in the United States and Canada must have nutrition labels that accurately reflect the contents of the food products. There are several nutrients that must be listed on the food label. They include: total Calories, total fat, saturated fat, cholesterol, total carbohydrates, dietary fiber, total sugars, added sugars and vitamin D, calcium, iron and potassium. The generic food label in Figure 1 shows these items as they currently appear on a food label (represents the nutrition facts for 2/3 cups of granola).

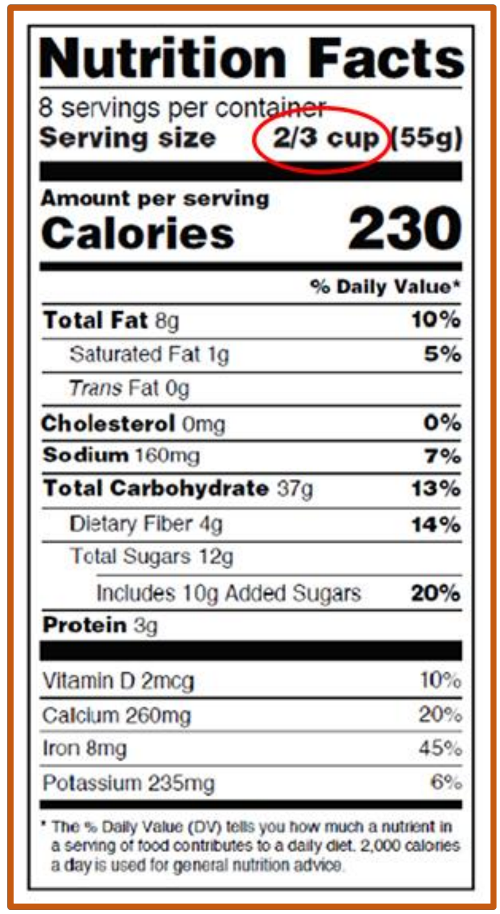


Figure 1: Granola food label. Typical items included on a standard food label (2/3 cup granola)

There are other types of information that are required by law to appear somewhere on the consumer packaging. They include:[1]

Name and address of the manufacturer, packager, or distributor

Statement of identity, what the product actually is

Net contents of the package: weight, volume, measure, or numerical count

Ingredients, listed in descending order by weight

The focus of this discussion will center on the basics of how to read a food label, how to interpret and use the Daily Values, and how to interpret the ingredient list and nutrient content claims.

Reading the Label

The nutrient content listed on the food label is based on the serving size indicated at the top of the nutrition fact panel. In 2016 the food label was updated, and serving sizes were adjusted to reflect typical American eating patterns. You might guess that the average serving size was normally increased to reflect the changes in our eating patterns since the label was first instituted decades ago. For instance, a serving of soda went from 8 ounces to 12 ounces, and a serving of ice cream went from 1/2 cup to 2/3 cup. The granola facts label in Figure 1 indicates a 2/3 cup serving has about 230 Calories. All of the rest of the nutrients listed also correspond to a serving size of 2/3 cup. Other guidelines on serving sizes are displayed in Figures 2 and 3.

Shopper reading labels

Nutrition Facts

1 serving per container

Serving size 1 bottle (20 fl oz)

Amount per serving

Calories 240

	% Daily Value*
Total Fat 0g	**0%**
Saturated Fat 0g	**0%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 75mg	**3%**
Total Carbohydrate 65g	**22%**
Dietary Fiber 0g	**0%**
Total Sugars 65g	
Includes 65g Added Sugars	**130%**
Protein 0g	
Vitamin D 0mcg	0%
Calcium 0mg	0%
Iron 0mg	0%
Potassium 0mg	0%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

For products that fall between 1 and 2 servings the nutrition facts will be listed for the entire product. For example, if a container of soda is 20 ounces, the nutrition facts will be based off of the 20 ounces even though the standard serving size for soda is 12 ounces. The rationale for this is typically a person will consume the whole container.

Figure 2: Designation of servings sizes for products that contain 1 and 2 Servings

Nutrition Facts

3 servings per container

Serving size 2/3 cup (87 grams)

	Per 2/3 cup		Per container	
Calories	**170**		**520**	
	% DV*		**% DV***	
Total Fat	**14%**	9g	**43%**	28g
Saturated Fat	**30%**	6g	**90%**	18g
Trans Fat		0g		0g
Cholesterol	**13%**	40mg	**40%**	120mg
Sodium	**2%**	50mg	**7%**	160mg
Total Carbs	**6%**	19g	**19%**	56g
Dietary Fiber	**0%**	0g	**0%**	0g
Sugars		19g		56g
Added Sugars		15g		45g
Protein		4g		12g
Vitamin D	0%	0mcg	0%	0mcg
Calcium	11%	110mg	34%	338mg
Iron	0%	0mg	0%	0mg
Potassium	5%	165mg	14%	500mg

* Footnote on Daily Values (DV) and calories reference to be inserted here.

In situations where you may eat more than the serving size, you simply need to multiply how many servings you ate by the values found in the Nutrition Facts panel. For example, if you ate 1 1/3 cups of the granola (see Figure 1), recognize you ate 460 Calories. All of the other nutrients would be doubled as well. When products contain 2 to 3 servings, a dual label may be required to help the consumer make informed choices (see Figure 3).

Figure 3: Designation of servings sizes for products that contain 2 to 3 servings

Daily Values (DV)

On the nutrition facts panel, the serving size is followed by the number of Calories in the listed serving size and then a list of selected nutrients. The "%DV" (**Percent Daily Value**) is on the far right-hand side. This number reflects how much 1 serving of that product is contributing to the recommended amount of that nutrient for someone consuming a 2000 Calorie diet. Sometimes the daily value represents a maximum amount we should be taking in for a particular nutrient and other times it is a goal. Generally, a percent DV of 5 is considered low and a percent DV of 20 is considered high. This means, as a general rule, for fat, saturated fat, *trans* fat, cholesterol, added sugars or sodium, look for foods with a low percent DV. The goal is to stay under 100% on a daily basis. Alternatively, when assessing your intake for nutrients like vitamin D, Calcium, Iron, Potassium and fiber, look for a high percent DV. The goal is to reach 100% over the course of a day's intake.

DIETARY COMPONENT	"OLD" DAILY VALUE (DV) *Used on old food labels*	CURRENT DAILY VALUE (DV) *Used on new food labels*
Total Fat	65 g	78 g
Saturated Fat	20 g	20 g
Cholesterol	300 mg	300 mg
Total Carbohydrate	300 g	275 g
Added Sugars	NA	50 g
Dietary Fiber	25 g	28 g
Protein	50 g	50 g
Sodium	< 2,400 mg	< 2,300 mg
Potassium	3,500 mg	4,700 mg
Vitamin A	5,000 IU	900 mcg RAE
Vitamin C	60 mg	90 mg
Vitamin D	400 IU	20 mcg
Vitamin E	30 IU	15 mg alpha-tocopherol
Vitamin K	80 mcg	120 mcg
Folate	400 mcg	400 mcg DFE
Thiamin	1.5 mg	1.2 mg
Riboflavin	1.7 mg	1.3 mg
Niacin	20 mg	16 mg NE
Vitamin B6	2 mg	1.7 mg
Vitamin B12	6 mcg	2.4 mcg
Biotin	300 mcg	30 mcg
Pantothenic acid	10 mg	5 mg
Calcium	1,000 mg	1,300 mg
Phosphorus	1,000 mg	1,250 mg
Iodine	150 mcg	150 mcg
Iron	18 mg	18 mg
Magnesium	400 mg	420 mg
Copper	2 mg	0.9 mg
Zinc	15 mg	11 mg
Chloride	3,400 mg	2,300 mg
Manganese	2 mg	2.3 mg
Selenium	70 mcg	55 mcg
Chromium	120 mcg	35 mcg
Molybdenum	75 mcg	45 mcg

g=gram, mg=milligram, mcg=microgram, IU=International Unit, DFE = Dietary Folate Equivalents, NE = Niacin Equivalents

Table 1: DVs based on a caloric Intake of 2,000 Calories (for adults and children four or more years of age)[2]

Determining the Percent Daily Value

The percent daily values of the energy containing nutrients such as carbohydrate, added sugars, protein and fat are based off recommend amounts of these nutrients for someone eating a 2000 Calorie diet. The other nutrients are based off values that have been suggested to maintain optimal health. Table 1 lists the daily values that are used for labeling purposes.

Ingredient List

It is required that the ingredients be listed by weight from highest to lowest. In the following product, the most predominant ingredient is whole wheat flour. Can you guess what this product is???

Ingredients: Whole wheat flour, water, sugar, wheat gluten, high fructose corn syrup, soybean oil, yeast, salt, soy lecithin, preservatives.

If you guessed "bread" you are correct. You can tell that it is whole wheat bread, because the first ingredient is whole wheat flour.

The ingredient list can also assist you in assessing the nutrient density of products. Consider the following beverages. Which one do you think will be more nutrient dense?

Product A Ingredients: Apple, grape and pomegranate juice from concentrate, fruit and vegetable juices (for color), blueberry juice from concentrate, natural flavors, raspberry juice from concentrate, modified gum acacia, vitamin C, citric acid.

Product B Ingredients: Filtered water, sugar, apple juice concentrate, citric acid, strawberry juice concentrate, natural flavor.

Both products contain juice, but product A would clearly be the more nutrient dense choice. It is composed of 100% fruit juices, with no added sugars. Product B contains added sugar as the primary ingredient after water. It also contains fruit juice but it is far down the list.

Interestingly there is more to this story; product A is definitely more nutrient dense, but its producers have been criticized for misleading advertising. This product is labeled as pomegranate, blueberry juice. Neither of those juices are a primary part of this product. The New

York Times reported that blueberry and pomegranate juices only contributed 0.5% of this product.[3] By correctly assessing the ingredient list, a savvy consumer would have been able to determine this on their own. As a person's understanding increases they become better able to be agents that act instead of being acted upon.

Claims on Labels

In addition to mandating nutrients and ingredients that must appear on food labels, any **nutrient-content claims** must meet certain requirements. For example, a manufacturer cannot claim that a food is fat-free or low-fat if it is not, in reality, fat-free or low-fat. Low-fat indicates that the product has three or fewer grams of fat per serving; low salt indicates there are fewer than 140 milligrams of sodium per serving, and low-cholesterol indicates there are fewer than 20 milligrams of cholesterol and two grams of saturated fat per serving (see Table 2).

Term	Explanation
Free	Infers a serving size of the product provides a dietary insignificant or trivial source of calories, fat, saturated fat, cholesterol, sodium or sugars. For example, a product that is labeled sugar or fat free would contain less than 0.5 g/serving. A sodium free product would contain less than 5 mg/serving.
Low	Used on products that contain small amounts of calories, fat, saturated fat, cholesterol or sodium. For example, a product that is labeled low in fat would contain 3 grams or less per serving. A low sodium product would contain 140 mg/serving or less
High/Excellent	Contains 20% of the nutrient's DV
Good Source	Contains 10 to 19% of the nutrients DV
Reduced	Indicates a product contains 25% less of calories, fat, saturated fat, cholesterol, added sugar or sodium as compared to a similar reference food. For instance a reduced sodium soy sauce would contain 25% less sodium that a standard soy sauce.

Table 2: Common label terms defined[4]

Health Claims

Often we hear news of a particular nutrient or food product that contributes to our health or may prevent disease. A health claim is a statement that links a particular food with a reduced risk of developing disease. For example, a health claim on a food product that state "reduces heart disease," (or any number of other possible approved health claims) must be evaluated by the FDA before it may appear on packaging. Prior to the passage of the NLEA products that made such claims were categorized as drugs and not food. All **health claims** must be substantiated by scientific evidence in order for it to be approved and put on a food label. To avoid having companies making false claims, laws also regulate how health claims are presented on food packaging. In addition to the claim being backed up by scientific evidence, it may never claim to cure or treat the disease. (For additional information go to FDA.gov).

3.2 Dietary Reference Intakes (DRI's)

The **Dietary Reference Intakes** (DRI's) are a set of evidence based standards developed by the Institute of Medicine to assess the dietary intake of healthy people. When looking at nutrient content of foods obtained from food labels or nutrient databases, the values mean little unless there is a standard to judge them from. The categories housed within the DRI's include the **recommended dietary allowances** (RDA's), **adequate intakes** (AI's), **tolerable upper intake level** (UL's), the **acceptable macronutrient distribution ranges** (AMDR's), **estimated energy requirement** (EER) and the **estimated average requirements** (EAR's). In this section, we will discuss the RDA's, AI's, EAR's and UL's; the AMDR's and EER's will be highlighted later (see Figure 4).

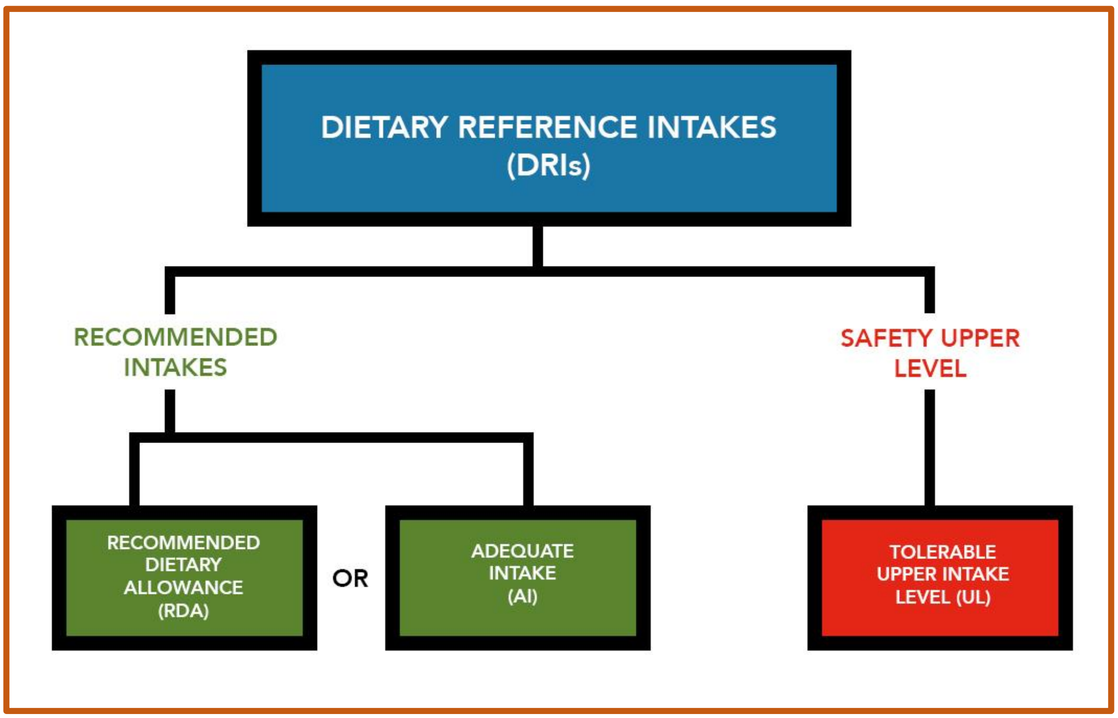


Figure 4: The dietary reference Intakes Includes recommended daily intakes (RDA's) and adequate intake (AI's) as well as intake levels that can be detrimental to health (tolerable upper intake level or UL's)

Establishing the recommendations

When establishing the dietary reference intakes, a group of experts examine the current peer reviewed literature for each of the essential nutrients. A method is selected that is thought to be the best measure of how much of that nutrient a person needs for short-term and long-term health. It might be based on a comparison of intake and losses or blood levels of the nutrient; or a more complicated test, such as one that measures the activity of an enzyme dependent on that nutrient. In the case of calcium, it is well understood that blood levels do not reflect calcium intake, so amounts needed to optimize bone mineral density was included in the establishment of the requirements.[5] When establishing needed intakes, populations are usually broken down by gender and age. But, even when groups of similar people are compared, nutrient needs are still spread out over a distribution. We are just biologically diverse. For instance, if the vitamin A requirements of a large group of women age 19-30 were determined, you would likely see a distribution as depicted in Figure 5. The amount of vitamin A that meets the need of 50% of this group is the **estimated average requirement** (EAR).

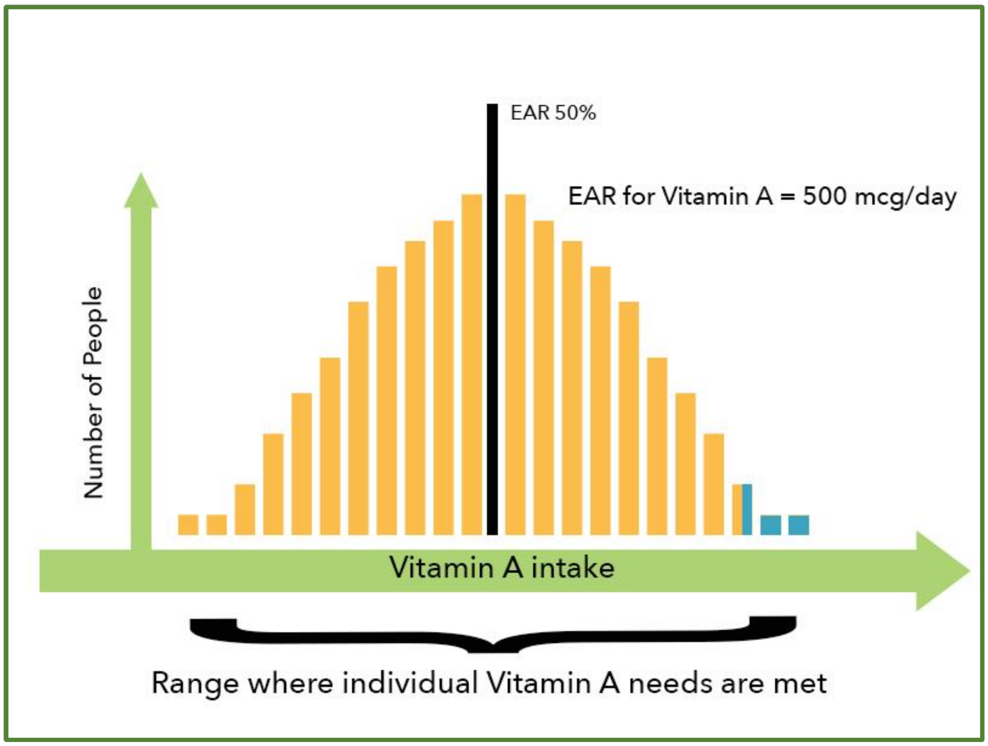


Figure 5: A hypothetical representation of Vitamin A needs of a group of women ages 19-30

If we think about this for a moment, the error of publishing this number (the EAR) as a recommended intake for a population becomes clear. The EAR for females 19-30 is 500 mcg/day. If a population set that as a standard to achieve and everyone reached that goal, half of the population would still be taking in insufficient amounts of that nutrient. With that understanding the recommendation for vitamin A (and most all nutrients) is set two standard deviations from the EAR, and covers 97-98% of the population that was studied. This recommendation is called the **recommended dietary allowance** (RDA). (See Figure 6).

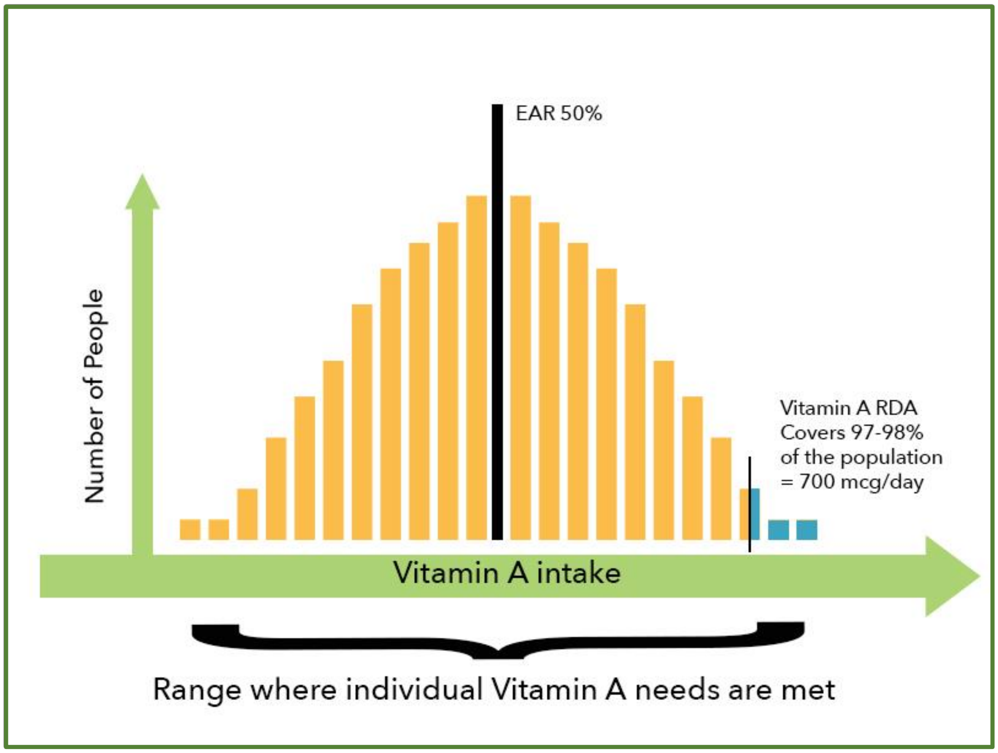


Figure 6: Setting RDA's

The RDA for vitamin A for a female 19-30 years of age is 700 mcg/day, 200 mcg higher than the EAR. For some of the nutrients, insufficient consistent scientific data is available to set an EAR and associated RDA. In those cases, a recommended intake is still provided, but it is labeled as an **adequate intake** (AI), instead of an RDA. It represents an estimation of dietary need based off typical intakes of healthy people.

Establishing recommended intake levels is not the only concern that needs to be addressed when discussing nutrient intake levels; excessive consumption of many of the vitamins and minerals can be harmful. Some have only mild effects; others can be lethal if excessive amounts are consumed. If a nutrient has a known toxicity, a **tolerable upper intake level** (UL) is set. For example, vitamin A for women 19-30 has a UL of 3000 mcg/day (remember the RDA was 700 mcg/day for women 19-30). It is typically very difficult to exceed the UL by eating food; overdoses of vitamins and minerals most often occur through supplementation. The UL represents the highest level of a nutrient that is likely to pose no adverse health effects. If a nutrient does not have a UL set, it is not necessarily safe to consume in large amounts. Such practices are how we discovered that some nutrients that did not have a UL needed one. Figure 7 correctly displays the appropriate view of most vitamin and minerals. Danger lurks on each end of the spectrum, too much or too little of a nutrient can be harmful. The idea that more of something good is always better, is not the case when considering vitamin and mineral intake.

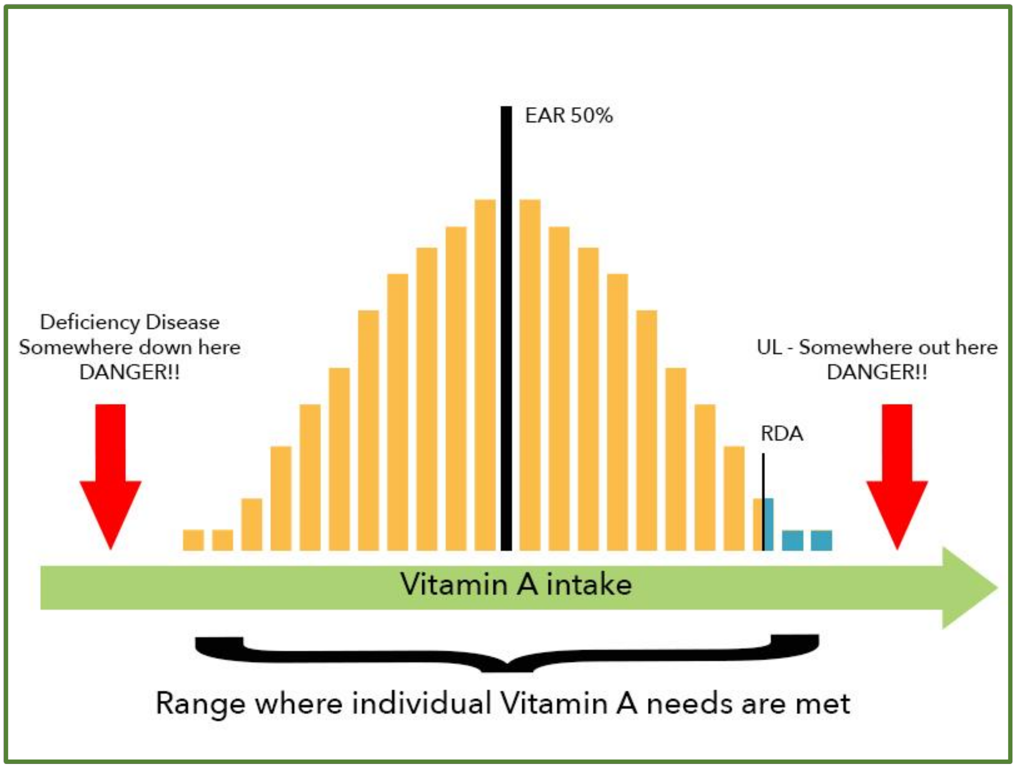


Figure 7: Setting the tolerable upper intake level (UL)

In summary, remember that the RDA's do not reflect your personal need; to find out your personal need, you would need to be tested individually. The recommendations are set generously, so if your intake reaches the RDA (or AI) it is most likely your intake is just fine. The DRIs are also not appropriate for people who are ill or malnourished, even if they were healthy previously.

3.3 Variety, Moderation and Balance

Food labels, nutrient databases, Daily Values and the DRI's are used to evaluate the nutrient content of foods. Next, tools that are available to evaluate intake from a food point of view will be addressed; they include the Dietary Guidelines for Americans and its visual representation, Choose MyPlate. Before starting this discussion, it will be important to understand the principles of variety, moderation and balance.

A healthy diet can best be achieved by selecting nutrient dense foods while following the principles of variety, moderation, and balance.

Variety

The foods we eat are typically grouped into 6 major categories: protein, grains, fruits, vegetables, dairy and oils. The principle of **variety** refers to consuming foods from each of the food groups on a regular basis. The principle of variety is represented by the United States Department of Agriculture's "MyPlate" eating pattern (see Figure 8). The MyPlate visual illustrates the importance of choosing foods from all of the food groups on a regular basis, and will be discussed in more detail later.

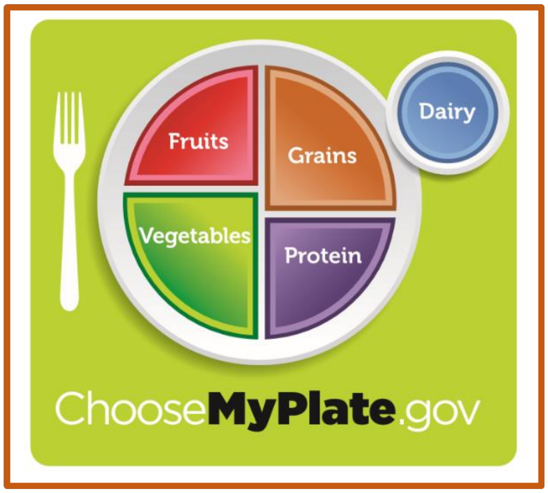


Figure 8: The United States Department of Agriculture's "MyPlate" eating pattern emphasizes choosing foods from each of the food groups on a regular basis

It is also important to apply the principle of variety within food groups as well. For instance, a person may choose to have a vegetable at every meal, but may only select between potatoes and corn. The principle of variety in the vegetable group would be best met by regularly choosing vegetables with a variety of colors. The different colored vegetables typically contain different essential nutrients and different phytochemicals.

Choosing a variety of foods within food groups is an important element of the principle of variety

In the United States wheat is the primary grain product in our food supply. We often overlook other healthy whole grains such as barley, quinoa, rye and buckwheat. Optimal health benefits come from applying the principle of variety when choosing grains as well. Plus, part of the fun of eating is finding a new healthy food you enjoy!

Moderation

The principle of **moderation** is applied by not eating to the extremes, neither too much nor too little. In places where food is abundant and easily accessed, overconsumption is a common problem. Overconsumption of calories, saturated fats, added sugars, sodium, and alcohol have been highlighted to Americans as dietary areas of particular concern[6].

Balance

The principle of **balance** brings eating into perspective. Eating French fries, cake, and ice cream each night with dinner will lead to health complications and doesn't match the principle of variety or moderation. The principle of balance teaches that it is okay to choose a dinner like that

The principle of balance is practiced when the selection of foods complement each other and manage overall caloric and nutrient intake occasionally, and when a less nutrient dense dinner is selected, your breakfast and lunch might be carefully selected with extra nutrient dense choices from the appropriate groups to balance out your intake.

3.4 2015-2020 Dietary Guidelines for Americans

The U.S. Departments of Health and Human Services (HHS) and of Agriculture (USDA) are required, by law, to publish evidence based nutrition and dietary recommendations every five years. These recommendations are called the ***Dietary Guidelines for Americans***. This publication promotes healthy eating and exercise practices to help support a healthy weight and reduce the risk of chronic disease throughout the lifespan.

The Dietary Guidelines is designed to help individuals 2 years and older consume a well-balanced and adequate diet. The information in this report is used to make public health education materials, policies and programs. The most current publication, the 2015 *Dietary Guidelines for Americans*, emphasizes five key elements to help Americans eat well and help prevent disease.

Figure 9: Components of a healthy eating pattern has both variety and limitations

1. Follow a Healthy Eating Pattern Across the Lifespan

A healthy eating pattern is not a strict set of rules or a list of good and bad foods. Instead, a healthy eating pattern is flexible and takes into account individual calorie needs, personal preferences, time and budget. Within a healthy eating pattern, it is best to include healthy choices in each of the food groups – vegetables, fruits, lean protein, low-fat dairy and grains – especially whole grains, and oils. Healthy eating patterns limit calories from added sugar, saturated, and *trans* fats and reduce sodium intake (see Figure 9).

You can build a healthy eating pattern by putting together foods from all food groups in different ways to match your personal preferences and situations. Figure 10 shows how each component of the sample meal displayed covers each of the recommended food groups. Food amounts can be adjusted to meet your personal calorie limits and preferences.

Figure 10: Example of how a thoughtfully selected meal can provide nutrients from each of the food groups.

The principle can be applied to a variety of eating styles. Figure 11 shows how food combination consistent with a vegetarian, Mediterranean and American styles can follow the principle promoted in the dietary guidelines.

2. Focus on Variety, Nutrient Density, and Amount

The principles of variety, nutrient density and amount (or moderation) are key principals in making good choices. Incorporating all food groups, including different foods from each food group, will help ensure variety and maximize the nutrient quality of your diet. **Nutrient density**, or the amount of nutrients you get per calorie, will help you reach your nutrient recommendations within a day without going over your calorie level. Amount is important as well. Serving sizes have increased in the last few decades and it has become easier to overeat. All foods can be enjoyed, if the amounts are appropriate.

Figure 11: Healthy food combinations consistent with different eating patterns

3. Limit Calories from Added Sugars and Saturated Fats and Reduce Sodium Intake

American consumption of **empty calories**, or foods that contain a lot of calories and not very many nutrients, mostly in the form of saturated fats and added sugar, has been estimated to be about three times what they should be.[7] It is difficult to meet your nutrient needs within a healthy caloric level when consumption of calories from added sugars and saturated fats is high. It is recommended that Americans reduce their intake of foods and beverages high in these components to be consistent with the following guidelines:[6]

- ✓ Consume less than 10% of total calories per day from added sugars
- ✓ Consume less than 10% of total calories per day from saturated fats
- ✓ Consume less than 2300 mg of sodium
- ✓ If alcohol is consumed, drink in moderation. Moderate drinking is defined as up to two drinks per day for men and up to one drink per day for women.

Figure 12 displays how Americans compare to the current recommendations for several selected food groups or dietary components; including added sugars, saturated fat and sodium.

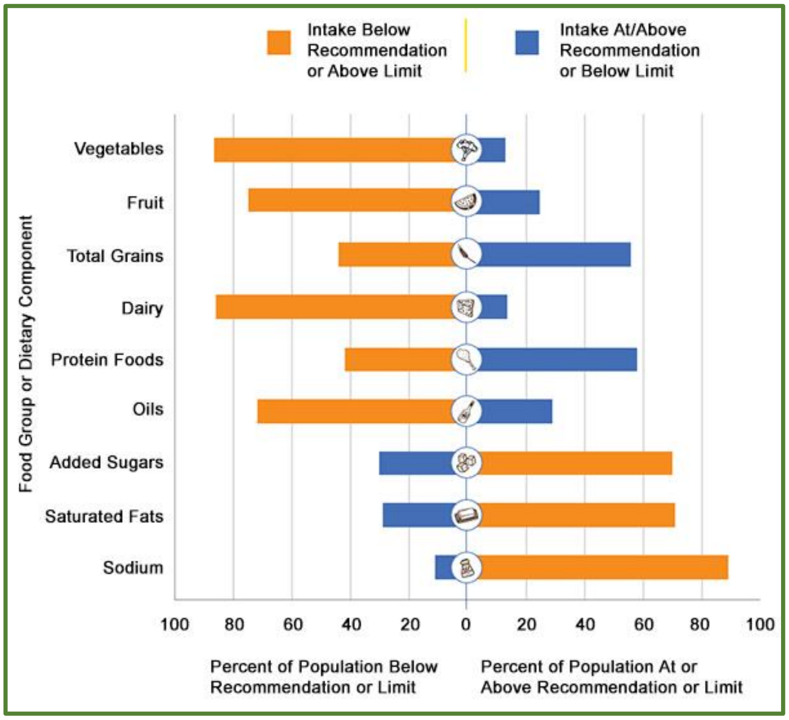


Figure 12: Current eating patterns in the United States show higher consumption of sugars, fats, and sodium, and lower consumption of other nutrition needs

4. Shift to Healthier Food and Beverage Choices

Emphasis on Added Sugar

Food is not the only source of calories and nutrients in our diets; beverages can play a big role in our daily intake of calories. In fact, almost half (47%) of American's added sugar intake comes from beverages which include soft drinks, fruit drinks, sweetened coffee and tea, energy drinks, alcoholic beverages and flavored waters. Intakes of added sugar are estimated to be about 13%

of total calories, above the less than 10% recommendation.[5] Strategies for lowering added sugar intake include switching to beverage choices without added sugar, decreasing portion size and frequency of these beverage options and drinking 100% fruit or vegetable juice and water. Other suggestions include decreasing portions and frequency of grain and dairy based desserts, switching from canned fruits with added sugar to fresh or frozen fruit without added sugar and unsweetened versions of yogurt.

Saturated fat

Do you have a favorite meal or casserole? Chances are it might be high in saturated fat. The category of "mixed dishes" is at the top of the list of foods that contribute to high intakes of saturated fat. While these foods can still fit into a healthy eating pattern, small changes to the recipes or eating them less frequently can decrease intake of saturated fat. Intakes of saturated fat are estimated to average about 11% of total calories, above the less than 10% recommendation.[6]

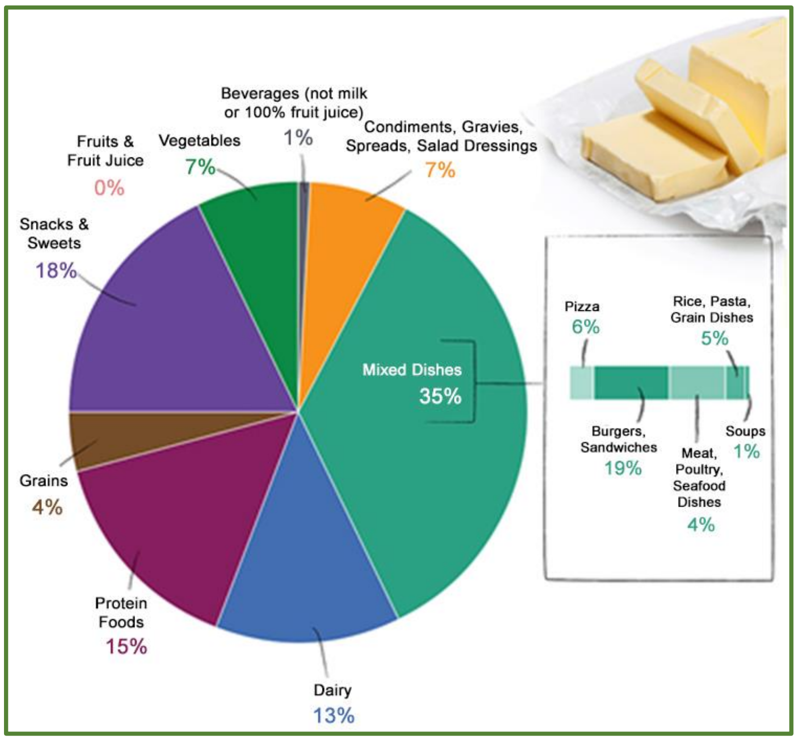


Figure 13: Saturated fat intake in America

Strategies for decreasing intake of saturated fats include replacing solid fats for cooking with oils high in polyunsaturated and monounsaturated fats, decreasing portion sizes of mixed dishes, replacing some of the high fat meats with vegetables, grains, lean meats and low-fat cheeses and replacing high fat dairy with low-fat options.

Sodium

Average sodium intake in America is higher than the Tolerable Upper Intake Levels (ULs) of 2300 mg/day. Adult men average an intake of 4,240 mg/day and adult women average an intake of 2,980 mg/day.[6] Most sodium intake comes from processed foods, while very little of the intake comes from preparing foods at home or adding salt to your food at the table.

Suggestions to help reduce intake of sodium include eating less processed and "instant" foods which tend to be higher in sodium. Reading food labels can be helpful as well when you look for "Reduced sodium", "low -salt" or "No salt added". Choosing unsalted canned vegetables, and preparing food at home more often can also help decrease sodium intake.

Remember that healthy eating patterns include personal preferences, so as you make these shifts to choices lower in saturated fat, added sugar and sodium, consider your personal preferences so you can maintain these changes.

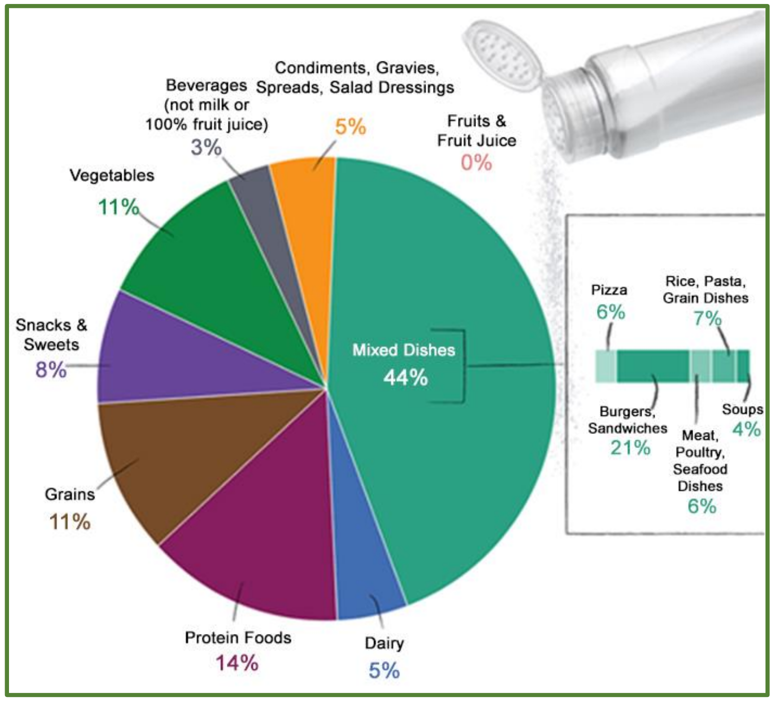


Figure 14: Sodium intake in America is primarily found in mixed dishes.

Alcohol

Dietary Guidelines suggests that if alcohol is consumed, intake should be moderate, or up to two drinks per day for men and up to one drink per day for women, and only by adults of legal drinking age. Calories provided by alcohol need to be accounted for in order to meet nutrient needs and stay within healthy calorie limits. The *Dietary Guidelines* does not recommend that you begin drinking if you currently do not drink alcohol. There are also times people should not drink, including during pregnancy.

Summary

Shifts to decrease these food components will help decrease risk of chronic disease. A healthy shift to increase certain food groups, such as vegetables, fruits, low-fat dairy and whole grains will also provide benefits. An increase in these foods can also reduce risk of chronic disease by providing nutrients Americans are generally low in such as fiber, potassium and calcium.

5. Support Healthy Eating Patterns for All

What affects your food and physical activity choices? Maybe you identified culture, traditions, cost, availability, goals or education as influences of your choices. *Dietary Guidelines* recognizes there are several factors that affect food and physical activity choices. The factors fall within these areas: Social and Cultural Norms and Values, Sectors, Settings and Individual Factors.[6]

3.5 Using Choose MyPlate to Evaluate Food Intake

In conjunction with the publication of the Dietary Guidelines, traditionally a graphic representation of the principles contained in the guidelines has also been released. In 1992 the food pyramid was introduced, and in 2005 it was updated. For many years, this stood as the symbol of healthy eating patterns represented in the Dietary Guidelines for Americans. However, some felt it was difficult to understand, so in 2011, the pyramid was replaced with **Choose MyPlate**.

Key Nutrients in the Food Groups

The five food groups in the MyPlate food guide are Fruits, Vegetables, Grains, Protein Foods, and Dairy. Food groups simplify implementing the dietary recommendations by placing the focus on food instead of nutrients. Each food group includes a variety of foods that have similar key nutrients (Figure 15).

Key Nutrients in Food Groups

Fruits/Vegetables Group
- Vitamin A, Vitamin C, Folate, Potassium
- If whole fruit/vegetable: Fiber

Grain Group
- Thiamin, Riboflavin, Niacin, Iron
- If whole grain: Fiber, Magnesium

Protein Foods Group
- Protein, Vitamin B-6, Niacin, Iron, Zinc
- If animal source: Vitamin B-12
- If legumes, nuts, or seeds: Fiber, Magnesium

Dairy Group
- Protein, Riboflavin, Calcium, Potassium
- If animal source: Vitamin B-12

Figure 15: Key Nutrients in MyPlate Food Groups

Key nutrients in the Fruits and Vegetable food groups are similar and include vitamin A, vitamin C, folate (one of the B vitamins), potassium, and fiber. Although juice contributes many of these nutrients, it is lower in fiber and so emphasis is placed on eating the whole fruit or vegetable.

Whole grains in the grain group provides thiamin, riboflavin, niacin, iron, magnesium, and fiber. However, several of the nutrients are lost when the whole grains are refined. Through the enrichment process, thiamin, riboflavin, niacin, and iron are added back along with the extra fortification of folate. However, fiber, magnesium, and other nutrients are not added back in.

The Protein Foods group includes a wide range of animal and plant foods. Key nutrients in the Protein Foods group include protein, vitamin B-6, niacin, iron, and zinc. Vitamin B-12 is also a key nutrient if the food is from an animal source. Legumes, nuts, and seeds provide fiber and magnesium.

The Dairy group includes milk, yogurt, cheese, and fortified soy beverages (such as soy milk). Other plant milks such as rice milk and almond milk are not included in this group because they do not provide protein. Key nutrients in this group include protein, riboflavin, calcium, and potassium. If the food is from an animal source, vitamin B12 is also a key nutrient.

How to Use the MyPlate Food Guide

The MyPlate graphic visually reflects how prevalent each of the food groups should be in our daily food choices. Fruits and vegetables should cover half of our plate; grains a quarter and protein a quarter. Dairy should also be a regular part of our daily choices. To use the tool as it is intended, a little extra insight is necessary.

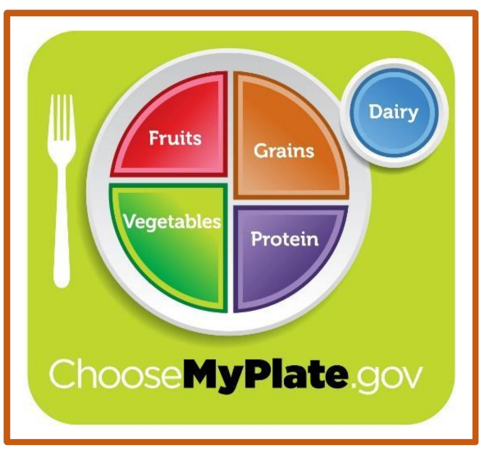


Figure 16: Choose MyPlate visual

When choosing foods to fill each section of the plate, we need to remember the principles of variety, moderation, balance and nutrient density. A few examples of how to apply this principle are: when choosing fruits and vegetables, be sure to select a wide variety of colors, selecting whole grains at least half the time, selecting lean protein sources such as chicken and fish more often, and increasing use of alternative protein sources such as legumes, nuts and seeds.

The amount of recommended food from each of the food group will vary depending on a person's caloric need.

The recommended amount of food from each of the food groups is listed in either cup or ounce equivalents. It is important to note the word "**equivalents"** when referring to the cup or ounce measures. For example, on a 2000 Calorie diet it is suggested a person eat 2 cup equivalents of fruit. But if looked at carefully it is noted that doesn't always translate to 2 cups of actual fruit. When fruit is dried, it takes less space. Only ½ cup of dried fruit is needed for a cup equivalent of fruit. For example, only ½ cup of raisins is needed to count as a cup equivalent of fruit.

Generally, a cup of raw or cooked vegetables or vegetable juice, or 2 cups of raw leafy greens count as one cup equivalent of vegetables. For example, 1 cup of raw carrots counts as 1 cup equivalent of vegetables. However, 2 cups of raw spinach (and other leafy greens) would be needed for 1 cup equivalent of vegetables. Raw leafy greens take more space than carrots.

The grain group is measured in ounce equivalents and is fairly straightforward. But, when choosing foods in this group it is important to be especially observant for added calories in the form of fat and sugars. For example, a two-ounce serving of a muffin or sandwich bread both contribute the same towards daily grain intake, but vary in calorie content because of the added fat in the muffin. Additional calories from added sugar or fats are often called empty calories.

The dairy cup equivalents are based on the calcium content of the foods in that group. A cup equivalent in the dairy group contains around 300 mg of calcium. When considering yogurt and milk, the conversion is straightforward a cup = a cup. The calcium content in cheese is concentrated when the excess fluids from milk fluids are removed in the cheese making process. Hence, a person only needs to eat 1.5 ounces of hard cheese (like cheddar cheese), or 2 ounces of processed cheese to get credit for a whole glass of milk (Figure 17).

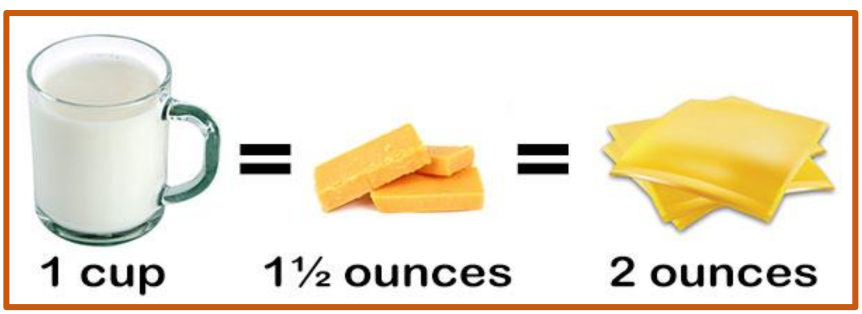


Figure 17: Cup equivalents from the Dairy Group is based on calcium content

When dealing with meat equivalents in the protein group, typically 1 ounce of meat equals 1-ounce equivalent in the Protein Foods. But the Protein Foods group is a diverse group, a variety of high protein non-meat foods need to be accounted for when scoring protein intake (such as nuts, seeds and legumes). Serving sizes for these products vary.

3.6 Translating Principles to Practice

Identifying Cups and Ounces

In order to translate principle into practice an understanding of what a cup or ounce of the various foods looks like can be helpful. Using familiar objects can be a good way to visualize the different serving sizes (see Figure 18).

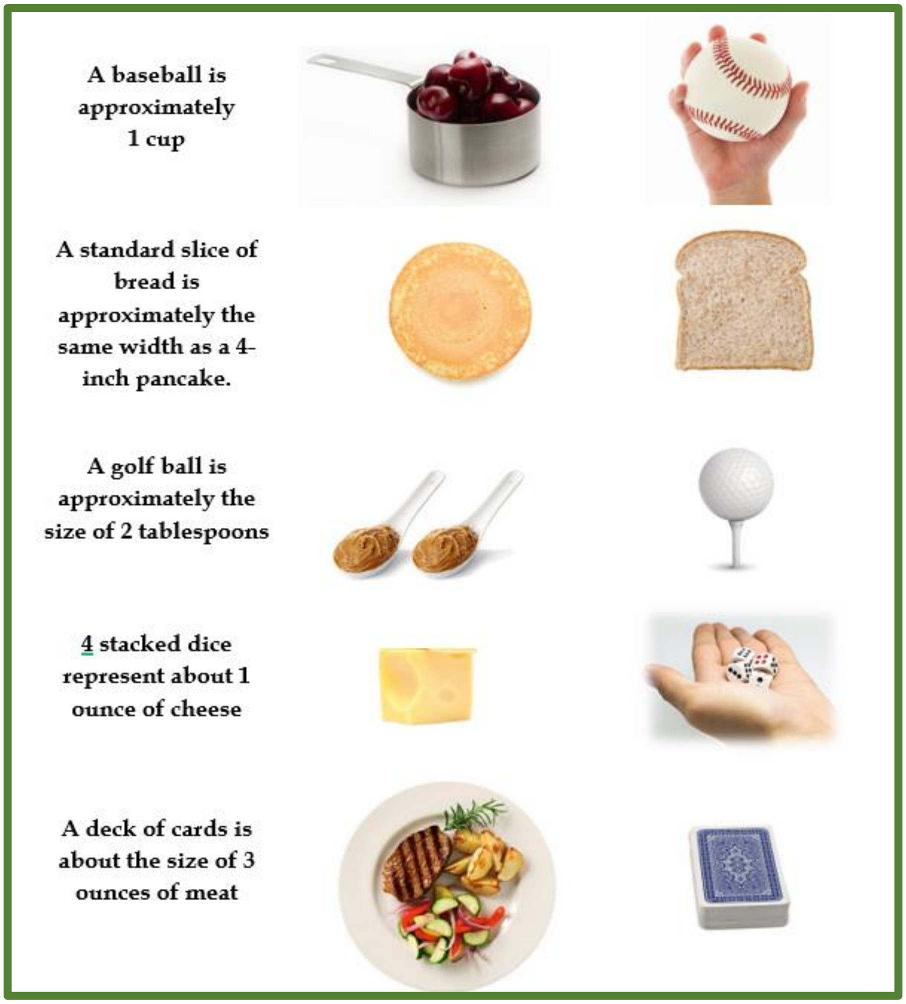


Figure 18: Measuring amounts of food using common objects

Finding the Right MyPlate Plan for You

Because people's body size, gender, age and activity differs, the amount of calories needed and as a result the amount of ounce or cup equivalents varies from person to person. By entering a person information at the ChooseMyPlate website, an appropriate set of recommendations is generated to match the profile of the person. To help demonstrate how serving amounts translate to food we will use a generic 2000 Calorie diet as an example. The amount of food this represents is depicted in Figure 19. When making food selection, it is important to remember to apply the principles of variety, balance, moderation and nutrient density. Occasionally choosing foods that include high amounts of added fats and sugars is okay and are accounted for within the MyPlate program, but generally it is important to make choices consistent with these principles.

Sample Menus for a 2000 Calorie Food Pattern

Use this 7-day menu as a motivational tool to help put a healthy eating pattern into practice, and to identify creative new ideas for healthy meals. Averaged over a week, this menu provides the recommended amounts of key nutrients and foods from each food group. The menus feature a large number of different foods to inspire ideas for adding variety to food choices. They are not intended to be followed day-by-day as a specific prescription for what to eat.

Spices and herbs can be used to taste. Try spices such as chili powder, cinnamon, cumin, curry powder, ginger, nutmeg, mustard, garlic powder, onion powder, or pepper. Try fresh or dried herbs such as basil, parsley, cilantro, chives, dill, mint, oregano, rosemary, thyme, or tarragon. Also try salt-free spice or herb blends.

While this 7-day menu provides the recommended amounts of foods and key nutrients, it does so at a moderate cost. Based on national average food costs, adjusted for inflation to March 2011 prices, the cost of this menu is less than the average amount spent for food, per person, in a 4-person family.

DAY 1

BREAKFAST
Creamy oatmeal (cooked in milk):
- *½ cup uncooked oatmeal*
- *1 cup fat-free milk*
- *2 Tbsp raisins*
- *2 tsp brown sugar*

Beverage: 1 cup orange juice

LUNCH
Taco salad:
- *2 ounces tortilla chips*
- *2 ounces cooked ground turkey*
- *2 tsp corn/canola oil (to cook turkey)*
- *¼ cup kidney beans**
- *½ ounce low-fat cheddar cheese*
- *½ cup chopped lettuce*
- *½ cup avocado*
- *1 tsp lime juice (on avocado)*
- *2 Tbsp salsa*

Beverage:
1 cup water, coffee, or tea**

DINNER
Spinach lasagna roll-ups:
- *1 cup lasagna noodles(2 oz dry)*
- *½ cup cooked spinach*
- *½ cup ricotta cheese*
- *1 ounce part-skim mozzarella cheese*
- *½ cup tomato sauce**

1 ounce whole wheat roll
- *1 tsp tub margarine*

Beverage: 1 cup fat-free milk

SNACKS
2 Tbsp raisins
1 ounce unsalted almonds

DAY 2

BREAKFAST
Breakfast burrito:
- *1 flour tortilla (8" diameter)*
- *1 scrambled egg*
- *⅓ cup black beans**
- *2 Tbsp salsa*

½ large grapefruit
Beverage:
1 cup water, coffee, or tea**

LUNCH
Roast beef sandwich:
- *1 small whole grain hoagie bun*
- *2 ounces lean roast beef*
- *1 slice part-skim mozzarella cheese*
- *2 slices tomato*
- *¼ cup mushrooms*
- *1 tsp corn/canola oil (to cook mushrooms)*
- *1 tsp mustard*

Baked potato wedges:
- *1 cup potato wedges*
- *1 tsp corn/canola oil (to cook potato)*
- *1 Tbsp ketchup*

Beverage: 1 cup fat-free milk

DINNER
Baked salmon on beet greens:
- *4 ounce salmon filet*
- *1 tsp olive oil*
- *2 tsp lemon juice*
- *⅓ cup cooked beet greens (sauteed in 2 tsp corn/canola oil)*

Quinoa with almonds:
- *½ cup quinoa*
- *½ ounce slivered almonds*

Beverage: 1 cup fat-free milk

SNACKS
1 cup cantaloupe balls

DAY 3

BREAKFAST
Cold cereal:
- *1 cup ready-to-eat oat cereal*
- *1 medium banana*
- *½ cup fat-free milk*

1 slice whole wheat toast
- *1 tsp tub margarine*

Beverage: 1 cup prune juice

LUNCH
Tuna salad sandwich:
- *2 slices rye bread*
- *2 ounces tuna*
- *1 Tbsp mayonnaise*
- *1 Tbsp chopped celery*
- *½ cup shredded lettuce*

1 medium peach
Beverage: 1 cup fat-free milk

DINNER
Roasted chicken:
- *3 ounces cooked chicken breast*

1 large sweet potato, roasted
½ cup succotash (limas & corn)
- *1 tsp tub margarine*

1 ounce whole wheat roll
- *1 tsp tub margarine*

Beverage:
1 cup water, coffee, or tea**

SNACKS
¼ cup dried apricots
1 cup flavored yogurt (chocolate)

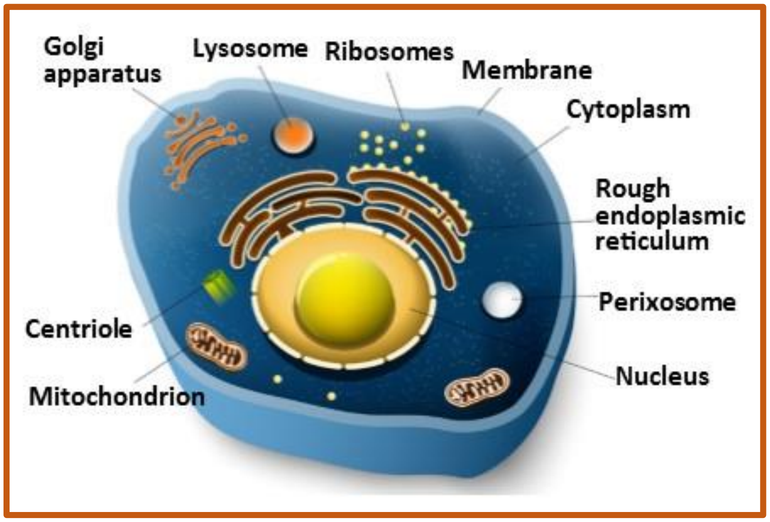
Figure 19: Sample menus for a 2000 Kcal meal plan

Chapter 4: Digestion

4.1 The Organization of the Human Body

The human body and the food we eat, like all matter on earth, are made up of atoms, the basic unit of a chemical element. These atoms combine to form molecules and then bind together to make bigger macromolecules. In living organisms, the macromolecules are organized into **cells**, the smallest and most basic form of life. The human body is comprised of trillions of cells, each is a compact and efficient form of life—self-sufficient, yet interdependent upon the other cells within your body to supply its needs.

Although we defined the cell as the "most basic" unit of life, it is structurally and functionally complex. A cell can be thought of as a mini organism consisting of tiny organs called **organelles**. The organelles are structural and functional units constructed from several macromolecules bonded together. A typical human cell contains the following organelles: the nucleus (houses the genetic material DNA), mitochondria (generates energy), ribosomes (produce protein), the endoplasmic reticulum (is a packaging and transport facility), and the Golgi apparatus (distributes macromolecules). In addition, human cells contain little digestive pouches, called lysosomes and peroxisomes, which break down macromolecules and destroy foreign invaders. All of the organelles are found in the cytoplasm of the cell. The cell's organelles are isolated from the surrounding environment by a plasma membrane.



A human cell

Single-celled organisms can function independently, but the cells of multicellular organisms (like the human body) are dependent upon each other and are organized into five different levels in order to coordinate their specific functions and carry out all of life's biological processes.

- **Cells.** Cells are the basic structural and functional unit of all life. Examples include red blood cells and nerve cells.

- **Tissues.** Tissues are groups of cells that share a common structure and function and work together. There are four types of human tissues: connective, which connects other types of tissues; epithelial, which lines and protects organs; muscle, which contracts for movement and support; and nerve, which responds and reacts to signals in the environment.

- **Organs.** Organs are a group of tissues arranged in a specific manner to support a common physiological function. Examples include the brain, liver, stomach, and heart.

- **Organ systems.** Organ systems are two or more organs that support a specific physiological function. Examples include the digestive system and central nervous system. There are eleven organ systems in the human body (see Table 1).

- **Organism.** An organism is the complete living system capable of conducting all of life's biological processes.

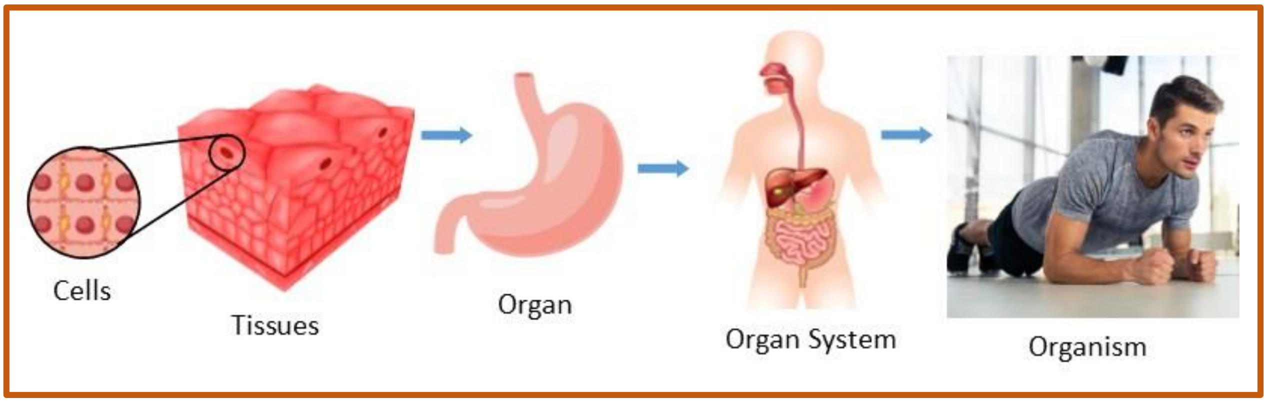


Figure 1: Cells are organized to form tissues, organs, systems, and whole organisms

Organ System	Organ Components	Major Function
Cardiovascular/ Circulatory	Heart, blood/lymph vessels, blood, lymph	Transport nutrients and waste products
Digestive	Mouth, esophagus, stomach, intestines	Digestion and absorption
Endocrine	All glands (pituitary, adrenal, thyroid, pancreas)	Produce and release hormones
Immune/ Lymphatic	White blood cells, lymphatic tissue, marrow	Defend against foreign invaders
Integumentary	Skin, nails, hair, sweat glands	Covers and protects the body; body temperature control
Muscular	Skeletal, smooth, and cardiac muscle	Body movement and structure
Nervous	Brain, spinal cord, nerves	Interprets and responds to stimuli
Reproductive	Gonads, genitals	Reproduction and sexual characteristics
Respiratory	Lungs, nose, mouth, throat, trachea	Gas exchange
Skeletal	Bones, tendons, ligaments, joints	Structure and support
Urinary	Kidneys, bladder, ureters	Waste excretion, water balance

Table 1: The major organ systems of the human body

4.2 Digestive System Overview

The digestive system is one of the eleven major organ systems of the human body and consists of four major functions: ingestion, digestion, absorption, and waste excretion. The food we eat, must be digested or broken down so that the nutrients it contains may be absorbed into the body and any waste can be eliminated.

Organs of the Digestive System

The **gastrointestinal tract**, also known as the GI tract, alimentary canal, digestive tract, or the gut, is a hollow tube-shaped organ that passes through the body and is about 30 feet long. The digestive system includes the mouth, pharynx, esophagus, stomach, small intestine, and large intestine—which includes the rectum and anus.[1] It also includes four supporting organs: salivary glands, liver, gallbladder, and pancreas (see Figure 2). The inside of the tract is called the **lumen**. The lumen is lined with mucosal tissue called the **mucosa**. There are also several layers of connective tissue and smooth muscle that surrounds the digestive tract. These layers help in the digestive process, provide protection and support, and nourishes the mucosa.

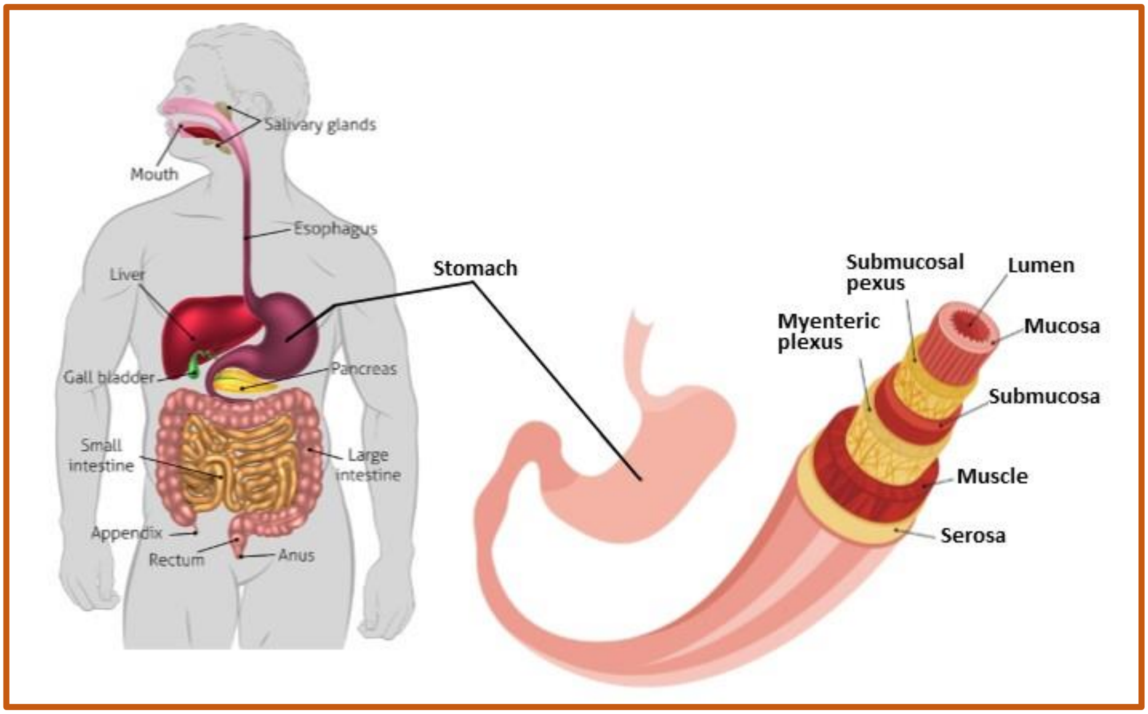


Figure 2: The digestive tract organs and close up of the layers of the intestinal tract wall

Chemical and Mechanical Digestion

Once you have eaten, your digestive system breaks down the food into smaller components. To do this, it functions on two levels, chemical and mechanical, both which occur in various organs throughout the GI tract. **Chemical digestion** involves enzymes in digestive secretions that break chemical bonds within nutrients so that they are small enough to be absorbed (see Table 2). These digestive secretions are produced by the salivary glands, stomach, pancreas, and small intestine.

Chemical Secretions	Function	Secreted From
Enzymes		
Amylases (salivary, pancreatic)	Digests starch into smaller carbohydrate molecules	Mouth and pancreas
Proteases (pepsin, trypsin, chymotrypsin)	Digests long protein chains into shorter fragments by breaking the peptide bonds	Stomach (pepsin) and pancreas (trypsin, chymotrypsin)
Lipases (lingual, gastric, and pancreatic)	Digests fats into glycerol and fatty acids	Mouth, stomach, and pancreas
Hormones		
Gastrin	Stimulates the stomach to release gastric acid	Stomach and duodenum
Secretin	Stimulates the secretion of pancreatic juice and enzymes	Small intestine
Cholecystokinin (CCK)	Stimulates the release of bile from the gallbladder and pancreatic enzymes	Small intestine
Other Secretions		
Saliva	Moistens mouth and food, eases swallowing, contains salivary amylase	Salivary glands
Mucus	Lubricates and coats the mucosa to protect it from digestive damage	Stomach, small and large intestines
Hydrochloric Acid (HCl)	An acid that lowers the pH in the stomach leading to the denaturation of proteins. It also activates pepsin which starts protein digestion by breaking the peptide bonds	Stomach
Bile	Emulsifies fat in the small intestine allowing for absorption	Liver (stored in the gallbladder)
Bicarbonate	An alkaline or basic substance that helps to neutralize stomach acid protecting the small intestine. This neutrality allows pancreatic enzymes to function	Pancreas (secreted into small intestine)

Table 2: The enzymes, hormones and digestive juices used in chemical digestion[2-10]

Mechanical digestion consists of chewing, crushing, and grinding to break apart food and then moving it through the GI tract using muscular contractions, called peristalsis and segmentation. **Peristalsis** is the involuntary circular waves of smooth muscle contraction that occurs throughout the GI tract and helps to mix food with the digestive secretions while propelling the food forward (see Figure 3). In contrast, **segmentation** sloshes food back and forth in both directions promoting further mixing of the food bolus. Once broken down into smaller nutrient particles, they will be absorbed and processed by cells throughout the body for energy or used as building blocks for new cells.

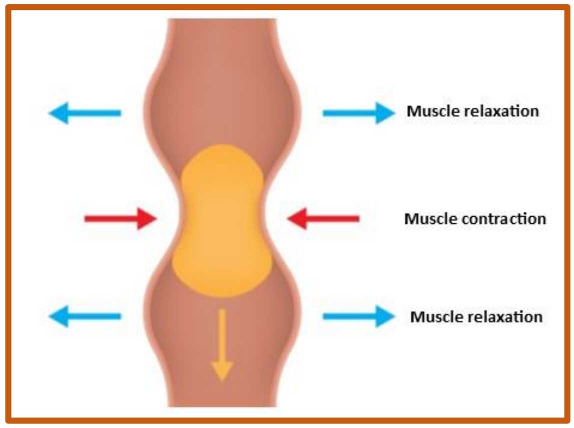


Figure 3: Peristalsis is rhythmic waves of muscle contraction and relaxation that moves the food through the digestive tract

4.3 Digestion

Digestion begins even before you put food into your mouth. Think about what happens when you are hungry, and you smell your first whiff of a freshly baked pizza or the sight of a plate of homemade gooey chocolate chip cookies. Your mouth will start to salivate with anticipation of taking your first bite. The sights and smells of food actually stimulate your body to send a message to your brain that it is time to eat. This sets into motion a cascade of events including the release of saliva and other digestive juices that prepares the body for digestion.

From the Mouth to the Stomach

The Mouth

Ingestion is the first step of the digestive process, which is the collection of food into the mouth (see Figure 4). It may seem like a simple process, but ingestion involves smelling food, thinking about food, and the involuntary release of **saliva** in the mouth to prepare for food entry. Enzymes including, **salivary amylase** are then released which start to break apart the components of the food. At the same time, chewing (mastication) starts to crush and grind the large food particles.

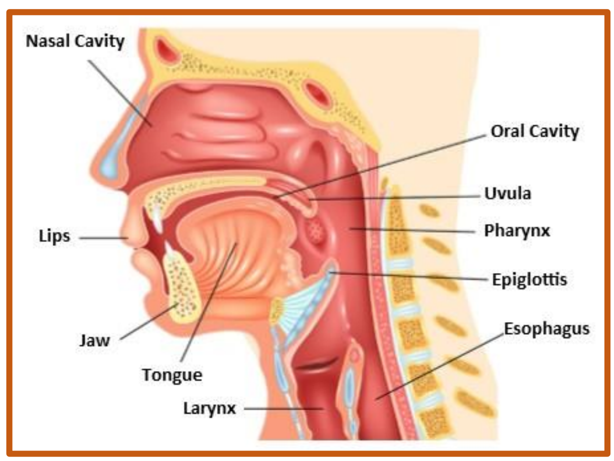


Figure 4: The digestive tract from the mouth to the esophagus

The Pharynx and Esophagus

The **pharynx** is responsible for swallowing. The swallowing process seems intentional or controlled at first because it requires conscious effort to push the food with the tongue back toward the throat, but after this, swallowing proceeds involuntarily, meaning it cannot be stopped once it begins. As you swallow, the bolus of chewed food is pushed from the mouth through the pharynx and into a muscular tube called the **esophagus**. As it travels through the pharynx, a small flap called the **epiglottis** closes, to prevent choking by keeping food from going into the trachea, the hollow tube that connects the larynx to the lungs. Peristaltic contractions in the esophagus propel the food down to the stomach. At the junction between the esophagus and stomach, a sphincter muscle (circular muscle in the digestive tract that controls the passage of food and liquids) remains closed until the food bolus approaches. The pressure of the food bolus stimulates this **lower esophageal sphincter** (see Figure 5) to relax and open and food then moves from the esophagus into the stomach. Solid food takes between four and eight seconds to travel down the esophagus, and liquids take about one second.

From the Stomach to the Small Intestine

The Stomach

When food enters the stomach, a highly muscular organ, powerful peristaltic contractions help mash, pulverize, and churn food into chyme. **Chyme** is a semiliquid mass of partially digested food that also contains gastric juices secreted by cells in the stomach. Included in these gastric juices is **hydrochloric acid** (HCl) which activates the enzyme **pepsin**, also secreted by the cells in the stomach.[2] Pepsin chemically breaks down food into smaller molecules. The length of time food spends in the stomach varies by the macronutrient (carbohydrates, proteins, and lipids) composition of the meal. A high-fat, high-protein, or high-fiber meal takes longer to break down than one rich in simple carbohydrates. It usually takes a few hours after a meal to empty the stomach contents completely. The chyme will leave the stomach passing through the **pyloric sphincter** (see Figure 5), a smooth muscle junction between the bottom of the stomach and the duodenum of the small intestine.

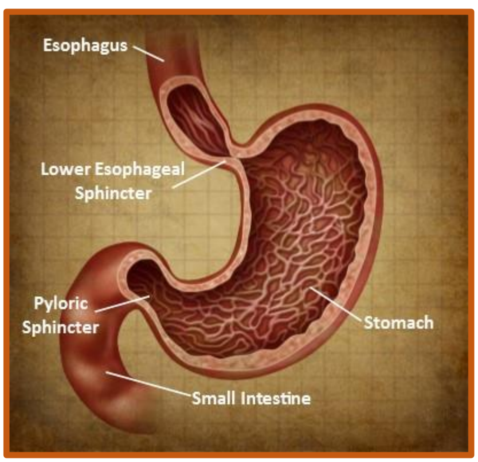
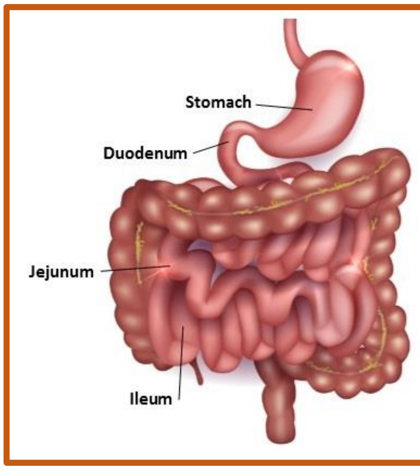


Figure 5: Placement of the lower esophageal and pyloric sphincters

Small Intestine

The small intestine is approximately 20 feet long and 1 inch in diameter.[11] It is divided into three structural parts: the **duodenum**, the **jejunum**, and the **ileum**. Once the chyme enters the duodenum (the first segment of the small intestine), the pancreas and gallbladder are stimulated and release juices that aid in digestion. Almost all the components of food are completely broken down to their simplest unit within the first 25 centimeters of the small intestine, in the duodenum. Instead of proteins, carbohydrates, and lipids, the chyme now consists of amino acids, monosaccharides, and emulsified fatty acids.



The small intestine is divided into three parts: the duodenum, jejunum, and ileum.

The next step of digestion, nutrient absorption, mostly takes place in the remaining segments of the small intestine—the jejunum and ileum. The small intestine is perfectly structured for maximizing nutrient absorption. Its surface area is greater than 200 square meters, which is about the size of a tennis court. The surface area of the small intestine increases by multiple levels of folding found in the lining of the small intestine (see Figure 6). These folds are covered with thousands of **villi**, which are tiny finger-like projections that are covered with even smaller hair-like projections, called **microvilli**. Both the villi and microvilli further increase the surface area available for absorption. Each villus contains blood capillaries and lymph vessels which carries the digested nutrients that have been absorbed throughout the body.

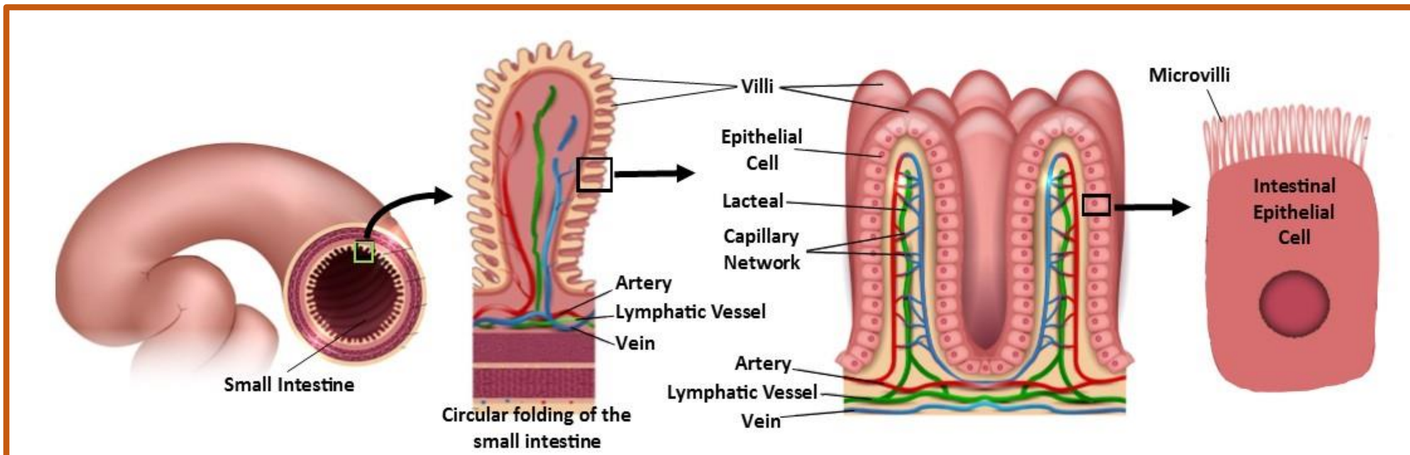


Figure 6: The intestinal folding, villi, and microvilli all increase the surface area of the small intestine to optimize nutrient absorption and is often called the brush border

From the Small Intestine to the Large Intestine

The process of digestion is fairly efficient. Any food that is still incompletely broken down (usually less than ten percent of food consumed) and the food's indigestible fiber content moves from the small intestine to the large intestine through the **ileocecal valve**, a connecting sphincter. The large intestine is about 5 feet long 3 inches in diameter and it consists of the colon, rectum and anus.[11]

The main task of the large intestine is to reabsorb water. Remember, water is present not only in solid foods, but also the stomach releases a few hundred milliliters of gastric juices and the pancreas adds approximately another 500 milliliters during the digestion of the meal. For the body to conserve water, it is important that the water be reabsorbed. In the large intestine, no further chemical or mechanical breakdown of food takes place, unless it is accomplished by the bacteria that inhabit this portion of the digestive tract. The number of bacteria residing in the large intestine is estimated to be greater than 100 trillion, which is more than the total number of cells in the human body (10 trillion). This may seem rather unpleasant, but the great majority of bacteria in the large intestine are harmless and most are even beneficial.

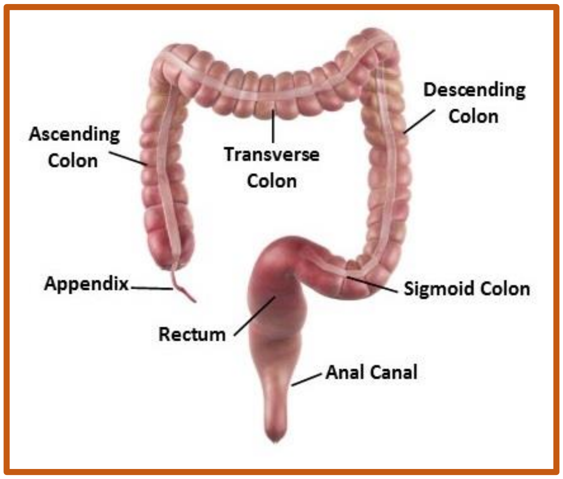


Diagram of the large intestine

From the Large Intestine to Elimination

After a few hours in the stomach, plus three to six hours in the small intestine, and about sixteen hours in the large intestine, the digestive process enters step four, which is the elimination of indigestible food as feces. Feces contain indigestible food and gut bacteria (almost 50 percent of the content is bacteria). It is stored in the rectum until it is expelled through the anus via defecation or elimination.

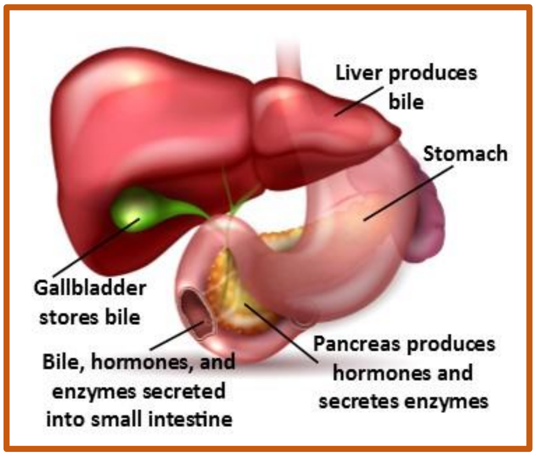
Accessory Organs: Salivary Glands, Liver, Gallbladder and Pancreas

Although the food we eat does not pass through the salivary glands, liver, gallbladder, or the pancreas these supporting or accessory organs are still critical to the digestive process.

The **salivary glands**, found in your mouth, start the digestive process by releasing saliva, a watery fluid that helps to soften the food that you eat and makes it easier to swallow. Saliva contains water, electrolytes, enzymes (including salivary amylase which starts to break down carbohydrates) and mucus.

The **liver** is one of the largest organs of the body. It assists in digestion by making 600 to 1,000 milliliters of **bile** each day.[12] Once made, the bile is collected, concentrated, and stored in the **gallbladder**. The gallbladder can hold 30 to 60 milliliters of bile at one time.

The presence of food in the stomach and small intestine stimulates the release of the hormone **cholecystokinin** (CCK) by the small intestine which then prompts the release of bile from the gallbladder into the duodenum.[7] The bile emulsifies or surrounds the fat allowing for the movement of fats in the watery environment of the small intestine.[12] Through the emulsification process, large fat globules are separated into smaller droplets or particles making it more available for digestion by the lipase enzymes.[13,14]



Accessory organs: liver, gallbladder, and pancreas assist with digestion

The **pancreas** secretes up to 1,500 milliliters per day of pancreatic juice through a duct into the duodenum of the small intestine. This fluid consists mostly of water, but it also contains bicarbonate and digestive enzymes. **Bicarbonate**, neutralizes the acidity of the stomach-derived chyme, raising the pH and making the small intestine environment more basic or neutral.[10] The neutral environment is needed for the **pancreatic enzymes** to function properly. These enzymes, released by the pancreas, help to further break down proteins, carbohydrates, and lipids (see Table 2 above in section 4.2 for further details on the digestive juices and enzymes).

4.4 Nutrient Absorption and Delivery

When the digestive system has broken down food to its nutrient components the body eagerly awaits absorption and delivery. For the nutrients to be used by the body cells they have to first leave the GI tract being absorbed through the intestinal wall and then delivered to one of the body's two transport systems: the circulatory (blood) or lymphatic systems. The choice of which system is used mainly depends on whether the nutrient is water or fat-soluble. Those nutrients that are water-soluble, such as glucose and amino acids are transported from the small intestine to the liver through the body's network of blood vessels and veins. Lipids and other fat-soluble nutrients are transported through the lymphatic system, before ever entering the blood.

Types of Absorption

Once the digested nutrients reach the small intestine they are absorbed by one of three methods: passive diffusion, facilitated diffusion, or active transport (see Figure 7). In **passive diffusion,** nutrients are moved across the intestinal cell membrane due to the concentration gradient that exists. This means that there is a difference in the number or amount of particles found on each side of the membrane. One side is higher or has more particles than the other side. For example, when the concentration is greater (more particles) in the GI tract than inside the intestinal cell (less particles), the nutrients freely, without needing energy or a transporter, move across the cell membrane. Similarly, in **facilitated diffusion** the nutrients are absorbed by moving from high to low concentration without needing energy. However, in facilitated diffusion a dedicated protein is needed to carry the nutrient across the cell membrane. In contrast, **active transport**, moves digested nutrients from a low to a high concentration requiring both energy and a protein carrier to move the nutrients across the cell membrane.

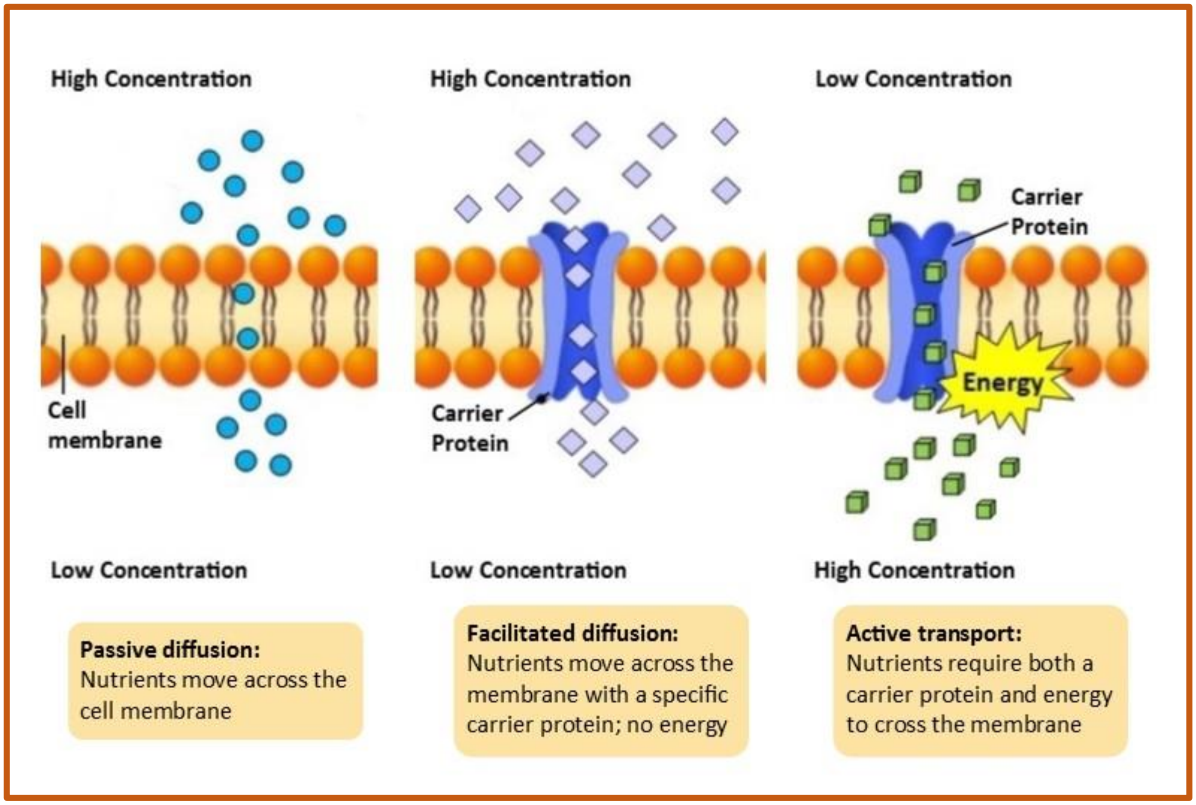


Figure 7: The three different small intestine absorption methods: passive diffusion, facilitated diffusion, and active transport

The Circulatory System

The **circulatory system**, also known as the cardiovascular system, circulates blood throughout the body (see Figure 8). The blood transports nutrients and oxygen to different organ and tissue cells of the body and removes carbon dioxide and other waste products from cells. This system consists of the heart, blood, and blood vessels. The heart pumps the blood, and the blood is the transportation fluid. The transportation route to all tissues is a highly intricate blood-vessel network, comprised of arteries, veins, and capillaries. **Arteries** are vessels that transport blood away from the heart while **veins** are vessels that transport blood towards the heart. Water-soluble nutrients absorbed in the small intestine travel mainly to the liver through the hepatic (liver) portal vein. The liver regulates the use of nutrients. Some nutrients are stored by the liver, some are changed into different forms, while others are released into the circulation and delivered out to the cells of the body.

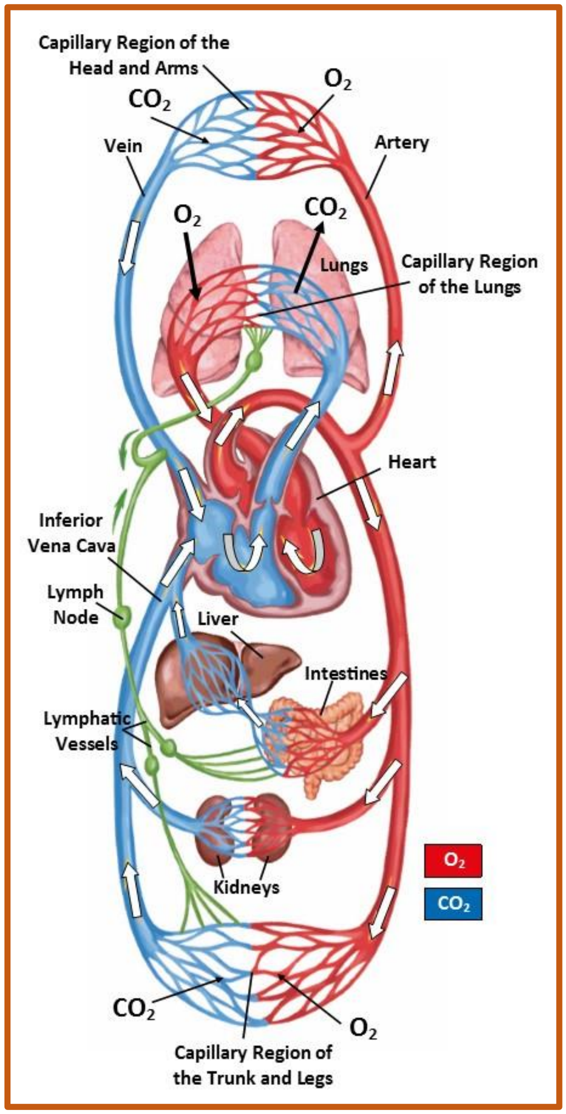


Figure 8: Blood circulation through the body. Red color indicates blood is rich in oxygen and blue is for blood that carries carbon dioxide. The green vessel represents the lymphatic vessels

From the liver, nutrients travel upward through the inferior vena cava blood vessel to the heart. The heart forcefully pumps the nutrient-rich blood first to the lungs to pick up some oxygen and then to all other cells in the body. Arteries become smaller and smaller on their way to cells, so that by the time blood reaches a cell, the artery's diameter is extremely small and the vessel is now called a **capillary**. Capillaries are the smallest of blood vessels and they exchange oxygen, nutrients, and wastes between the blood and body tissues.[15] The reduced diameter of the blood vessel substantially slows the speed of blood flow. This dramatic reduction in blood flow gives cells time to pull the nutrients out of the blood and exchange metabolic wastes.

The Lymphatic or Immune System

Think of the **lymphatic** system as the body's drainage system. It consists of tubes, vessels, and other lymphatic organs that transport a fluid called **lymph**. Lymph is made up of whatever needs to be drained or moved from one place in the body to another. The lymphatic system has three main functions. First, it returns excess fluid from the tissues to the blood. Next, it defends the body against attacking microorganisms and disease. Finally, and most important in our discussion of digestion, it transports most fats and fat-soluble vitamins before they enter into the blood stream.

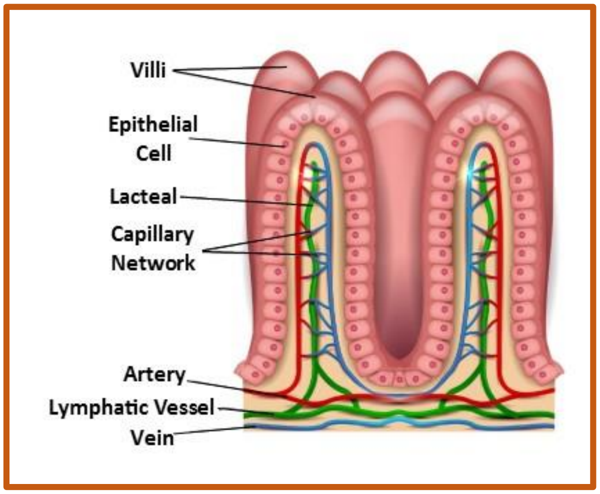


Figure 9: Villi containing both blood and lymph vessels for nutrient absorption

The process of absorption of these fat-soluble nutrients is similar to other nutrients except that the fat-soluble nutrients are packaged into fat transporters and pulled into lacteals and not into the blood capillaries. The **lacteals** are tiny lymph vessels which are also found in the middle of each small intestine villi (see Figure 9). The fat transporter or package is absorbed through the wall of the villi and enters into the lacteal. The lymphatic vessels then move or transport these fat transporters containing the fat-soluble nutrients and connect with the bloodstream near the heart (see Figure 8). So these nutrients enter the general circulation of the blood prior to passing through the liver.

Waste Removal

After digestion, any of the nutrients or other food material not absorbed into the body, such as fiber, will be eliminated through the feces. Waste products also accumulate inside the body and must be removed such as carbon dioxide, minerals, and nitrogen-containing materials. For example, after the breakdown of protein, urea, a nitrogen-containing waste product, must be eliminated. Through the circulatory system, the waste is picked up from the cells and excreted from the body through the lungs (carbon dioxide) or the skin. However, the kidney plays the main role in this waste elimination by filtering water and other waste materials from the blood and then concentrating the waste in the urine and excreting it out of the body.

4.5 Metabolism

The organ systems of the body require fuel and building blocks to perform the many functions of the body. Once our food is digested and absorbed, the blood transports the nutrients to the cells where they are used in processes of metabolism. **Metabolism** is defined as the sum of all chemical reactions required to support life. Some of these reactions help us break down and release energy from carbohydrates, fats, proteins, and alcohol. Others allow us to build and make new substances. A group of chemical reactions in the body that progresses as a sequence from start to finish is called a **metabolic pathway**.

All the pathways that take place in the body can either be categorized as **catabolism**, the process of breaking down materials, or **anabolism**, the process of building larger materials from smaller components. Catabolic processes release energy and anabolic processes consume energy.

Catabolism and Energy Production

Each of the macronutrients, glucose, fatty acids, and amino acids, can be catabolized or broken down to release energy. Although these macronutrients do contain low energy bonds, they are not very useful to the cell in this form. As a result, they must undergo **cellular respiration** which is a process that transforms the food macronutrient energy into cellular energy.[16] This cellular energy is called **adenosine triphosphate (ATP)** and it contains very high energy bonds which when broken down and released can be used to perform cellular work such as active transport, muscle contractions, growth, and repair of tissues. All organisms from bacteria to humans use ATP as their main energy source.[16]

In cellular respiration, glucose, fatty acids, and proteins are converted into carbon dioxide, water, and ATP when oxygen is present (see Figure 10). First the macronutrients are broken down to form acetyl-CoA, a two-carbon molecule. Next, each acetyl-CoA enters the **citric acid cycle**, a multi-step circular pathway which produces ATP, carbon dioxide (CO_2), and high energy electrons (e-). These electrons are carried by molecules into the inner membrane of the mitochondria in preparation for the next stage, the **electron transport chain**. In this metabolic pathway, energy is released in the form of ATP as electrons are sequentially transferred between multiple proteins. At the same time, oxygen combines with electrons and hydrogen to form water.

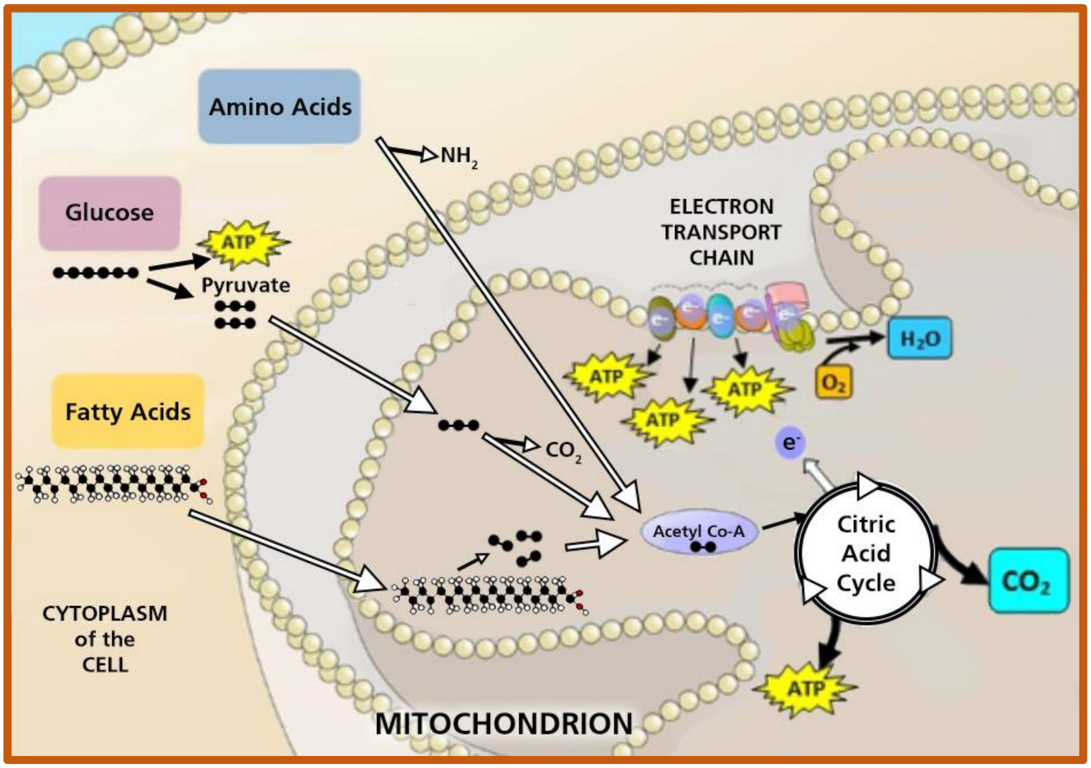


Figure 10: In the presence of oxygen, cellular respiration converts glucose, fatty acids, and amino acids into ATP or energy, carbon dioxide, and water

Anabolism and Building

The energy released by catabolic pathways powers anabolic pathways in the building of macromolecules, cells, and tissues. Anabolic pathways are required to build new tissue, such as muscle, after prolonged exercise or the remodeling of bone tissue, a process involving both catabolic and anabolic pathways. Anabolic pathways also build energy-storage molecules, such as glycogen, the glucose-storage molecule. The glucose, fatty acids, and amino acids not being used for energy can be diverted and used as building blocks for these anabolic pathways.

4.6 Digestive Health and Disorders

The GI tract allows us to obtain the nutrients that we need on a day to day basis. It also helps to protect the body from disease-causing organisms and contaminants. Although the GI tract usually works well, there are times that problems arise causing uncomfortable symptoms and problems. Some of these concerns are minor and infrequent, such as heartburn, while others can be more serious such as stomach ulcers and colon cancer.

Food Allergies

Paying attention to the way individuals react to various foods is essential in determining what foods may specifically affect a person adversely. Food allergies are one of the many ways in which different body make-ups affect nutritional concerns. It is estimated that 3.5 to 4 percent of the overall population have food allergies; however, there are likely many more people who say they have food allergies than actually do.[17] This is because food sensitivity or intolerance is different from a medically-determined food allergy. When someone has a food allergy, the immune system mistakenly attacks a fragment of digested food (usually the protein component of a food), such as the protein component of peanuts, as if it were a threat and antibodies are produced. Doctors sometimes test for food allergies by using skin-prick tests or blood tests to look for the presence of antibodies. However, these types of tests are not always reliable as they can sometimes yield a false positive result. By far, the most valuable tests for determining a food allergy is the Double Blind Placebo Controlled Food Challenge (DBPCFC), which involves administering the food orally and then denoting the signs and symptoms of the allergic response. In contrast, a food sensitivity or intolerance does not stimulate the immune system, but can cause similar symptoms as a food allergy.

Food allergy symptoms usually develop within a few minutes to two hours after a person has eaten a food to which they are allergic. These symptoms can range from the annoying to the potentially fatal, and include: severe headaches or migraines, a tingling mouth, swelling tongue and/or throat, difficulty breathing, hives, stomach cramps, diarrhea, vomiting, drop in blood pressure, loss of consciousness, and death.

There are no clear treatments for food allergies. Epinephrine is used to control severe reactions. The only certain way to avoid allergic reactions to food is to avoid the foods that cause them. Beyond avoidance, this can mean reading food labels carefully, or even calling manufacturers for product information. Ninety percent of food allergies are caused by these eight foods: milk, eggs, peanuts, tree nuts, fish, shellfish, wheat (this is different than celiac disease), and soy.

Celiac Disease

Celiac disease is an autoimmune digestive disorder, not a food allergy, which damages the small intestine. It is caused by an abnormal immune reaction of the small intestine cells to a type of protein, called gluten found in wheat, barley, and rye. When gluten-containing foods are consumed the antibodies attack cells lining the small intestine leading to a destruction of the small villi projections (see Figure 12). Villi destruction is what causes many of the symptoms of celiac disease. The destruction of the absorptive surface of the small intestine results in the malabsorption of nutrients, so that while people with this disease may eat enough, nutrients do not make it to the bloodstream because absorption is reduced.

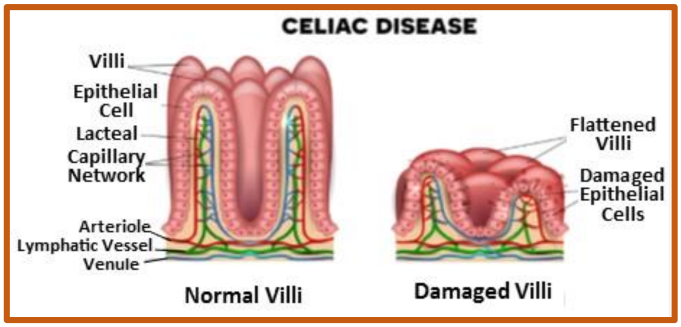


Figure 11: Normal intestinal villi compared to damaged villi resulting from celiac disease

Celiac disease develops in about 1 in 100 people worldwide.[18] It is an inherited disorder meaning it can only develop in individuals that have particular genes. These genes are common and are found in about one-third of the population; however, only 3 percent of individuals with the genes will ever develop celiac. This suggests that there are other factors, possibly environmental, that influence the initiation of the disease.[18]

Symptoms can vary and range from mild to severe and can include pale, foul-smelling, fatty, loose stools, abdominal pain, bloating, gas, diarrhea, constipation, weight loss and in children, a failure to grow and thrive. The symptoms can appear in infancy or much later in life, even at age seventy. Celiac disease is not always diagnosed because the symptoms may be mild. A large number of people have what is referred to as “silent” or “latent” celiac disease.

Celiac disease diagnosis requires a blood test and a biopsy of the small intestine. Because celiac disease is an autoimmune disease, antibodies produced by white blood cells circulate in the body and can be detected in the blood. However, the damage to the small intestine villi can only be detected with a biopsy, a procedure that removes a portion of the tissue from the damaged organ.

Fortunately, celiac disease can be treated. Once diagnosed, a person follows a gluten-free diet for life. This requires dedication and careful detective work to seek out and avoid foods with hidden gluten. For those who are sensitive to gluten, it is good to know that corn, millet, buckwheat, rice, quinoa, and oats do not contain the proteins that make gluten. However, some people who have celiac disease also may have an adverse response to products containing oats. This is most likely the result of cross-contamination of grains during harvest, storage, packaging, and processing. After eliminating gluten from the diet, the tissues of the small intestine rapidly repair themselves and usually heal in less than six months.

Gastroesophageal Reflux Disease

Gastroesophageal reflux disease (GERD) is a persistent form of acid reflux that occurs more than two times per week. Acid reflux, also known as **heartburn**, occurs when the acidic contents of the stomach leak backward into the esophagus and cause irritation (see Figure 11). It is estimated that GERD affects 20 percent of the US population.[19]

The most common GERD symptom is regular heartburn, but people with GERD may also experience regurgitation (flow of the stomach's acidic contents into the mouth), pain in the upper abdomen or chest region, frequent coughing, respiratory problems, and painful or trouble swallowing.

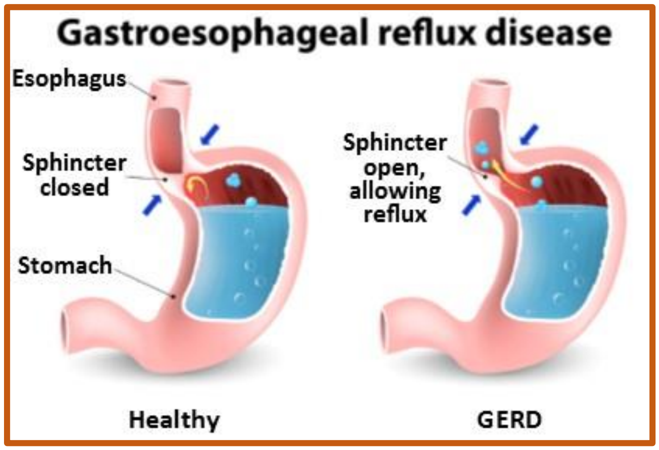


Figure 12: GERD takes place when the lower esophageal sphincter opens allowing stomach contents to flow back into the esophagus

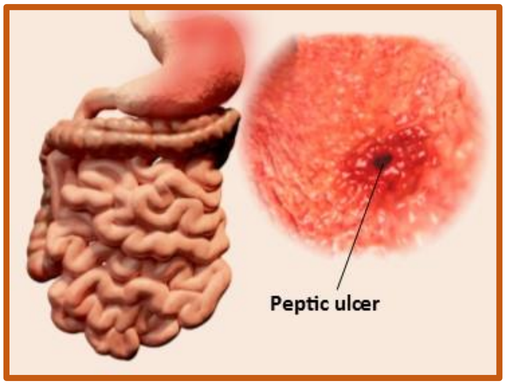
GERD occurs when the lower esophageal sphincter (see Figure 11) weakens or relaxes when it should not, allowing the stomach contents to flow back into the esophagus. Certain things can weaken or relax the sphincter including increased pressure on the abdomen such as in obesity or pregnancy, certain medications, and smoking.

The first approach to GERD treatment is dietary and lifestyle modifications. Recommendations suggest that you reduce weight if you are overweight or obese, avoid foods that worsen GERD symptoms, eat smaller meals, stop smoking, and remain upright for at least three hours after a meal. Foods that worsen GERD symptoms are foods that increase stomach acidity or slow gastric emptying and include chocolate, garlic, greasy (higher fat) or spicy foods, peppermint, caffeine, alcohol, and tomato-based foods.

There are also many medications available to treat GERD, including antacids, histamine (H2) blockers, and proton-pump inhibitors. When these treatment approaches do not work, surgery may also be an option. The most common surgery involves reinforcing the sphincter that serves as a barrier between the stomach and esophagus.

Peptic ulcers

A **peptic ulcer** is an open sore that forms in the lining of the esophagus, stomach, or upper small intestine when the protective mucus layer has been reduced or damaged. The lining is then

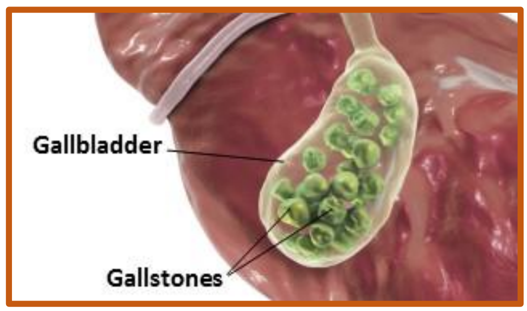


Peptic ulcers are sores that can occur in the lining of the esophagus, stomach, or upper small intestine

exposed to gastric acids leading to the ulcer. Specifically, long-term use of nonsteroidal anti-inflammatory drugs (NSAIDs) such as aspirin or ibuprofen may result in an ulcer as they decrease the protective mucus layer. Even more common, these ulcers are caused by the ***H. pylori*** **bacteria** which damages the mucous layer of the stomach and small intestine exposing the lining to damage. Luckily, the *H. pylori* bacteria can easily be treated with antibiotics. The most common symptom of a peptic ulcer is a dull or burning pain in your stomach region. Signs of red blood in the stools or having black stools is an indication of a more series ulcer that should be addressed with your doctor immediately.[20]

Gallstones

Gallstones are hard particles, like rocks, that form in the gallbladder and can range in size from a grain of sand to a golf ball.[21] A person may develop a single large gallstone, hundreds of tiny gallstones, or both. These stones can cause sudden pain in the upper right abdomen when the gallbladder contracts. They are formed by imbalances in the substances that make up bile such as cholesterol, bilirubin, and calcium. These substances accumulate in the gallbladder and can block bile from entering the small intestine which may lead to reduced fat absorption. Why these imbalances occur is unknown.



Gallstones found in the gallbladder can be painful and can block bile from entering the small intestine

Often gallstones are asymptomatic or do not cause pain and treatment is not necessary. However, when a person is having pain or other symptoms the typical treatment is surgery to remove the gallbladder. As the gallbladder is not an essential organ, a person can live normally without it. After surgery, the bile which is made in the liver will drip directly into the small intestine rather than being stored in the gallbladder.[21]

Irritable Bowel Syndrome

Irritable bowel syndrome (IBS) is a common disorder that affects the large intestine and is associated with a range of symptoms including abdominal pain, bloating or distension, gas, constipation, and diarrhea. Interestingly, IBS produces no permanent structural damage to the large intestine as often happens to patients who have more series intestinal disorders such as celiac disease.

It is estimated that IBS affects between 7 and 15 percent of the population and is more prevalent in women than men.[22] The exact cause of IBS is not clearly understood, but it is thought to result from a combination of altered gut microbiota, hypersensitivity to intestinal pain (visceral hypersensitivity), changes in the GI motility, and low-grade inflammation.[23] There is no specific test available to diagnose IBS, so diagnosis is often a process of ruling out other conditions that have similar symptoms, such as celiac disease. These tests might include stool analysis, blood tests, x-rays, an endoscopy, or colonoscopy.

Symptoms of IBS significantly decrease a person's quality of life and as with GERD, the first treatment approaches for IBS are diet and lifestyle modifications with the goal to reduce common triggers. These triggers or stimuli are not always the same for all people with the condition. Large meals and foods high in fat and added sugars, or those that contain wheat, rye, barley, peppermint, and chocolate can intensify or bring about symptoms of IBS. Additionally, beverages containing caffeine or alcohol may worsen IBS. Stress and depression may compound the severity and frequency of IBS symptoms. People with IBS are often told to keep a daily food journal to help identify and eliminate foods that cause the most problems. Other recommendations are to eat slower, add more fiber to the diet, drink more water, and to exercise. There is also a fairly new, research-based dietary treatment that is gaining popularity due to its positive results called the low fermentable, oligo-, di-, mono-saccharides and polyol (FODMAP) diet. This diet is discussed in more detail below.

Finally, there are some medications, many of which can be purchased over-the-counter, to treat IBS and the resulting diarrhea or constipation. Sometimes antidepressants and drugs to relax the colon may also be prescribed.

FODMAP Diet

FODMAPs (fermentable oligosaccharides, disaccharides, monosaccharides, and polyols) are a group of highly fermentable but poorly absorbed short-chain carbohydrates and polyols found in foods.[24] Fermentation of these FODMAPs by the bacteria in your large intestine is completely normal and healthy; however, for people with IBS eating high FODMAP foods may trigger increased symptoms of excess gas, bloating, cramping, diarrhea and/or constipation.

The FODMAP diet is a two-part elimination diet that first restricts these highly fermentable short-chain carbohydrates and polyols (the FODMAPs) and then slowly reintroduces specific FODMAPs as tolerated.[25] In both randomized clinical trials and nonrandomized intervention studies, the

FODMAP diet has been shown to significantly reduce the severity of IBS symptoms and increase quality of life.[26] These results are exciting and have given individuals with IBS an additional treatment option. However, even as the research shows promising results, a person should use caution before trying the diet as the research is still in its infancy and long-term results and physiological consequences are not known.[25] As this is a complicated diet to initiate and is highly restrictive and can lead to nutritional deficiencies, it should be initiated and supervised by a trained registered dietitian nutritionist or gastroenterologist.

Probiotics and Prebiotics

When we hear the word "bacteria" or "microorganism" we most likely think of disease. However, our bodies are full of bacteria. In fact, the bacteria in our bodies outnumber human cells by 10 to 1.[27] The large community of microorganisms found in the gut is called the **gut microbiota** or gut flora. Most of these microorganisms are found in the large intestine and are harmless or even beneficial to our health. For instance, they have many important functions including making certain vitamins, metabolizing nutrients, and stimulating immunity.[28,29]

Examples of fermented food containing probiotics- kimchi, red beets, apple cider vinegar, yogurt, sauerkraut, and cucumber pickles

Bacteria can also be consumed to improve human health. Live microorganisms that provide health benefits when consumed in adequate amounts are called **probiotics**.[30] They can be found in supplements or food that has been prepared by bacteria fermentation. Some of these foods include yogurt, kefir, sauerkraut, tempeh, and kimchi. Probiotics contain many different types of microorganisms. The most common groups include *Lactobacillus* and *Bifidobacterium* and within each of these groups there are different species and each species has many different strains. [27]

Preliminary research has shown that probiotics can be helpful in digestive health by:

- Maintaining a desirable gut microbiota
- Protecting the GI tract from unwanted microorganisms or preventing their growth
- Assisting the gut microbiota in returning to normal levels after antibiotic use or disease
- Stimulating immune response[27]

Specifically, probiotics have been shown to be effective in preventing antibiotic-associated diarrhea and improving IBS symptoms.[31,32] However, it is important to keep in mind that the research is still in its early stages. Not all probiotics are alike. Rather, they are strain specific and benefits cannot be generalized to other species or other strains of the same species.[33] For instance, just because one type of *Lactobacillus* provides a health benefit does not mean another type of *Lactobacillus* will have the same benefit. This large variety makes research and defining definitive effects difficult. Even for conditions that have been studied the most, it is still not known for sure which probiotics are most helpful, how much should be used, and who is most likely to benefit.[27] So, before going out and buying probiotics, which can be expensive, an individual should use caution and make sure to research the type of probiotics that will most likely lead to the benefits they are seeking.

Probiotic supplements can contain different strains of Lactobacillus or Bifidobacterium and may benefit gut health

Non digestible food components that promote the growth of helpful bacteria in your gut are called **prebiotics**. Prebiotics include a range of different dietary fibers including fructooligosaccharides (such as inulin), and galactooligosaccharides. Understanding what food components may or may not work effectively as a prebiotic can be quite complicated to sort out. Rather than worrying about these details you can increase the prebiotics in your diet by eating more fruits, vegetables and whole grains. Specific food examples that are rich in prebiotics are bananas, onions, garlic, leeks, asparagus, artichokes, beans and whole-grain foods.

Foods that contain both probiotics (live heath promoting bacteria) and prebiotics (food for the bacteria) are referred to as synbiotics. Both supplements and specially designed food products are available that contain both probiotics and prebiotics. You can create your own symbiotic meal by eating a food with probiotics like yogurt with a food with prebiotics such as a banana.[34]

Chapter 5: Carbohydrates

Daniel, Shadrach, Meshach, Abednego appeared to do quite well physically eating pulse (KJV, Daniel 1: 15-16). The LDS Bible Dictionary defines pulse as: *The Hebrew word denotes seeds, and may include the grains of leguminous vegetables or any other edible seeds.*[1]

Carbohydrates are an important energy source for the body and the primary energy source for the central nervous system. They are found primarily in plants. Carbohydrates found in whole foods like vegetables, fruits, whole grains and unsweetened dairy foods promote good health. Sugars and other refined carbohydrates are not nutrient-dense food sources and should be limited in our food intake.

5.1 Types of Carbohydrates and Their Food Sources

The name "carbohydrate" reflects the basic structural composition of carbohydrates; A carbohydrate contains carbon and water (carbo-hydrate). Plants make carbohydrate by absorbing energy from the sun to combine carbon dioxide from the air with water from the soil. Carbohydrates are broken down into two types, **simple** carbohydrates, and **complex** carbohydrates.

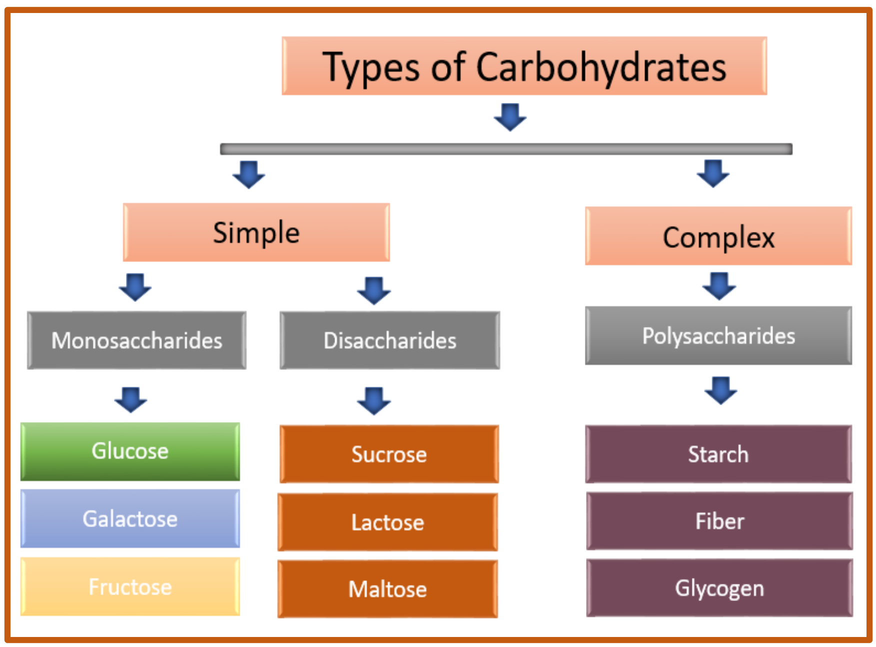


Figure 1: Overview of carbohydrates dividing the group into simple and complex, and further dividing simple carbohydrates into monosaccharides and disaccharides

Simple Carbohydrates

The simple carbohydrates are commonly called "sugars" and are composed of two main groups, the **monosaccharides** and the **disaccharides**.

Monosaccharides

Monosaccharides consist of a single carbohydrate unit called a “saccharide” (saccharide is the Latin word for “sugar”.) There are three monosaccharides: glucose, galactose, and fructose.

Glucose: All organisms from bacteria to plants to animals use glucose as a fuel source to create energy. Under normal conditions, the brain and central nervous system are dependent on glucose as its energy source. Glucose as a monosaccharide is found in some fruits and honey. Although glucose by itself does not exist in large amounts in most food, it is a major component of other types of carbohydrates.

Galactose: The monosaccharide galactose differs from glucose in only one way. The difference is the position of one hydroxyl (−OH) group attached to a carbon atom (see Figure 2). This small structural alteration causes galactose to be less stable than glucose. As a result, the liver rapidly converts it to glucose. As a monosaccharide, there is very little galactose in our diet. Most of the galactose we consume is part of the disaccharide lactose, which is found in milk.

Fructose: Structurally, fructose is different from glucose or galactose because its ring contains only five carbons. However, it contains the same number of carbon, oxygen, and hydrogen, as glucose and galactose. Fructose in the liver may be used for energy, converted to glucose, or converted to fat. Like galactose, fructose is not typically used directly as an energy source for other body cells. Fructose is found in our food supply naturally in fruits, honey, and anything containing the disaccharide sucrose. The amount of fructose in the American food supply has increased over the last 30 years due to the growing use of the sweetener high fructose corn syrup and sucrose in beverages, bread, and many other products.

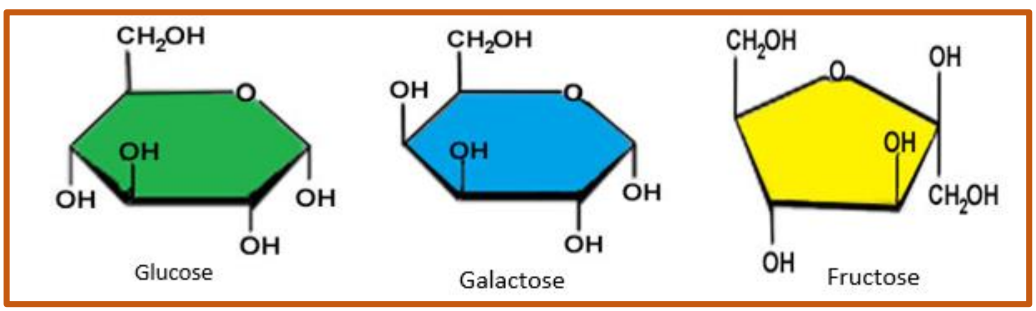


Figure 2: Structure of the monosaccharides

Disaccharides

Disaccharides are composed of two monosaccharides linked together. The three disaccharides are sucrose, lactose, and maltose. These disaccharides all contain at least one glucose molecule (see Figure 3).

Sucrose: Sucrose is composed of a glucose molecule and a fructose molecule bonded together. Sucrose, or table sugar, is made by extracting and purifying the sucrose from sugar beets and sugar cane. Sucrose may be found in some fruits and some vegetables, however, the majority of the sucrose that we consume is found in sweetened beverages and foods like cake, cookies, candy, energy drinks, and soda.

Lactose: Lactose is composed of a glucose molecule and a galactose molecule bonded together. Lactose is commonly known as milk sugar and is found in dairy products such as milk and yogurt.

Maltose: Maltose is composed of two glucose molecules bonded together. It is not commonly found in foods but is a common breakdown product of plant starches.

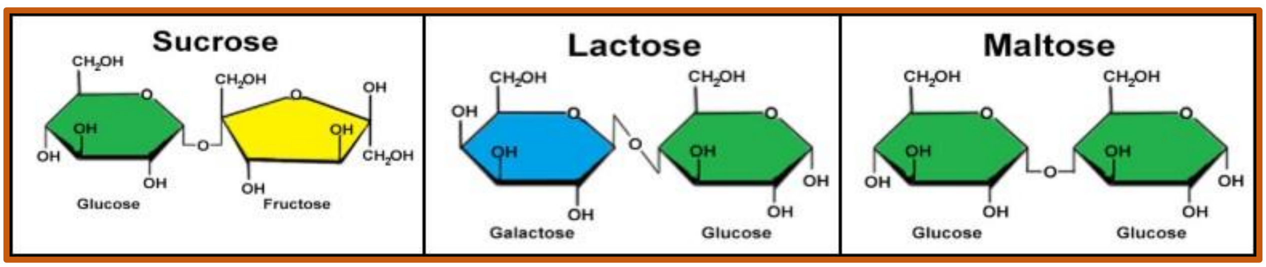


Figure 3: Structure of the disaccharides

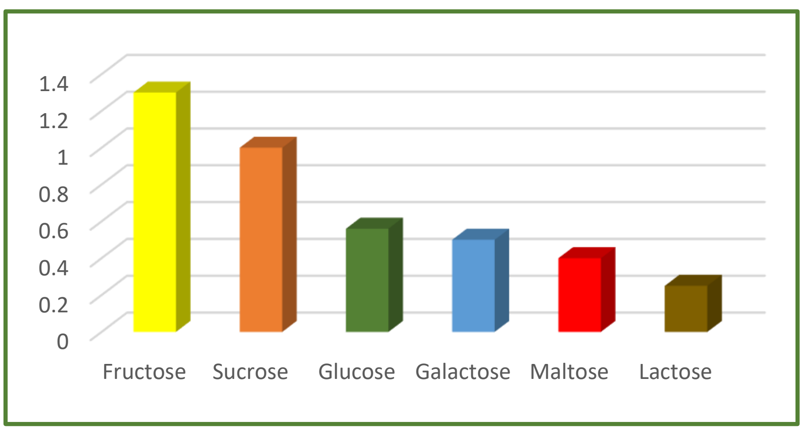


Figure 4: Relative sweetness of sugars

The monosaccharides and disaccharides have varying degrees of sweetness (see Figure 4). When the purified simple carbohydrates are added in the processing or preparation of foods, they are referred to as **added sugars**. These added sugars contribute additional calories to foods but provide no additional nutrients thereby diminishing the **nutrient-density** of food products.

Sugars added in this way are often referred to as **empty calories**. Currently, high fructose corn syrup is one of the most common added sugars used in the food industry in America. It is a liquid blend of the monosaccharides glucose and fructose. Its composition is similar to sucrose (50% glucose, 50% fructose) but the monosaccharides are not bonded together as they are in sucrose. The amount of fructose in high fructose corn syrup in soda can range from 40% to 65%.

Complex Carbohydrates

Complex carbohydrates are **polysaccharides**, long chains of monosaccharides that may be branched or not branched. There are two main groups of polysaccharides: **starches** and **fibers**.

Starches

Starch molecules are found in abundance in grains, legumes, and root vegetables, such as potatoes. **Amylose**, a plant starch, is a linear chain containing hundreds of glucose units. **Amylopectin**, another plant starch, is a branched chain containing thousands of glucose units. These large starch molecules are the energy storage for plants. Both amylose and amylopectin are found in starchy foods. Amylose, which is shorter and unbranched, is more abundant than amylopectin in foods (see Figure 5).

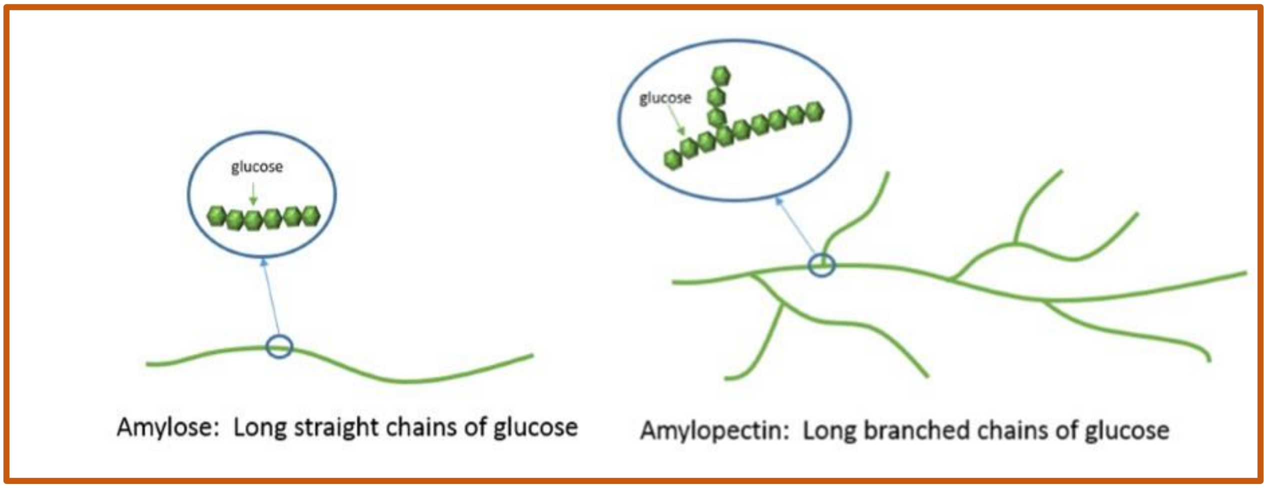


Figure 5: The starches amylose (straight) and amylopectin (branched)

Humans and animals can store glucose in the liver and muscle in the form of polysaccharide called **glycogen**. Glycogen is similar to amylopectin, but is more branched. The high degree of branching in glycogen allows it to break down quickly to glucose when energy is needed by cells in the body.

During exercise, the amount of glycogen available throughout extended exertion becomes an important factor in performance.

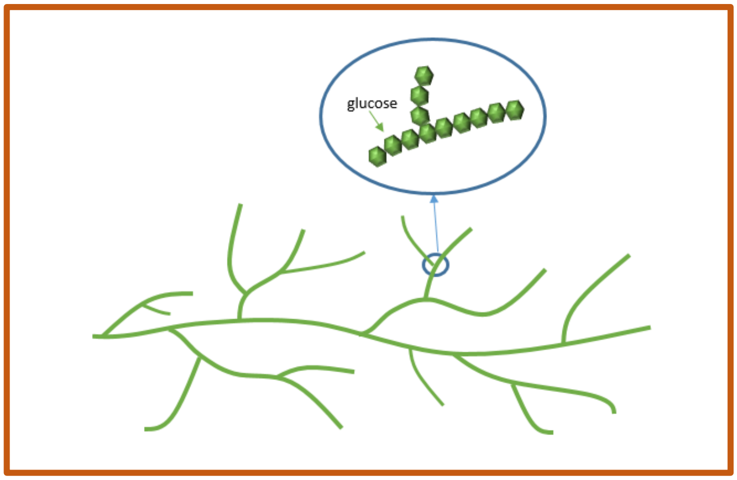


Figure 6: Glycogen: Long highly branched chains of glucose

Fiber

Most fibers are polysaccharides that are highly branched and cross-linked. Some examples of dietary fibers are **pectin**, **gums**, and **cellulose**. Humans do not produce the enzymes that can break the bonds in these compounds. However, bacteria in the large intestine (colon) contain the enzymes to break down some types of fiber. The digested fiber can then serve as an energy source for the bacteria and for body cells. Fiber is very beneficial to human health in a number of different ways. The Dietary Guidelines Advisory Committee clearly identify the importance of fiber for colonic health and the maintenance of regular bowel movements in their recommendations. It also states that, "a growing body of evidence also suggests that fiber may play a role in preventing coronary heart disease, colorectal and other cancers, type 2 diabetes and obesity."[2] Fiber is one of the nutrients considered to be inadequate in the diets of Americans.

Fiber-rich foods including grains, fruits, and nuts

Fiber is categorized as either **water-soluble** or **water-insoluble**. Inulin, pectin and guar gum are water-soluble fibers found abundantly in peas, dried beans, oats, barely, and rye. Good dietary sources of water-insoluble fibers like cellulose and lignin are found in brown rice, cracked wheat, flax, carrots and cabbage. As the name implies, soluble fibers dissolve in water and form a viscous gel-like substance. Insoluble fibers do not readily dissolve in water and do not form a gel-like substance. Insoluble fiber is sometimes referred to as "roughage". Insoluble fiber creates a structural matrix in the large intestine, and soluble fiber forms a gel.

Generally, soluble fibers are more easily accessible to bacterial enzymes in the large intestine and are broken down to a greater extent than insoluble fibers. The differences in their physical properties account for the varied health benefits that are associated with each type of fiber.

Soluble Fibers	Insoluble Fibers
Stool regularity (keeps things moving)	Stool regularity (keeps things moving)
Calorie control (helps you feel full)	Calorie control (helps you feel full)
Regulation of blood sugar levels	Lowers risk for diverticulosis & hemorrhoids
Reduced cholesterol levels	

Table 1: Positive effects of the different fiber types[3]

Fiber can also be discussed as **dietary fiber** or **functional fiber**. As it sounds, dietary fiber is fiber that comes naturally in the foods that are eaten. Functional fibers have been added to foods and can also be beneficial to humans. Functional fibers may be extracted from plants and purified, or it can be synthetically made. Psyllium-seed husk acts as a functional fiber when it is added to products to increase fiber levels. Scientific studies show that consuming psyllium-seed husk can reduce blood-cholesterol levels. This health claim has been approved by the FDA. Total dietary fiber intake is the sum of dietary fiber and functional fiber consumed.[4]

Traditional method of making flour

Refined Versus Unrefined Carbohydrates

In ancient times, whole grains were cracked open using quern stones (stones used for hand grinding). This required hours of hand labor. As technology slowly advanced, the quern stone was modified and became the millstone. It was not until the advent of water wheels that human labor to produce flour out of whole grains was reduced. About 2,500 years ago, the Romans started milling flour by turning one millstone wheel against another stone that did not move. The turning was done by animals, slaves, and later by waterwheels.

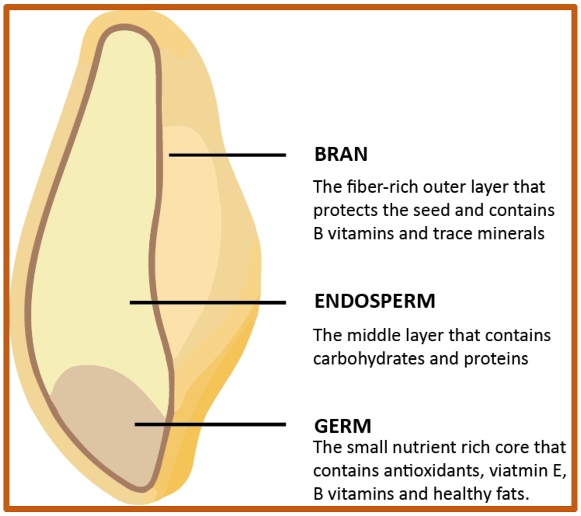


Figure 7: Components of a Whole Grain

Wheat was the grain of choice for many cultures, as it not only produced white flour but also contained gluten. Gluten is a substance that gives wheat bread its elasticity and lightness in texture. In America, Oliver Evans built the first flour mill, which was powered by a watermill. It used a series of elevators that moved grain through the mill, cleaning it first, then grinding and sifting it. Today, modern milling processes are faster and much more sophisticated, but work on the same basic principles. The process of milling breaks the hard outer bran coat of the wheat or other seeds. For example, white rice has also been refined from brown rice. The cracked seed can then be ground more finely into whole-wheat flour, or sifted in preparation to make refined wheat flour (white flour). In the refining process, the bran and germ are usually removed from the whole grain. The bran and germ are the nutrient dense parts of the grain containing the majority of the fiber, vitamins, minerals and healthy fat. In former times, the whitest flour was chosen to make bread for the wealthy, and the coarsest was given to the poor.

The fine texture, lighter color and blander taste of the flour of refined grains is preferred by most consumers over the coarser texture, darker color and richer flavor of whole grain flours. Equally important to the food industry is the removal of the fat and fiber that can contribute to rapid spoilage. Unfortunately, the over-use of refined grain flours has led to justified health concerns. In America in the early 1900s, several diseases stemming from vitamin and mineral deficiencies, such as pellagra (deficiency of niacin, B_3), beriberi (deficiency of thiamin, B_1), and anemia (iron deficiency), plagued many people. A public health campaign was initiated that required that all refined grain products be **enriched.** Enrichement is the adding back in of nutrients that are lost during processing, specifically the vitamins, **thiamin, riboflavin and niacin** and the mineral **iron**. In 1998 the vitamin **folate** was added to the list of required nutrients. These changes have been beneficial but they do not compensate for the other nutrients lost in the refining process.

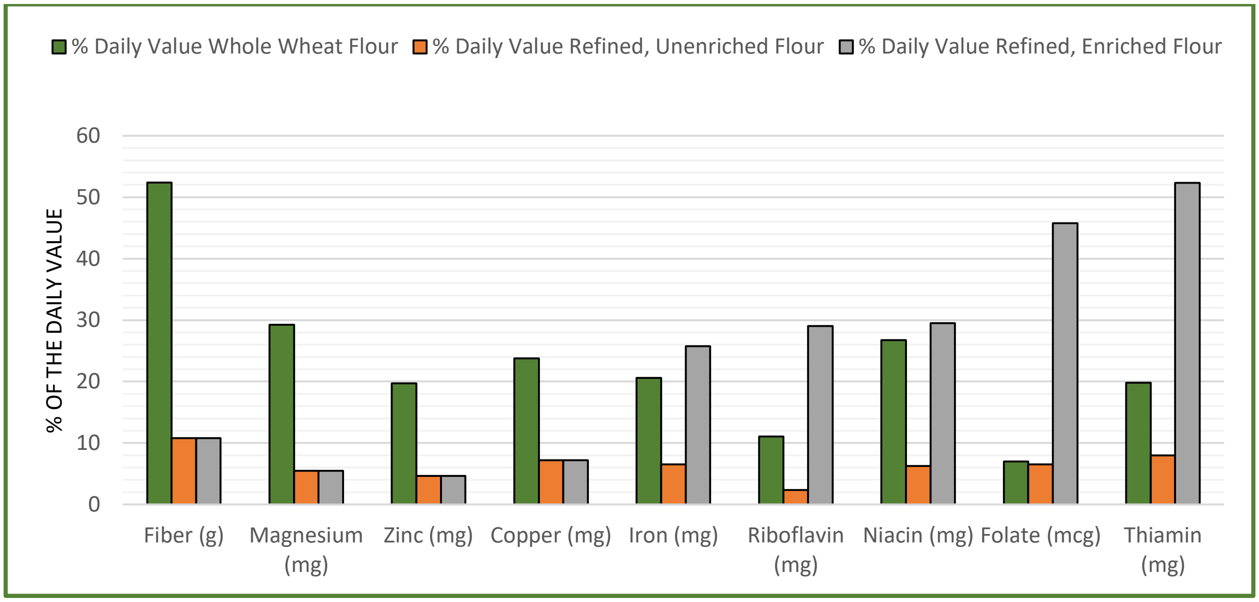


Figure 8: Effects of refinement and enrichment on nutrient content of wheat flour (100 gram serving)

The comparison of the nutrient composition of whole grains and refined grains in Figure 8 is clear evidence for the importance of choosing whole grains over refined grains when planning meals. The levels of riboflavin, niacin, and thiamin are clearly restored back into refined grains, but fiber, magnesium, zinc and copper remain reduced. A number of other nutrients and phytochemicals are lost in processing but are not reflected in this graph. The Dietary Guidelines for Americans recommend that at least half of our grain choices come from whole grains because the overwhelming scientific evidence supports the importance of eating whole grains over refined grains for optimal health. Regular consumption of whole grains has been associated with a reduction in coronary heart disease, cardiovascular disease, cancer, and diabetes.[5] It is important to minimize the consumption of refined grain foods which often have added fats and sugars, and instead choose nutrient-dense whole grain foods to help avoid chronic disease.

5.2 Digestion, Absorption and Metabolism of Carbohydrates

The only carbohydrates that can be absorbed are monosaccharides such as glucose, fructose, and galactose. The goal of carbohydrate digestion is to break down the polysaccharides and disaccharides to these three monosaccharides.

From the Mouth to the Stomach

The **mechanical** and **chemical** digestion of carbohydrates begins in the mouth. Chewing, also known as mastication, crumbles the carbohydrate foods into smaller and smaller pieces. The salivary glands in the oral cavity secrete saliva that coats the food particles. Saliva contains the enzyme, **salivary amylase**. This enzyme breaks the bonds between the glucose units in starch. The salivary amylase breaks down amylose and amylopectin into smaller chains of glucose, called dextrins, and the disaccharide maltose. Only about five percent of starches are broken down in the mouth. When carbohydrates reach the stomach, no further significant chemical breakdown occurs because the amylase enzyme does not function in the acidic conditions of the stomach. However, the mechanical breakdown is ongoing—the strong peristaltic contractions of the stomach mix the carbohydrates into a more uniform mixture called chyme.

From the Stomach to the Small Intestine

The **chyme** (mixture of food and digestive juices) is gradually expelled into the upper part of the small intestine through the pyloric sphincter. Upon entry of the chyme into the duodenum, the pancreas releases pancreatic juice through a duct into the duodenum. This pancreatic juice contains the enzyme **pancreatic amylase** which resumes the breakdown of dextrins into shorter carbohydrate chains. Eventually, starch is broken down completely into maltose. Additionally, enzymes are secreted by the intestinal cells that line the villi (brush border) which continue the breakdown of the disaccharides lactose, maltose, and sucrose. The enzyme **sucrase** breaks sucrose into glucose and fructose molecules. Then the enzyme **Maltase** breaks the bond between the two glucose units of maltose. The enzyme **lactase** breaks the bond between galactose and glucose. Figure 9 shows the breakdown of lactose by lactase in the brush border of the small intestine. The process is similar for each of the disaccharides. Once carbohydrates are chemically broken down into single sugar units (glucose, fructose or galactose) they are then transported into the intestinal cells. Glucose and galactose are moved into the cell via active transport; fructose is moved in via facilitated diffusion.

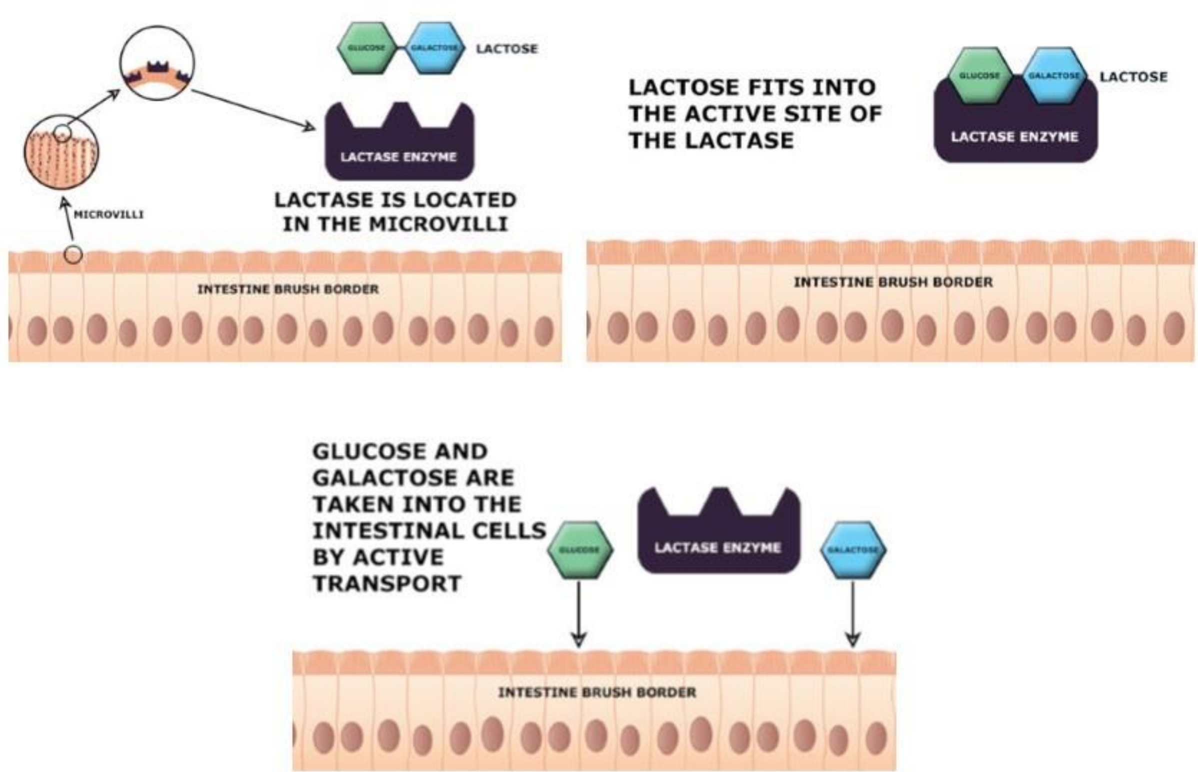


Figure 9: Three images showing the breakdown of lactose by lactase at the small intestine brush border

When people do not have enough of the enzyme lactase, lactose is not sufficiently broken down resulting in a condition called **lactose intolerance**. The undigested lactose moves to the large intestine where bacteria are able to digest it. The bacterial digestion of lactose produces gasses which can lead to the symptoms of diarrhea, bloating, and abdominal cramps. Lactose intolerance usually occurs in adults and is more common in certain nationalities. In the United States, it is more common for African Americans, Hispanics/Latinos, Native Americans and Asian Americans to have lactose intolerance than those of European descent.[6] Most people with lactose intolerance can tolerate some amount of dairy products in their diet. Cheese is typically better tolerated because most of the lactose is removed when the milk is processed into the cheese. Yogurt is also better tolerated due to the bacterial action on the lactose in the yogurt. There are also products specially formulated for people that experience lactose intolerance. A commercially produced lactose-free milk has already had all the lactose broken down into glucose and galactose before it is sold in the store. The severity of the symptoms a person experiences depends on how much lactose is consumed and the degree of lactase deficiency.

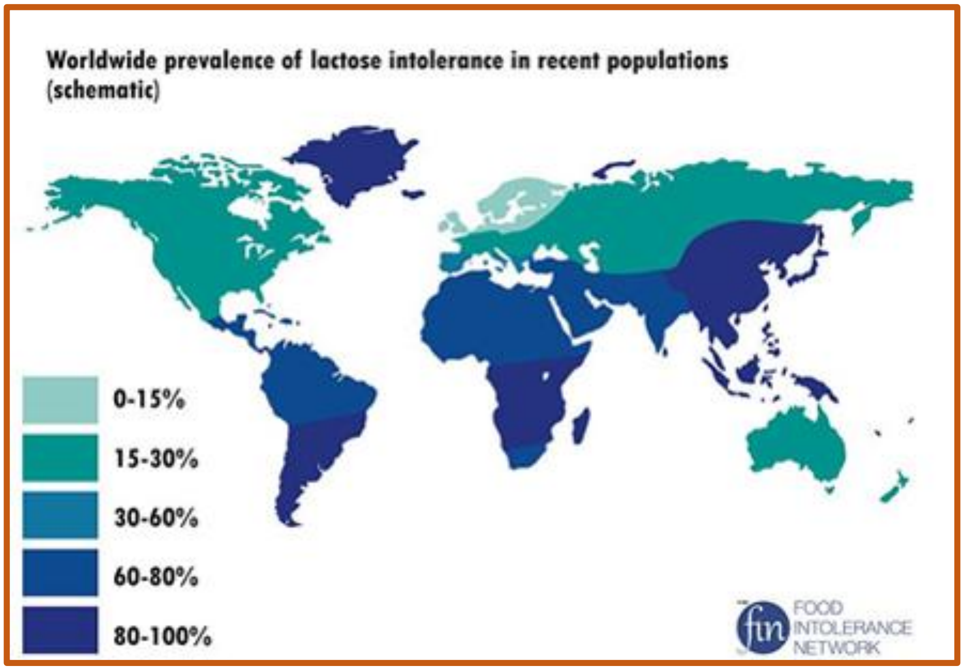


Figure 10: Worldwide incidence of lactose intolerance

Absorption: Going into the Blood Stream

After the monosaccharides (glucose, fructose, and galactose) are absorbed, they move into the bloodstream and move directly to the liver via the portal vein where they are taken up by the liver cells. The liver cells can use small amounts of fructose for energy or convert it to glucose or fat. The fat can either be stored in the liver or transported out of the liver. Liver cells convert galactose to glucose. The liver closely regulates what happens to glucose. It can use some of the glucose to meet its energy needs; it can store the glucose as glycogen; it can convert the glucose to fat, or it can release the glucose into the blood- stream for use in other tissues. For example, glucose is a very important energy source for the central nervous system and to maintain energy levels in the muscle during rigorous activity. Glucose can be used as an energy source the cells in the body. Like the liver, the muscle can also store glucose as glycogen. Because blood glucose levels have to be maintained in a certain range, the liver tightly controls how much glucose is released into the bloodstream.

In the big picture, regardless of what carbohydrate goes into our mouth, the only carbohydrate that is made widely available to our body tissues is glucose. The liver is the primary control center that makes this happen. Interestingly, if the liver were to fail in its job, significant damage to the body would occur. Galactose and fructose cannot be metabolized well in other body tissues and can be harmful to them.

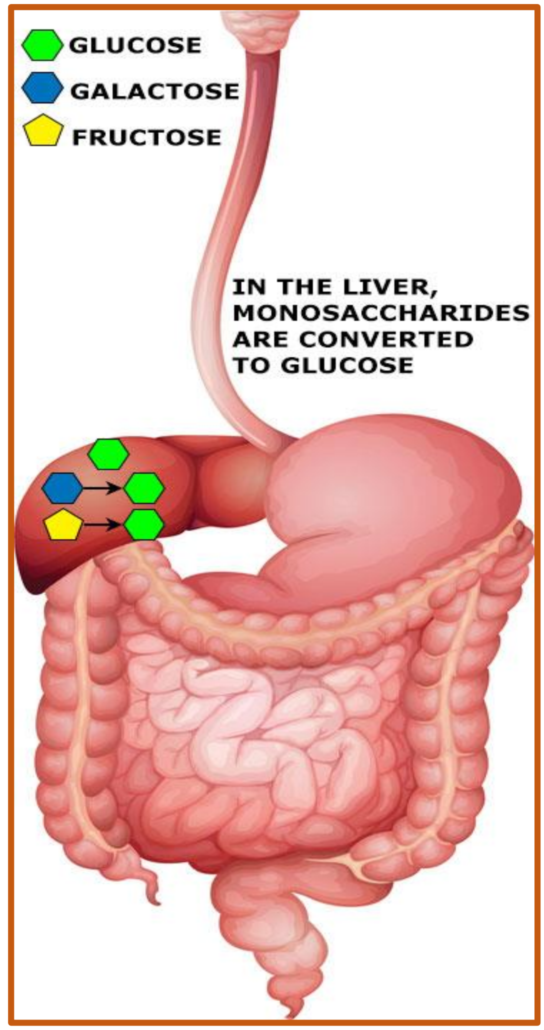


Figure 11: The conversion of fructose and galactose to glucose in the liver

Leftover Carbohydrates: The Large Intestine

Almost all of the carbohydrates, except for dietary fiber, are efficiently digested and absorbed into the body in the small intestine. The undigested dietary fiber moves on to the large intestine. Within the large intestine, the bacteria break down some of the dietary fiber and use it for energy. In this role, the fiber is acting as a prebiotic as discussed in the digestion chapter. The products of bacterial digestion of fiber are short-chain fatty acids and some gasses (It sounds odd, but the bacteria metabolize the fiber and produce very small fats). The short-chain fatty acids can be used by the bacteria to make energy. They also can be absorbed by the cells of the large intestine. They can either be metabolized by the cells in the large intestine or released into the blood stream for use by other body cells. The yield of energy from dietary fiber is about 2 Calories per gram for humans but this is highly dependent upon the fiber type. These short-chain fatty acids are typically considered a benefit to the body.

5.3 Carbohydrate Regulation in the Body

Glucose is an important energy source for almost all cells in the body and of primary importance for the central nervous system. Glucose levels in the blood are tightly controlled; having either too much or too little glucose in the blood can have health consequences. Glucose levels are regulated in the blood through a feedback mechanism. An oven is a good example of how this

Setting the temperature control on oven as a comparison to glucose regulation

process works. When you set the temperature to cook homemade bread at 375°F, the thermostat senses the temperature and sends an electrical signal to turn the elements on and heat up the oven. When the temperature reaches 375°F, the thermostat senses the temperature and sends a signal to turn the element off.

Similarly, your body senses blood glucose levels and maintains the glucose "temperature" in the target range. The glucose thermostat is located within the cells of the pancreas. After eating a meal containing carbohydrates, glucose levels rise in the blood. Insulin-secreting cells in the pancreas (beta cells) sense the increase in blood glucose and release the hormone **insulin**, into the blood. Insulin sends a signal to the body's cells to remove glucose from the blood by transporting it from the blood to the insides of the cells (see Figure 12A/B). The presence of insulin in the blood signals the body that it has just been fed and that there is fuel (glucose) for the cells to use. Insulin has an opposing hormone called glucagon. As the time after a meal increases, glucose levels decrease in the blood. Glucagon-secreting cells in the pancreas sense the drop in glucose and, in response, release **glucagon** into the blood. Glucagon signals the liver to break down glycogen and release the stored glucose into the blood (see Figure 12A/B). In addition, glucagon can initiate the production of glucose from other substances, such as protein and glycerol in the liver. This pathway is called **gluconeogenesis**. Under normal circumstances, glucagon is able to release glucose from glycogen and increase glucose production in the liver to maintain blood sugar in the normal target range of 70-120 mg/dl (about 1 teaspoon). This allows for a continuous supply of glucose to tissues. A constant supply of glucose is particularly important for the brain and central nervous system which both rely on glucose as an energy source.

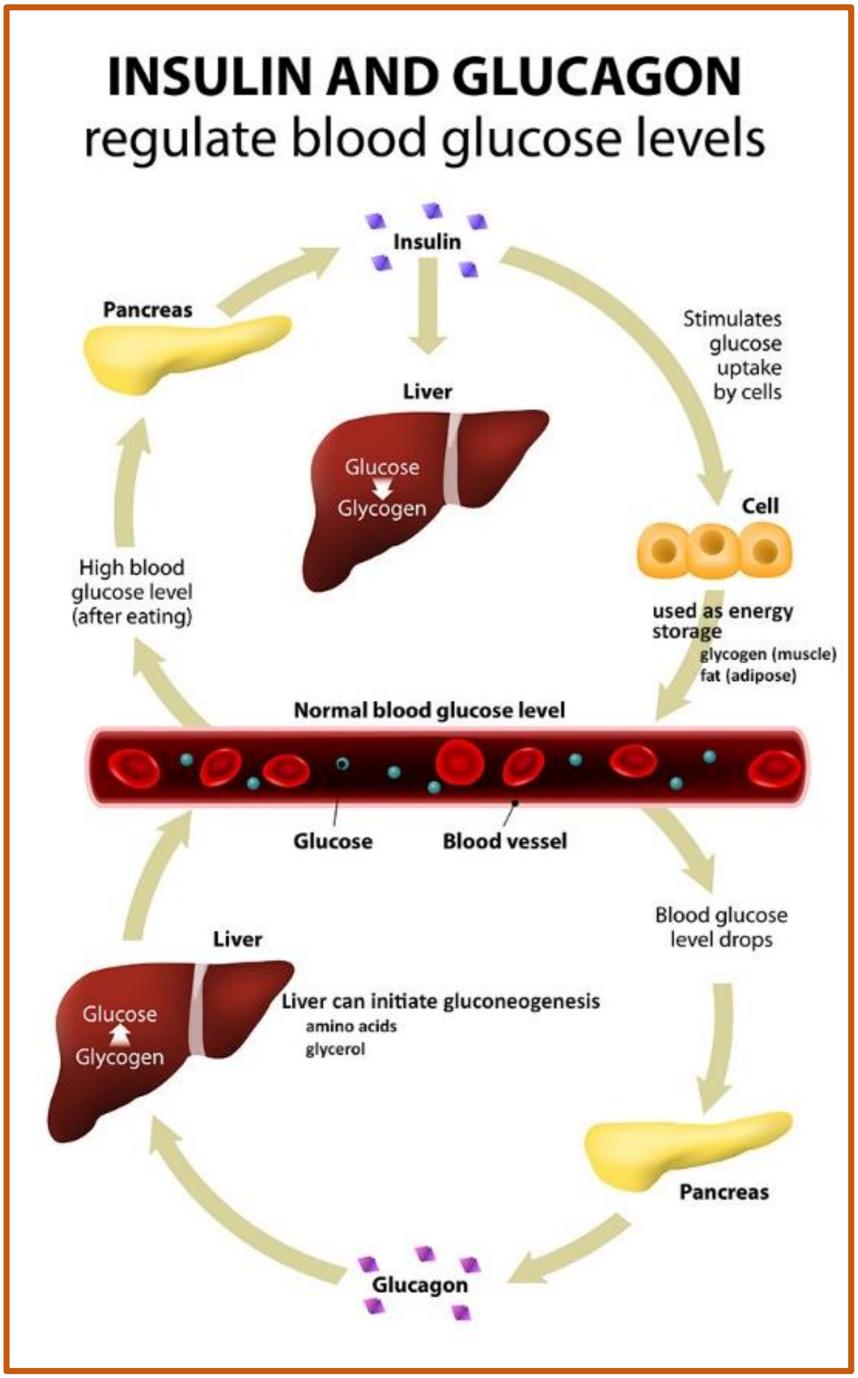


Figure 12A: Insulin and Glucagon regulate sugars in the blood

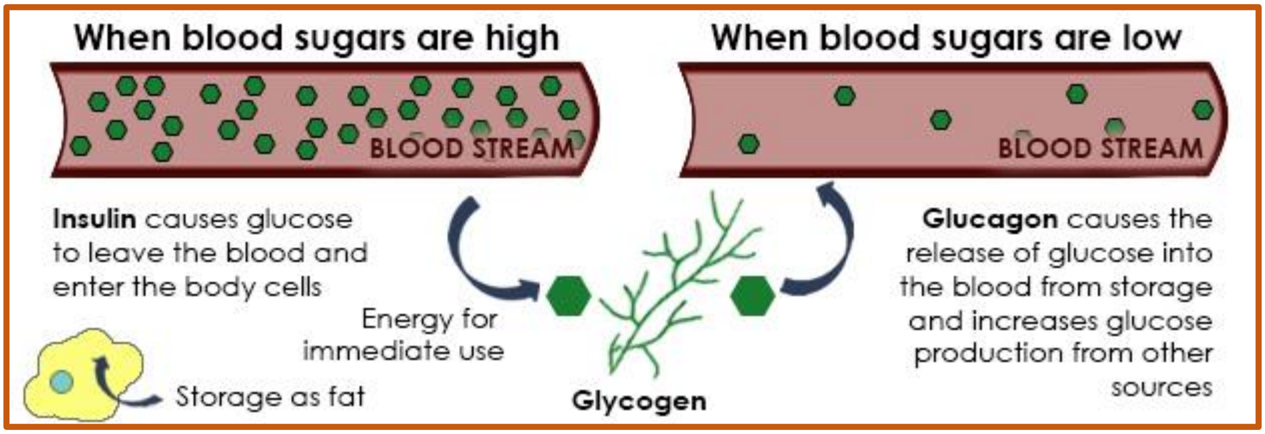


Figure 12B: The role of insulin and glucagon in the regulation of blood sugars

Taking a close look at diabetes is a good way to gain a better understanding and appreciation for carbohydrate regulation in the body. Diabetes is categorized into two basic forms, Type 1 and Type 2. **Type 1 diabetes** develops when the pancreas stops producing insulin. As a result, the blood glucose derived from the carbohydrates that are eaten gets stuck in the blood stream and can't get into the liver and adipose cells. A normal blood glucose level ranges between 70–120 mg/dl. A person with untreated type 1 diabetes may have blood sugars 800- 1000 mg/dl. If not treated this will eventually be deadly. In **type 2 diabetes** the pancreas is still producing plenty of insulin, and initially even excessive amounts of insulin are produced, but the body cells will not respond to it. This is referred to as being insulin resistant. Even though these two types of diabetes appear similar in many ways, the treatment approach is very different. Type 1 diabetes requires insulin treatments. Since insulin levels are above normal in type 2 diabetes giving additional insulin is not often a good approach. Lifestyle change, including dietary changes, and medications are used to treat type 2 diabetes.

Glycemic Index

Not all carbohydrates affect the blood glucose with the same intensity and speed. Some foods raise blood sugars rapidly and with a higher intensity, other foods have a lower and more gradual response. The magnitude in which a food raises blood glucose is called the **glycemic index**. Refined foods and foods high in amylopectin and simple sugars like glucose tend to have a high glycemic index value. Whole foods high in fiber, fat and fructose tend to have a lower glycemic index. For instance, a potato is very high in amylopectin and amylose and has a very high glycemic index. However, if you eat the potato with the skin, the glycemic index of the potato drops because of the fiber that is found in the potato skin. The fiber slows the absorption of the glucose in the intestine. Alternatively, if you put butter on the potato, the glycemic index drops because of the fat content. The presence of fat in the digestive tract slows digestion. High glycemic foods raise blood sugars quickly and intensely; in conjunction, they also tend to raise insulin levels higher and faster. The presence of insulin in the blood globally sends a message to store not only glucose, but fat as well, and in some people is associated with weight gain and the potential problems that can be associated with excess weight. There is some evidence that indicates those who choose low glycemic foods more often may have a lower risk of developing diseases such as Type 2 diabetes and cardiovascular disease.[7]

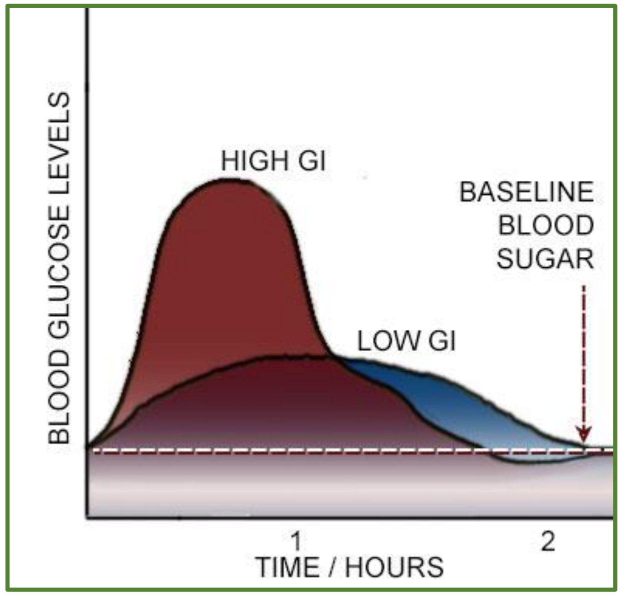


Figure 13: The glycemic index measures the effects of foods on blood-glucose levels

Nonetheless, caution should be exercised using the glycemic index to judge the healthiness of foods and in the determination of what foods to eat. For example, because French fries are deep fried they have a lower glycemic index than a baked potato. Based on the glycemic index alone a person could "incorrectly" conclude that eating the French fry is better than eating the potato. The potato is much more nutrient dense than the fry. Also, foods are rarely eaten alone. Combining low and high glycemic index foods in a meal can balance out the overall glycemic effect. A person's glycemic response to foods will also change depending on a variety of factors, such as fitness level, the time of day food is eaten, and the temperature of the food. In addition, meats and fats do not have a GI since they contain very little carbohydrates. However, that should not make them available for over-consumption. The best way to naturally achieve practical glycemic moderation is to choose nutrient-dense, whole foods as much as possible and practice the principles of variety, moderation, and balance as described in Choose MyPlate and the Word of Wisdom. This would include regular consumption of whole grains, fruits, vegetables, nuts, seeds, and legumes.

5.4 Functions of Carbohydrates

There are five primary functions of carbohydrates in the human body. They are, energy production, energy storage, building macromolecules, sparing protein, and assisting in lipid metabolism.

Energy Production

The chief role of carbohydrates is to supply energy to all body cells. Most cells can use glucose and fat as effective energy sources. But some cells are highly dependent on glucose alone. For example, red blood cells and brain cells depend greatly on glucose. Muscle cells use both carbohydrate and fat effectively, but when activity is very intense glucose use become a priority. About 70 percent of the glucose entering the body from digestion is redistributed (by the liver) back into the blood for use by other tissues. Cells that require energy allow the movement of glucose from the blood into the cell through a transport protein in their membranes. The energy from glucose comes from the chemical bonds between the carbon atoms. Sunlight energy was required to produce these high-energy bonds in the process of plant photosynthesis. Cells in our bodies break these high energy bonds found in glucose releasing energy for our use. This process is called cellular respiration.

A cell uses many chemical reactions in multiple enzymatic steps to allow for a slow and efficient release of energy held within the chemical bonds in glucose. This is necessary because the cells cannot use carbohydrate, protein or fat directly for energy; they must have Adenosine Triphosphate (ATP). The following analogy can be used to demonstrate this principle. An employer has 10 workers. Each is paid $10 per day. At the end of the day, the employer goes to

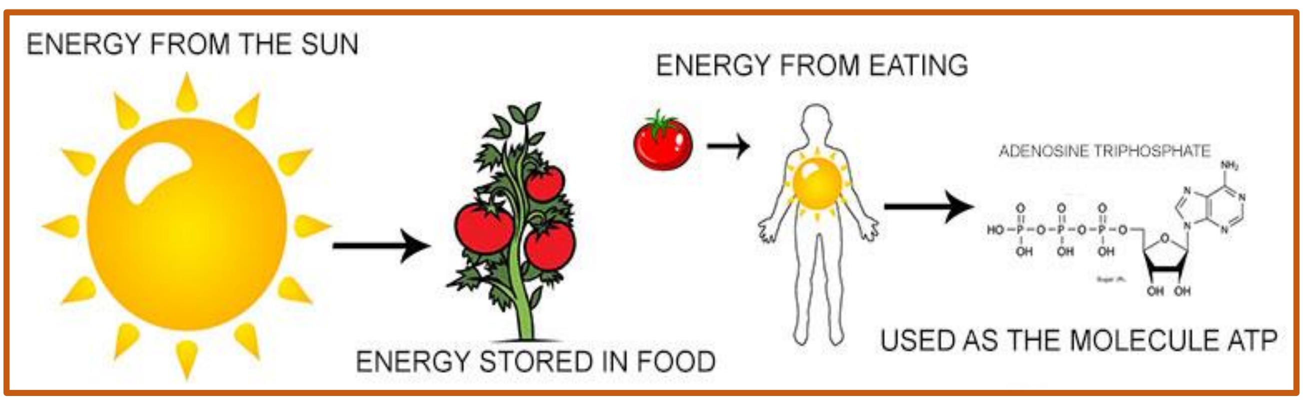


Figure 14: The conversion of complex energy forms to simple usable forms

the bank to get $100 to pay his workers. If the bank gives the employer a $100 bill, will the boss be able to pay his workers? No. Even though the $100 bill is the correct amount of money to pay the workers, the worth of the money cannot be shared with the workers when it is in the form of just one bill. Converting the $100 bill into smaller units of $10 bills, enables the boss to distribute the value of $100 among the workers. Likewise, food contains lots of valuable energy, but it is useless to the various cells of the body until it can be converted into smaller, usable units called **ATP** (see Figure 14)

The first stage in the breakdown of glucose is called **glycolysis**. Glycolysis, or the splitting of glucose, occurs in an intricate series of ten enzymatic-reaction steps in the cytoplasm of cells. At the end of glycolysis, glucose (6 carbons) has been split into two molecules of pyruvate (3 carbons each). A little bit of energy (in the form of ATP) is extracted from the conversion of glucose to pyruvate, but the vast majority of the energy is still locked up in the pyruvate or other by-products. The rest of the energy will be extracted from the pyruvate inside the mitochondria. This is why the mitochondria are called the power center of cells (see Figure 15).

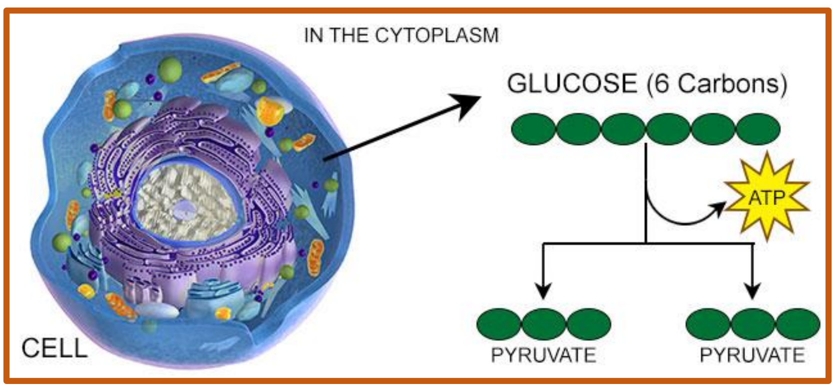


Figure 15: In the cytoplasm of the cell, glucose is converted to 2 molecules of pyruvate. If oxygen supply is low, the pyruvate is converted to lactate.

For the next phase of energy extraction to happen, sufficient oxygen must be available in the mitochondria. If oxygen is in short supply, the pyruvate will be stuck in the cytoplasm of the cell and be converted to lactate. The most common example of this occurs in high intense activity (like a 100-meter sprint). In this situation, our need for energy has exceeded our body's ability to take in oxygen and deliver it to the muscle and lactate levels increase in the body. This is called **anaerobic glycolysis** and can only continue for a short period. When a critical level of lactate is reached, metabolism slows down to allow the oxygen supply to catch up.

The second stage of glucose breakdown occurs in the mitochondria. The pyruvate molecules move out of the cytoplasm into the mitochondria. There they are converted to a compound called acetyl-CoA. Acetyl-CoA enters another pathway called the **Krebs cycle** (or the citric acid cycle or TCA cycle –they are all the same thing). There, the remaining energy is extracted from what was once glucose and is prepared for conversion to ATP. The electron transport chain is the final piece of the process. Most of the ATP production occurs within the electron transport chain (see Figure 16).

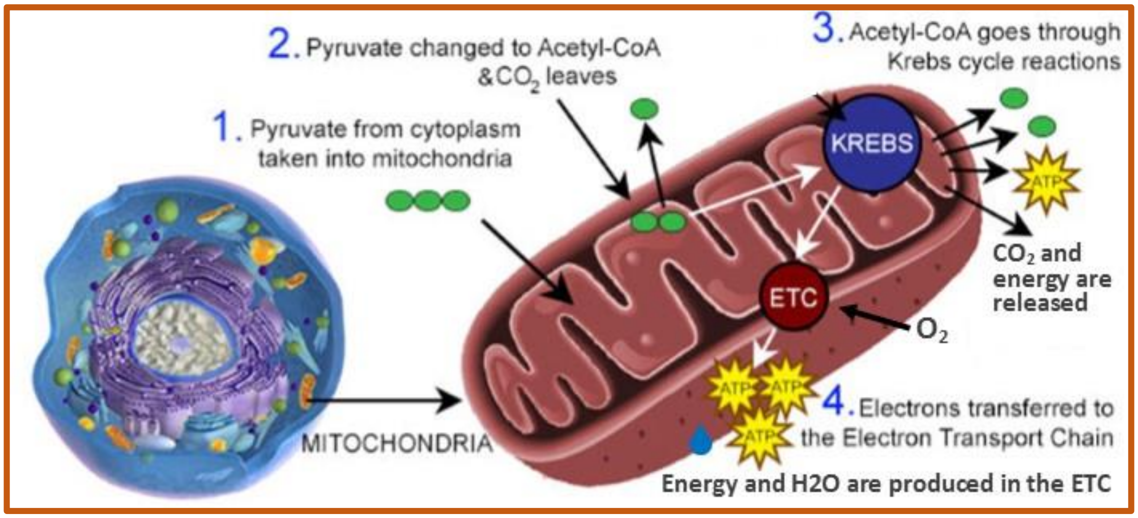


Figure 16: Within the mitochondria pyruvate is converted to acetyl-CoA and the energy extraction is completed

Energy Storage

If the body already has enough energy to support its functions, the excess glucose can be stored as glycogen (the majority of which is stored in the muscle and liver). A molecule of glycogen may contain more than fifty thousand single glucose units and is highly branched, allowing for the rapid release of glucose when it is needed to make cellular energy. (Figure 17 shows the branch structure of glycogen.) In-between meals or during exercise are times when the body relies on glycogen stores to provide glucose for energy. During rigorous

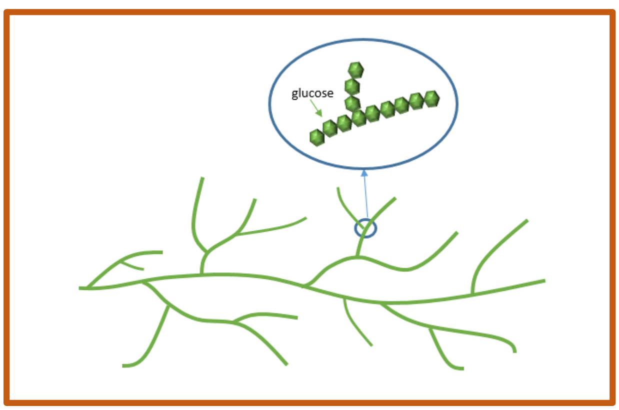


Figure 17: Glycogen

exercise, glycogen stores can be used up within 1-2 hours. This is the point during physical exertion that athletes refer to as hitting the wall or bonking. The body still has plenty of fat to provide energy, but ATP cannot be made nearly as fast from fat as it can be from carbohydrate. During exercise, this can be a problem if an athlete is trying to keep up a high level of exercise intensity.

Building Macromolecules

Although most absorbed glucose is used to make energy, some glucose is converted to ribose and deoxyribose, which are essential building blocks of important macromolecules, such as RNA, DNA, and ATP. If all of the energy, glycogen-storing capacity and building needs of the body are met, excess glucose can be used to make fat. This is why a diet too high in carbohydrates and calories can add on the fat pounds—a topic that will be discussed later.

Sparing Protein

In a situation where there is not enough glucose to meet the body's needs, glucose is made from some amino acids through a process called **gluconeogenesis**. Because there is no way for the body to store large pools of free amino acids, this process requires the catabolism (break down) of muscle tissues to provide amino acids for glucose production. Consuming enough carbohydrate to provide for the body's glucose needs allows the body to spare the body's protein for its primary functions, like building muscle. Under normal circumstances, gluconeogenesis can produce glucose at a sufficient speed to maintain normal blood glucose levels, such as during an overnight fast. In situations where glucose is in high demand, such as during prolonged rigorous exercise, gluconeogenesis will not produce glucose quickly enough to meet the body's needs. During rigorous exercise, eating food sources of glucose becomes essential to sustain performance as well as spare protein.

Preventing Ketosis

Adequate glucose levels in the blood prevent the development of **ketosis**. Ketosis is a metabolic condition resulting from an elevation of ketone bodies in the blood. Ketone bodies are an alternative energy source that cells, including brain cells, can use when glucose supply is insufficient, such as during fasting. Ketone bodies are made from lipid when carbohydrate resources are insufficient. Ketone bodies are acidic and high elevations in the blood can cause the body to become too acidic. Highy elevated ketone levels is rare in healthy adults but can occur with alcohol abuse, severe calorie restriction and in individuals who have Type 1 diabetes.

The minimum amount of carbohydrate in the diet required to inhibit ketosis in adults is approximately 50 grams per day.

Carbohydrates are critical to support life's most basic function—the production of energy. Without energy, none of the other life processes are performed. Although our bodies can synthesize glucose, it comes at the cost of protein destruction. As with all nutrients, carbohydrates are to be consumed in moderation as having too much or too little in the diet may lead to health problems.

5.5 Role of Grains in Health and Disease

The inclusion of nutrient dense carbohydrates in meal planning is consistent with current science and revelation. After extensive research and review of the literature, the group of experts that wrote Dietary Guidelines for Americans 2015 maintained that appropriate selection of carbohydrate rich foods is consistent with optimal health. The Word of Wisdom is also clear in its support of grains of all types, as well as fruits and vegetables for health promotion. Obesity and many other health problems appear to be unfairly blamed on carbohydrates as a whole. BUT… when choosing carbohydrate rich foods there are some important considerations:

Various types of grains including oats, rice, wheat, barley, and buckwheat

1. When choosing grains, choose a variety of nutrient-dense whole grains. Much of what is made available to the consumer is refined grains that contain added fats and sugars.
2. Be aware of added sugars contribution to the total carbohydrate content in any product you may choose (remember sugars are also in the carbohydrate family). Added sugars add calories but little vitamins and minerals.

Excessive consumption of refined carbohydrates with added fats and sugars, especially when connected with the over-consumption of calories, is detrimental to health.

Refinement

The refining process of grains removes many important nutrients. By law, thiamin, riboflavin, niacin, iron and folate must be added back (enriched). However, other important nutrients remain lost from the grain, such as fiber, magnesium, zinc, copper and many phytochemicals as well (Refer to Figure 8 in section 5.1).

There is a wealth of scientific evidence that supporting that replacing refined grains in the diet with whole grains that decrease the risk of developing a number of common serious health issues.[8] Americans typically do not consume 50% or more of their grain food choices as whole grains. Across all age groups nearly 100% of American's do not meet this goal (see Figure 18).[9]

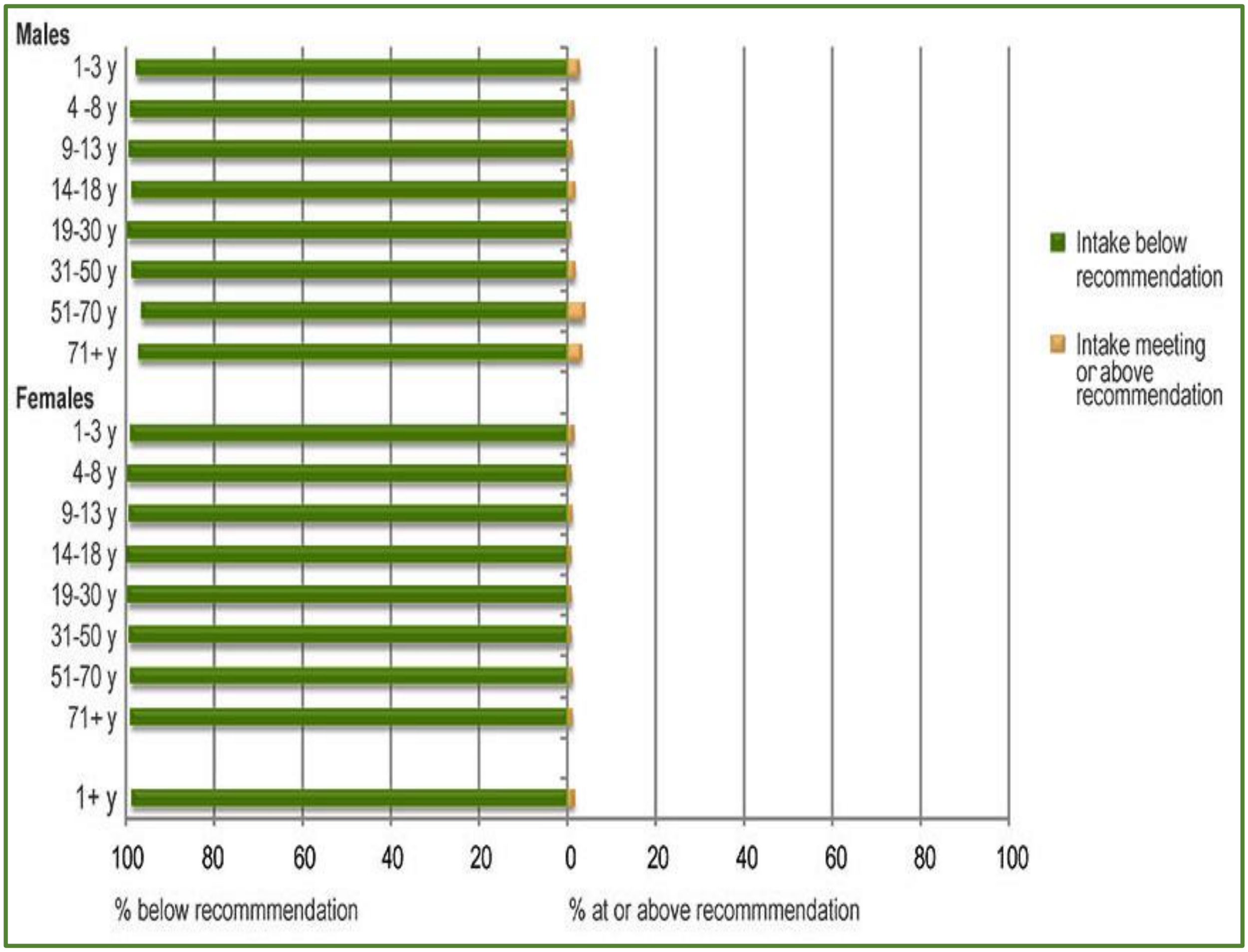


Figure 18: Percent of Americans meeting the whole grain recommendations[2]

A large meta-analysis published in the British Medical Journal in 2016 reported that the consumption of whole grains was associated with a reduction in coronary heart disease, cardiovascular disease, respiratory disease, infectious disease, diabetes and mortality from all causes.[1] Both the American Heart Association and the American Cancer Society support the consumption of whole grains for disease prevention.[10,11]

The Word of Wisdom specifically mentions the use of wheat, but several times emphasizes that all grains are ordained for the use of men. Many areas of the world are not able to grow wheat well. Over time, as exposure to different grain products produced around the world has increased in the United States, a wide variety of healthy options have been made available. Grains differ in their nutritional content, availablity and cultural acceptance, When possible, choose a variety of whole grains to meet your nutriitonal needs. Refer to Table 2 for a comparison of the nutritional content of several whole grains.

Nutrients	Whole wheat flour (100g)	Quinoa, uncooked (100g)	Millet, raw (100g)	Rye grain (100g)	Flaxseed (100g)
Calories (kcal)	340	368	378	338	534
Protein (g)	13.21	14.12	11.02	10.34	18.29
Fiber (g)	10.7	7	6.7	15.1	27.3
Calcium (mg)	34	47	8	24	255
Potassium (mg)	363	563	195	510	813
Copper (mg)	0.41	0.59	0.75	0.367	1.22
Selenium (µg)	61.8	8.5	2.7	13.9	25.4
Niacin B-3 (mg)	4.957	1.52	4.72	4.27	3.08
Folate (µg)	44	184	85	38	87
Betaine (mg)	72.8	630.4	n/a	146.1	3.1
Polyunsaturated fats (g)	1.167	3.292	2.134	0.767	28.73

Table 2: Nutrient comparison of several whole grain products (100 grams is roughly ¾ cups)

Whole Grains and Colon Health

One of the ways that whole grains promote good health is through their contribution to daily fiber intake. The benefits of fiber were outlined earlier in this chapter. Many whole grains are particularly rich in insoluble fiber. Insoluble fiber is particularly good at preventing constipation and the development of diverticulosis and diverticulitis. **Diverticulosis** is a harmless condition characterized by out-pocketings of the colon. **Diverticulitis** occurs when the out-pocketings in the lining of the colon become inflamed and can be painful (see Figure 19).

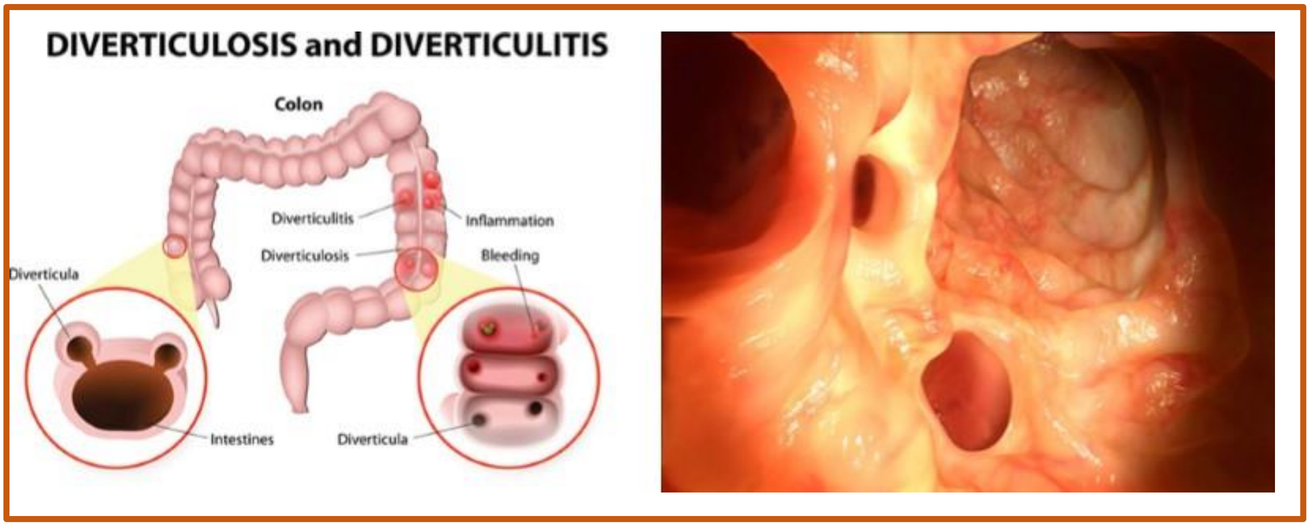


Figure 19: Diverticulosis and diverticulitis

More than 50% of the population of the United States will have diverticulosis by the age of 50. Often, no symptoms are associated with this condition, most people will be unaware they have it. Symptoms may include cramping, bloating and constipation or more serious symptoms such as bleeding. Ten to 25% of people that have diverticulosis will go on to develop diverticulitis. (4) Diverticulitis can be very painful and potentially dangerous. Evidence supports the use of fiber in the prevention and treatment of this disease.[12] The beneficial effects of fiber may not only be from the direct presence of fiber in the colon (softens stools, keeps things moving), but also because some fiber (prebiotics) support the good bacteria living in our colon.

Identifying whole grains

The identification of whole grain products can be a challenge when you are in the grocery store. "Whole grains" on the label does not always mean the product is made with 100% whole grains. It is important to realize that brown colored breads are not always healthier than white bread because the brown color may come from molasses or caramel. The Food and Drug Administration (FDA) has provided the food industry with specifics on how to label whole-grain foods. The best method to ensure the product is made from 100 percent whole grains is to check the ingredient list. One-hundred percent whole-grain products list **whole** grains or **whole**-wheat flour most often as the first ingredient. One-hundred percent whole grain products do not contain other refined flours such as wheat flour (which is just white flour), yellow corn flour or other refined grain products. The Dietary Guidelines for Americans gives this advice to those choosing 100% of their grains from whole grain sources:

> *"Those who consume all of their grains as whole grains should include some grains, such as some whole-grain ready-to-eat breakfast cereals, that have been fortified with folic acid. This is particularly important for women who are or are capable of becoming pregnant, as folic acid fortification in the United States has been successful in reducing the incidence of neural tube defects during fetal development."*[2]

Whole Wheat Bread

5.6 Added Sugars

Added sugars are sugars that have been added to food products during preparation or processing. Added sugars do not include sugars that occur naturally in whole foods (such as those found in fruits like berries, bananas, apples). Agave, brown sugar, corn syrup, dextrose, fructose, high fructose corn syrup, honey, maple syrup, raw sugar and sucrose (table sugar made from sugar cane or sugar beets) are all considered "added sugars" when added to foods. All added sugars contribute calories, but no additional nutrients. In fact, the overconsumption of sugar has been implicated in the development of type 2 diabetes and other chronic metabolic diseases. The amount of added sugar in a processed food is listed on the Nutrition Facts label. The names of the added sugars must be included in the ingredient list. It is required that added sugars are listed as individual items in the ingredient list. (See example on Figure 20.)

Nutrition Facts

8 servings per container
Serving size **2/3 cup (55g)**

Amount per serving	
Calories	**230**
	% Daily Value*
Total Fat 8g	**10%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Cholesterol 0mg	**0%**
Sodium 160mg	**7%**
Total Carbohydrate 37g	**13%**
Dietary Fiber 4g	**14%**
Total Sugars 12g	
Includes 10g Added Sugars	**20%**
Protein 3g	
Vitamin D 2mcg	10%
Calcium 260mg	20%
Iron 8mg	45%
Potassium 235mg	6%

* The % Daily Value (DV) tells you how much a nutrient in a serving of food contributes to a daily diet. 2,000 calories a day is used for general nutrition advice.

Ingredients: Whole grain rolled oats, **brown sugar**, vegetable oil, **honey**, raisins, wheat, salt

Figure 20: Identification of added sugars in food products (The added sugars are outlined in red in the ingredient list)

It is helpful to understand that 4 grams of added sugar on a food label represents about a teaspoon of added sugar. For instance, many commercial yogurt products have as much as 12 grams of added sugar. This represents three teaspoons of added sugar in a 6 or 8-ounce yogurt. All the sugar in a soft drink is added sugar. One 20-ounce soft drink may contain up to 65 grams of added sugar or roughly 16 teaspoons (Figure 21).

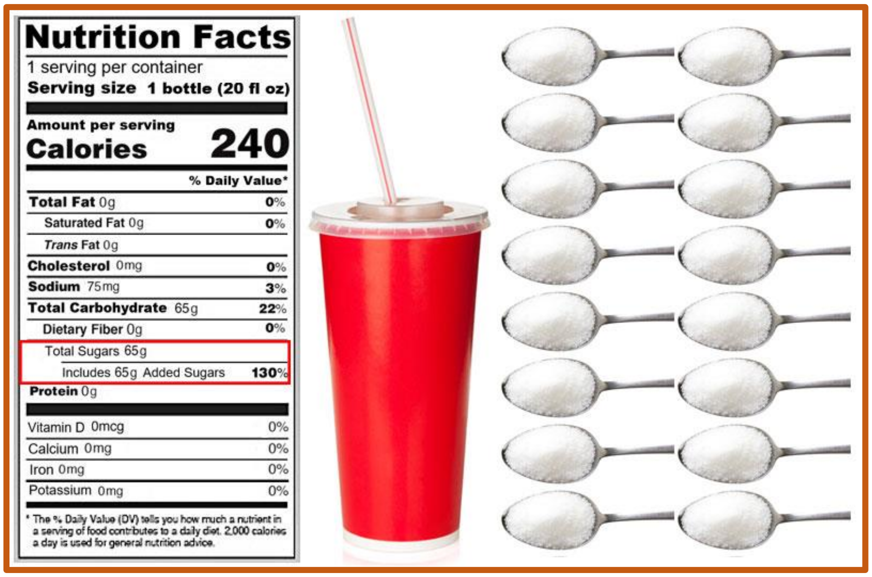


Figure 21: This 20-ounce can of soda contains 65 grams of added sugar (This translates to about 16 teaspoons of "Added Sugar")

According to the report given in the 2015-2020 Dietary Guidelines for Americans, the majority of the added sugar consumed in the American diet comes in the form of beverages such as "soft drinks, fruit drinks, sweetened coffee and tea, energy drinks, alcoholic beverages, and flavored waters" (see Figure 22).[15] Snacks and sweets such as "cakes, pies, cookies, brownies, doughnuts, sweet rolls, and pastries; dairy desserts such as ice cream, other frozen desserts, and puddings; candies; sugars; jams; syrups; and sweet toppings" are also significant contributors.[15] It is also important to note that another 18% of the added sugars in our diet come from foods made from grains and flours, dairy and combination foods such as frozen meals. These are items we often don't even suspect of containing added sugars. "Added sugars account on average for almost 270 Calories, or more than 13 percent of calories per day in the U.S. population and are particularly high in children, adolescents and young adults."[2] According to the math, that amount of added sugars (if eaten in excess of caloric needs) could account for 28 pounds of weight gain in 1 year.

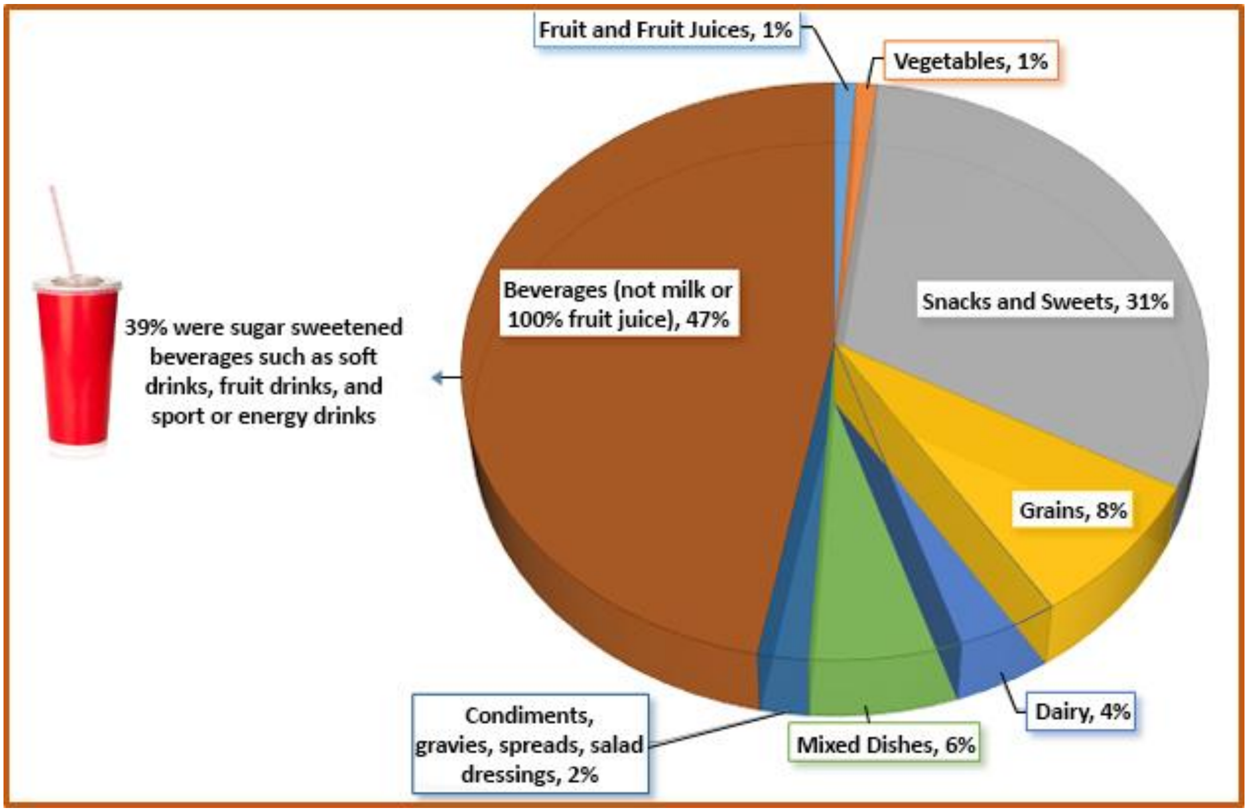


Figure 22: Sources of added sugars in the American diet[2]

Health Implications of Added Sugar

To understand the magnitude of the health problem in the United States, consider this: approximately 130 million adults are overweight (BMI of 25 to 29.9) and 30% of these people are obese (BMI of 30 or more). Overweight and obesity also affects young adults, youth, children and babies. Serious health consequences often follow them into adulthood. Negative health consequences strongly linked to being overweight or obese include: type 2 diabetes, cardiovascular disease, arthritis, depression and some cancers.

An obsession with sugary foods and beverages, and refined grains contribute to the epidemic proportion of people who experience overweight and obesity. Other contributing factors are: the consumption of processed foods instead of whole foods, and a sedentary lifestyle. The magnitude of the role of added sugars in America's health crisis is slowly becoming more clear. Research links sugar consumption to increased risk for developing several chronic metabolic diseases such as: heart disease, liver disease, weight gain, obesity and type 2 diabetes. Sugar sweetened beverages (soda, sport drinks, and fruit drinks) are big offenders.

Whether different sugars have differing negative metabolic effects is a hot topic both in research and the popular media. For example: High fructose corn syrup (HFCS) has been targeted as being unhealthier than regular sugar. HFCS is an inexpensive liquid sweetener made from corn. It is composed of a sucrose solution of glucose and fructose. (Sucrose is 50% glucose and 50% fructose.) In HFCS, the percentage of fructose is higher than glucose which makes HFCS sweeter than sucrose because fructose tastes significantly sweeter than glucose. HFCS contains more fructose than sucrose. Because of its low cost, sweeter taste, and ease of mixing into a wide variety of processed foods, food manufacturers often use HFCS instead of sugar. Despite all the hype about high fructose corn syrup, there is not clear evidence to support that it is more detrimental to health than other common sweeteners that are added to foods.

Sugar Intake Guidelines

All sugars are rich in calories and exceedingly poor in nutrients. The Dietary Guidelines for Americans 2015-2020 and the World Health Organization recommends no more than 10% of our caloric intake should come from added sugars. This is an “upper limit” and not a goal amount to be consumed each day.) For example: For a woman eating 2000 Calories per day, this is equal to no more than 12.5 teaspoons of added sugar per day. Data from 2001-2004 show that Americans eat an average of 22.5 teaspoons of added sugars each day. The American Heart Association’s recommendation for maximum sugar consumption is even more aggressive: For women the recommendation is no more than 6 teaspoons (25 grams) of added sugars per day, and for men the recommendation is no more than 9 teaspoons (36 grams) of added sugars per day. This guideline was established in 2010 after a review of the literature regarding the effects of sugar consumption on heart health. In its Dietary Reference Intakes (DRIs), the Institute of Medicine recommends limiting added sugar consumption to no more than 25% of total energy. (This is not a recommended intake.)

5.7 Carbohydrate Recommendations- Summary

In this chapter, you learned what carbohydrates are, the different types of carbohydrates in your diet, and that excess consumption of some types of carbohydrates cause disease while others decrease disease risk. Carbohydrate recommendations may vary from organization to organization. Throughout this course, we will focus on the guidelines given in the 2015-2020 Dietary Guidelines for Americans and the Dietary Reference Intakes (DRIs) published by the Food and Nutrition Board. General carbohydrate recommendations are summarized in Table 3.

Carbohydrate Intake Recommendations	
Total Carbohydrates (gm)	130 g/day: This is the minimum amount of carbohydrate recommended per day for proper neurological function. Most people need substantially more carbohydrate per day to sustain typical activity levels.
Carbohydrate as a Percentage of Calories (AMDR)	45-65% of total Calories (adults)
Added Sugars	Less than 10% of total Calories
Fiber	38 g/day (adult men), 25 g/day (adult women), or 14 g/1000 calories
Type of Carbohydrate Intake	Make at least half of your grains a whole grain

Table 3: Recommended carbohydrate intake[14,15]

Dietary Fiber Recommendations

The adequate intake (AI) for Total Fiber is based on data which showed that 14 grams per 1000 Calories (14 g/1000 Calories) reduced the risk of coronary heart disease.[16] Age and gender-specific AIs were set by taking 14 g/1000 Calories and multiplying it by the median energy intake for each group. For example, you will find that the Total Fiber AI on the DRI tables for adult men and adult women ages 19-50 is 38 g/day and 25 g/day, respectively. However, some diet analysis programs recommend individual Total Fiber intake based on the 14 g/1000 Calories and multiply it by the individual's recommended calorie intake. Either AI recommendation, the gender-specific age recommendation or the calorie-based recommendation, can be used and is helpful to ensure adequate consumption of fiber.[16]

It's the Whole Nutrient Package

In choosing dietary sources of carbohydrates, the best ones are those that are nutrient dense. This means they contain substantial amounts of essential nutrients per calorie of energy. In general, nutrient-dense carbohydrates are minimally processed and include whole-grain bread and cereals, low-fat dairy products, fruits, vegetables, and legumes (beans). In contrast, dietary carbohydrates that are not nutrient dense are often referred to as "empty-calorie" foods. They are highly processed and often contain added sugars and fats. Soda, cakes, cookies, and candy are examples of empty-calorie carbohydrates. Unfortunately, some products can masquerade as healthy, but contain a lot of added sugars. For example, many dairy products, granola bars and bread products contain substantial amounts of added sugars. Collectively, foods containing high amounts of added sugars are often referred to as 'bad carbohydrates,' as they are known to cause health problems when consumed in excess; but if eaten in moderation these types of products can still be included as part of a healthy diet.

Nonnutritive Sweeteners

Sweeteners can be sub-divided into two group: **nutritive** and **non-nutritive**.[17] Nutritive sweeteners contain carbohydrate and energy (usually 4 kcal/gram) and include the simple sugars that have already been discussed (mono and disaccharides in their various forms). The **sugar alcohols** (polyols) are also a type of nutritive sweetener that has not yet been touched on. They provide ~2 kcals/gram and have some physiological benefits when compared to the other nutritive sweeteners. For example, they have fewer calories per gram (2 verses 4 kcal/gram), they have a minimal effect on blood sugar levels (which may have benefits for individuals with diabetes), and they either don't cause cavities or may inhibit cavity production. The sugar alcohol "xylitol" has been promoted as actually being anti-cariogenic (or cavity preventing). Examples of the sugar alcohols are listed in Table 4.

Because of their properties, they have been added to food products for many years as a means of decreasing amounts of added sugars while maintaining a certain level of sweetness. Sugar alcohols are useful, but they are not as sweet as other non-nutritive sweeteners and in some cases can cause gastrointestinal distress when used heavily.[16]

Example of Sugar Alcohols	Relative Sweetness Compared to Sucrose
Sorbitol	50%-70%
Mannitol	50%-70%
Xylitol	100%
Erythritol	60%-80%
Lactitol	30%-40%
Maltitol	90%
Isomalt	45%-65%

Table 4: Some common sugar alcohols[17]

Nonnutritive sweeteners have taken the forefront in the market as an option to provide sweetness without the negative health effects of sugar. For example, non-nutritive sweeteners have little to no effect on blood sugar levels, they do not promote tooth decay and they make a lower contribution to total caloric intake. Generally, the nutritive sweeteners come from natural sources and the nonnutritive sweeteners are made by chemical methods. Exceptions to this rule are stevia and monk fruit (lua han gua extract) which are both extracted from plants. The nonnutritive sweeteners that are chemically produced (also called artificial sweeteners) have to be tested for safety and then approved by the FDA before they can be marketed in the United States. For each of the sweeteners an **Acceptable Daily Intake (ADI)** is also established. The ADI represents the amount of the sweetener (by body weight) that can be safely consumed every day over a lifetime without adverse effects.[17] The values are set with a generous safety factor. Some of the approved non-nutritive sweeteners and their ADI's are listed in Table 5. None of these sweeteners contain any appreciable calories.

Example of Non-Nutritive Sweeteners	Relative Sweetness compared to Sucrose	Acceptable Daily Intake (ADI)
Acesulfame K	200 x sweeter	15 mg/kg body weight
Aspartame	200 x sweeter	50 mg/kg body weight
Neotame	7000 - 1300 x sweeter	0.3 mg/kg body weight
Saccharin	200-700 x sweeter	15 mg/kg body weight
Stevia	200-400 x sweeter	4 mg/kg body weight
Sucralose	600 x sweeter	5 mg/kg body weight

Table 5: Some common nonnutritive sweeteners[17]

Because nonnutritive sweeteners contribute sweet taste but with greatly reduced calories compared to sugar, it seems logical to conclude that they might be a helpful tool for weight loss. However, research provides mixed results. The 2015-2020 Dietary Guidelines Advisory Committee states, "There is insufficient evidence to recommend the use of low-calorie sweeteners as a strategy for long-term weight loss and weight maintenance."

The use of non-nutritive sweeteners in the management of diabetes has provided options for those with this disease. It has allowed individuals with diabetes to enjoy sweet flavored products more often in a manner that allows better dietary control and overall diet quality. It is important to note that while these products do provide a sweet sensation, they do not provide all the textural qualities nutritive sweeteners provide.

Chapter 6: Protein

> Yea, flesh also of beasts and of the fowls of the air, I, the Lord, have ordained for the use of man with thanksgiving; nevertheless, they are to be used sparingly (D&C 89:12)
>
> For whoso 'biddith to abstain' from meats, that man should not eat the same, is not ordained of God. For, behold, the beasts of the field and the fowls of the air, and that which cometh of the earth, is ordained for the use of man for food. (D&C 49: 18-19)

Protein comprises a significant part of the human body. Protein's functions in the body are diverse. Its importance can be seen on a large scale because it serves a significant structural role in muscle, bone matrix, hair etc., but if one were to look microscopically, protein can be seen playing critical roles in maintaining the life of each cell of the body. Protein contains calories (4 kcal/gram), but because of protein's important structural and regulatory roles, mammals do not to use substantial amounts of protein for energy, instead it is saved for its other roles.

6.1 Protein Food Sources

Dietary protein intake is necessary to sustain life. It is found in a wide variety of foods. When food sources of protein are spoken of, most often foods such as meat, poultry, fish, and dairy products come to mind. Indeed, these are rich sources of protein. Some plant foods are also high in protein such as legumes, which include dried beans like kidney, pinto and black beans as well as dried peas and lentils, and many nuts and seeds. Some are surprised to find that most grains also contain a modest amount of protein and most all vegetables contribute a little bit of protein to our diet as well. The only food group that typically provides little protein is the fruit group.

An interesting alternative source of protein that is commonly used worldwide is insect protein. Insect eating is referred to as entomophagy. While insects are not widely accepted as a protein source in the United States at this time, they are generally rich in nutrition, environmentally friendly to produce and are a cost-efficient source of protein. With an expected increase in the cost of meat over the next 30 years, the use of insects as a protein source is an interesting consideration.[1]

Insects are a protein source in most of the world.

In this chapter, we will explore the chemical composition of proteins, how proteins are made and what they do in the body. We will then look at the similarities and significant differences between plant and animal proteins. We will also review how to determine daily protein recommendations and ways to get an adequate intake from foods.

6.2 Amino Acids and Proteins

Amino Acids

Amino acids are the building blocks of protein. This can be illustrated using a beaded necklace analogy. The beaded necklace represents a protein, and the individual beads represent amino acids. Accordingly, to understand protein, a person first has to understand amino acids.

Meats, nuts, eggs, and other protein sources

Amino acids are composed of the elements carbon, hydrogen, oxygen, and nitrogen. Each amino acid consists of a central carbon atom connected to a side chain, a hydrogen, a nitrogen-containing ***amino*** group, and a carboxylic ***acid*** group—hence the name "amino acid." All amino acids contain these four basic features. The arrangement of the amine group, the acid group and the hydrogen around the carbon center is the same for all amino acids (see Figure 1). Only the side chain (R) differs between amino acids. There are 20 different amino acids commonly used in building proteins. With deductive reasoning the conclusion can then be drawn that there are 20 different R groups, which is correct!

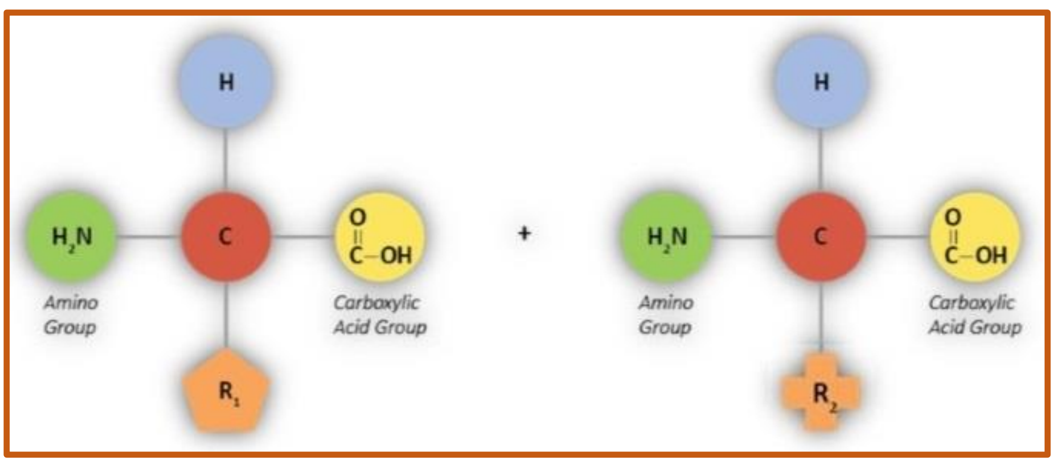


Figure 1: Structure of an amino acid

Types of Amino Acids

There are 20 different amino acids that are used to make proteins. If you consider the length of most proteins (hundreds of amino acids long) and the number of possible combinations that can be created with 20 different amino acids, it is apparent why every protein produced in the body can have a unique structure. Of these 20 amino acids, only 9 are considered essential (required to be consumed in the diet.) The other 11 amino acids can be produced by the body from other substances and are therefore considered non-essential. The **essential and non-essential amino acids** are listed in Figure 2.

Essential Amino Acids	Non-Essential Amino Acids
Histidine	**Alanine**
Isoleucine	**Arginine**
Leucine	**Asparagine**
Lysine	**Aspartic Acid**
Methionine	**Cysteine**
Phenylalanine	**Glutamic Acid**
Threonine	**Glutamine**
Tryptophan	**Glycine**
Valine	**Proline**
	Serine
	Tyrosine

Figure 2: Amino acids

In order for the body to make the non-essential amino acids, a source of nitrogen is needed. One of the key ways proteins differ structurally from carbohydrates and fats is they contain nitrogen in their structure. One of the sources for non-essential amino acid production can be fat or carbohydrate. For example, the amino acid glutamine is a non-essential amino acid. It can be made from part of the monosaccharide "glucose" when the body needs it. However, a critical limitation is that glucose does not contain nitrogen. To complete the non-essential amino acid, the needed nitrogen will be transferred from another source through a process called **transamination**. Often the source of nitrogen will be another amino acid that is plentiful in the body at that time.

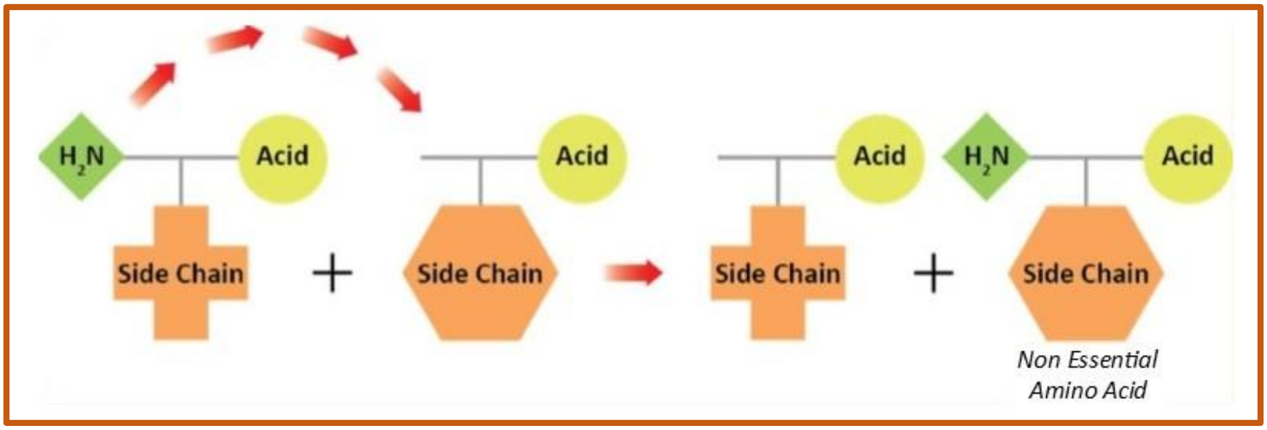


Figure 3: Transamination

Under special circumstances, some non-essential amino acids can become essential amino acids. These unique amino acids are referred to as **conditionally essential amino acids**. A classic example of this is the genetic disease phenylketonuria (**PKU)**. This genetic disorder is caused by an error in the DNA. This error prevents the production of an enzyme needed to convert phenylalanine (an essential amino acid) to tyrosine (a non-essential amino acid). Tyrosine is a non-essential amino acid because it can be made from phenylalanine. When people have this genetic error, they cannot break down the amino acid phenylalanine or produce tyrosine (see Figure 4). Tyrosine now becomes an essential amino acid since the body cannot make it from phenylalanine due to the missing enzyme.

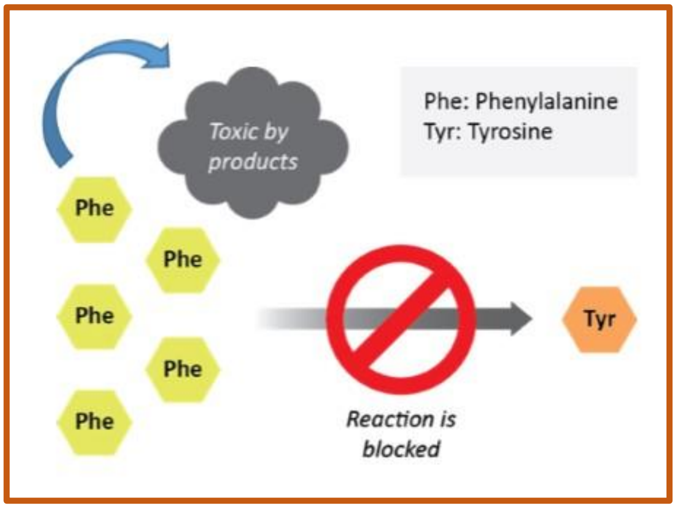


Figure 4: Conversion of phenylalanine to tyrosine is blocked in PKU

Even though phenylalanine is an essential amino acid, individuals with PKU end up with too much phenylalanine. The excess phenylalanine is converted to secondary products (toxic byproducts) that are harmful to the body. Untreated PKU will lead to seizures and poor intellectual development. Treatment for PKU includes a specialized diet that restricts phenylalanine along with the consumption of a special formula that includes essential amino acids.[2]

Peptide Bonds

Proteins are constructed by linking amino acids together in a chain, similar to the beads on a necklace. The beads (amino acids) are held together by bonds. The bonds between amino acids are called **peptide bonds**. Peptide bonds are formed between the acid and the amine group with the removal of water (see Figure 5). Two amino acids form a **dipeptide**, three amino acids form a **tripeptide**, and several amino acids bonded together form a **polypeptide**.

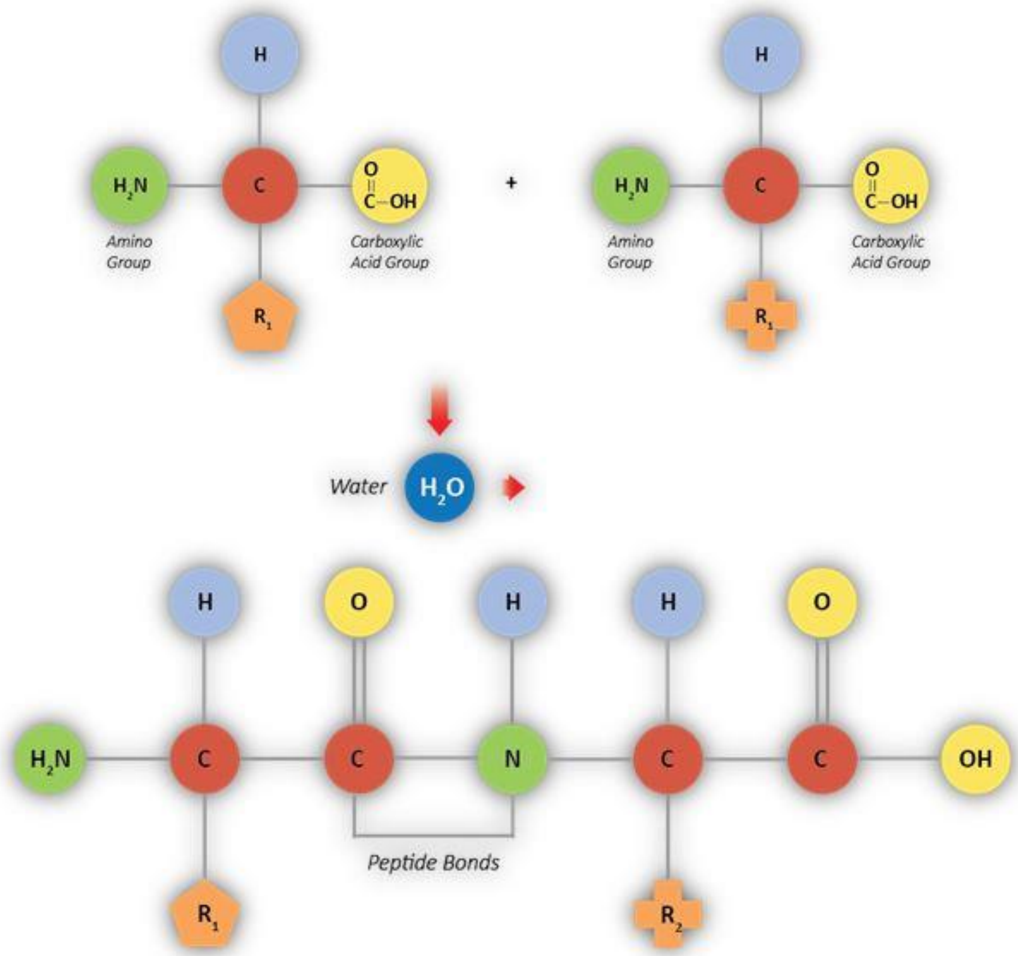


Figure 5: Formation of a peptide bond

Protein Folding

Once a protein is formed the protein will fold into a functional shape. After a protein is made, chemical and structural forces will ensure that it will fold into the same shape every time. The proteins shape is essential for it to function properly.

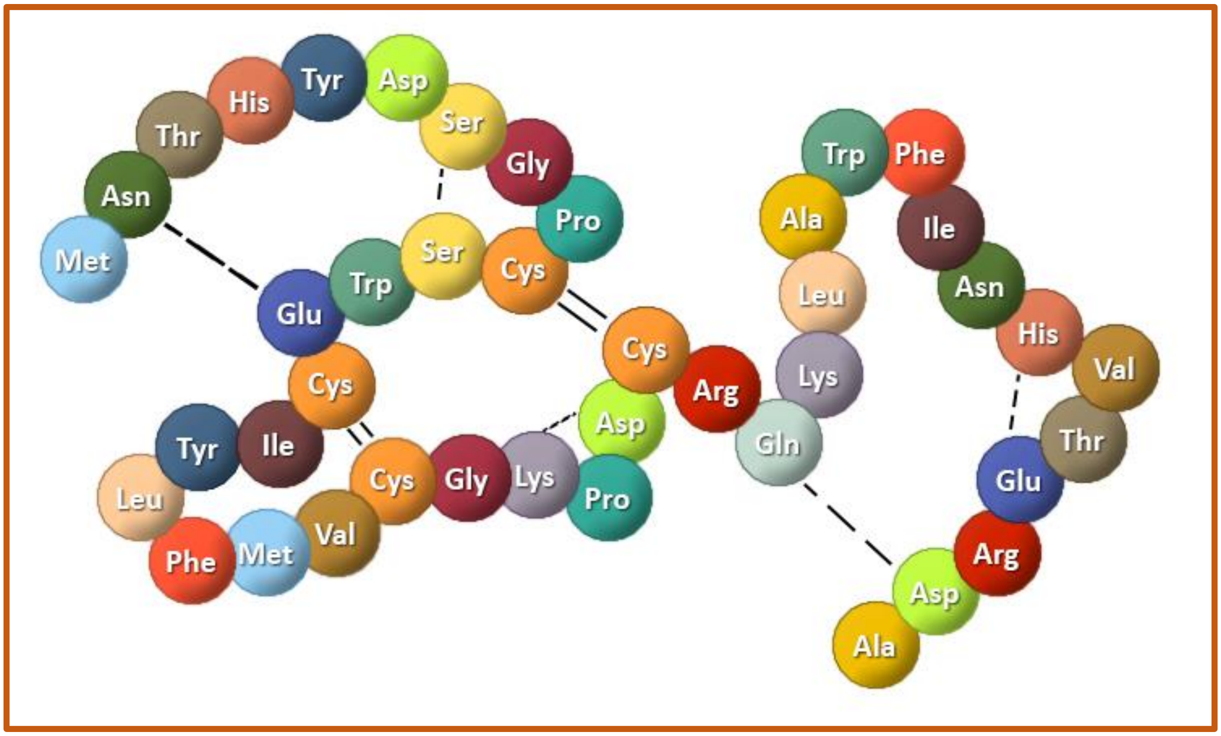


Figure 6: Folded protein

When a protein unfolds it can no longer function properly. The unfolding process is referred to as **denaturation**. Forces that can cause a protein to denature include: heat, change in acid-base balance, alcohol and physical force. For example, when the digestive enzyme amylase enters the stomach it is denatured by the stomach acid and will no longer break down starch. If important body proteins become denatured, harm can occur to the body. Examples are illness that may cause a high grade fever or a change in body pH.

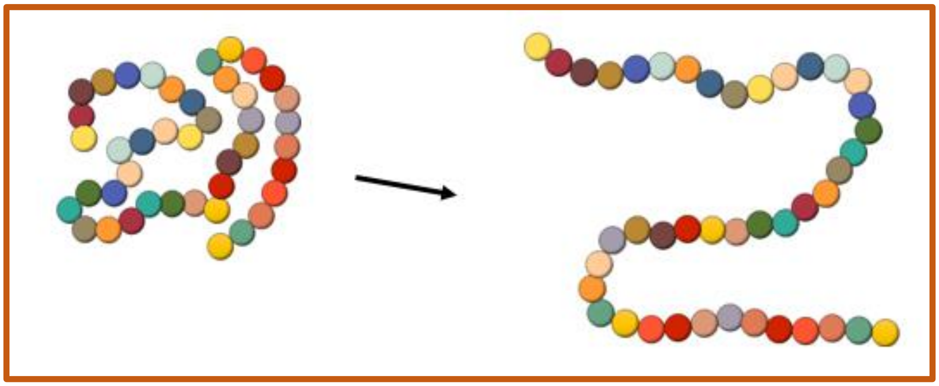


Figure 7: Denaturation

Whether they recognize it or not, most people have seen the process of denaturation. Cooking an egg is a demonstration of the process of denaturation. When a raw egg is cracked into a hot pan, the egg white is initially clear, but quickly starts to turn opaque. With exposure to heat, the proteins in the egg white unfold and the denatured proteins link together. Light can no longer penetrate the egg white and it is no longer transparent.

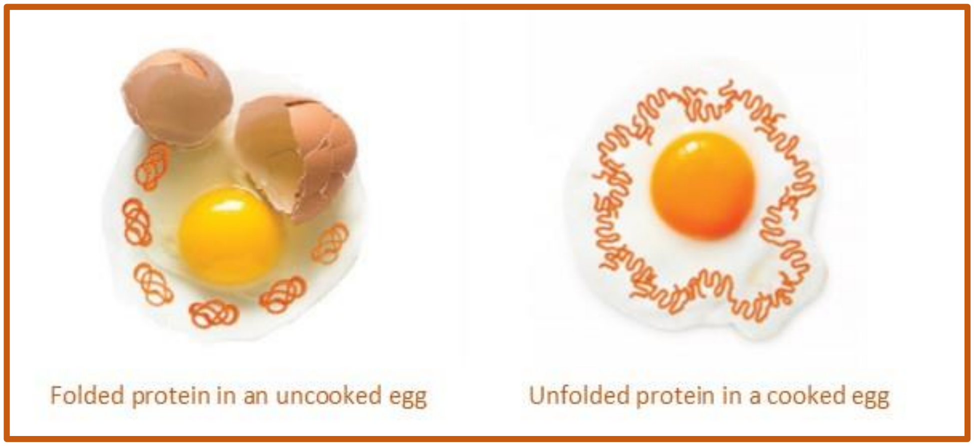


Figure 8: Denaturation in the cooking process of an egg

When protein is eaten in food, it will most likely still be in a folded shape. While in some cases the process of denaturation is harmful to the body, in order to digest and absorb proteins they first must be denatured in our stomach.

6.3 Protein Digestion and Absorption

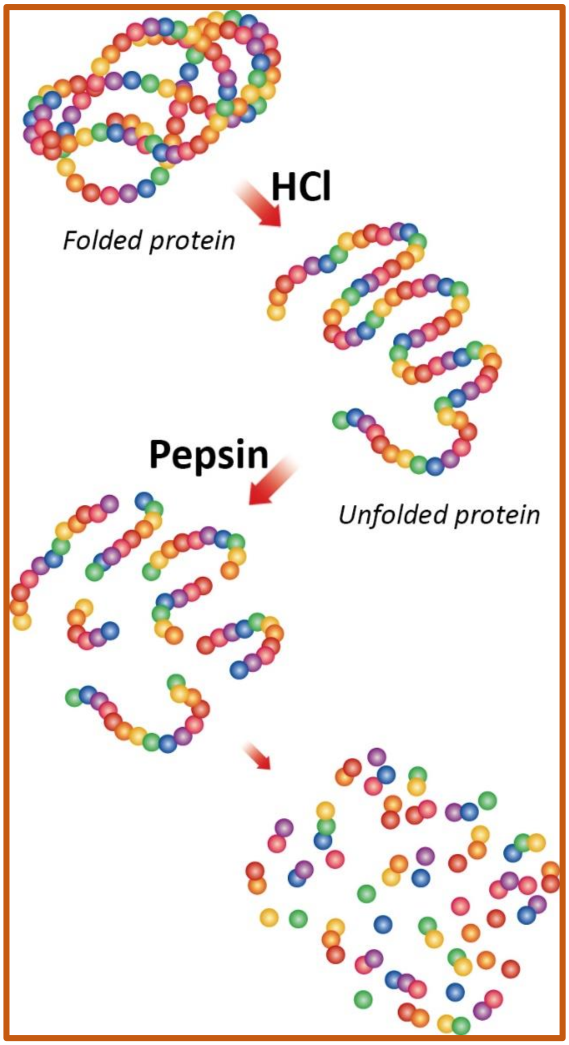


Figure 9: Action of Pepsin

In order to be absorbed, proteins need to be broken down. The body can absorb single amino acids, dipeptides, or tripeptides. Typically, nothing larger than a tripeptide is safely absorbed. In the mouth, large protein pieces can be mechanically separated through chewing, but the chemical digestion (breaking of peptide bonds) of protein begins in the stomach. The stomach releases gastric juices containing hydrochloric acid and the enzyme pepsin, which initiate the breakdown of the protein. The acidity of the stomach facilitates the unfolding of the proteins (denaturation). Pepsin, which is secreted by the cells that line the stomach, dismantles the protein chains into smaller and smaller fragments by breaking the peptide bonds (see Figure 9).

Although the chemical digestion of protein begins in the stomach, the majority of the digestion occurs in the small intestine. The pancreas secretes digestive juices that contain the enzymes trypsin and chymotrypsin that continues the chemical digestion of protein in the small intestine. The cells that line the small intestine (brush border cells) release other enzymes that finalize the process by breaking the small protein fragments into the individual amino acids, dipeptides, and tripeptides. The muscle contractions of the small intestine mix and propel the digested proteins to the absorption sites. In the lower parts of the small intestine, the amino acids are transported from the intestinal lumen into the intestinal cells to the blood. Once the amino acids are in the blood, they are transported to the liver. As with other macronutrients, the distribution of amino acids to other body locations is regulated by the liver.

6.4 Protein Synthesis

Once the proteins are digested and the amino acids are absorbed, the cells throughout the body will use the amino acids to build proteins necessary for cellular function. The building of a protein consists of a complex series of reactions that can be summarized into three basic processes: transcription, translation, and protein folding.

The information to build every protein needed by the human body is contained in the DNA. Every cell of the body has a copy of this information in its nucleus. When a particular protein is needed, the part of the DNA that contains the instructions to build the protein of interest is copied. In order for the copy to be made, the segment of the DNA that contains the pertinent information is unzipped so it can be read. The process of copying the DNA is called **transcription.** The copy of the DNA segment is called messenger RNA (mRNA).

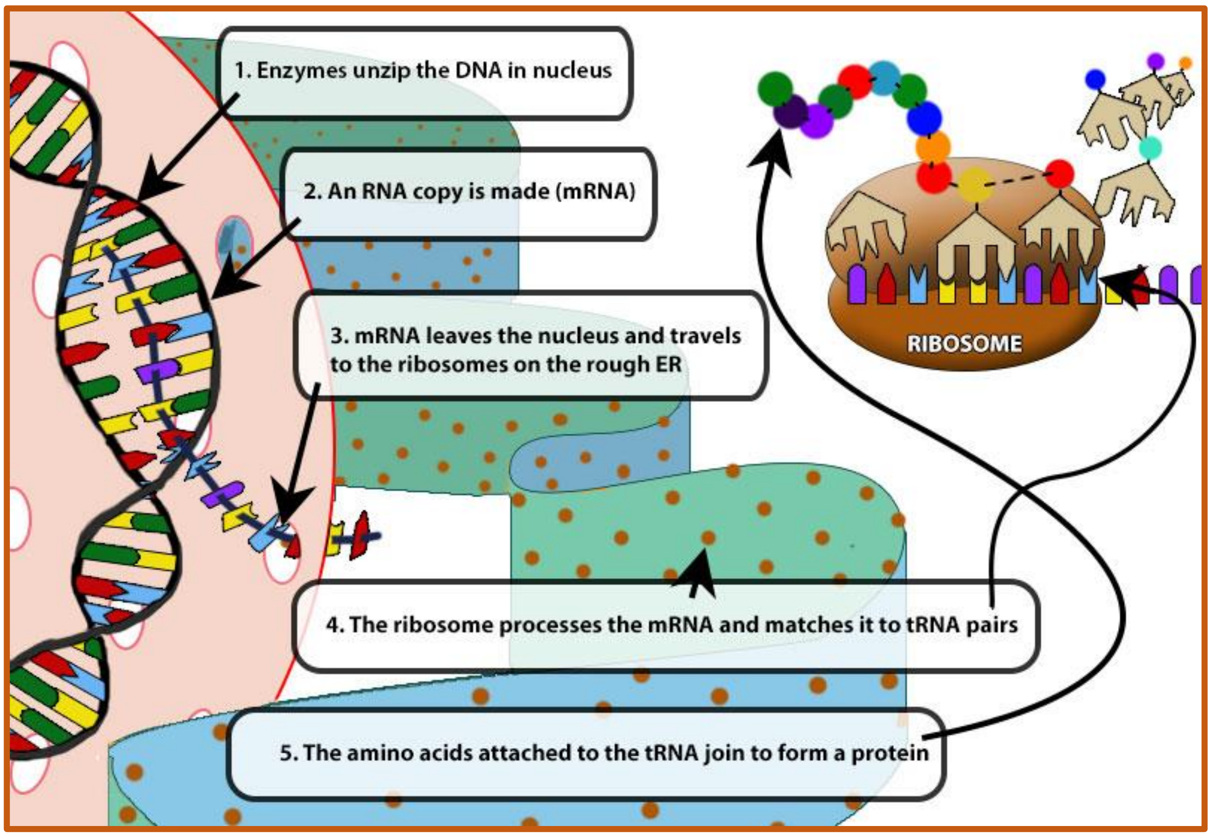


Figure 10: Protein synthesis

The mRNA leaves the nucleus and enters the cytoplasm of the cell where proteins called **ribosomes** (these are usually anchored on the endoplasmic reticulum) read the information contained in the structure of the mRNA and construct the appropriate protein. The specific order of the amino acids in the new protein is important. If an error exists in the order of the amino acids, significant health issues can occur. Cystic fibrosis, hemochromatosis, and phenylketonuria are a few examples of diseases caused by an error in the DNA sequence.

The process of constructing a protein is called **translation**. As mentioned earlier, the amino acids are connected together using special bonds called peptide bonds. Transfer RNA (tRNA) bring the needed amino acids to the ribosomes where they are then bonded together in the correct sequence. Every protein in the body has its own distinctive sequence of amino acids. As a result, the unique chemical and structural forces in action within that protein result in a unique folding structure that is consistent each time that protein is made.

6.5 Protein Turnover

Just as some plastics can be recycled to make new products, amino acids are recycled to make new proteins. All cells in the body continually break down proteins and build new ones, a process referred to as ***protein turnover***. Every day the breaking down and building of proteins account for about 10-25% of the energy we expend at rest.[3] To form these new proteins, amino acids from food and those from body protein breakdown are placed into an "**amino acid pool**" (see Figure 11).

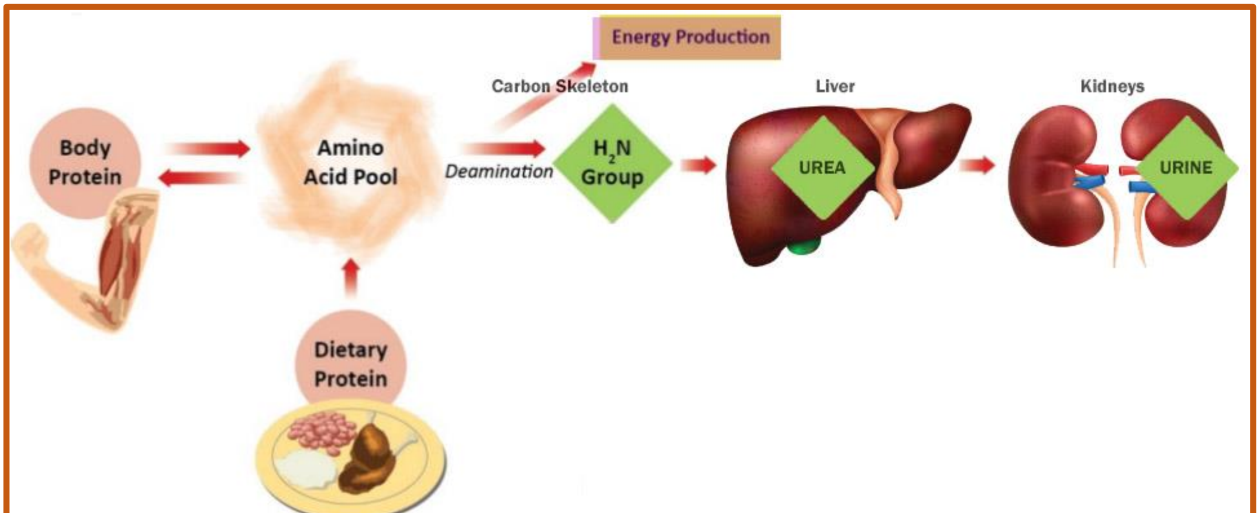


Figure 11: Amino acid pool

The amino acid pool is a term used to describe amino acids that are free to be used throughout the body. When an amino acid is needed to build a protein, it can be taken from this pool of available amino acids. The amino acid pool accounts for less than one percent of total body protein content. It is not big enough to be considered a storage reserve of protein, so a consistent intake of good quality protein is still important for optimal health. Amino acids are primarily used to build proteins. They are also needed to build other nitrogen-containing compounds, such as DNA and RNA. To some extent, amino acids can be used to produce energy.

The fraction of protein that is used for energy (typically about 5% of the protein that is taken in) has to be prepared before it can be metabolized for energy within cells. The body's energy extraction systems are geared to handle carbohydrate and fat. As emphasized several times, proteins are mostly made from the same materials as carbohydrate and fat (carbon, hydrogen and oxygen), but they also contain nitrogen. That amino or nitrogen group (in the form of ammonia) must be removed before the amino acids in the proteins can be turned into usable energy (ATP). The removal of the amino or nitrogen group from the amino acids is called **deamination**. The liver processes the amino or nitrogen group (ammonia) into **urea**. The urea is then released into the blood. The kidneys filter urea out of the blood and excrete it in the urine. The use of protein for energy increases when other energy sources are lacking. This might occur during starvation or lengthy rigorous exercise. Under these circumstances. the body must use muscle tissue to supply the needed protein. During periods of high protein low carbohydrate intake, protein use for energy also increases. In these circumstances adequate fluid consumption is encouraged to allow the kidneys to handle all the urea produced from the increased protein metabolism.

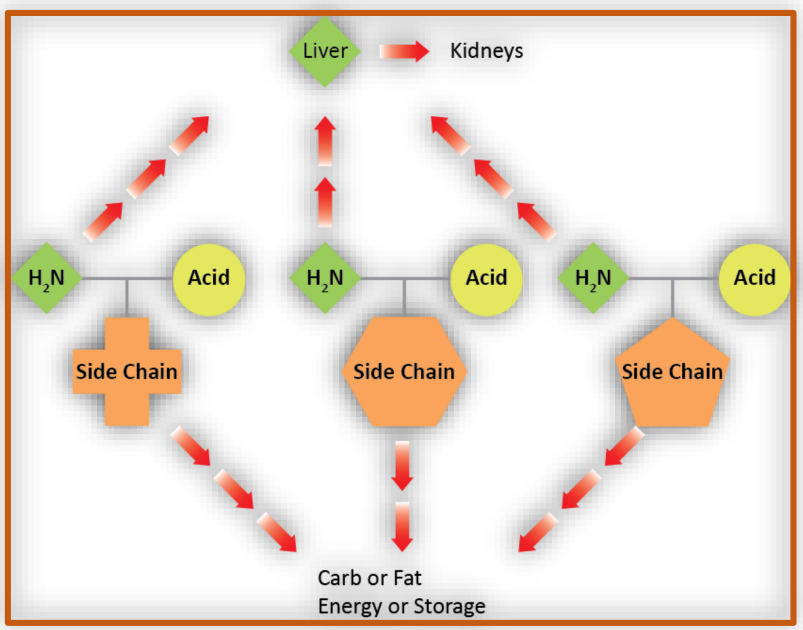


Figure 12: A closer look at deamination

6.6 Functions of Proteins

Proteins play a variety of roles in the body, including structural, regulatory and energy production.

Structure

More than one hundred different **structural proteins** have been discovered in the human body. Structural proteins are needed in just about every tissue in the body. One of the most abundant is collagen, which makes up about 1/3 of all body protein.[4] Collagen makes up 30 percent of bone tissue and comprises a large part of tendons, ligaments, cartilage, skin, and muscle. Collagen is a strong, fibrous protein. Collagen fibers in the skin's dermis provide it with structure, and the accompanying elastin protein fibrils make it flexible. Pinch the skin on your hand and then let go; the collagen and elastin proteins in the skin allow it to go back to its original shape. Another strong, fibrous protein is keratin, which is what skin, hair, and nails are made of. Vitamin C is important in collagen formation and vitamin A impacts keratin production. The devastating effect of deficiencies of these vitamins will be discussed more fully later.

Regulation

Proteins regulate body processes in a variety of ways. **Enzymes** are proteins that assist chemical reactions. An enzyme provides a site for a chemical reaction to happen (this is known as "catalysis"-see Figure 13). **Hormones** can also be made of protein. Hormones are chemical messengers that direct cellular process. Insulin, a hormone that regulates blood glucose levels, is a good example of a protein based hormone.

Proteins also play a role in managing the body's fluid and acid-base balance. A protein in the blood called albumin helps keep water in the blood vessels, so it does not leak out into the tissues. Protein malnutrition can cause low blood albumin levels, which in turn can cause excess fluid to go into the tissues. The excess accumulation of fluid in the tissues is called **edema**.

Edema in the feet

Most chemical reactions in the body will occur only in a narrow range of pH (a measure of how acidic or basic something is). Proteins act to prevent changes in body pH levels, in this role they are referred to as **buffers**.

Most of the **transporters** that move nutrients and waste products in and out of cells and throughout the body are proteins. The immune system's attack and destroy functions that protect our bodies from harmful invaders are dependent on enzymes and **antibodies**, which are also proteins. Proteins are important!

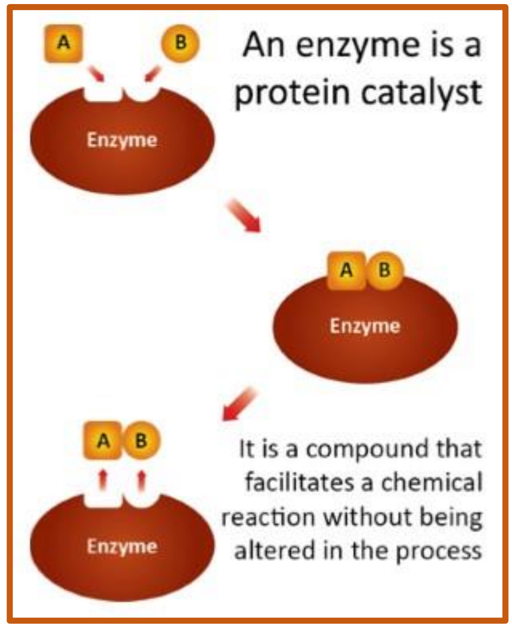


Figure 13: Function of an enzyme

Energy Production

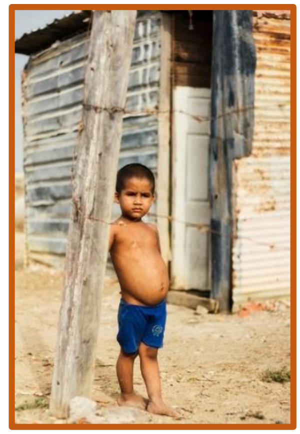
Protein provides 4 Calories per gram. The body prefers to use lipid and carbohydrate as its primary energy sources but does burn a little bit of protein for energy each day. Under certain circumstances the amount of protein used for energy will increase. Typically, this would occur when other energy sources are lacking such as during starvation or long bouts of exercise, or simply when more protein is eaten, more protein is used for energy. Part of the broken-down protein can also be turned into glucose. The central nervous system can only use glucose for energy. When glucose is in short supply (like during a period of starvation, or at the end of exhausting bouts of exercise) protein is broken down. Through the process of gluconeogenesis in the liver, some of the amino acids are converted to glucose. This will supply the needed glucose for the central nervous system.

6.7 Protein Undernutrition

Protein undernutrition is a consequence of inadequate consumption of dietary protein. Understanding the functions of protein leads to an understanding of the characteristics of chronic protein deficiency. Low protein diets negatively impact immunity, growth, development, fluid balance and many other body processes. Two manifestations of severe protein deficiency are kwashiorkor and marasmus. Both are conditions of insufficient protein and calorie intake, with each having distinct characteristics.[8]

Kwashiorkor

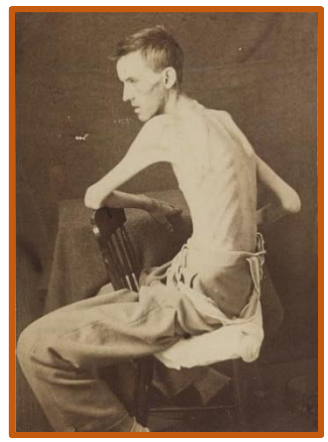
Kwashiorkor comes from a language of Ghana. It means "disease of deposed child". Deposed child refers to a child who is no longer being breastfed because of the birth of a new baby.[5] In place of breast milk, the child is fed a watery, low protein, but adequate calorie porridge made from grain. Kwashiorkor is caused by a deficiency in dietary protein. It is characterized by swelling (edema) of the feet and abdomen, poor skin health, growth retardation, low muscle mass, and liver malfunction. In kwashiorkor, the child does not appear dramatically thin because enough calories are consumed to prevent muscle wasting.



Child with kwashiorkor

Marasmus

Marasmus comes from a Greek word meaning "withering" or "to waste away". Marasmus is a severe deficiency of both protein and calories over an extended period of time. Starvation is another name for marasmus.



Man with marasmus

Marasmus is characterized by an extremely thin or "wasted" appearance because both muscle and fat stores have been depleted to meet the basic needs of the body. Other symptoms include poor skin health, growth retardation, fatigue, hunger and diarrhea. Marasmus is most likely to occur in areas of the world where food is chronically scarce due to entrenched poverty, famine or civil unrest. It can occur in people of any age. However, the statistics for children are grim. A 2020 World Health Organization reported that world-wide, 47 million children under the age of 5 are "wasted" and 14.3 million are "severely wasted". [9] Children under the age of one may be so severely wasted that their body weight may be as much as 60 percent less than that of a normal child of the same age.[6]

Marasmus is seen to a much lesser degree in affluent areas of the world. It is usually associated with severe illness (cancer or end stage dementia) and anorexia nervosa.

6.8 Protein Recommendations

Throughout this course, we will focus on the guidelines given in the 2015-2020 Dietary Guidelines for Americans and the Dietary Reference Intakes (DRIs) published by the Food and Nutrition Board. General protein recommendations are summarized in Table 1.

Protein Intake Recommendations	
Protein RDA	0.8 grams protein per kilogram body weight (adult)
Protein as a Percentage of Calories (AMDR)	10-35% of total Calories (adults)
Type of Protein Intake	Consume a variety of protein foods, including seafood, lean meats and poultry, eggs, legumes (beans and peas), and nuts, seeds, and soy products

Table 1: Recommended protein intake

The appropriate amount of protein in a person's diet is that which maintains a balance between what is taken in and what is used. The RDAs for protein were determined by assessing **protein balance**. How much protein goes into a person is pretty easy to track; a simple dietary intake can determine this. But how much protein is used in the body is harder to track. The presence of nitrogen is the element that sets protein apart from the other macronutrients. When proteins are broken down and amino acids are catabolized, nitrogen is released, turned into urea by the liver, and excreted in the urine. By collecting the urine and looking at the nitrogen content, the amount of protein lost from the body can be estimated. The protein RDA, therefore, is the amount of protein recommended for a person to consume in their diet to balance the amount of protein lost. For healthy adults, this amount of protein was determined to be 0.8 grams of protein per kilogram of body weight. You can calculate your exact recommended protein intake per day based on your weight by using the following equation:

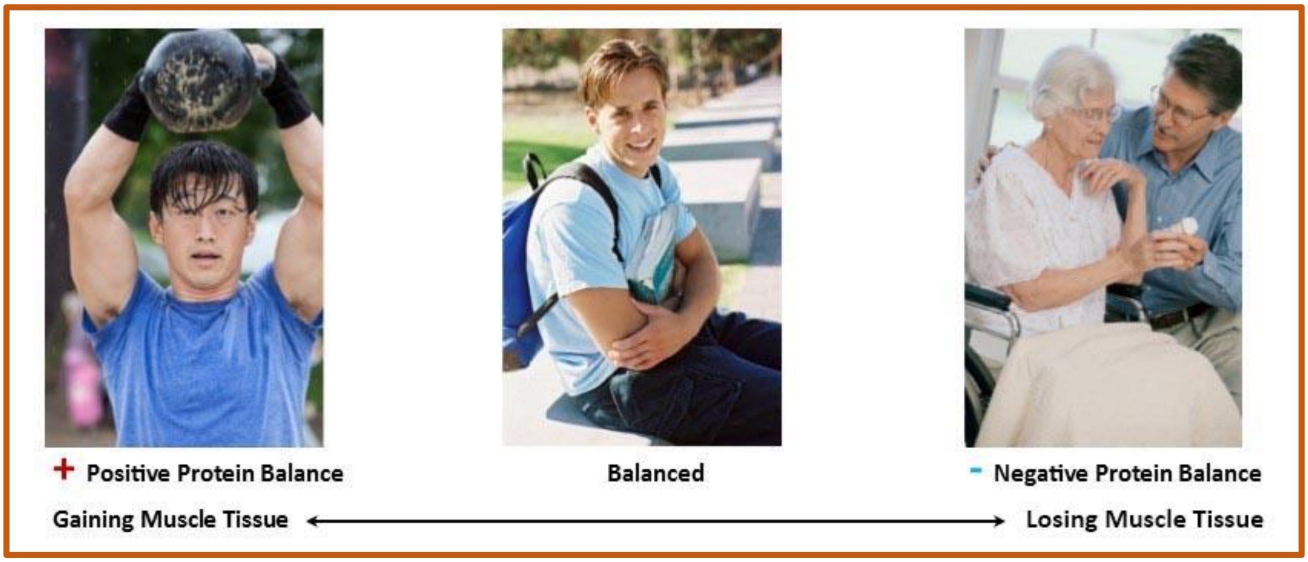
Estimating Protein Needs

Example: If a person weighs 140 pounds (lbs), simply convert that weight to kilograms:

$$\frac{140 \text{ lbs}}{2.2 \text{ lbs/kg}} = 63.6 \text{ kg then multiply that number by } 0.8 \text{ g/kg}$$

63.6 kg x 0.8 g/kg = **51 g of protein per day**

A person is in a state of protein balance when protein input equals the amount of protein lost (as determined by the amount of nitrogen lost from the body). A person is in negative protein balance when the amount of nitrogen lost is greater than the amount consumed in protein foods. Negative protein balance means that the body is losing more protein than is being consumed. This state of imbalance can occur in people who have certain diseases such as cancer or muscular dystrophy. In these diseases, muscle protein breakdown can exceed protein intakes. Positive protein balance occurs when a person intakes more nitrogen from protein foods than is being lost. Positive protein balance occurs during periods of active muscle tissue growth such as pregnancy, child and adolescent development and athletic training.



Protein for Performance

Regular, rigorous physical activity increases a person's protein needs. Exact requirements are dependent on a variety of factors including the type of activity, intensity of the activity, frequency of exercise, training level, calorie and carbohydrate intake and food choices. Instead of 0.8 g/kg it is suggested that intake levels between 1.2-2.0 g/kg per day will meet athletic needs.[7] It is expected that protein recommendations for any athlete will change regularly based on their training cycle and should be adjusted as needed. It is important to note that 0.8 g/kg is adequate for most physically active people. The higher intake guidelines are reserved for intense levels of performance.[7]

The example below uses 1.3 g/kg to estimate protein needs for an endurance athlete. On a typical training day, a protein intake of 1.3g/kg is a good starting point for an endurance athlete. On high intensity training days, or days that focus on resistance exercises, a protein intake from 1.5-2.0g/kg may be more appropriate to accommodate an increase in muscle tissue stress. The higher protein recommendations for athletes fall within the AMDR guidelines for protein (10-35% of total daily calories). These increased protein needs can be met by eating common, high quality protein foods. Protein supplements and protein fortified foods are not necessary to meet these increased protein needs.

Estimating Protein Needs (Endurance Athlete)

Example: Convert the runner's weight to kilograms as before

$$\frac{140 \text{ pounds}}{2.2 \text{ pounds/kg}} = 63.6 \text{ kg}$$

then multiply that number by 1.3 g/kg

63.6 kg x 1.3 g/kg = **83 g of protein per day**

Protein intake beyond these recommendations has not been shown to further enhance muscle gains for competitive athletes under normal circumstances. The timing of protein intake is another consideration that may impact muscle recovery and gains. For example, 20 grams of high-quality protein is recommended within 2 hours after exercise to optimize muscle growth and recovery.[7]

6.9 Protein Quality

While protein is contained in a wide variety of foods, it differs in quality. High-quality protein contains all the essential amino acids in the proportions needed by the human body. Foods that provide low amounts of one or more of the essential amino acids are called **incomplete proteins**, those that contain all the essential amino acids in good proportions are called **complete proteins**. The digestibility of the protein also needs to be considered when judging the quality of protein. Generally complete proteins are also digested well.

Plant-Based Complete Proteins	
Quinoa	
Amaranth	
Soy Beans	

Table 1: Examples of plant-based complete proteins

High-quality protein is typically found in animal products like meat, fish, poultry, milk, eggs and cheese. Plant protein is typically lower in quality. For example, legumes, nuts and seeds are high in protein, but the quality of the protein is low (incomplete protein). There are a few exceptions to this general pattern. For example, gelatin is an animal derived protein, but it is very low quality. On the other side the protein in quinoa, amaranth, and soy are plant based proteins that are very high quality (complete protein).

Protein complementation

The discussion up to this point could lead some to believe that animal protein consumption, or regular consumption of one of the few high-quality plant protein sources would be necessary to maintain proper growth and development, but this is not true. If combinations of lower quality protein sources are included in a person's diet on a regular basis, they typically will **complement** each other to form a complete protein. For instance, many grains are typically lacking in the amino acid lysine and possibly threonine (called the **limiting amino acids**), but adequate in the other essential amino acids; whereas legumes are low in methionine but adequate in lysine and threonine. If eaten together they compensate for the weakness of the other. This is called **protein complementation**. For example, a wheat tortilla with black beans is a good example of the principle in action. Complementary protein sources do not have to be consumed at the same time—as long as they are consumed within the same day in adequate amounts, protein needs will be met.

Foods	Limiting Amino Acid	Complementary Food	Application
Legumes	Methionine	Grains, nuts, seeds	Hummus and flat bread
Grains	Lysine, Threonine	Legumes	Wheat tortilla with black beans
Nuts and Seeds	Lysine	Legumes	Salad with kidney beans and assorted nuts and seeds

Table 2: Complementation of proteins

6.10 Protein Choices

Based on our discussion of protein quality, in general, animal proteins appear to have some clear advantages over plant proteins when discussing efficiency. This would be particularly important if protein resources are scarce; the efficiency of animal protein would be very beneficial. But when resources are plentiful and complementary proteins are readily available, there are other important factors to consider when selecting where most of our protein comes from. Epidemiological evidence supports a relationship between meat intake, especially red meat, and the incidence of many chronic diseases, such as cancer, cardiovascular disease, and diabetes. The exact reason for this is unclear, and hard to sort out due to a lot of confounding factors. For instance, as protein intake from meat goes up, often saturated fat, cholesterol, and caloric intake increase as well. It is hard to tell which variable is responsible for the associated health concern.

In chapter 3 we discussed the principles outlined in the Dietary Guidelines for Americans. Health benefits of increasing whole grains and vegetable intake were clear. Whole grains can be an excellent contributor to our overall protein intake. Complete grain proteins such as soy, quinoa, and amaranth are good nutrient-dense options to consider, especially when sources of animal protein are scarce or not included in the diet. Most vegetables only provide modest amounts of protein, but if legumes (black beans, lima beans, chickpeas, lentils, peanuts etc.) are included regularly, they are packed with protein that can be easily complemented to make a complete protein. Nuts and seeds are another excellent plant-based protein source. The current guidelines allow for a wide range of protein intakes, anywhere from 10-35% of daily calories. Protein is not recommended as the primary macronutrient in our diet but may make up to a third or slightly more of our calories.

Figure 14: Examples of legumes

In the Word of Wisdom, we are counseled to eat meat sparingly. It is important to recognize the terms protein and meat cannot be used interchangeably. By using a rich source of plant proteins, a person's diet can be higher in protein, but meat can still be used sparingly. Having a balanced diet rich in plant proteins containing whole grains, beans and peas, and nuts and seeds is consistent both with the doctrine found in the Word of Wisdom and with current scientific evidence that encourages a more plant-based food eating patterns. A biblical example of plant-based sources of protein is the pulse, the edible seeds of plants in the legume family, eaten by Daniel, Shadrach, Meshach and Abednego.

Chapter 7: Lipids

Natural sources of lipids include plant and animal sources.

7.1 Introduction to Lipids

The study of lipids is an exciting and often controversial area of nutrition. Most consumers recognize a relationship between lipid intake, cardiovascular disease, weight control and a number of other health-related conditions. Indeed, the amount and types of lipids consumed is related to these health parameters, but the vast and varied role of lipid in a wide variety of body functions is often overlooked. A certain amount of lipid is necessary in our diet to avoid disease. Some populations have done very well eating large amounts of certain types of lipids, such as the Inuit that eat a hefty amount of fish fat and people of the Mediterranean that use substantial amounts of olive oil. Lipid contains nine Calories per gram versus four in protein and carbohydrate, so logically it is often associated with body weight gain, but historically our ability to store fat has also been essential for survival.

Lipids have a chemical composition mainly of carbon, hydrogen, and oxygen. They perform three primary biological functions within the body:

- they serve as structural components of cell membranes
- function as energy storehouses
- function as important signaling molecules.

In food systems fats are also an important flavor and textural component. A pie crust just isn't the same without the flaky texture provided by the fat.

7.2 Categories of Lipids

Lipids are a family of organic compounds that are mostly insoluble in water. Lipids are typically broken into three classes: the glycerides, sterols, and phospholipids.

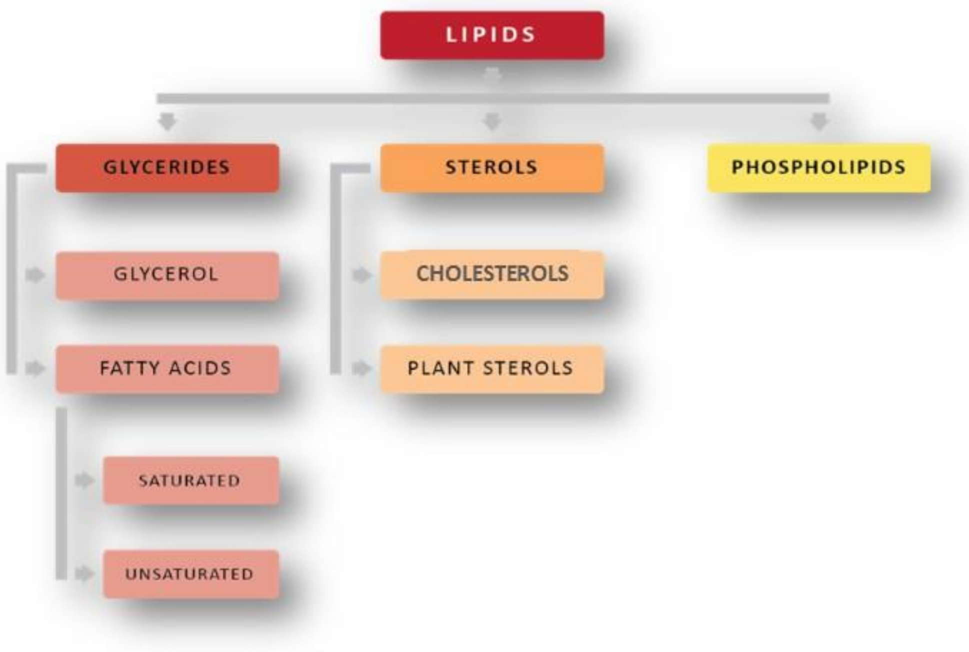


Figure 1: Categories of lipids include glycerides, sterols, and phospholipids.

The Glycerides

Practically, the terms fats, oils, and glycerides are discretionary and can be used interchangeably. In this chapter when we use the word fat when we are referring to any glyceride. Fats make up more than 95 percent of lipids in the diet and are commonly found in a wide variety of foods. Fried and processed foods, butter, whole milk, cheese, cream cheese, and some meats are examples of foods that contain fat that when isolated it is solid at room temperature (see Table 1). Avocados, olives, corn, vegetable oils, seeds, and nuts are foods that contain fat that when isolated are liquid at room temperature (technically oils). The glycerides can be subdivided into the **fats**, which are solid at room temperature and the **oils** that are liquid at room temperature.

Lipid Type		Common Foods
Solid Fats (Saturated Fats)		Fried and processed foods, butter, whole milk, cheese, cream cheese, and some meats are examples
Liquid Fats (Unsaturated Fats)		Avocados, olives, corn, vegetable oils, seeds, and nuts

Table 1: Sources of lipids

The main structural components of all the **glycerides** include carbon, oxygen and hydrogen. The lines in the figure below (Figure 2) represent the number of bonds that are possible on each element. Carbon can be bound to four other elements, oxygen can be bound to two and hydrogen to one other element. These patterns of bonding will be apparent as we start to look at the structure of the glycerides.

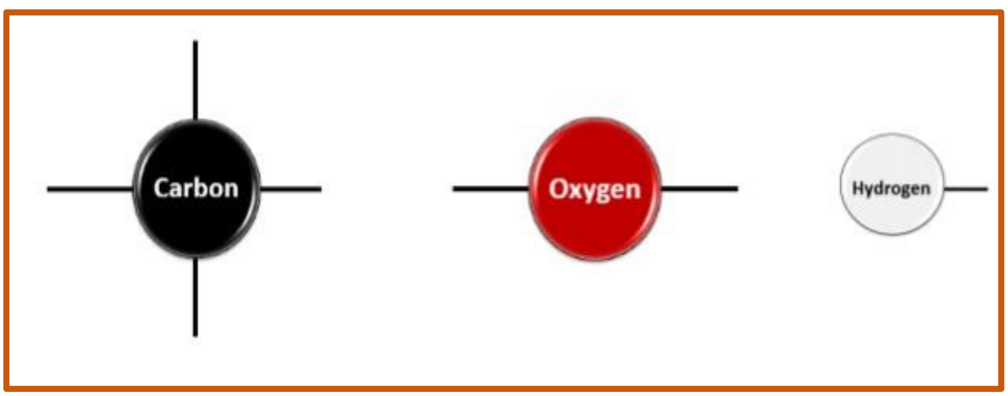


Figure 2: Elements found in glycerides

Triglycerides are the main form of fat found in the body and in the diet. Fatty acids and glycerol are the building blocks of triglycerides. To form a triglyceride, a glycerol molecule is joined to three fatty acid chains (see Figure 3). Triglycerides contain varying mixtures of fatty acids. Glycerides can also exist as **diglycerides** and **monoglycerides** (see Figure 4). **Glycerol** is a small molecule made up of only 3 carbons. Fatty acids are larger structures varying in length from 4 to 24 carbons long in food; both also contain oxygen and hydrogen. Fatty acids have an acid group located at one end of the carbon chain.

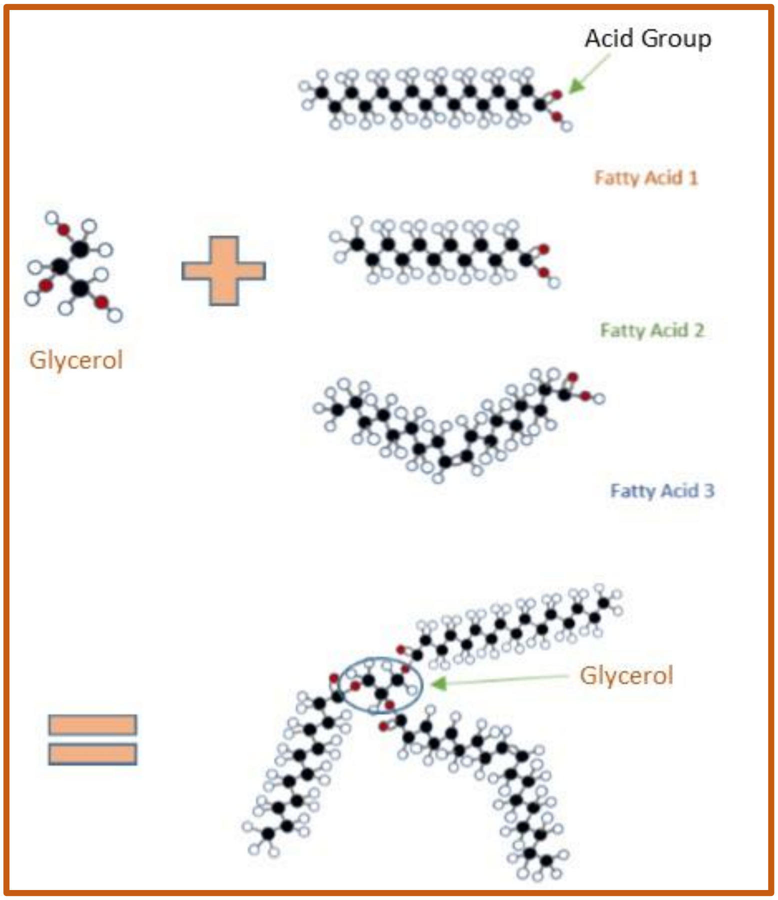


Figure 3: Formation of a triglyceride from a glycerol and three fatty acids

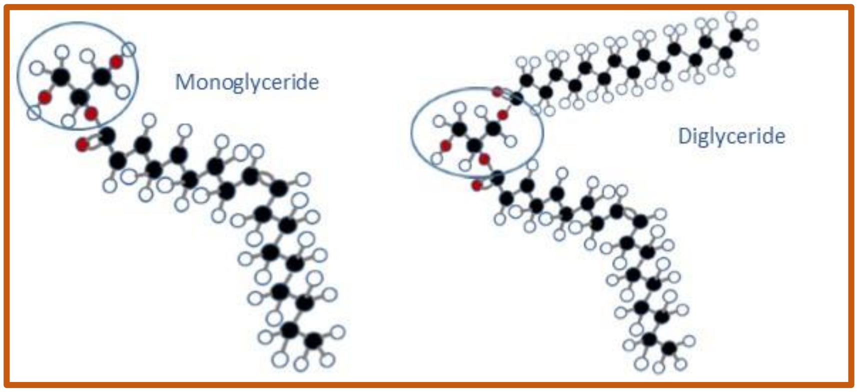


Figure 4: Mono and di-glycerides

Phospholipids

Structurally **phospholipids** are similar to triglycerides, yet they have a uniquely different function. Like triglycerides, phospholipids have a glycerol backbone. But unlike triglycerides, phospholipids only have two fatty acid molecules attached to the glycerol backbone. In place of the third fatty acid chain, phospholipids have a phosphate group. This unique structure makes one end of phospholipids water-soluble and the other end fat-soluble.

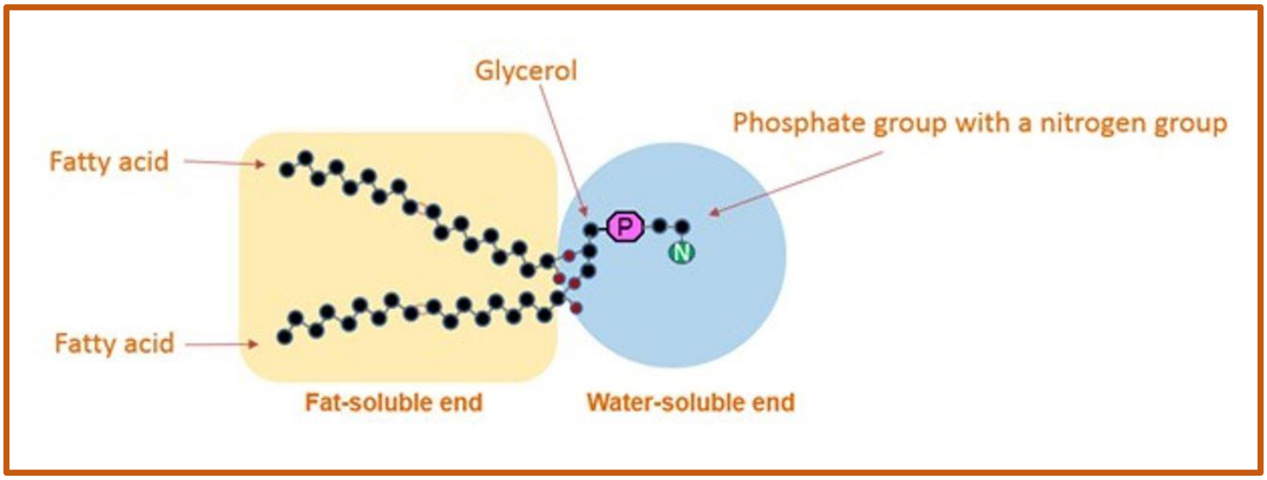


Figure 5: Structure of a phospholipid showing the fat-soluble and the water-soluble ends

Phospholipids are referred to as **amphiphilic**—the fatty-acid sides are **hydrophobic** (dislikes or repels water), and the phosphate group is **hydrophilic** (likes or attracts water).

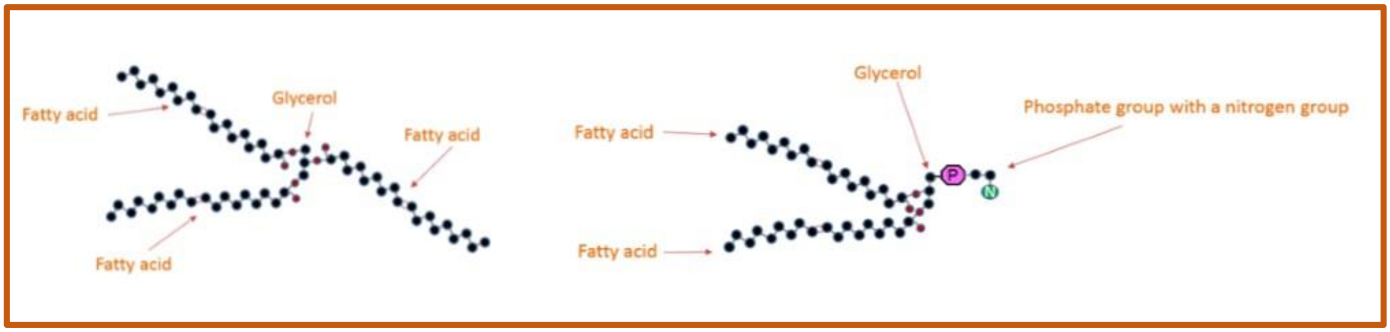


Figure 6: Structure of a triglyceride compared to a phospholipid

The unique structure of a phospholipid allows it to interface between water- and fat-soluble substances. The presence of phospholipids in foods or the body allows fat-soluble and water-soluble substances to exist together comfortably. This is called emulsification, and phospholipids can be referred to as **emulsifiers**. For example, mayonnaise is made of water-soluble (vinegar) and fat-soluble substances (oil). It also contains egg yolk which is a source of phospholipid. When mixed together just right the oil and vinegar associate well together in the presence of the phospholipids. Phospholipids are common in sauces and creams.

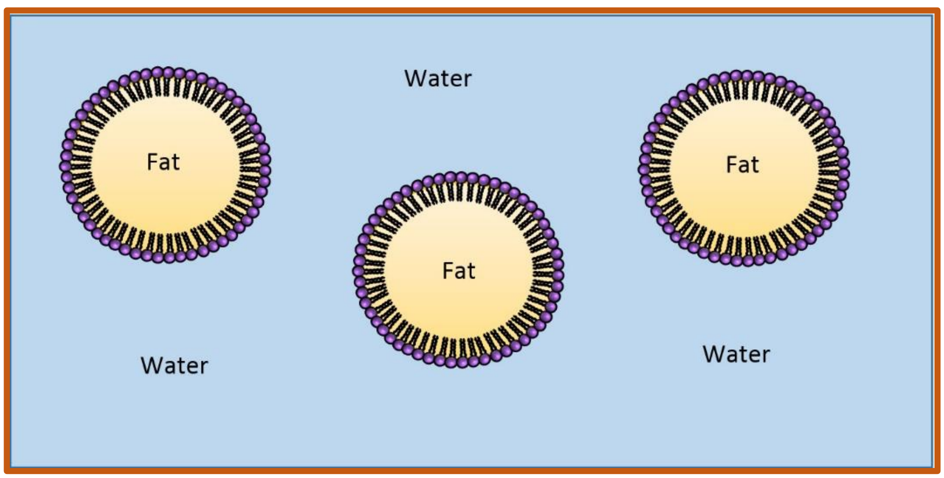


Figure 7: Lipid droplets surrounded by phospholipids are suspended in water.

In the body, phospholipids have a variety of roles. They bind together to form cell membranes. The amphiphilic nature of phospholipids governs their function as components of cell membranes. The phospholipids form a double layer in cell membranes, thus effectively protecting the inside of the cell from the outside environment while at the same time allowing for transport of fat and water through the membrane. They also assist in the transport of fat and cholesterol in the blood stream.

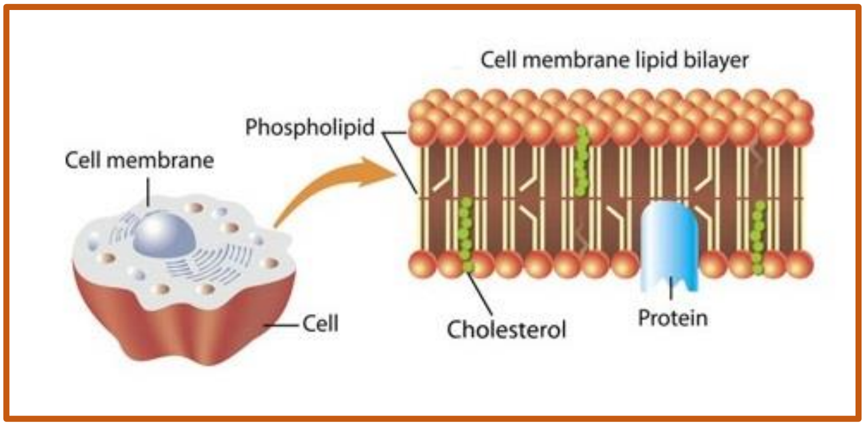


Figure 8: Role of phospholipids in cellular membranes

Sterols

Sterols have a very different structure from triglycerides and phospholipids. Most sterols do not contain any fatty acids but rather are multi-ring structures. They are complex molecules that contain interlinking rings of carbon atoms, with side chains of carbon, hydrogen, and oxygen attached. **Cholesterol** is the best-known sterol.

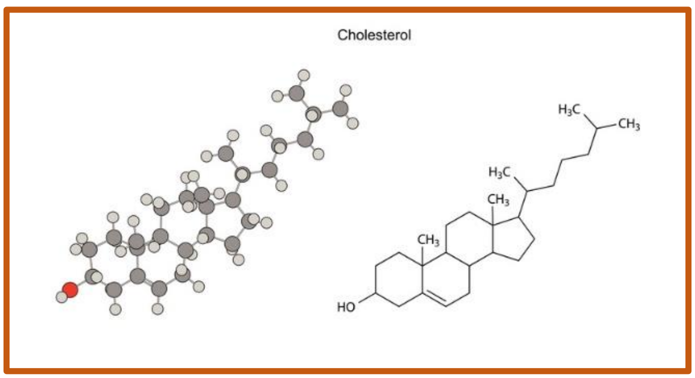


Figure 9: Structure of cholesterol

Because cholesterol is part of the plaque that narrows the arteries that can result in heart attacks and strokes, it has developed a negative image. Cholesterol has specific beneficial functions to perform in the body. Like phospholipids, cholesterol is present in all body cells as it is an important substance in cell membrane structure (see Figure 10). Approximately 25 percent of the cholesterol in the body is localized in brain tissue and is important in cellular function.

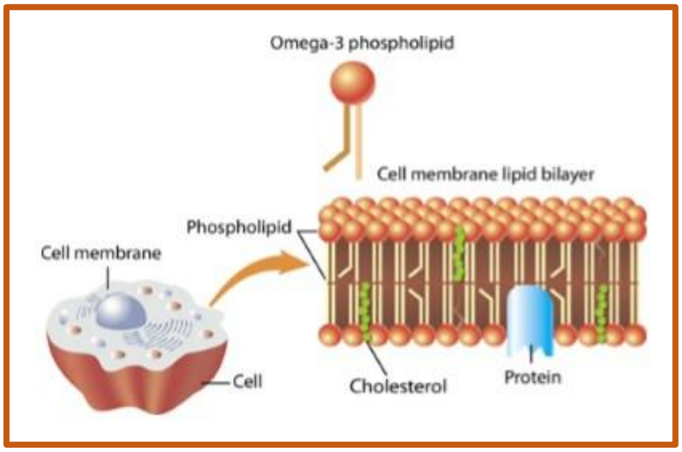


Figure 10: Cholesterol's place in the cellular membrane

Cholesterol is also used in the body to make a number of important compounds, including vitamin D, sex hormones (e.g. progesterone, testosterone, estrogens), and bile for digestion of fats.

Although cholesterol is preceded by its infamous reputation, it is clearly a vital substance in the body that poses a concern only when there is excess accumulation. Cholesterol is not essential in the diet because it can be synthesized by the liver. Many foods contain cholesterol. Typically, when we eat more cholesterol, the body will reduce production of cholesterol to maintain a balance in the body. Foods that are rich in dietary cholesterol include liver, eggs, red meats, and shellfish. Almost any animal product will contain some cholesterol. Plant products do not contain cholesterol, but some plants do contain other types of sterols (and stanols) that do resemble cholesterol in structure. Some of these **plant sterols** can inhibit cholesterol absorption in the human body, which can contribute to lower cholesterol levels.[4] Naturally, these plant sterols are found in foods such as nuts, vegetable oils, seeds, cereals, and beans, but can also be found in other food from fortification or can be purchased in a supplement form.[5]

7.3 Types of Fatty Acids

Chain Length

Fatty acids can come in different lengths of carbon chains: short-chain (4-7 carbons), medium-chain (8-12 carbons) and long-chain (more than 12 carbons). The length of the carbon chain of the fatty acids affects the melting point. The shorter the chain length the lower the melting point.

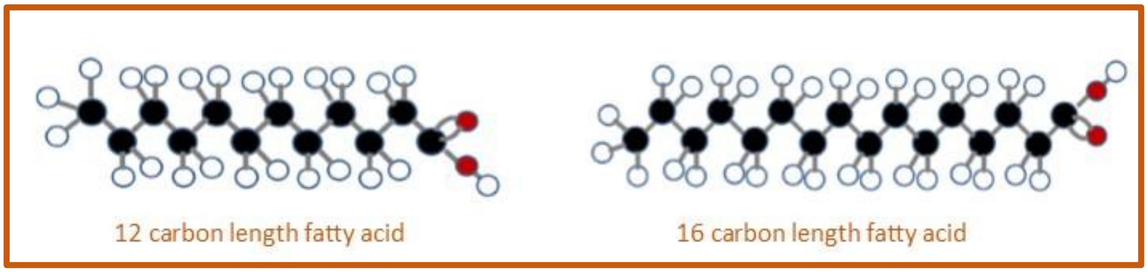


Figure 11: Fatty acids of varying chain lengths

Saturation

Fatty acids can vary in length but also in the number of double bonds. Fatty acid chains are held together by carbon atoms that attach to each other and to hydrogen atoms. The term saturation refers to whether or not a fatty acid chain is filled (or "saturated") to capacity with hydrogen atoms. If each available carbon bond holds a hydrogen atom, we call this a **saturated fatty acid** chain. All carbon atoms in a saturated fatty acid chain are bonded with single bonds.

Sometimes the chain has a place where hydrogen atoms are missing. This is referred to as the point of unsaturation. When one or more bonds between carbon atoms are a double bond (C=C), that type of fatty acid is called an **unsaturated fatty acid**, as it has one or more points of unsaturation. Any fatty acid that has only one carbon to carbon double bond is a **monounsaturated fatty acid**, examples of oils high in monounsaturated fatty acids include olive, canola and avocado. A **polyunsaturated fatty acid** is a fatty acid with two or more carbons to carbon double bonds or two or more points of unsaturation. Soybean oil contains high amounts of polyunsaturated fatty acids.

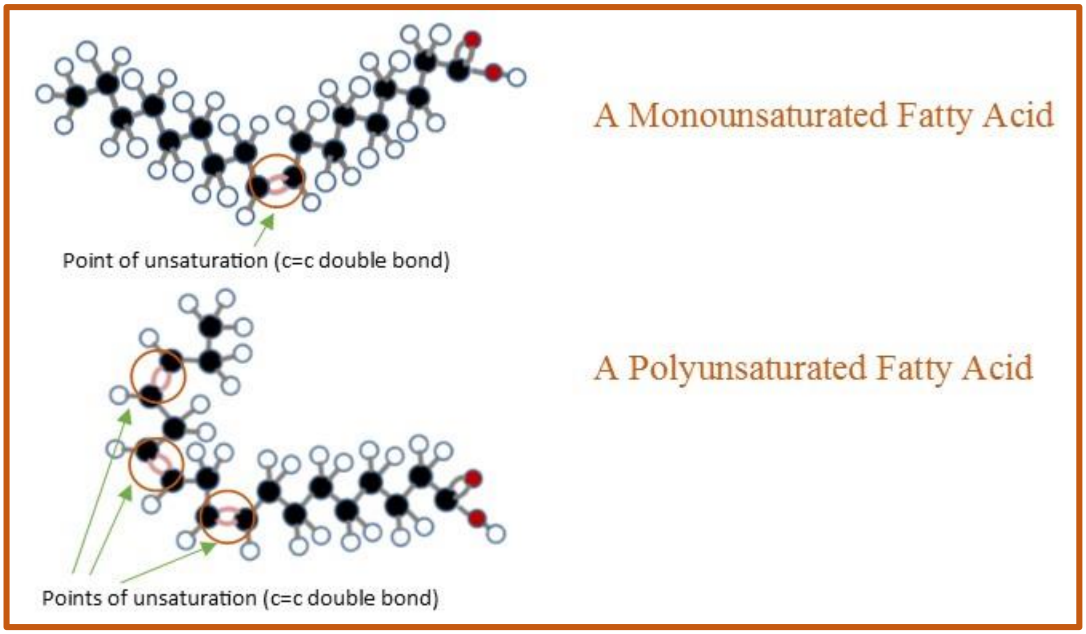


Figure 12: Mono and poly-unsaturated fatty acids

Foods that have a high amount of saturated fat include whole milk, cheese, and many meat products. Fats from these foods will typically be solid at room temperature when separated out of the food. Butter is a good example of this principle in action. When milk fat is separated out of the milk and turned into butter, it remains solid at room temperature. The exception to this rule is the tropical oils (coconut and palm). They have a high percentage of saturated fatty acids but are considered oils. The short length of their fatty acid chains (they contain many fats only 8-12 carbons long and are called medium chain fatty acids) cause them to melt at a lower temperature.

Foods rich in unsaturated fatty acids include olives, avocadoes, fish, nuts and seeds. When the oil is extracted from these foods it is liquid at room temperature. Knowing the connection between chain length, degree of saturation, and the state of the fatty acid (solid or liquid) can be helpful in making food choices. Generally having a diet rich in unsaturated fatty acids is better for a person's cardiovascular health than a diet rich in saturated fatty acids.[1] If the fat is visible it can be a useful tool to judge what type of fat you are eating. The difficult part is the fat is often hidden inside the structure of the food and it isn't always possible to tell. These types of fats are called hidden fats. For example, most biscuit recipes include a fair amount of saturated fat. The fat provides the flaky texture, but most people cannot tell fat was included.

Cis and *Trans* Fatty Acids

The introduction of a carbon double bond in a carbon chain, as in an unsaturated fatty acid, can result in different structures for the same fatty acid composition. When the hydrogen atoms are bonded to the same side of the carbon chain, it is called a **cis fatty acid**. Because the hydrogen atoms are on the same side, the carbon chain has a bent structure. Naturally occurring fatty acids usually have a cis configuration (Figure 14). When the hydrogen atoms are attached on opposite sides of the carbon chain, a ***trans* fatty acid** is formed (Figure 13). These fatty acids are usually linear shaped.

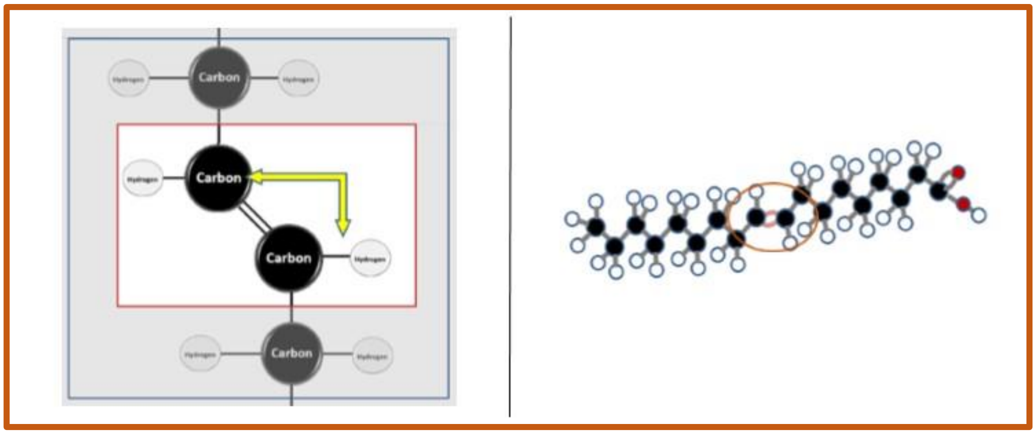


Figure 13: Example of a trans double bond

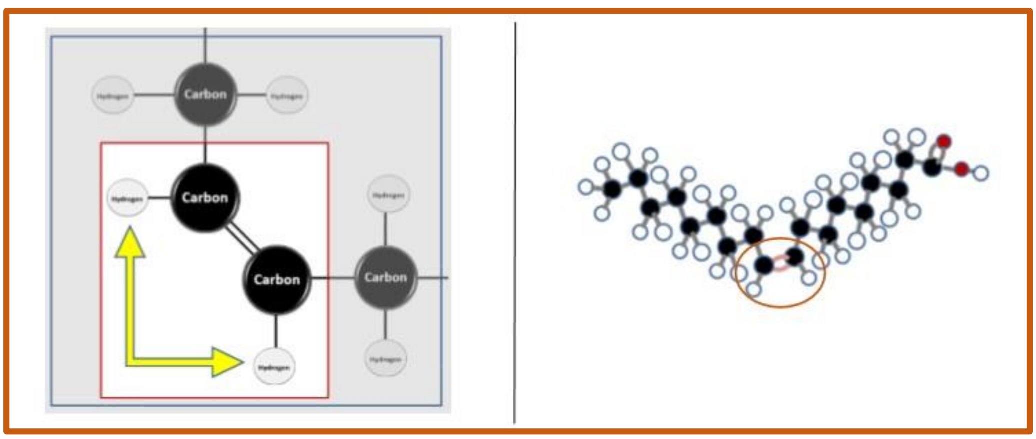


Figure 14: Example of a cis double bond

Unlike cis fatty acids, most trans fatty acids are not found naturally in foods but are a result of a process called **partial hydrogenation**. Hydrogenation is the process of adding hydrogen to an unsaturated fatty acid. Double bonds between carbons are broken to receive the hydrogen. This is how vegetable oils are converted into semi-solid fats like margarine. During partial hydrogenation, some of the unsaturated fatty acids become saturated and some of the unsaturated fatty acids' bonds shift from cis bonds to *trans* bonds (Figure 15).

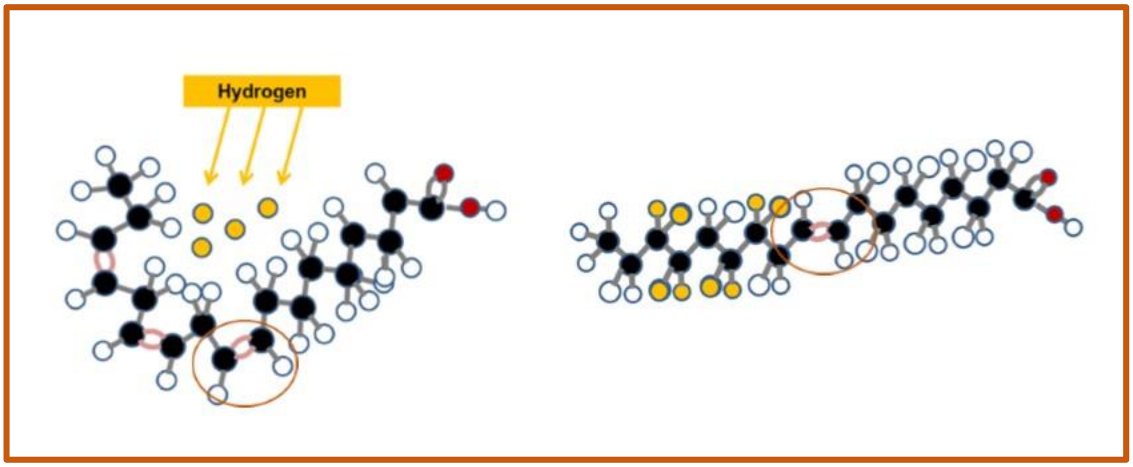


Figure 15: An example of a cis bond shifting to a trans bond during partial hydrogenation

When the partial hydrogenation process was first introduced, it appeared to be a good way to produce shelf-stable, low-cost margarines as an alternative to butter. Over time, research showed a high intake of the artificial trans fats created from partial hydrogenation was associated with increased risk for cardiovascular disease.[2] There are naturally occurring trans fats in some foods, but these trans fats are not likely harmful.

In the United States, the Food and Drug Administration is in the process of eliminating partial hydrogenated fats from foods. In place of partial hydrogenated fats, some producers include fully hydrogenated fats or various forms of saturated fats such as coconut and palm oil (see Figure 16). The **fully hydrogenated** process results in converting all the unsaturated fatty acids to saturated fatty acids (see Figure 17). These options eliminate the trans fats from partial hydrogenation from food.

 Strategy #1	**Ingredients:** Roasted peanuts, sugar, fully hydrogenated rapeseed and soybean oils, mono and diglycerides
 Strategy #2	**Ingredients:** Roasted peanuts, sugar, palm oil, salt, mono and diglycerides

Figure 16: Strategies used to eliminate trans fats in food products; the items in red replaced partially hydrogenated vegetable oils

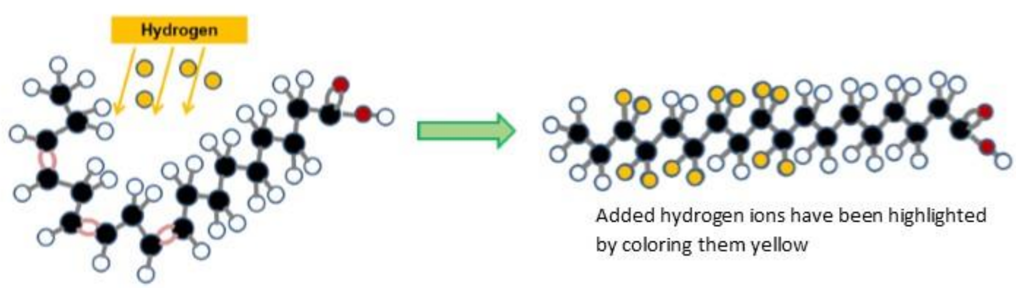


Figure 17: The process of full hydrogenation (100%) removes all the double bonds in the fat, removing the possibility for the formation of trans fats, but leaving the fat completely saturated.

Essential Fatty Acids

Fatty acids are vital for the normal operation of all body systems. The fatty acids the body can make are called **non-essential fatty acids**. The fatty acids the body cannot make are called **essential fatty acids** and must be obtained from food. The two essential fatty acids are **alpha-linolenic acid (ALA)** and **linoleic acid** and are both 18 carbons long. The essential fatty acids are part of two larger families of fatty acids called the omega-3 and omega-6 fatty acids.

The omega 3 fatty acids have their first double bond three carbons from the omega end of the fatty acid (see Figure 18). The omega 6 fatty acids have their first double bond 6 carbons from the omega end.

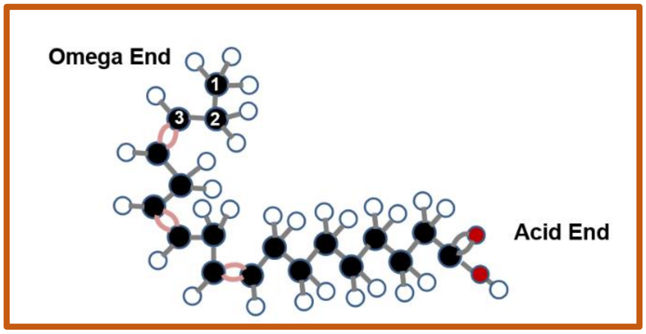


Figure 18: Example of an omega-3 fatty acid

The key fatty acids in the omega-3 family include alpha-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA). Although our body cannot make alpha-linolenic acid (ALA), it can make the small amounts of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) from alpha-linoleic acid (ALA). Consequently, EPA and DHA are not considered essential. The key fatty acids in the omega-6 family are linoleic acid (LA) and arachidonic acids (AA). Similar to EPA and DHA, our body can make arachidonic acid (AA) from linoleic acid and is not considered essential (see Figure 19).

All the fatty acids in the omega-3 and omega-6 families have biologically significant functions and are important dietary components. Some of these fatty acids are precursors to important compounds called **eicosanoids**. Eicosanoids are powerful hormones that are involved in the regulation of many important body functions including clotting, inflammation, and blood pressure control.[3]

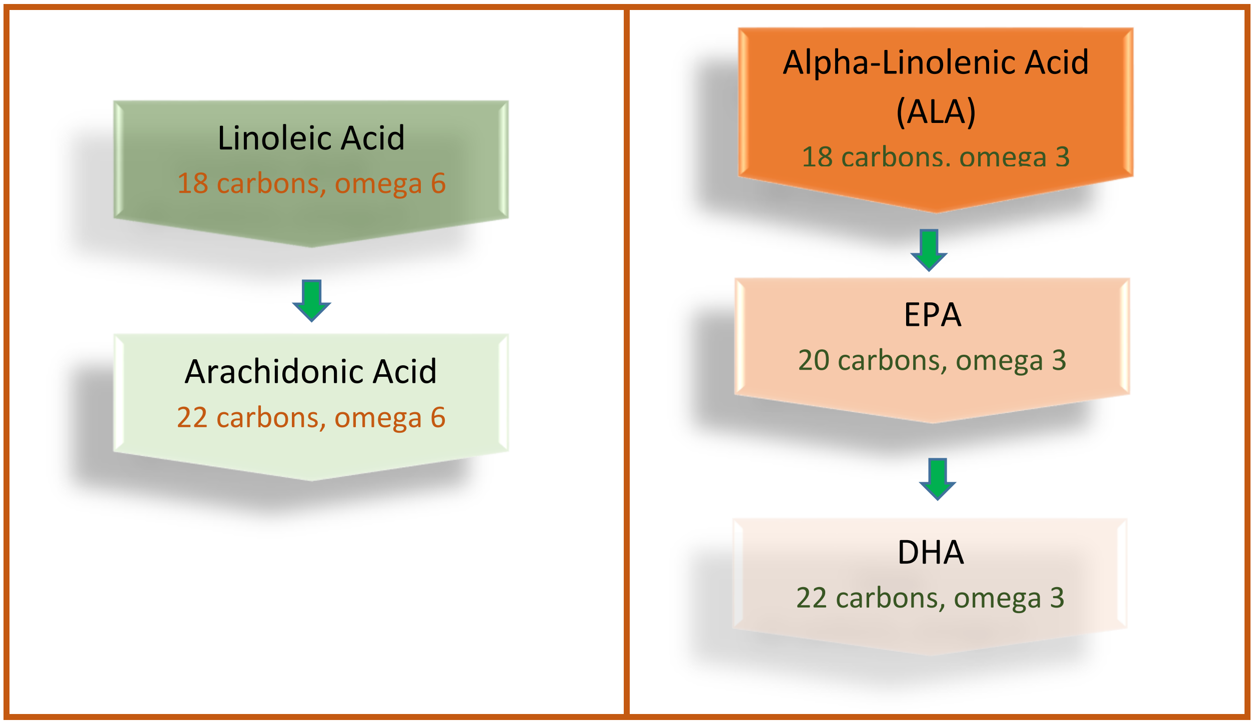


Figure 19: Omega-6 and Omega-3 fatty acids

Alpha-linolenic acid and linoleic acid are found in several plant oils and food (Figure 20). Because these essential fatty acids are easily accessible in our food supply, an essential fatty acid deficiency is rare and would typically be associated with some type of fat malabsorption disease (like cystic fibrosis). Although both omega-3 and omega 6-fats are important to include in our diets, the intake of omega-3 fatty acids have generally been low. It is recommended to include more food sources of omega-3 fatty acids.

Omega-6 Fatty Acid	Omega-3 Fatty Acids
Linoleic Acid	Alpha Linolenic Acid (ALA)
Safflower oil, sunflower oil, corn oil and some nuts and seeds (primarily plant sources)	Chia seeds, flax seeds, walnuts, canola oil and soybean oil (primarily plant sources)
Arachidonic Acid	EPA + DHA
Animal products such as chicken eggs and beef	Fatty fish such as salmon, sardines, mackerel and trout, algal oil and human milk

Figure 20: Dietary sources of omega-3 and omega-6 fatty acids

7.4 Digestion and Absorption of Lipids

Lipids are large molecules and generally are not water-soluble. Like carbohydrates and protein, lipids are broken into small components for absorption. Since most of our digestive enzymes are water-soluble, for digestion to occur and fat to be absorbed, the body has a distinctive system for dealing with dietary fat.

Functions of Lipids in Food

Smell, Taste and Texture

Fat contains dissolved compounds that contribute to mouth-watering aromas and flavors. Fat also adds texture to food. Baked foods are supple and moist. Frying foods locks in flavor and lessens cooking time. How long does it take you to recall the smell of your favorite food cooking? What would a meal be without that savory aroma to delight your senses and heighten your preparedness for eating a meal?

Fat plays another valuable role in nutrition. Fat contributes to satiety, or the sensation of fullness. When fatty foods are swallowed the body responds by enabling the processes controlling digestion to retard the movement of food along the digestive tract, thus promoting an overall sense of fullness. Oftentimes before the feeling of fullness arrives, people overindulge in fat-rich foods, finding the delectable taste irresistible. Indeed, the very things that make fat-rich foods attractive also make them a hindrance to maintaining a healthful diet.

Pastries contain fats that give a rich taste, buttery smell, and flaky texture

From the Mouth to the Stomach

The first step in the digestion of triglycerides and phospholipids begins in the mouth as lipids encounter saliva. The physical action of chewing mixes the food with saliva. The salivary glands produce the enzyme lingual lipase which initiates the process of digestion. Gastric lipase continues the digestive process when the food reaches the stomach, but collectively the effects of these enzymes on fat digestion are small. The majority of fat digestion occurs in the small intestine.

Small Intestine

As stomach contents enter the small intestine, for effective digestion the fatty material in our food must mix with the water fluids of the digestive system by emulsification. Phospholipids are present in our foods and some of the digestive juices and can contribute to the emulsification process, but bile salts produced in the liver are the key emulsifiers in the small intestine. Like phospholipids, bile salts contain hydrophilic and hydrophobic properties. They are produced in the liver from cholesterol and stored in the gallbladder until they are needed (see Figure 21).

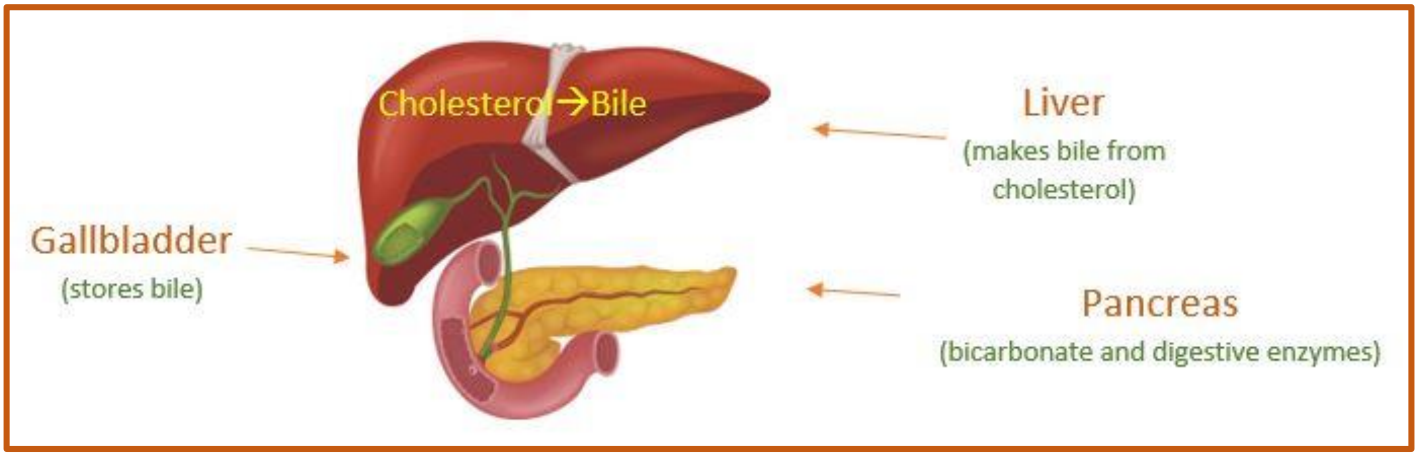


Figure 21: The accessory organs and digestion – The liver makes bile, the gallbladder stores bile, and the pancreas produces bicarbonate and digestive enzymes.

The emulsification of the dietary fat by the bile increases the surface area of lipids over a thousand-fold, making them more accessible to the digestive enzymes. The small droplets of fat surrounded by bile are called **micelles** (Figure 22).

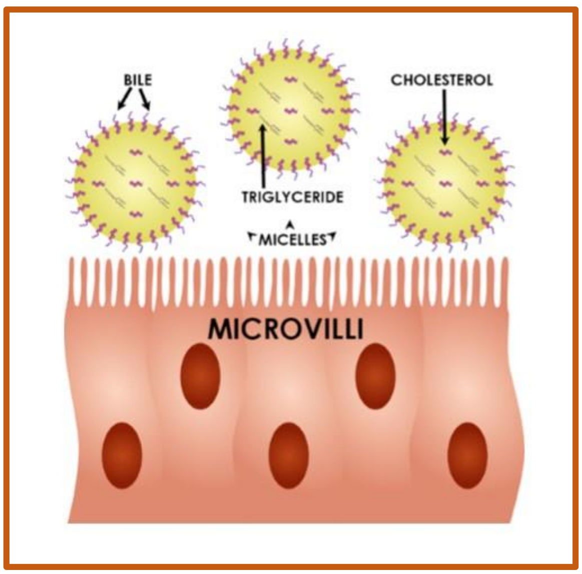


Figure 22: Bile and micelle formation

Once the stomach contents have been emulsified by the bile in the small intestine, pancreatic lipase, in the process of chemical digestion, severs fatty acids from the glycerol backbone of triglycerides and diglycerides. The pancreatic lipase ultimately breaks down the triglycerides into free fatty acids and monoglycerides.

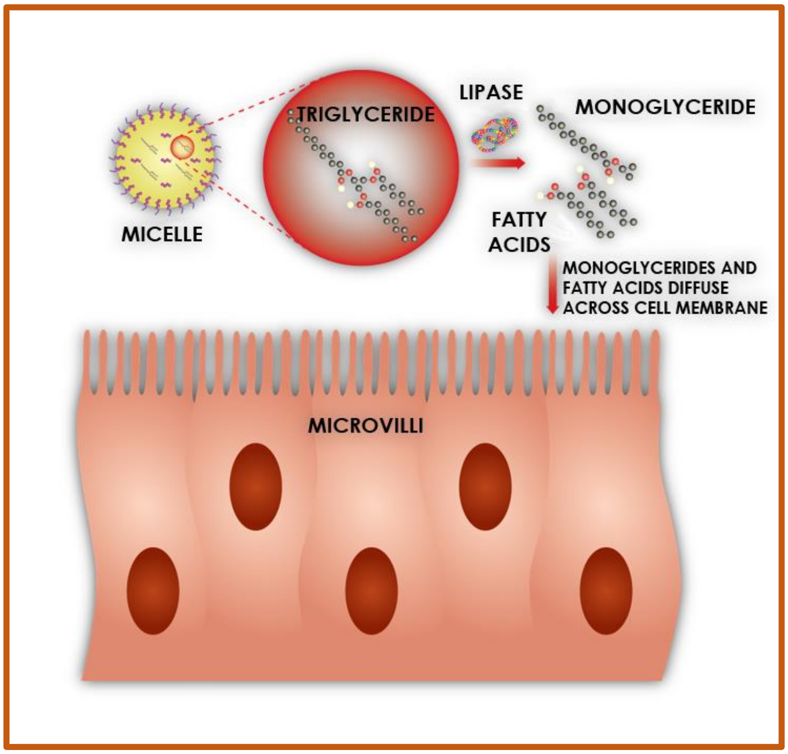


Figure 23: Lipid digestion

In the form of free fatty acids and monoglycerides, the dietary fat is now able to be absorbed. The micelles can move to the lining of the small intestine, and the fat components are released and distributed into the cells of the digestive tract lining. Phospholipids follow a similar digestive path as the triglycerides but only require that one of the fatty acids be removed. Cholesterol does not require any chemical digestion to be absorbed.

Transport of Fats in the Blood Stream

Just as lipids require special handling in the digestive tract to move within a water-based environment, they require similar handling to travel in the bloodstream. These carriers of triglycerides and cholesterol are called **lipoproteins** (see Figure 24). Lipoproteins are made of phospholipids and proteins.

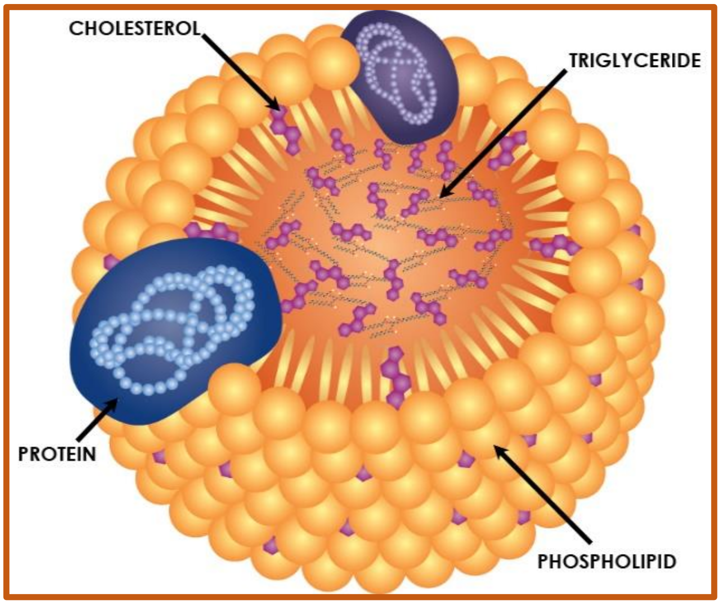


Figure 24: Lipoprotein

Inside the intestinal cells, the digested monoglycerides and fatty acids are reassembled into triglycerides and phospholipids and packaged in the lipoprotein called a **chylomicron**. The chylomicron leaves the intestine and enters the lymphatic system and will soon be released into the bloodstream via the jugular vein in the neck. Chylomicrons transport dietary fats perfectly through the body's water-based environment. As it circulates, it can deliver triglycerides and cholesterol to body cells that need it (e.g. muscle and adipose tissues). Eventually, the remnant of the chylomicron is delivered to the liver (it is called a chylomicron remnant).

The liver also produces lipoproteins, but they are different in size and composition than the chylomicron. The lipoproteins that primarily originate from the liver are very **low-density lipoproteins** (VLDL) and **high-density lipoproteins** (HDL). **Low-density lipoproteins** (LDL), are formed from VLDL after it is released from the liver. These lipoproteins are the ones often discussed when assessing a person's risk for cardiovascular disease. VLDL and LDL carry triglycerides and cholesterol to body cells. HDL's job is to carry cholesterol from the body cells back to the liver. Both of these jobs are important and necessary. The trouble starts when the levels of these particles become abnormal. Increased LDL levels are strongly related to the risk of heart attack and stroke. For this reason, LDL has been inappropriately called "the bad cholesterol". All the lipoproteins contain cholesterol, even HDL. Structurally there is no difference between the cholesterol in these particles. A more appropriate way to make this statement is to say that it is bad to have high levels of the lipoprotein LDL in your blood.

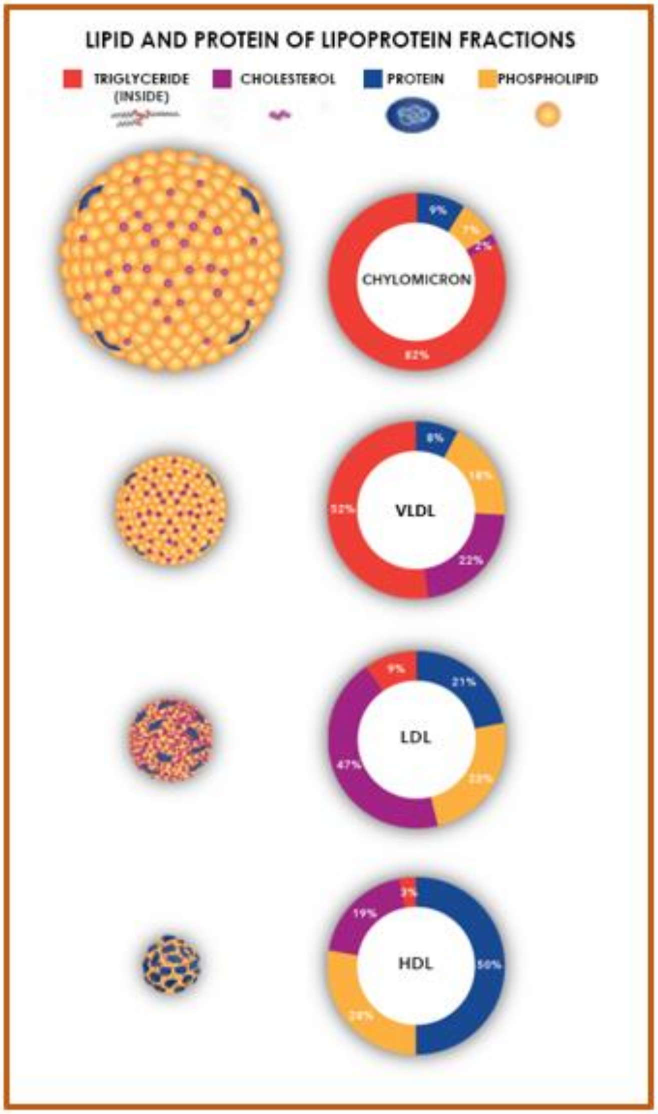


Figure 25: Classes of lipoproteins and their relative sizes and components.

Chylomicrons, the largest, are filled mostly with triglycerides.

Very low-density lipoproteins are smaller with an increase of cholesterol and fewer triglycerides. They contain the least protein.

Low-density lipoproteins have the largest amount of cholesterol, but also an increase of proteins

High-density lipoproteins contain the highest protein percentage of all the micelles

7.5 Functions of Lipids

Functions of Lipids in the Body

Energy Source

Carbohydrate is often associated with energy for activity. For rigorous activity carbohydrate is indeed a vital fuel, but it can come as a surprise to learn that dietary or stored fat is the primary source of energy for typical daily activities. While **glycogen** (stored carbohydrate) provides a ready source of quick energy, lipids are an excellent stable energy reserve. Glycogen is quite bulky with heavy water content; thus, the body cannot store large amounts. Alternatively, fats are packed together tightly without water and store far greater amounts of energy in a reduced space.

An American football lineman needs more calories than a less active person.

A gram of fat contains more than double the amount of energy (9 kcal/gram) than a gram of carbohydrate (4 kcal/gram). During high-intensity activity the muscles depends largely on carbohydrate, but for typical day-to-day activities, fat is an excellent dense energy source to fuel muscle activity. The Martin and Willy handcart companies experienced a period of prolonged starvation. Adipose tissue would have been a very important supply of energy. Twenty pounds of fat tissue represents a reserve of about 70,000 Calories. For most of us, it is unlikely we will experience prolonged starvation, but periods of illness, or other physical stressful times, a small reserve of adipose tissue might be helpful. When energy needs are high, fat is also an excellent way to get a lot of calories while minimizing the volume of food needed. For example, certain types of athletes, people who have physically demanding jobs, and those recuperating from serious illness can have high caloric needs. Professional football lineman may require 6000-8000 Calories per day to maintain their weight and activity level. Eating that many calories a day can become difficult day in and day out. The inclusion of ample amounts of good fats in their diet helps reduce the total volume of food that needs to be consumed.

Conversely, an overabundance of adipose tissue can result in undue stress on the body and be detrimental to your health. A serious impact of excess fat is its association with the accumulation of too much cholesterol in the arterial wall, which can thicken the walls of arteries and lead to cardiovascular disease. Thus, while some body fat is critical to our survival and good health, in large quantities it can be a deterrent to maintaining good health. Because of the high caloric density, a high fat intake can easily lead to over consumption of calories and excess weight gain. Cholesterol, one of the other key members of the lipid family, is not metabolized and therefore is not an energy source for the body.

"During our sojourn at this camp we were placed under very trying circumstances: being reduced to very low rations of flour, a scanty supply of clothing and in addition to these evils, it became our painful duty to bury very many of our friends and traveling companions" (LDS Church Archives)

Some handcart companies faced starvation

Structural and Regulatory Roles

Phospholipids and cholesterol are important structural components of cellular membranes. Without those two lipids, cells would not exist. Cholesterol has a key regulatory role as a precursor to important hormones such as estrogen and testosterone. The omega-3 and omega-6 fatty acids give rise to eicosanoids that influence blood pressure, clotting and inflammation. The insulation around nerve cells in the brain is a fatty substance called myelin. Without this covering, function deteriorates. Adipose tissue is also a regulator. When fat stores are full, it produces a hormone called leptin that under normal circumstances reduces hunger in order to reduce caloric intake.

Insulation and Protection

Up to 30 percent of body weight is comprised of fat tissue. Some of this is made up of visceral fat or adipose tissue surrounding delicate organs. Vital organs such as the heart, kidneys, and liver are protected by visceral fat. The composition of the brain is 60 percent fat, demonstrating the major structural role that fat serves within the body. You may be most familiar with subcutaneous fat, or fat underneath the skin. This blanket layer of tissue insulates the body from extreme temperatures and helps keep the internal climate under control. It also gives the body the extra padding required

A skier needs insulation

when engaging in physically demanding activities such as ice- or roller skating, horseback riding, or skiing.

Bioavailability and Essentiality

Some of our essential vitamins and health promoting phytochemicals are fat-soluble. Vitamins A, D, E and K are known as the fat-soluble vitamins. Lycopene (found in tomatoes) is an example of a fat-soluble phytochemical. Often these compounds are found in food containing fat, but not always. For example, a salad with green leafy vegetables, carrots, tomatoes and broccoli contains little fat, but several of these fat-soluble compounds. Consequently, eating salad with an oil-based dressing will increase the absorption of these fat-soluble substances.

Salad with an oil-based dressing

It is also known that when fat is excluded from the diet that growth, skin integrity and life expectancy are impaired. The inclusion of alpha-linolenic acid (ALA) and linoleic acid have been shown to prevent the deficiency symptoms. As a result, they are recognized as essential fatty acids.

Tools for Change

While fats provide delicious smells, tastes, and textures to our foods, they also provide numerous calories. To allow your body to experience the satiety effect of the fat before you overindulge, try savoring rich foods. Eating slowly will allow you to both fully enjoy the experience and be satisfied with a smaller portion. Remember to take your time. Drink water in between bites or eat a lower fat food such as fruits and vegetables before and after a higher fat food. The lower-fat foods will provide bulk, but fewer calories.

7.6 Lipids and Health

Heart disease and stroke, two forms of **cardiovascular disease**, remain among the top 5 leading causes of death in the United States according to the CDC.[6] According to the US Department of Health and Human Services (HHS), many of the risk factors associated with the development of cardiovascular disease are controllable such as high blood pressure, high cholesterol, cigarette smoking, diabetes, poor diet, physical inactivity, being overweight, and obesity.[7] This segment of the material will focus on how the selection of dietary lipid can impact some of the risk factors associated with the development of cardiovascular disease.

Cardiovascular Disease

The amount and the type of fat that composes a person's dietary profile can have a profound effect upon the way fat and cholesterol is metabolized in the body. In order to connect dietary fat intake to cardiovascular disease risk, it is important to reflect upon the lipoproteins produced in the intestinal tract and in the liver.

Each of the lipoproteins described in Table 2 (below) serves important physiological roles in managing fat and cholesterol delivery in the body. Levels of these lipoproteins can be measured in the blood through a simple test. Prior to a blood lipid test the person is asked to fast for 12 hours, this allows for most of the chylomicrons to be cleared from the blood by the liver. This is important because the level of chylomicrons in the blood is mostly a reflection of what a person ate during their most recent meal. Remember, the job of a chylomicron is to carry lipid that has been absorbed from food eaten to the liver. Whether a person had a hamburger, fries and shake for lunch is not the important piece of information to gather from a lipid test. Total fat and cholesterol levels in the blood after fasting and the amount of cholesterol found in HDL and LDL are reflective of long-term dietary and lifestyle choices and directly related to cardiovascular disease risk.

Table 2: Lipoproteins produced in the body

Lipoprotein	Where it is Produced	Function
Chylomicron	Gastrointestinal tract	A large particle rich in triglyceride, carries lipids to body cells from the gut
VLDL and LDL	VLDL is produced in the liver and becomes LDL during circulation	VLDL and LDL are smaller in size than a chylomicron and serve to carry lipid from the liver. VLDL transports triglycerides to the cells of the body. LDL deli Plaque cholesterol to the cells.
HDL	Produced primarily in the liver	HDL is a small dense particle rich in protein that carries lipid away from body cell back to the liver

Healthy levels of these are described in Table 3. When total cholesterol and LDL are high, and HDL are low, through a complex process involving the immune system, oxidation and inflammation, LDL particles can start to collect underneath the epithelial lining of blood vessels. This is the beginning stages of what is called **plaque**.

	Desirable levels (mg/dl)	Too high or low (mg/dl)
Total Cholesterol	Less than 200	Greater than 240
LDL Cholesterol	Less than 100	Greater than 160
HDL Cholesterol	Greater than 60	Less than 40
Triglyceride	Less than 150	Greater than 200

Table 3: Suggested blood lipid levels[8]

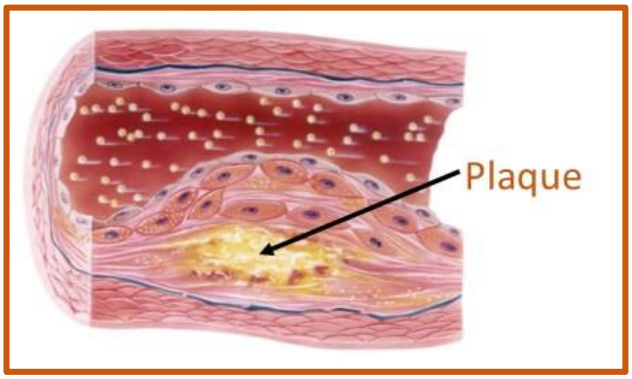


Figure 26: The formation of plaque

When the lipid deposit gets big enough, the plaque can rupture blocking a blood vessel leading to the heart or brain resulting in an event such as a heart attack or a stroke (see Figure 27).

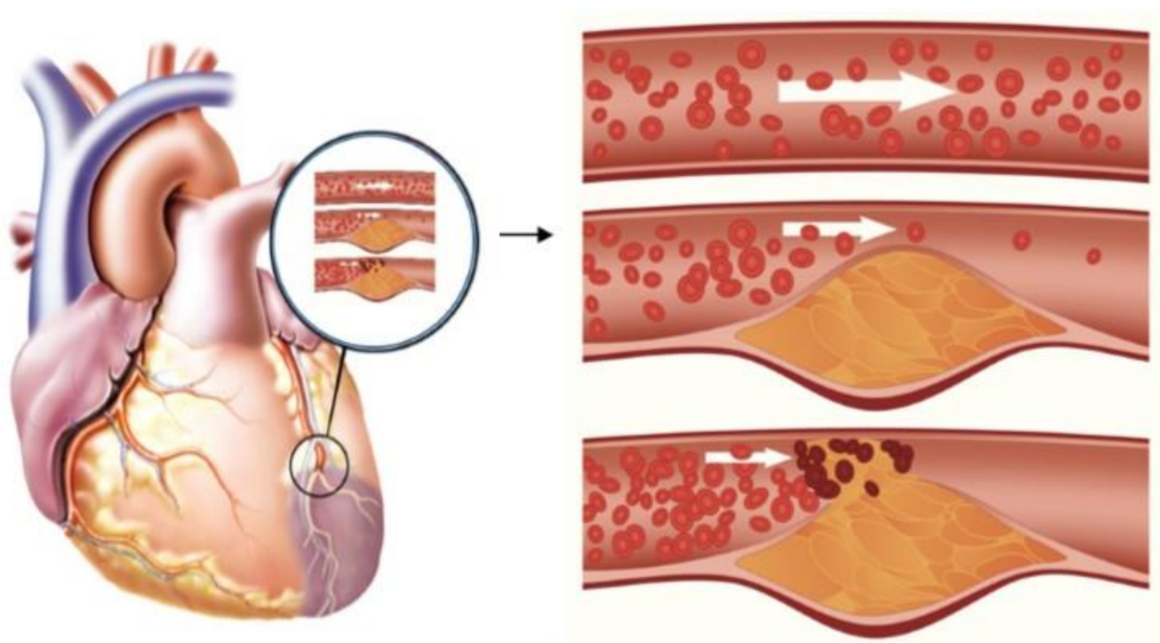


Figure 27: Plaque development leading to a heart attack or stroke

7.7 Lipid Recommendations

Lipid recommendations may vary from organization to organization. Throughout this course, we will focus on the guidelines given in the 2015-2020 Dietary Guidelines for Americans and the Dietary Reference Intakes (DRIs) published by the Food and Nutrition Board. General lipid recommendations are summarized in Table 4.

Lipid Intake Recommendations	
Total Fat as a Percentage of Calories (AMDR)	20-35% of total Calories (adults)
Saturated Fat	Less than 10% of total Calories
Type of Lipid Intake	Replace saturated fat with unsaturated fats Increase intake of foods with omega-3 fatty acids

Table 4: Recommended lipid intake[24,25]

7.8 Dietary Lipids and Cardiovascular disease

Cholesterol

Surprisingly dietary cholesterol intake is not of primary interest when discussing lipid intake and cardiovascular disease. The liver's ability to increase or decrease cholesterol production can compensate for changes in dietary intake. For most people, it plays a minor role as compared to other dietary and lifestyle factors on lipoprotein levels. The current Dietary Guidelines for Americans does not list a quantitative value for daily cholesterol intake, but that does not mean it should be consumed without discretion.[19] It is still an important factor in building a healthy dietary intake, and the principle of moderation should be practiced.

Fatty Acids

Trans fats

The amount and type of dietary fatty acids consumed have an important role in the prevention or development of cardiovascular disease. *Trans* fats produced through the process of partial hydrogenation have the most significant impact on serum lipoprotein levels as compared to all other fats. *Trans* fat is recognized to increase LDL cholesterol and decrease HDL cholesterol. This type of influence on lipoproteins levels is the worst possible scenario in regard to cardiovascular disease risk. In the United States, the amount of *trans* fat from partially hydrogenated fat is decreasing because the Food and Drug Administration is in the process of eliminating partial hydrogenated fats from food. Nevertheless, it is still important to be an educated label reader. The food labeling laws require that *trans* fats be listed as its own line item, which in general makes them easy to spot. But, legally if the trans-fat level per serving is less than 0.5 grams the trans-fat amount on the label be listed as zero and can be labeled trans-fat free. If in the ingredient list "partially hydrogenated vegetable oil" is listed, it is likely there are still *trans* fats in the product even if it says zero on the label. *Trans* fats should be excluded as much as possible from the diet.

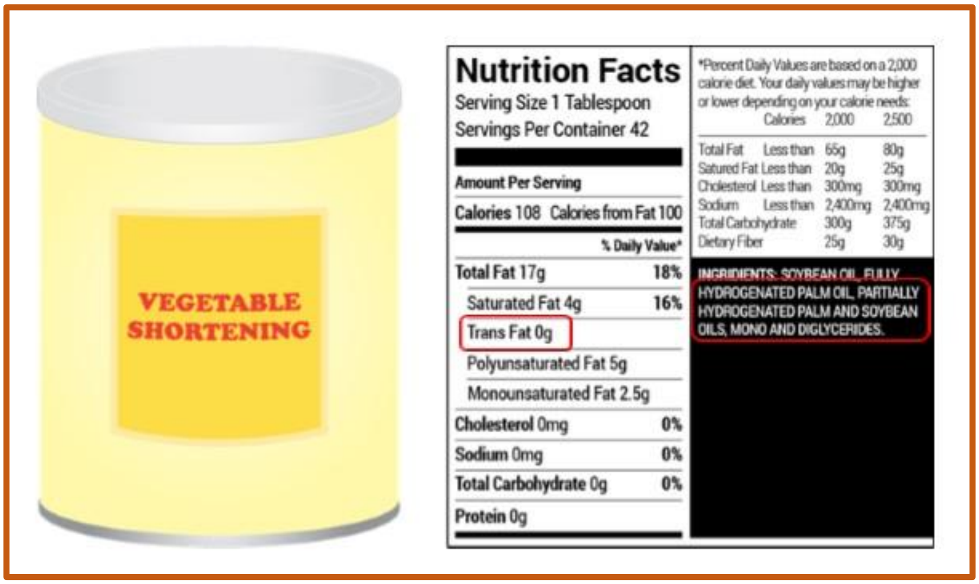


Figure 29: Trans fats and the food label: If the trans fat content is less than 0.5 grams/serving it can be listed as 0 grams

Saturated fats

High dietary consumption of saturated fat is associated with increased LDL levels and risk for cardiovascular disease. Saturated fats are found largely in animal products, some plants (such as coconut and palm oil) and many processed foods. Efforts to reduce saturated fat intake for many individuals is an important health consideration. But reducing saturated fat and replacing it with refined carbohydrates or added sugars has been shown to increase disease risk.[20] It is important to replace excess saturated fat with healthy oils or other healthy dietary options such as whole grains products. For example, if you decided to reduce your saturated fat intake by reducing the butter you put on your white bread and rolls by heaping them with jelly instead, this will reduce your saturated fat intake, but is unlikely to improve your health risk. Eating a whole grain piece of bread with a natural nut butter spread would represent a positive dietary change to reduce saturated fat. It is recommended that saturated fat intake be kept under 10% of total calories.[19]

Mono and Polyunsaturated fats

As alluded to in the saturated fat discussion, the replacement of saturated fat with unsaturated fats has a positive effect on lipoprotein types and total cholesterol levels and overall cardiovascular disease risk. Replacing saturated fats from animal products and tropical oils with plant oils and foods high in plant oils such as avocados, olives and many nuts and seeds can lower LDL and total cholesterol levels.

Heart-healthy foods include unsaturated fats

The omega-3 polyunsaturated fatty acids EPA and DHA may impact cardiovascular disease risk positively in a unique way as compared to other unsaturated fats. As precursors to the eicosanoids they can benefit cardiovascular health by reducing inflammation, blood pressure and blood triglyceride levels[10]. DHA and EPA are primarily found in fatty fish such as salmon, trout, and sardines. Recent evidence supports that health benefits associated with these oils may be connected directly to fish consumption and not fish oil supplementation.[20] The plant omega-3 fatty acid alpha linolenic acid (ALA) is a precursor to EPA and DHA and can contribute to body DHA and EPA levels when eaten regularly in the diet.

Fruits, Vegetables, and Whole Grains

In general, a diet high in fruits, vegetables, nuts and seeds and whole grains is associated with a reduced risk of cardiovascular disease.[21,22] These types of food choices do contain the good oils that have been discussed, but their positive association with heart health is likely much more involved. These foods are rich in a wide variety of health promoting phytochemicals and fiber. They tend to have a low caloric density and help control obesity which is strongly linked to cardiovascular disease. The Dietary Guidelines for Americans outlines dietary principles consistent with cardiovascular health. The DASH Eating Plan and the Mediterranean diet are good examples of eating styles that reflect heart healthy choices.

Alcohol and Heart Disease

Caloric content

Alcohol contains 7 kcal per gram, and in some places is a significant contributor to daily caloric intake. For example, an average 12-ounce beer contains about 150 calories. If a person were to consume 1 can a day for a year, that would translate to caloric intake of 54,750 calories. If taken in excess to caloric need, in theory that would translate to a weight gain of about 16 lbs.

What constitutes a drink

A standard drink is equal to 14 grams (0.6 ounces) of pure alcohol.[9] Practically, that translates to the following serving sizes of popular types of alcohol containing beverages:

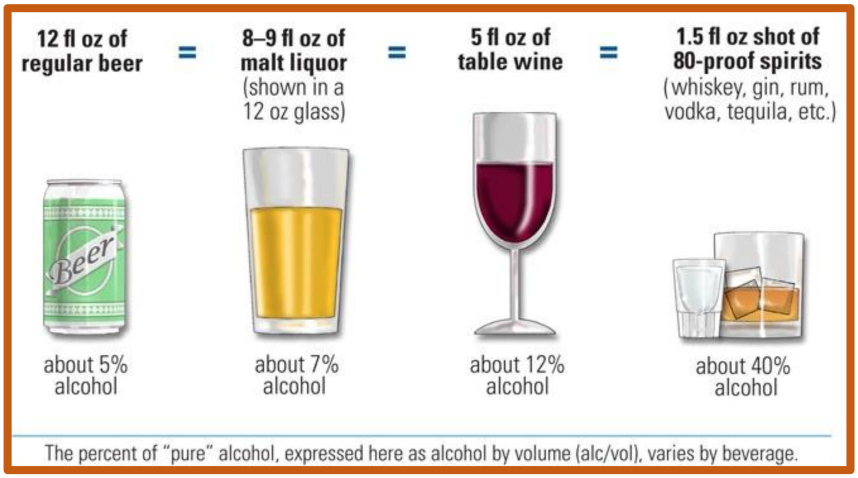


Figure 28: What constitutes a drink

According to the Dietary Guidelines for Americans, **moderate alcohol consumption** is defined as having up to 1 drink per day for women and up to 2 drinks per day for men[10]. This definition is referring to the amount of alcohol consumed on any single day and is not intended as an average over several days. For men, **heavy alcohol consumption** is typically defined as consuming 15 drinks or more per week. For women, heavy drinking is typically defined as consuming 8 drinks or more per week. **Binge drinking** is when men consume five or more drinks, and when women consume four or more drinks, in two hours or less[11].

Alcohol and health

It is clear that excessive alcohol consumption has devastating effects both in the short and long term. In 2012 roughly 6% of global deaths (3.3 million), were attributed to alcohol use[12]. The figure is much higher for 20-39 year olds (25%)[12]. The short-term negative effects included errors in judgement that have been shown to lead to problems such as poor moral choices and unplanned pregnancies, violence, automobile accidents and alcohol poisoning[13]. For pregnant women, any amount of alcohol intake can lead to immediate damage to the developing fetus, resulting in life long impairment to the child known as fetal alcohol spectrum disorder (FASD). There is no level of alcohol intake that is considered safe during pregnancy. Long-term effects of excessive alcohol use include liver damage, increased risk of some cancer, domestic problems, depression, and cardiovascular disease[13].

Although a variety of studies have linked moderate alcohol consumption to a reduced risk of cardiovascular disease, and the promotion of moderate alcohol consumption for cardiovascular health has become popular,[14] more recent evidence has shed doubt upon the conclusions drawn from these studies[15]. New research links even moderate or light consumption of alcohol with increased risk of some forms of cancer[16,17]. Looking at all these variables collectively, it is clear why the American Heart Association[18] and the authors of the Dietary Guidelines for Americans[18] do not recommend people start drinking for health benefits. Recent scientific evidence validates the wisdom of the council given almost 200 years ago in D&C 89.

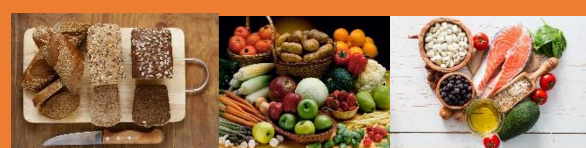
Limit	Emphasize
	
Keep saturated fat intake to less than 10% of caloric intake Minimize *trans* fat	Choose a diet rich in mono and polyunsaturated fats
Keep added sugars less than 10% of caloric intake	Choose a diet rich in whole grains, nuts, and seeds, fruits and vegetables
Keep sodium intake less than 2300 mg/day	Choose fish rich in omega-3 fatty acids two times a week
Limit red meats and processed meats	Consume a calorie level that allows for the maintenance of a healthy weight
If you don't drink alcohol, do not begin If you do drink alcohol do so in moderation	

Table 5: Summary of key dietary recommendations for cardiovascular health[17,18,20]

Chapter 8: Fluid and Electrolytes

8.1 Introduction to Water

Water is the foundation of life. Maintaining the right level of water in the body is crucial to survival. Too little or too much water in the body affects body function and ultimately will become fatal. Water levels must be tightly regulated and a regular supply of water is critical. A lack of water is lethal more quickly than any of the other essential nutrients. The body will typically only survive for several days without water. Sensory proteins monitor the body's water status and send messages about fluid levels to the brain. By manipulating thirst and regulating urine concentration, the body works to balance body water levels.

Desert plants and animals must conserve the water they acquire

Functions of Water

Water uses in the human body can be loosely categorized into four basic functions: transportation vehicle, medium for chemical reactions, lubricant/structural component and shock absorber, and temperature regulator.

Transportation

Water is truly an impressive substance. It has been called the "universal solvent" because more substances dissolve in it than any other fluid. Molecules dissolve in water because of the hydrogen and oxygen molecules ability to loosely bond with other molecules. Molecules of water (H_2O) surround substances, suspending them in a sea of water molecules. The solvent action of water allows for substances to be more readily transported. A pile of undissolved salt would be difficult to move throughout tissues, as would a bubble of gas or a globule of fat. Blood, the primary transport fluid in the body is about 78 percent water. Dissolved substances in blood include proteins, lipoproteins, glucose, electrolytes, and metabolic waste products, such as carbon dioxide and urea, all of which are either dissolved in the watery surrounding of blood to be transported to cells to support basic functions or are removed from cells to prevent waste build-up and toxicity.[1]

Medium for Chemical Reactions

Water is required for chemical reactions to occur in the body. It serves as the transport vehicle that brings enzymes and compounds together and allows reactions to occur. Water is also used directly in the breaking and forming of some bonds. For example, when peptide bonds are formed (the bond that joins amino acids during the formation of proteins), water is produced; when the bond is broken, water is used.

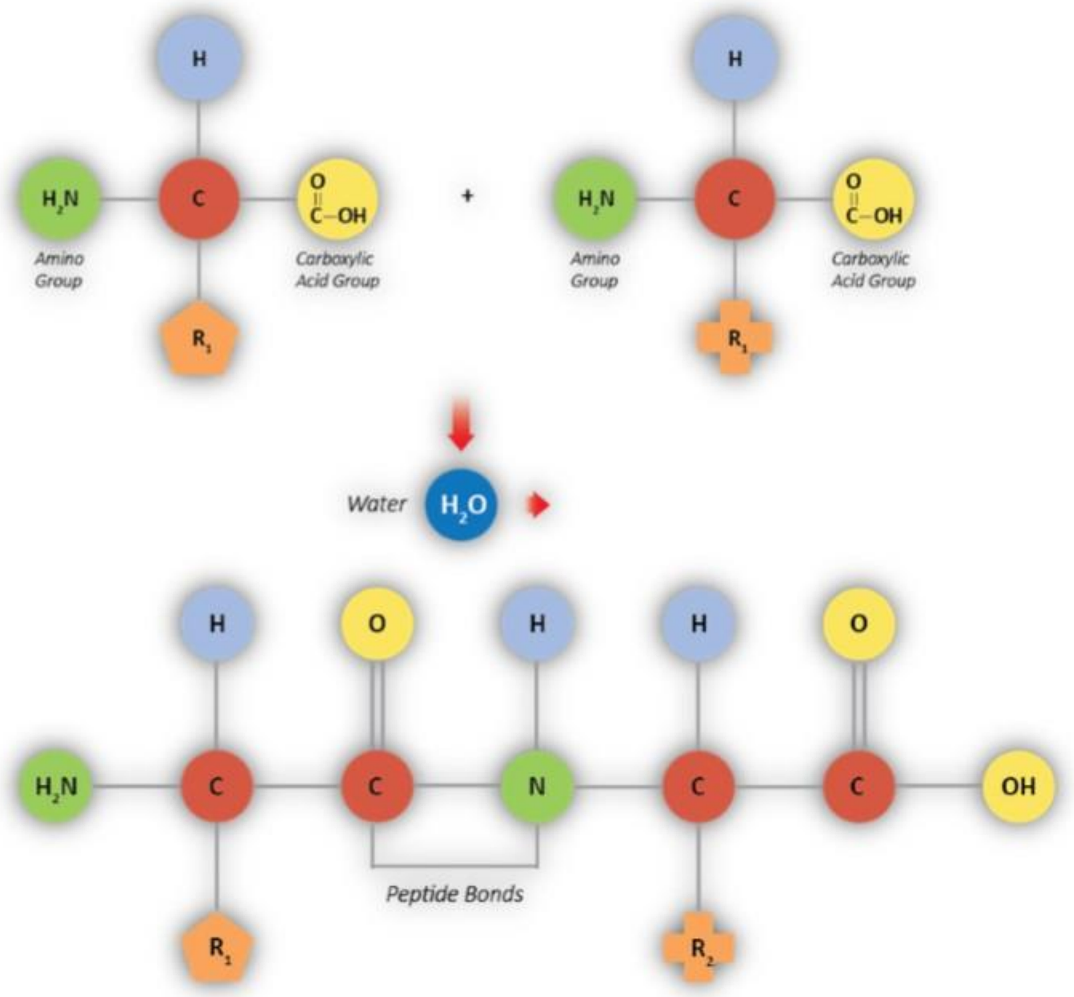


Figure 1: Release of water during the formation of a peptide bond

Lubricant, Structural Component and Shock Absorber

Transparent figure showing joint stress

Many may view the slimy products of a sneeze as gross, but sneezing is essential for removing irritants and could not take place without water. Mucus, which is not only essential to discharge nasal irritants, but is also required for breathing, transportation of nutrients along the gastrointestinal tract, and elimination of waste material. Mucus is more than 90 percent water.

Water is also the main component of the lubricating fluid between joints. Movement would be painful without the lubricating and cushioning power of water.

Water is an important structural component throughout the body. The presence of water in every cell, the vascular system, spinal fluid and even the eye is important to maintain body structure. Without water, these structures would collapse. Its ability to assist cells, tissues and body cavities maintain shape is also central to water's role as a shock absorber. Just two weeks after fertilization, water fills the amniotic sac in a pregnant woman. Water has a variety of roles in pregnancy, but of central importance is its ability to provide a cushion of protection for the developing embryo.[1]

Water as a Temperature Regulator

Man perspiring after exercise

It is well recognized that coastal cities tend to have more moderate temperature changes than do deserts. Large bodies of water can regulate the temperature of land masses because it has a capacity to absorb and emit large amounts of heat. Body water has a similar function. Human life is supported within a narrow range of temperature, with the temperature set point of the body being 98.6°F (37°C). Too low or too high of temperature causes enzymes to stop functioning and metabolism to halt. If body temperatures are too low muscle failure occurs and hypothermia sets in. When body temperature is too high, the central nervous system fails and death results. We experience temperature changes each day, the presence of water in our body helps to minimize the effect of these changes. When the body begins to overheat (as might occur during exercise) the body releases water in the form of **sweat**. As the sweat evaporates from the body it dissipates large amounts of heat with it. Without this function of water, physical activity could quickly become lethal.[1]

8.2 Water Balance

About 60% of our body weight is water, making it the most abundant component. In the body water exists inside of cells (**intracellular water**) and outside of cells (**extracellular water**). Examples of extracellular water include fluid found in the blood, lymph and spinal cord. About 2/3 of body water is intracellular and 1/3 is extracellular. Changes in the amount or composition of body fluids can impact body systems such as, muscle function, kidney function, pH balance and temperature regulation. Careful regulation of fluid levels is critical. A complex monitoring and communications system involving the brain, kidneys, nervous system and endocrine system result in the adjustments of body fluid levels and composition as needed.

Water Gains and Losses

It is important that over a days' time that water intake and output balances. The body's monitoring system does an excellent job maintaining consistent fluid levels under normal circumstances.

Water Out

Total water output per day would typically fall between 2000 to 3000 milliliters/day,[1] but this can vary dramatically depending on environmental conditions and activity levels. The body loses fluid primarily through the kidneys, skin and respiratory system. Small losses also occur through the digestive system.

Typical Fluid Losses[2]

Kidneys	1500 milliliters
Skin	450 milliliters
Respiratory system	300 milliliters
Fecal	150 milliliters

Total = 2400 milliliters (~10 cups)

Students walking together

Water In

Water intake comes from fluid ingestion (as water or any other liquid), water in food and metabolic water. Metabolic water is water that is created during metabolism. For example, when carbohydrate, protein or fat are broken down for energy the end products of the process include ATP (energy), carbon dioxide and water.

Typical fluid intake to balance loses[2]

Fluid	1700 milliliters
Food	400 milliliters
Metabolic Water	300 milliliters

Total = 2400 milliliters (~10 cups)

A family eating outside together

It can be remarkable how much water is found in many common foods. A person may not be surprised to learn watermelon is over 90% water, but it might not be as intuitive to recognize a piece of salmon is 60% water.

Food	Percent water
Watermelon	91%
Spinach (raw)	91%
Non Fat Vanilla Yogurt	79%
Pasta, cooked	62%
Salmon, Atlantic, cooked	60%
Cheddar cheese	37%
Almonds	4%
Peanut butter	1%

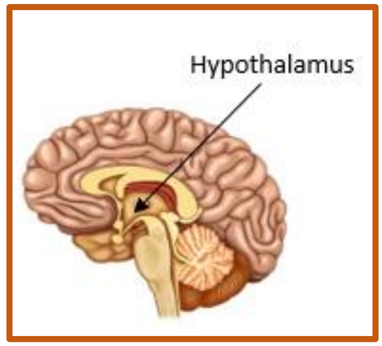
Table 1: Water content of selected foods

Regulating fluid intake

When the body's water levels are low, the volume of fluid in the blood goes down and the concentration of dissolved substances in the blood increases. Changes in the concentration of dissolved substances in blood are expressed in terms of **osmolarity**, which is an expression of the number of particles dissolved in a kilogram of solvent. Both changes in concentration and volume are recognized by the body and are involved in initiating a complex interaction of hormonal and neural signals that help adjustments to compensate for the detected low fluid levels. The hypothalamic region of the brain and kidney are key tissues associated with fluid regulation. Ideally fluid levels are controlled by conscious eating and drinking habits, the systems described below are primarily a backup mechanism to balance fluid levels when things go wrong.

Hypothalamus Role in Regulating Fluid Balance

The **hypothalamus** is often referred to as the "thirst center". Changes in fluid balances and even more importantly blood osmolarity are detected in the hypothalamus. The hypothalamus initiates a desire to drink and retention of fluid in the kidneys (resulting in a decrease in urine production) based on its own monitoring of body conditions and feedback coming from the kidneys. **Anti-diuretic hormone** (ADH) is a hormone produced by the hypothalamus and stored in the pituitary (a small gland adjacent to the hypothalamus). When released it prompts the kidneys to reserve water, resulting in a decrease in urine production. When a person is sweating heavily and is dehydrated is an example of when the pituitary would release ADH.



Hypothalamus helps to regulate fluid balance

Kidneys Role in Regulating Fluid Balance

A primary function of the **kidneys** is to filter blood and remove wastes. But they also play a major role in fluid balance. The kidneys are two bean-shaped organs, each about the size of a fist and located on either side of the spine just below the rib cage. Kidneys have sensors that detect blood volume based on pressure in the kidney's blood vessels. When blood volume is low, the kidney detects decreased pressure and secretes the enzyme, **renin**. Renin's presence in the blood activates a protein called **angiotensin**. The inactive form of angiotensin is produced in the liver and released into the blood. When activated it becomes angiotensin. Angiotensin interacts with the hypothalamus initiating or supporting the message to release ADH and increase fluid consumption. Eventually it also impacts the amount of sodium retained in the kidney by stimulating the production of another

Torso showing kidneys

compound called **aldosterone** (from the adrenal cortex). Increased sodium retention ultimately impacts fluid retention as well.

In summary, the hypothalamic region of the brain and the kidneys have a central role in controlling fluid levels in the body. The hormones angiotensin, aldosterone and anti-diuretic hormone are the key messengers released by these tissues to orchestrate needed changes. Changes in thirst and urine volume and concentration are the primary means the body used to control balance.

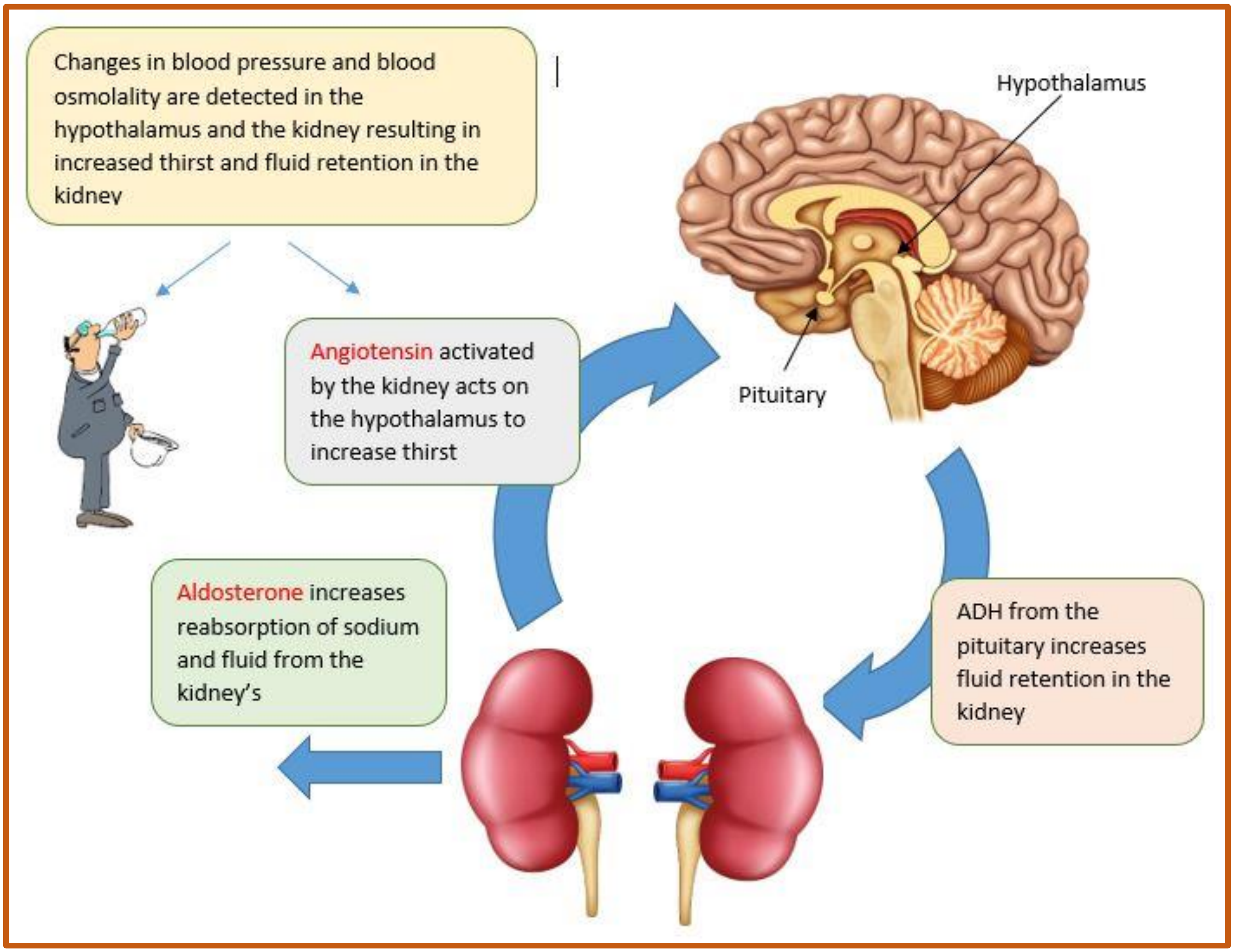


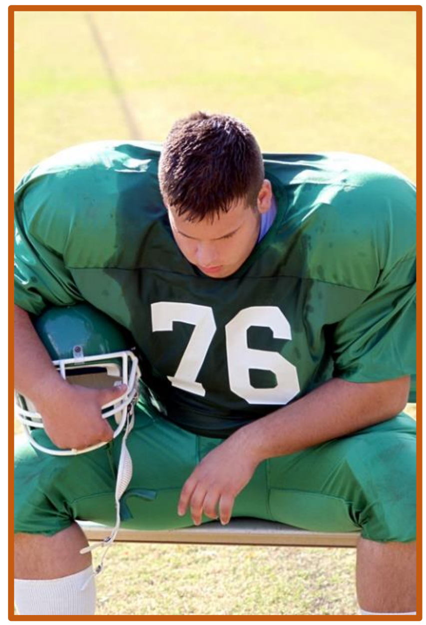
Figure 2: Regulation of fluid balance

Water Recommendations

The Food and Nutrition Board of the National Academy of Medicine has set the Adequate Intake (AI) for water for adult males at 3.7 liters (15.6 cups) and at 2.7 liters (11 cups) for adult females.[2] This recommendation includes water from all beverages and foods; it is not a recommendation for direct water intake. There has not been any official recommendation for daily plain water consumption set by the Food and Nutrition Board or any other authorized agency, despite popular belief. Typically, about 20% of the recommended fluid intake comes from food sources and about 80% from liquids. The vast majority of healthy people can best meet fluid needs by simply letting thirst guide their intake.

Dehydration

The Food and Nutrition Board's daily fluid recommendations are general guidelines for fluid intake under normal circumstances. But in reality, fluid needs can vary significantly based on age, physical activity level, climate and also some diseases that may impact kidney function. For example, some athletes practicing in the middle of a hot summer day with heavy clothing on, can lose up to 2.5 liters (10 cups) of fluid from sweat per hour.[3] During a two-hour practice that could equal five liters (20 cups) of fluid. To maintain balance substantially more fluid would be needed than the amounts suggested in the daily recommendations. Despite the body's complex system to compensate for imbalances in fluid intake and output, there is a point where insufficient intake can no longer be managed, and **dehydration** ensues. Initially thirst may be the only indication of mild dehydration, but as the severity of dehydration progresses, symptoms such as muscle weakness, headache, irritability and dizziness can develop. Severe dehydration will be characterized by serious symptoms such as a rapid heart rate, low blood pressure, delirium, loss of sweating and unconsciousness. Eventually death will ensue. Besides athletes, other populations at risk for dehydration include the elderly and infants. Also, certain diets may increase the risk of dehydration such as high sodium, high protein, and high fiber.



Athlete perspiring heavily

There are a wide variety of ways to monitor hydration status; a couple of practical methods include urine color and body weights. Urine color is not a perfect indicator of hydration status, but it can be rough gauge of insufficient fluid intake. Clear to pale yellow urine is a sign of adequate hydration. Dark orange yellow urine is a sign of severe dehydration.

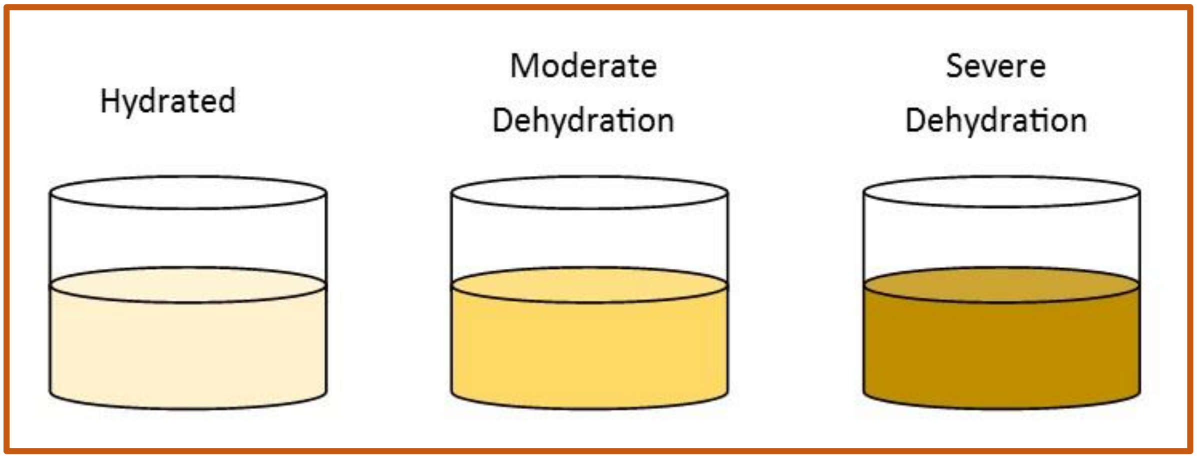


Figure 2: Urine hydration color chart

Athletes can benefit from tracking weight changes during exercise. Taking a weight before and after practice is a reflection of fluid losses. Each pound of body weight lost represents a loss of 2 cups (16 ounces) of fluid. It is important that a dry weight is used and any fecal or urine losses are also considered in the weight change. It is recommended that a person not lose more than 2% of their body weight from fluid during exercise.[3] For each pound of weight lost it is recommended that a person gradually drink 2.5-3 cups of water to replace the losses before the next bout of exercise.

Over-hydration or Water Toxicity

Maybe not as intuitive as the concerns associated with under-consumption of fluid, overconsumption of fluid can be just as deadly. No upper limit was set for water. It is difficult to determine the amount of fluid that is dangerous since it can vary depending on a number of factors including body size, body sodium levels and how fast the fluid is consumed. If enough fluid is taken in a short period of time, it can overwhelm the kidney's ability to compensate by increasing urine production, resulting in the dilution of blood sodium levels. This condition is referred to as **hyponatremia** (low levels of sodium in the blood). A dilution of blood sodium levels causes an osmotic imbalance that can lead to swelling in the brain. Initial symptoms may include confusion and disorientation progressing to seizures, coma and death.[2,3] Ironically, symptoms of water toxicity can often appear very similar to the symptoms of dehydration. Water intoxication is not likely to occur under normal circumstances but typically requires aggressive consumption of large amounts of fluid in short periods of time (e.g. water drinking games or challenges) or the replacement of large amounts of water and electrolytes (sweat) lost with plain water.

8.3 Electrolytes

When discussing body fluids and fluid balance, sodium, potassium and chloride are typically the electrolytes of primary interest. An **electrolyte** is a positively or negatively charged inorganic compound that when in solution is capable of conducting electrical currents. They are a significant player in maintaining the body's fluid balance and in neuron function. Electrolytes that are positively charged are called **cations** (+) while negatively charged electrolytes are called **anions** (-). Sodium (Na^+) is positively charged and is primarily located on the outside of cells. Potassium is positively charged and is found primarily inside cells (K^+). Chloride is negatively charged and located primarily outside of cells (Cl^-). Knowing the main location of the electrolytes in the body is important. For example, when a person sweats heavily, we know that the sweat is produced from fluid outside cells; as a result, large amounts of sodium and chloride are lost and much lower levels of potassium. Understanding this principle allows for the development of the best strategies to replace sweat losses. The body is able to maintain the distribution of the electrolytes using pumps that move the electrolytes across membranes.

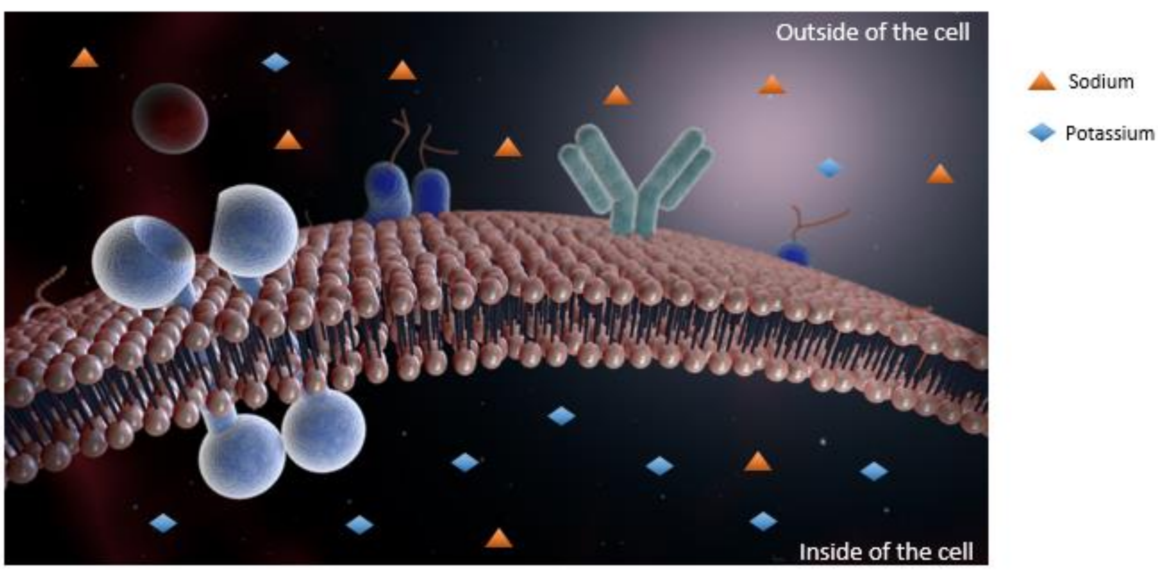


Figure 4: The distribution of the cations sodium and potassium in the body

Functions of Electrolytes

Fluid Balance

The movement of water across semipermeable membranes, also known as **osmosis,** is affected by the amount of electrolytes and other substances dissolved in the fluids. This principle is applied in the body in the regulation of fluid balance and is displayed in Figure 5. Salt water, which is high in sodium chloride (salt), pulls the fresh water across the membrane. The amount of force exerted by the salt water is called the **osmotic pressure**.

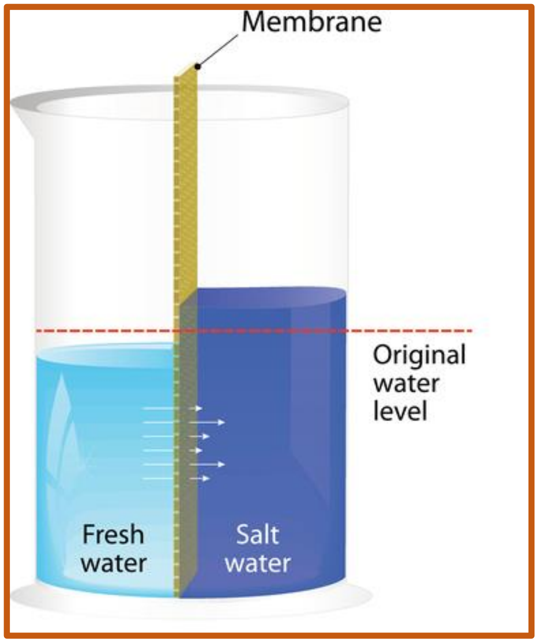


Figure 5: Movement of water across a semipermeable membrane

The body is able to pump electrolytes and other substances across membranes in the body in such a manner that maintains fluid balance. Water will follow the movement of the electrolytes. Disruptions in the system can be manifested in a number of ways. One example of a disruption in the fluid balance system is the presence of edema.

Nerve Conduction

The nervous system uses electrolyte pumps to maintain a high level of sodium outside of the nerve cell and a high level of potassium inside the cell. A gradient such as this represents potential energy. It is not natural for the electrolytes to stay separated in this manner in fluid systems. It takes energy to keep it this way. A nerve impulse is initiated when a sufficient stimulus opens gates on the nerve and lets the sodium and potassium rush across the membrane. This starts a process that allows a message to be moved down a nerve. Once the signal is ended, sodium and potassium pumps are able to restore the sodium/potassium gradient (see Figure 6).

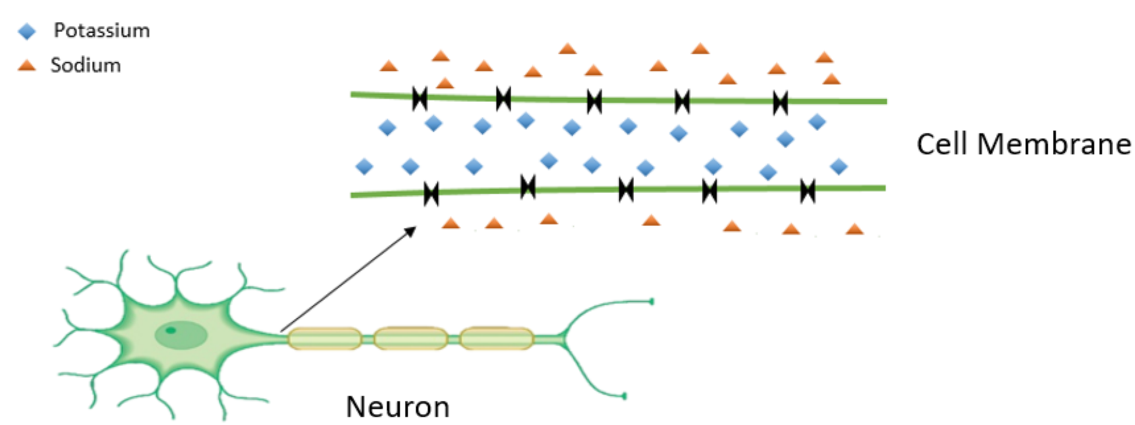


Figure 6: Electrolytes role in nerve conduction

Electrolytes are also involved in the contraction of muscles and in the transport of some nutrients; for example, sodium is necessary for the active transport of glucose in the small intestine.

Control of Electrolyte Levels

Considering the important function of electrolytes, it is vital that the body has methods for regulating levels. The hypothalamus and kidney have sensors that detect changes in blood osmolarity. The brain will initiate thirst in an effort to dilute the blood if osmolarity is high and the kidney can retain or increase the excretion of solutes as needed. For example, after a meal high in salt (sodium-chloride), sodium and chloride levels increase in the blood. Sensing this, the brain induces a drive to drink and the kidney increases the excretion of sodium. By so doing sodium balance is restored. In some people the increase in fluid intake associated with the high sodium intake can temporarily increase blood pressure. In an effort to dilute sodium levels the body becomes temporarily fluid overloaded which increases the volume of blood in the blood vessels. The increased volume in the blood vessels can increase pressure. The fluid retention can also show up on the scale as a small change in weight. Ideally the kidney will increase urine production quickly and make the necessary adjustments in body fluid levels.

Foods high in sodium includes fast foods and snacks

Drastic changes in blood electrolyte levels are life threatening. Heavy sweating, prolonged and intense diarrhea and vomiting, certain medications and pH problems are all examples of situations that might raise or lower specific electrolytes and may require prompt medical treatment.

8.4 Dietary Sources of Electrolytes

Sodium

The Food and Nutrition Board of the National Academy of Medicine has set the adequate intake (AI) for sodium at 1500 mg per day and an upper limit of 2300 mg per day.[2] Table salt is approximately 40 percent sodium and 60 percent chloride. As a reference point, only ⅔ teaspoon of salt is needed in the diet to meet the AI for sodium, and just over 1 teaspoon of salt will reach the UL. When sweating and other mediums of sodium loss are at a minimum, needs can be as low as 200 mg per day[2]. It is important to emphasize that sodium is an essential dietary nutrient. It has functions that are critical for health and survival. Emphasis is usually focused on over-consumption of sodium because under normal circumstances, with typical dietary intake, inadequate sodium intake is unlikely, but in many regions of the world over-consumption is common. In the United States, it is estimated that on average individuals consume greater than 3400 mg of sodium per day.[4] Sodium does occur naturally in many foods, but the primary source of this sodium in the U.S. is added sodium in processed foods (Table 2).

Less Processed	More Processed
 **1 cup fresh tomatoes: 7 mg**	 **½ cup tomato Sauce: 581 mg**
 **3 ounces' pork roast: 57 mg**	 **1 ounce pepporoni: 448 mg**
 **1 cup milk: 107 mg**	 **2 ounces processed cheese: 936 mg**
 **1 medium baked potato: 8 mg**	 **Medium French fry: 221 mg**

Table 2: Comparison of the sodium content of foods

A fresh meat (3 ounces), baked potato (medium) and fresh vegetable (3/4 cup) with a glass of milk with no added salt would have about 200 mg of sodium. In contrast a meal including more highly processed foods such 3 slices of pepperoni pizza with fries and a 16-ounce soda would typically have closer to 2800 mg of sodium. Even after butter is added to the baked potato and the low processed meal is lightly salted it will still be well below the sodium level of the more processed meal. Food producers are required by law to list the amount of sodium contained in their product on the food label and is a good way to monitor sodium intake. It is also helpful to know that claims such as "low sodium" or "reduced sodium" are legally defined and can only be used when certain criteria are met (see Table 3).

Label Descriptor	Definition
Sodium Free	Less than 5 mg of sodium per serving
Very Low Sodium	35 mg of sodium or less per serving
Low Sodium	140 mg of sodium or less per serving
Reduced Sodium	At least 25% less sodium than the regular product
Light/Lite	At least 50% less sodium than the regular product

Table 3: Sodium descriptors on labels[5]

Potassium

During processing the level of sodium often increases in food. In contrast the amount of potassium often decreases. A good dietary intake of potassium is protective against high blood pressure. The National Academy of Medicine based their adequate intakes (AIs) for potassium on the levels associated with a decrease in blood pressure, a reduction in salt sensitivity, and a minimal risk of kidney stones.[2] For adult male and females above the age of nineteen, the adequate intake for potassium is 4.7 grams per day.[2]

Healthy foods rich in potassium

Fruits and vegetables that contain high amounts of potassium are spinach, broccoli, peas and legumes, tomatoes, potatoes, bananas, apples and apricots. Whole grains and seeds, certain fish (such as salmon, cod, and flounder), and meats and dairy are also high in potassium. The Dietary Approaches to Stop Hypertension (DASH diet) emphasizes potassium-rich foods and will be discussed in greater detail in the next section.

Chloride

Most chloride in the diet comes from salt and therefore from processed foods. (Salt is 60 percent chloride.) A teaspoon of salt equals 5.6 grams, with each teaspoon of salt containing 3.4 grams of chloride and 2.2 grams of sodium. The chloride AI (adequate intake) for adults, set by the National Academy of Medicine, is 2.3 grams.[2] Therefore, just ⅔ teaspoon of table salt per day is sufficient for chloride as well as sodium. Chloride may also be found in small amounts in some foods independent of sodium; instead it can be bound to potassium as the salt potassium chloride. Some salt substitutes will use potassium chloride as a replacement option for sodium chloride.

8.5 Electrolytes in Health and Disease

Electrolyte Imbalances

Maintaining normal electrolyte levels in body fluids is essential for life. Changes in sodium and potassium levels are a primary focus when electrolyte imbalances are discussed, but other electrolytes such as calcium and magnesium have important roles as well. When electrolytes are out of balance, prefixes such as hypo and hyper are used to indicate the direction of change. For example, low blood sodium and potassium levels are referred to as hyponatremia and hypokalemia, respectively. High blood sodium and potassium are referred to as hypernatremia and hyperkalemia, respectively. Changes in blood sodium and potassium can be very serious and may be brought on for a variety of reasons. Changes in blood pH, diarrhea, vomiting, medications, kidney problems, hormonal imbalances, inadequate or excessive fluid intake, and even excessive bleeding can affect electrolyte levels.[6] Sweating can be a common cause associated with electrolyte imbalances. Because sweat is made from extracellular fluid (sodium is high in extracellular fluid) sodium imbalance is a common concern with heavy sweating. Replacing heavy sweat losses with pure water, or over consuming fluid can both lead to hyponatremia. In most cases, sodium losses incurred by sweating can be replaced through regular dietary intake, but sodium intake levels above the UL may be needed to replenish losses. In situations of prolonged sweating in hot environments, electrolyte replacement may be necessary during the activity. Recommendations will vary depending on individual sweat rates, sweat salt levels (amount and composition of sweat various significantly from person to person), environmental conditions and length of exercise.[6] The symptoms of hyponatremia include headache, personality changes, irritability, nausea, muscle twitching, and in severe cases, seizures, coma and death.[6]

Water alone does not replace electrolyte loss

8.6 High Blood Pressure (Hypertension)

Blood pressure is the force of moving blood against arterial walls. It is reported as the systolic pressure over the diastolic pressure. The **systolic** number indicates how much pressure is exerted on the artery wall while the heart is beating. The **diastolic** number indicates how much pressure is exerted on the artery wall while the heart is at rest. The force of blood against an artery is measured with a blood pressure monitor. The results are recorded in millimeters of mercury, or mmHg. A **desirable blood pressure range** is less than 120/80 mmHg.[8] There is a condition called

Healthcare professional taking a patient's blood pressure

Hypotension which is defined as a blood pressure lower than 90/60 mmHg. Adequate but not excessive intake of fluids and sodium can help maintain a healthy blood pressure. **Hypertension** is high blood pressure and defined as a sustained blood pressure of 130/80 mmHg or greater (see Table 4).

Blood Pressure Category	Systolic (mm Hg)		Diastolic (mm Hg)
Normal	Less than 120	AND	Less than 80
Elevated	120-129	AND	Less than 80
High Blood Pressure (hypertension) Stage 1	130-139	OR	80-89
High Blood Pressure (hypertension) Stage 2	140 or Higher	OR	90 or higher

Table 4: Blood pressure ranges[8]

Hypertension is a risk factor for cardiovascular disease, and reducing blood pressure has been found to decrease the risk of dying from a heart attack or stroke. The American Heart Association reports that over 85 million Americans have high blood pressure and nearly 20% don't even know they have it.[8] It is often referred to as a silent killer since most often there are no symptoms associated with high blood pressure until significant physical damage has occurred.[8] The constant increased pressure in the blood vessel system that is associated with high blood pressure can not only damage the blood vessel system and heart, but other organs as well, such as the kidneys and eyes. There are a variety of risk factors associated with the development of high blood pressure, which include:[9]

- Age (older adults are at higher risk)
- Ethnicity (e.g. African Americans are at higher risk than Caucasians)
- Overweight or Obesity
- Gender
- Lifestyle habits (physical activity, alcohol consumption, diet, etc.)
- Family history

Many of the risk factors associated with developing high blood pressure are not within a person's control, but some are; lifestyle habits and body weight can be influenced by personal choices. Dietary patterns are recognized as influential in preventing and treating high blood pressure. Dietary recommendations include limiting sodium intake, limiting alcohol intake, controlling caloric intake to maintain a healthy weight and general principles that promote heart health such as choosing whole grains, a wide variety of fruits and vegetables and lean protein sources, with an emphasis on plant proteins such as legumes, fish, nuts and seeds and limiting saturated fats and added sugars. These principles have been collected into an eating plan referred to as DASH (Dietary Approaches to Stop Hypertension). Clinical trials using the DASH Eating Plan in comparison to a typical American diet, have shown reduction in blood pressure, weight and LDL cholesterol levels.[10,11] The DASH Eating Plan is rich in calcium, magnesium, potassium, fiber and protein and low in sodium, added sugars and saturated fats.

Food Group	Recommendations	Serving Size Examples
Grains (whole grains are recommended)	6-8 servings	1 slice (1 ounces) bread 1 ounce of dry cereal ½ cup cooked rice, pasta, or cereal
Vegetables	4-5 servings	1 cup raw leafy vegetables ½ cup raw or cooked vegetables ½ cup vegetable juice
Fruits	4-5 servings	¼ cup dried fruit ½ cup fresh, frozen or canned fruit ½ cup fruit juice
Fat free or low-fat milk products	2-3 servings	1 cup milk or yogurt 1 ½ ounces of cheese
Lean meats, poultry, fish and eggs	6 servings or less	1 once of cooked lean meats, or fish 1 egg
Nuts, seeds and legumes	4-5 servings per week	1/3 cup or 1 ½ ounces nuts 2 tablespoons peanut butter ½ cup cooked legumes (dry beans/peas)
Fats and oils	2-3 servings per day	1 teaspoon soft margarine 1 teaspoon vegetable oil 1 tablespoon mayonnaise
Sweets and added sugars	5 servings or less per week	1 tablespoon sugar 1 tablespoon jelly or jam 8 ounces lemonade

Table 5: DASH Eating Plan for the 2000 Calorie level[12]

How the DASH Eating Plan so rapidly reduces blood pressure is still not clear. Speculation has focused on the mineral content of the plan. The high potassium, calcium and magnesium and low sodium content of the DASH eating style can by physiologically justified as a contributor in the observed reduction in blood pressure. Recent evidence has also shed light on another possible mechanism. Many vegetables are rich in nitrates. Mounting evidence supports a significant effect of nitrates on blood pressure levels; the increase in nitrate intake associated with a DASH eating style may be a key component in the quick effect on blood pressure that is observed when this style of eating is adopted.[13]

8.7 Evaluating Dietary Supplements

When to Choose a Supplement

Before discussing how to choose and evaluate dietary supplements, it is important to explore how they are best used, what they can do, and what they don't do. This discussion will focus on vitamin and mineral supplements as opposed to other types of dietary supplements such as herbal supplements. In the Dietary Guidelines for Americans 2015 it states that nutritional needs should be met by food.[10] Vitamin and mineral supplements should "not" be viewed as a means to compensate for a poor dietary intake in most cases. When supplements are used to cover up a poor diet, they may prevent deficiencies of specific vitamins and minerals. However, they will not compensate for the health impact of poor dietary choices, such has high amounts of added sugars or saturated fats, or low fiber intake. It also will not provide all the other health promoting non–nutrient compounds that are found in food, such as the phytochemicals. When a person fully understands all the ways good food choices impacts health, the recommendation to choose food over supplements is easily understood.

Dietary supplements may be taken as pills and capsules

With that preface, it is important to understand there are also times vitamin and mineral supplements are an excellent tool to promote health. In the Dietary Guidelines for Americans, 2015 it also states "In some cases, fortified foods and dietary supplements may be useful in providing one or more nutrients that otherwise may be consumed in less than recommended amounts or that are of a particular concern for specific population groups".[10] Vitamin D supplements for people living at high latitudes in the winter is an example of appropriate use of supplementation. The 37th parallel is the cutoff typically used. This is roughly a line from San Francisco to Richmond, Virginia. Those living above this line may struggle with Vitamin D synthesis in winter months.[14] It can be difficult for many cultures to get adequate vitamin D from natural food sources. Fortified foods and supplements can be an important tool to maintain adequate Vitamin D levels when sun exposure is not adequate. Genetic conditions or specific health problems may also necessitate some types of supplementation. During pregnancy, iron and folic acid supplementation are often recommended to ensure the needs of the developing infant and mother are met. These are examples of specific situations where supplements are used to meet a clearly identified need. The elderly, vegan vegetarians, people with malabsorptive conditions or on calorie restrictive diets are additional examples where certain forms of supplementation may be beneficial.

Choosing a Supplement

When choosing a supplement there are several important matters to consider. First, as already discussed, be sure there is an identified need not being met by a balanced diet. If a need is identified, then there are several important considerations to reflect on when making a selection.

Quality of vitamin and mineral supplements

Unlike drugs, under most circumstances proof of effectiveness and safety of dietary supplements does not have to be submitted to the **Food and Drug Administration** (FDA) before the supplement is marketed. If any supplement appears to be harmful, the FDA can require the product be removed, but only after evidence is secured. The FDA has established good manufacturing practices that have been designed to help prevent the inclusion of wrong ingredients, inaccurate levels of ingredients and contamination. Companies are required to follow these practices. The FDA does inspect facilities to see if these practices are followed, but policing the industry as a whole is largely impossible. It is logical, that generally supplement companies work to produce a good supplement, but research has shown that quality/purity of supplements do vary, sometimes dramatically and on a rare occasion in a manner that is harmful.[15,16] From a consumer standpoint, it is difficult to discern which supplements may be a problem. There are several private agencies that offer testing to supplement companies. These companies include: [17,18]

1. U.S. Pharmacopeia
2. ConsumerLab.com
3. NSF International

If asked by the supplement company, these agencies will test their product to verify that the product does not contain harmful levels of contaminants, contains what the labels states is in the product and that it has been manufactured well (e.g. it will dissolve).[10] If a product carries the seal of approval from one of these companies, the consumer can be assured this level of quality has been met. It does not, however, verify the supplement is effective or safe.

The FDA and **Federal Trade Commission** also monitor supplements to ensure that claims on labels and package inserts are truthful and not misleading.[10]

Safety and effectiveness of vitamin and mineral supplements

Vitamin and mineral supplements are biologically active agents and need to be treated with respect. If a person is pregnant, nursing, taking medications or has other special health conditions it may be best to consult with a health care provider about supplements you may be considering. For example, supplementation of certain vitamins and minerals may enhance or inhibit the action of some medications. Certain health conditions may warrant fairly high doses of certain vitamins and minerals and need to be prescribed by a health care provider and tolerance monitored over time. Under normal circumstances a consumer can use the supplement label to help them make wise decisions about the choice of a supplement. Selecting a supplement with 100% or less of the Daily Value (DV) is a wise standard to use. It is important to recognize the intakes of vitamins and minerals above the RDAs and AIs are not generally recognized to be beneficial in a healthy person; nor have taking supplements in general been shown to have health benefits. But if a supplement is chosen with this guideline in mind, it is not likely to be harmful either (see Figure 7).

Supplement Facts

Serving size: 1 tablet   Servings per container: 70

	Amount per serving	% DV*
Vitamin A (50% as Beta Carotene)	5,000 IU	100%
Vitamin C (Ascorbic acid)	60 mg	100%
Vitamin D (as Cholecalciferol)	400 IU	100%
Vitamin E (dl-alpha tocopherol)	30 IU	100%
Vitamin B1 (Thiamin)	1.5 mg	100%
Vitamin B2 (Riboflavin)	1.7 mg	100%
Vitamin B3 (Niacin)	20 mg	100%
Vitamin B6 (Pyridoxine)	2 mg	100%
Folic Acid (5-methyl tetrahydrofolate)	400 mcg	100 %
Vitamin B12 (methylcobalamin)	6 mcg	100%
Biotin	300 mcg	100%
Calcium	300 mg	30%
Magnesium	400 mg	100%
Iron	8 mg	44%
Zinc	15 mg	100%
Iodine	150 mcg	100%

*Percent Daily Values are based on a 2,000 calorie diet

Figure 7: A vitamin and mineral supplement supplying 100% or less of the DV of selected nutrients

If a supplement does contain greater than 100% of the DV, it is wise to check the contents against the Tolerable Upper Intake Level (UL) for that nutrient. To do this you will need a copy of the DV and UL tables. In Figure 2 it shows that vitamin B6 is at 5000% of the DV. The amount of vitamin B6 in the supplement is 100 milligrams. The UL for B6 shown in the DRI tables is 100 mg for a young adult. This supplement contains the UL for vitamin B6 before any consideration has been made for dietary intake.

Supplement Facts

Serving size: 1 tablet   Servings per container: 70

	Amount per serving	% DV*
Vitamin A (as 50% as Beta Carotene)	5,000 IU	100%
Vitamin C (Ascorbic acid)	60 mg	100%
Vitamin D (as Cholecalciferol)	400 IU	100%
Vitamin E (dl-alpha tocopherol)	90 IU	300%
Vitamin B1 (Thiamin)	20 mg	1333%
Vitamin B2 (Riboflavin)	1.7 mg	100%
Vitamin B3 (Niacin)	120 mg	600%
Vitamin B6 (Pyridoxine)	100 mg	5000%
Folic Acid (5-methyl tetrahydrofolate)	400 mcg	100 %
Vitamin B12 (methylcobalamin)	100 mcg	1667%
Biotin	295 mcg	100%
Calcium	300 mg	30%
Magnesium	200 mg	52%
Iron	8 mg	44%
Zinc	15 mg	100%
Iodine	150 mcg	100%

*Percent Daily Values are based on a 2,000 calorie diet

Check all the circled nutrients against the Upper Intake Levels

Figure 8: A vitamin and mineral supplement supplying greater than 100% of the DV for some of the selected nutrients

Even if the nutrient does not exceed the UL, high doses of nutrients should be approached with some caution. Today's food supply is heavily fortified with vitamins and minerals. Some products contain enough added vitamins and minerals that for all practical purposes they could be viewed as a supplement. To assess safety, a person should consider their current dietary intake, use of fortified foods, as well as the levels of nutrients in any supplement that may be used. For example, many cold cereals may contain fortification up to 100% of many, if not most all the vitamins and minerals. Serving size is typically around ¾ cup. It would not be uncommon for some people to eat several servings at one meal, and may have cereal on several occasions within a day. For a few nutrients, the cold cereal alone may put them over the UL.

Other Dietary Supplements

Vitamin and mineral supplements are not the only types of dietary supplement that can be found on the market. They include a number of other types of products, such as **herbal supplements** and are regulated under the same guidelines as vitamin and mineral supplements. The number of herbal supplements available makes it unreasonable to adequately cover the topic in this material. In addition, herbal supplements can contain powerful biologically active agents; and should be treated with care. Just because they come from plants, doesn't make them safe. Herbal supplements have the same questions and concerns regarding quality and purity as vitamin and mineral supplements. Also, because they are typically derived from plants the amount of active agent in the plant may not be clear to the consumer. The level of active agent can vary depending on the conditions where the plant was grown. If used, dosage should be carefully researched, and use of herbal supplements in pregnancy, with medications or other herbals, or when other health conditions are present, should be discussed with a health professional. The National Institute of Health has developed a website that summarizes what is known about a number of commonly used herbal products, but it does not address dosage recommendations.[19] In summary, if used, select herbal supplements with care and in conjunction with your health professional if needed. Other types of supplements include amino acids and tissue extracts.

Loose herbs and pills

Chapter 9: Minerals

9.1 Introduction to Minerals

Creation of the earth

The book of Genesis teaches us that our physical bodies were formed from the dust of the earth.[1] The details of the process God used to create the bodies of our first parents' has not been revealed, but today's science can certainly verify that the elements found in the earth are consistent with elements that make up a human body. The periodic table is a collection of the known elements. Regular dietary intake of many of the elements is necessary to sustain life. Carbohydrate, protein, fat, water and vitamins are essential nutrients that are composed of combinations of different elements; structurally these essential nutrients are mostly carbon, hydrogen, oxygen, nitrogen, and some sulfur (see highlighted elements in Figure 1). These elements are organized into essential organic (carbon-containing) compounds by plants and animals that humans then eat to sustain life. In addition, a number of other elements in the periodic table are also dietary essentials but perform their function as inorganic elements (do not contain carbon.) These are referred to as the essential minerals and must be consumed in the diet for health to be sustained.

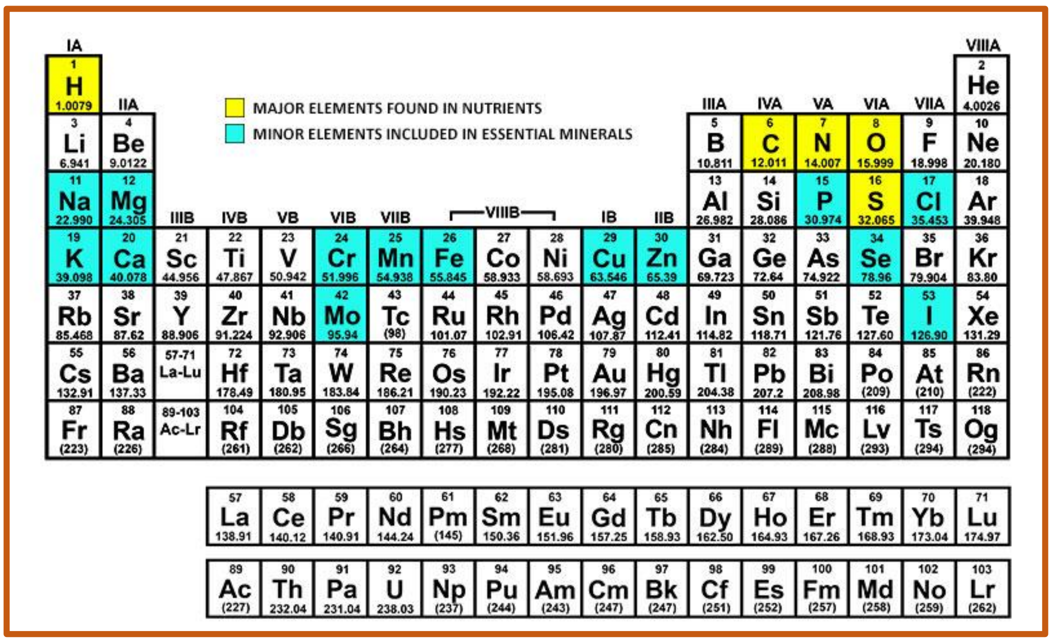


Figure 1: Periodic table of elements

The essential minerals can then be further subdivided into two groups: the major minerals and trace minerals. **Major minerals** are needed by adults in quantities greater than 100 mg/day. Minerals needed in amounts of 100 mg/day or less are grouped into the **trace** and **ultra-trace minera**l categories. For the ease of discussion, the trace and ultra-trace minerals will be grouped into one category and referred to as trace minerals (see Figure 2).

Greater than 100 mg

Major Minerals	
Sodium[a]	Calcium
Potassium[a]	Phosphorus
Chloride[a]	Magnesium
Sulfur	

Less than 100 mg

Trace Minerals	
Iron	Selenium
Zinc	Chromium
Iodine	Manganese
Copper	Fluoride[b]
Molybdenum	

[a]Electrolytes
[b]Fluoride is not considered an essential nutrient but included with the trace minerals due to its protective role, primarily against tooth decay

Figure 2: Major and trace minerals

By studying the highlighted minerals on the periodic table, it is apparent that only a fraction of the elements has been established as essential. It is interesting to note that the discussion on the essentiality of a number of the remaining minerals is still open. For example, boron, vanadium, silicon, and arsenic are among those minerals that are not considered essential currently but are under discussion as possible essential nutrients. The inclusion of arsenic may be curious to some, due to its high toxicity even in very small quantities. But the fact that many of the minerals, if taken in excess, can be dangerous makes the consideration of arsenic in extremely low doses more understandable.

Functions of Minerals

Because of their physical properties, minerals are often recognized for their structural role. For example, minerals are a primary component of bones and teeth. Minerals also play a substantial regulatory role. For example, they are key cofactors in many enzymatic reactions affecting key events such as DNA transcription, metabolism and muscle contraction. A **cofactor** is a metallic substance that is necessary for an enzyme to function properly. The minerals sodium, potassium, and chlorine have a unique role in fluid balance and nerve conduction. Because of their close association with water, they were discussed in the fluid chapter.

Minerals in our food supply

Where we get our food, how the food is processed, and how we prepare our food can alter the mineral content, particularly in plant-based foods. For example, in many areas of the world iodine has been leached from the soil. Plants grown in these areas will be low in iodine. Plants grown in iodine-rich soils versus iodine-poor soils may have 100 times more iodine content.[2] The mineral content of animal-based foods are often higher than plant-based foods because the animal eats the plants and concentrates the minerals from the plants to the desired level.

The processing of food can decrease or increase the mineral content of foods. For example, when grains such as wheat and rice are processed, often the bran and germ are removed, which contain a substantial amount of the important minerals found in these grains. In the United States, it is required by law that iron is added back in. Unfortunately, other minerals originally found in the grains such as magnesium, zinc, and copper are not required to be added back in (see Figure 3). In contrast, sodium levels are often increased. This is not a desired change for most people.

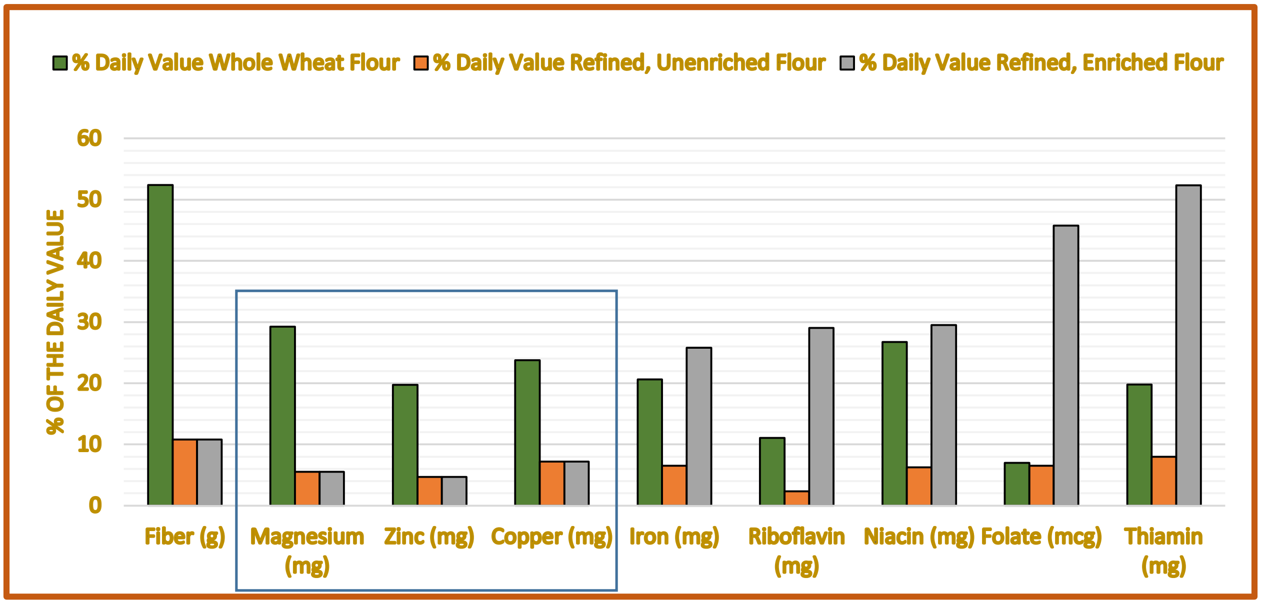


Figure 3: Removal of magnesium, zinc and copper during processing

Minerals may be intentionally added to some foods for specific health benefits. For example, iodine is added to salt. While these carefully selected additions to our food have proven helpful, the random fortification of minerals and vitamins to processed food products has become so common that the wisdom of this continued pattern can be questionable.

Minerals can also sneak into our food supply unintentionally. For example, cooking with cast iron cookware can increase the iron content of the food, and iodine has found its way into our milk supply due to its use as a sterilization agent in the milking process. Neither of these additions are harmful, and in some cases there could be a health benefit. However, the unintentional addition of potentially harmful levels of minerals may be a concern.

Bioavailability

Food composition tables list the amount of the various minerals found in many foods. What is not clear from these tables is the actual ability of the body to absorb and use the minerals in a particular food. The term **bioavailability** is used to describe this principle. Generally, it is other substances that are in the food that affect the bioavailability of minerals. Minerals found in animal products generally have a higher bioavailability compared to minerals found in plant-based foods. The presence of phytates, oxalates, and polyphenols such as tannins in plant-based foods all negatively affect the bioavailability of certain minerals. For example, oxalates (found in some leafy greens vegetables like spinach) negatively impact the absorption of calcium. Phytates (found in whole grains) negatively impact the absorption of zinc. Some might wonder if this is a justification to eat refined grains more often, but despite the decreased bioavailability of zinc in whole grains, the increased levels of zinc in the whole versus refined grains more than makes up for the difference in bioavailability.[3]

Minerals of similar charge can compete for absorption; for example, calcium and iron are both positively charged minerals and compete for absorption. Under normal dietary circumstances, the effect is small, but if large amounts of these minerals are taken as supplements the concern increases. In contrast, the effect of substances on the bioavailability of minerals is not always negative; the presence of vitamin C with certain forms of iron can increase the availability of iron. The nutritional need of an individual can also positively impact the bioavailability of some nutrients. For example, during pregnancy the bioavailability of several nutrients increases to meet the increased need of the mother and developing fetus.

Mineral Bioavailability	
Lower Bioavailability	Higher Bioavailability
Phytates Oxalates Polyphenols (Tannins) Mineral Supplements with same charge	*Generally animal foods* *Stage in lifecycle (example pregnancy and calcium)* *Vitamin C and non-heme iron* *Vitamin D and Calcium*

Table 1: Factors influencing mineral bioavailability

9.2 Major Minerals

Calcium

Calcium makes up 1-2% of an adult human's body weight. Greater than 99% of total body calcium plays a structural role and is found in the bones and teeth. The other 1% is found in body fluids. Despite the magnitude of difference in calcium content between the two compartments, the calcium found in body fluids is no less important. Because of calcium's complex role, overall intake and regulation of calcium levels are important not only for structural reasons but for the maintenance of a wide variety of other critical functions.

Functions of Calcium

The most familiar function of calcium is to provide structure for the human body. As an integral part of bone, it provides a strong framework that determines body shape and allows a person to move. The calcium in bones is actually part of a mineral complex called hydroxyapatite.

The skeleton: the calcium in the bone serves as a calcium reserve

It may be surprising to learn that calcium has several other functions besides helping to make bones strong. In fact, calcium levels in body fluids play a critical role in blood clotting, nerve conduction, muscle contraction, and blood pressure regulation. These calcium functions are critical to life. Providing calcium for functions other than structure is so critical, that the body will take calcium from bones when there is not enough calcium in the diet to maintain the necessary calcium levels in body fluids. Long-term low calcium intake will result in a continual slow release of calcium from bone and increases risk for osteoporosis. It may take several years before the impact on bone density is realized. Eating calcium rich foods over a lifetime is an important part of preventing the geriatric disease of osteoporosis.

Regulation of calcium

Some of the key hormones involved in the maintenance of blood and tissue calcium levels include parathyroid hormone (PTH), calcitonin, and vitamin D. If blood calcium levels start to decrease, the parathyroid gland releases PTH and vitamin D is activated in the kidney. PTH signals the kidneys to reduce the loss of calcium in the urine and signals the bone to release calcium into the blood. Activated vitamin D enhances calcium absorption from the intestines and also stimulates bone to release calcium. If blood calcium levels start to rise, the hormone calcitonin reduces calcium absorption, increases calcium release into the urine, and helps promote calcium deposition into the bone, reducing calcium blood levels to normal (see Figure 4). Barring certain disease states and extreme variation in calcium intake, these hormones work together to maintain a fairly constant blood calcium level regardless of typical intake levels.

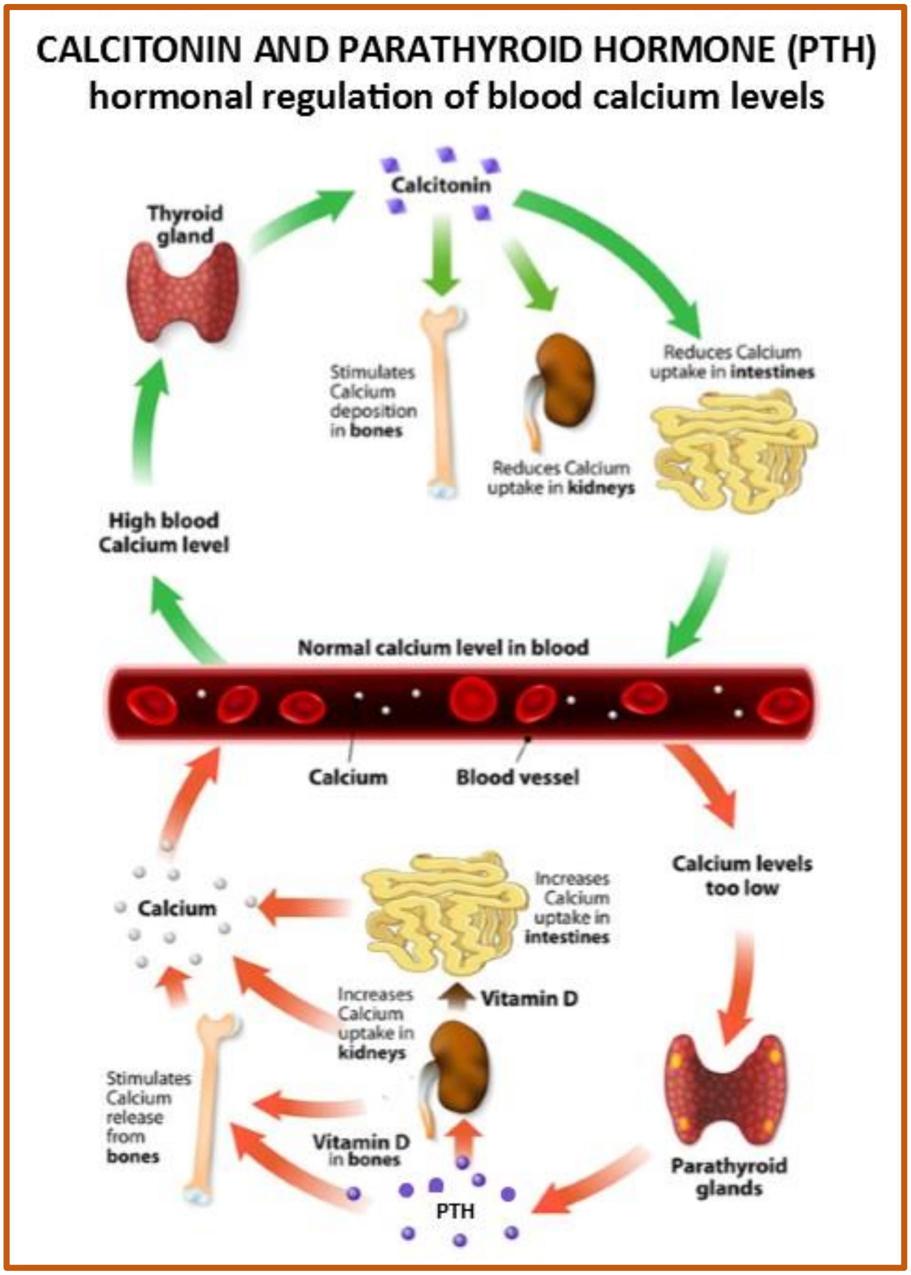


Figure 4: Regulation of blood calcium levels

Bone Development

Understanding bone development will be important when calcium deficiency is discussed. We often think of bone as a static mass of mineral. In reality, bone is a dynamic porous tissue made up of protein and mineral complexes that are constantly changing. Its unique organic and inorganic components give it both flexibility and strength. Bone has a complex network of blood vessels and nerves to allow for nutrient delivery and communication. Bone mineralization begins before birth and reaches its peak between 20 to 30 years of age.[4] The majority of the mineralization occurs in childhood and adolescence which are both critical period of bone development. During these times, bones are continually growing and changing shape. In adulthood, bones stop growing but are still going through a **bone remodeling** process (breaking down and rebuilding). The two main types of cells that are key in this process are osteoblasts and osteoclasts; osteoblasts are bone builders and osteoclasts break bone down. Maximizing peak bone development is important since bone mass declines in the later part of life. Achieving a higher peak bone mass translates to a decreased risk for osteoporosis later in life. Dietary intake of a wide variety of nutrients will affect bone development. Stressors placed on bone, such as those that occur in some types of exercise, can also increase bone density.

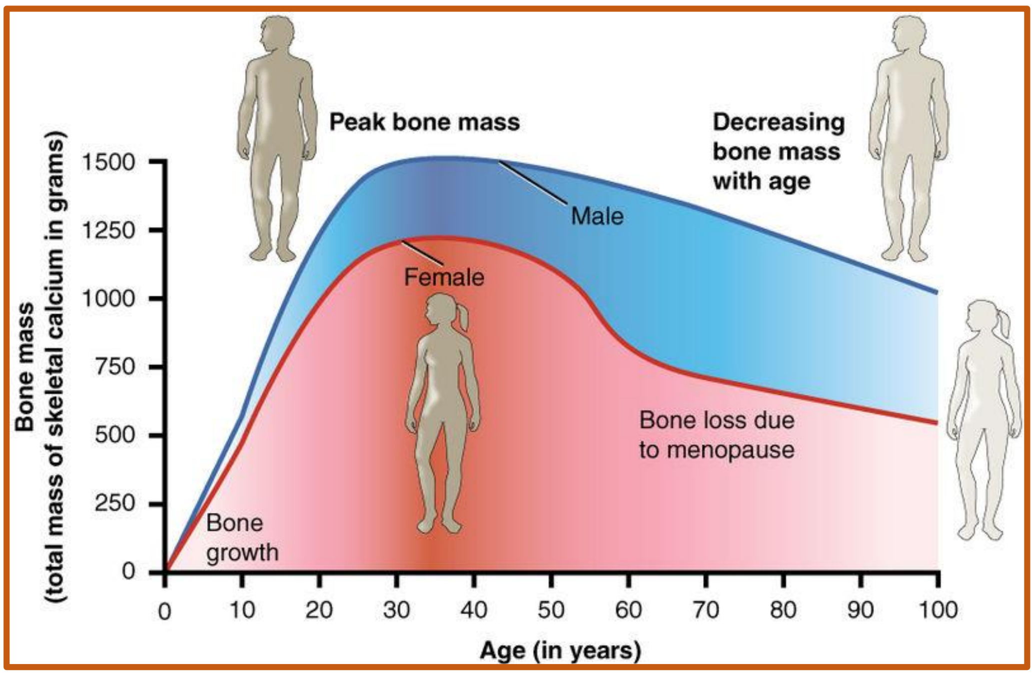


Figure 5: Bone mass over time

Calcium Recommendations and Deficiency

Calcium recommendations change over the lifespan (see Table 2). During the adolescent and teen years, calcium recommendations are higher to accommodate bone growth and development. Recommendations drop to 1000 mg/day in adulthood. Calcium absorption drops with age and women have a greater bone loss after menopause. Consequently, recommendations increase to 1200 mg/day for females over the age of 50 and for men over the age of 70. Interestingly the calcium recommendations during pregnancy and lactation are the same for non-pregnant and lactating women of the same age. This is because during pregnancy dietary absorption of calcium doubles. This increased absorption ensures adequate calcium availability for the growing baby and the increased needs of the pregnant woman.

Age Range	RDA	UL
9-18 (male/female)	1300 mg/day	3000 mg/day
19-50 (male/female)	1000 mg/day	2500 mg/day
51-70 (males)	1000 mg/day	2000 mg/day
51-70 (females)	1200 mg/day	2000 mg/day
>70 (male/female)	1200 mg/day	2500 mg/day
14-18 (pregnant/lactating)	1300 mg/day	3000 mg/day
19-50 (pregnant/lactating)	1000 mg/day	2500 mg/day

Table 2: Recommended calcium intake levels[5]

Because of the dynamic nature of bone and the vast amount of available calcium in the bone, the key functions of calcium (nerve conduction, muscle contraction etc.) are typically maintained regardless of calcium intake. It is usually not until later in life that a deficiency of calcium in the bone manifests itself as **osteoporosis**. Osteoporosis (porous bone) is a disease of low bone mass leading to an increased risk of fractures.[6] In the United States, it is estimated that 53 million people either have osteoporosis or are at high risk secondary to low bone mass.[6] It is a serious and debilitating disease.

Figure 6: Normal bone, progressing to osteoporotic bone

Low calcium intake is certainly a risk factor for osteoporosis, but there are other factors that affect bone density as well. Other nutrients such as vitamin D, protein, phosphorus, magnesium and vitamin K are also important in bone development and can potentially impact bone density. Women are at a much higher risk for osteoporosis than men for several reasons. On average, women have a lower peak bone mass than men. As a result, after age 40 when bone mass starts to decline, women have less mass to draw upon. Hormones also have a significant role in the maintenance of bone mass in women. When estrogen levels decrease at menopause, bone loss accelerates in women increasing the likelihood of the development of low bone mass. Osteoporosis typically occurs in old age, but under certain circumstances it can also develop at a young age. For example, female athletes that struggle with amenorrhea (lack of menstruation) secondary to inadequate caloric intake, can become osteoporotic at an early age due to changes in estrogen levels. (See Figure 6 for an example of osteoporotic bone). Not surprisingly, as the density of bone decreases the risk of fractures increases. For older individuals, a fracture associated with osteoporotic bones is difficult to heal and affects not only quality of life but also life expectancy.[7]

Foods high in calcium

Dietary sources of calcium and prevention of osteoporosis

Dairy products are naturally one of the densest sources of dietary calcium. Fortunately for the many people who are not able to eat dairy products because of lactose intolerance or allergies, there are many other calcium-rich foods that can be eaten (see Table 3).

Food (dairy)	Calcium (mg)	Food (non-dairy)	Calcium (mg)
Milk, 1% (8 ounces)	305 mg	Sardines, canned with bones (3 ounces)	325
Yogurt, plain (8 ounces)	209 mg	Collard Greens (1 cup cooked)	268
Cheese, Cheddar (1 ounce)	200 mg	Tofu, firm (½ cup)	253
		Almonds (1/2 cup whole)	192
		Turnip greens (1 cup cooked)	197
		Kale (1 cup cooked)	94
		Tahini (sesame seed paste, 1 Tbsp)	63
		Broccoli (1 cup cooked)	62

Table 3: Sources of calcium

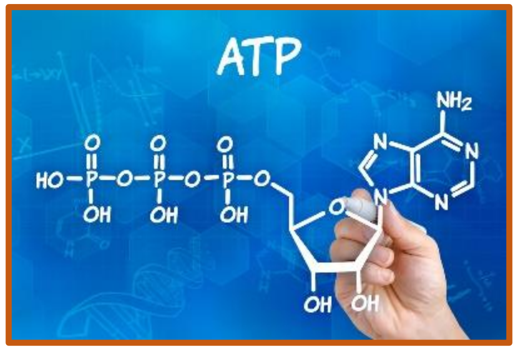
When vitamin D levels are low, the absorption of calcium from food and supplements decreases from 25-33 percent to less than 10-15 percent.[32] The bioavailability can decrease depending on other food components that may be present during digestion and the amount of calcium taken in at a given time. About 25-30% of dietary calcium is typically absorbed.[8] Many green vegetables have a significantly higher absorption rate (50-70%), but will vary drastically depending on the presence or absence of binders such as oxalates. For example, spinach contains calcium, but only about 5% of the calcium can be absorbed because of the oxalate content of spinach.[9] If calcium is taken as a supplement, it is recommended to take a dose of 500 milligrams or less because the calcium absorption decreases when higher amounts are taken.

Some of the risk factors associated with osteoporosis such as age, gender, genetics, and nationality are not controllable, but other factors are. A healthy balanced diet that supplies an adequate amount of calories as well as all the essential nutrients, particularly those involved in bone development, is important. Regular weight-bearing exercise will increase bone density. For example, sports such as volleyball, soccer, basketball, and racquetball will build bone density better than sports like swimming or cycling. Other lifestyle factors such as smoking and alcohol consumption can negatively impact bone mass. These prevention strategies work in two ways. If followed early in life they help peak bone mass to be achieved, and if continued throughout life, they can also minimize the rate of bone loss that inevitably occurs after age 40. The most potent preventive action to decrease the risk of osteoporosis is to establish healthy practices during childhood and adolescence.[4] Unfortunately, some adolescents struggle making food choices that allow them to get adequate calcium and other important minerals necessary for bone health. A well-rounded diet adequate in vegetables and dairy products is key to meeting these goals.

Extremely high intakes of calcium in a short amount of time, or chronic exposure to high calcium intake, can be harmful. This can lead to calcium deposits in soft tissues such as the kidney and heart, increase the risk for kidney stones and possibly increase the risk for cardiovascular disease. The UL for calcium has been set at 2500 mg/day.[5]

Phosphorus

Phosphorus is the second most abundant mineral in the human body. Eighty-five percent of it is housed in the skeleton. In addition to serving as a primary mineral in the skeleton, phosphorus in the form of phosphate is a component of RNA and DNA, the energy-storing molecule ATP (adenosine triphosphate), and phospholipids. Because phosphorus is present with calcium in mineralized bone, it is also regulated by the parathyroid hormone, calcitonin, and calcitriol (the active form of vitamin D.)



Structure of adenosine triphosphate

Food Sources and Recommendations for Phosphorus

In comparison to calcium, most Americans are not at risk of having a phosphate deficiency. Phosphate is present in many popular foods including meat, fish, dairy products, processed foods, and beverages. Phosphate is added to many foods because it acts as an emulsifying agent, prevents clumping, improves texture and taste, and extends shelf-life. The average intake of phosphorus in US adults ranges between 1,000 and 1,500 milligrams per day, well above the RDA of 700 milligrams per day. The UL set for phosphorous is 4,000 milligrams per day for adults and 3,000 milligrams per day for people over age seventy[5].

Magnesium

Approximately 60 percent of magnesium in the human body is stored in the skeleton, making up about 1 percent of mineralized bone tissue. Magnesium is not an integral part of the hydroxyapatite crystal, but it does reside on the surface of the crystal and helps maximize bone structure. Studies link magnesium deficiency with an increased risk for osteoporosis.[10,11] It may be connected with osteoporosis due to its direct structural role in bone, but magnesium is also associated with the activity of several hormones linked to bone remodeling such as vitamin D. A magnesium-deficient diet is associated with decreased levels of parathyroid hormone and decreased activation of vitamin D, which may lead to an impairment of bone remodeling.

In addition to participating in bone maintenance, magnesium has a wide variety of other functions in the body. In every reaction involving the cellular energy molecule (ATP), magnesium is required. More than three hundred enzymatic reactions require magnesium. Magnesium plays a role in the synthesis of DNA and RNA, carbohydrates, and lipids, and is essential for nerve conduction and muscle contraction. Another health benefit of magnesium is that it may decrease blood pressure.

Food Sources and Recommendations for Magnesium

Magnesium is part of the green pigment *chlorophyll*, which is vital for photosynthesis in plants; therefore, green leafy vegetables are a good dietary source for magnesium. Good sources of magnesium also include legumes, nuts, seeds, and whole grains. Hard water also contains some magnesium. Drinking two liters of hard water can provide about 52 milligrams of magnesium. Most people in America do not fulfill the RDA for magnesium in their diets. Typically, Western diets have a low intake of fish, green leafy vegetables, whole grains, and nuts, making it difficult to achieve the recommendations.

Foods high in magnesium

The RDAs for magnesium for adults between ages nineteen and thirty are 400 milligrams per day for males and 310 milligrams per day for females. For adults above age thirty, the RDA increases slightly to 420 milligrams per day for males and 320 milligrams for females.[5]

9.3 Trace Minerals

Iron

Iron (Fe) is probably one of the most recognized minerals of all the essential minerals. Many people have experienced the fatigue that can be associated with low iron levels and understand its role in the blood. Less well understood are the best dietary strategies to ensure adequate but not excessive iron intake, and the diverse role of iron in the body.

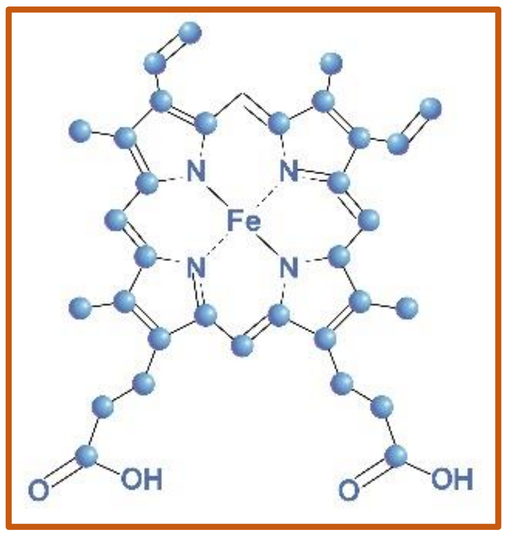


Figure 7: Structure of heme iron

Functions

Iron is a key participator in oxygen delivery. Red blood cells contain the oxygen-carrier protein **hemoglobin**. It is composed of four globular polypeptides (proteins), each containing a non-protein complex called **heme** (see Figure 7). Heme is a ring-like structure containing carbon, hydrogen, and oxygen. Iron is found in the center of each heme. When all these components are present, hemoglobin is an efficient carrier of oxygen (see Figure 8). In the muscle, a similar structure used to transport oxygen is called **myoglobin**. The majority of the body's iron (approximately 70%) is found in the red blood cells of hemoglobin and myoglobin.[31] In addition, many of the proteins of the electron-transport chain contain iron. It is vital for the synthesis of ATP. Iron is also a cofactor for hundreds of enzymes participating in events such as DNA synthesis and detoxification reactions in the liver.

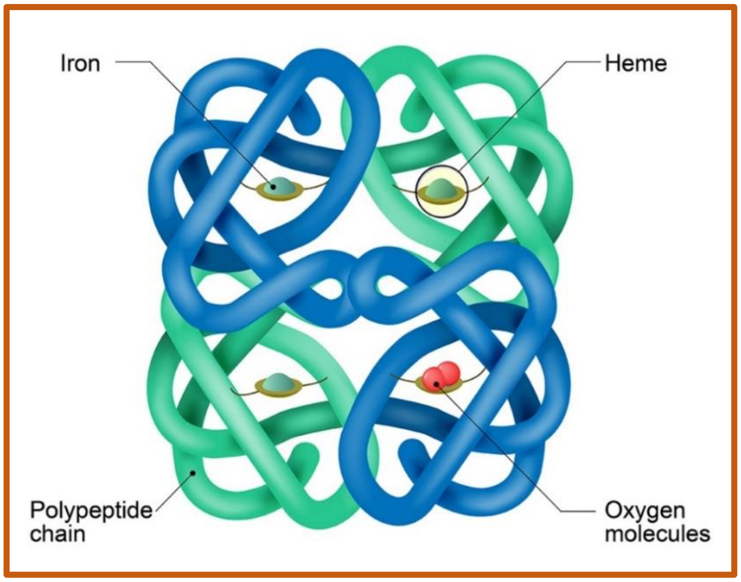


Figure 8: Structure of hemoglobin

Food sources

Dietary iron is found in two basic forms, **heme** and **non-heme**. When eating animal products such as meat, fish, and poultry, much of the iron that is ingested is still a part of a hemoglobin or myoglobin complex. The digestive process breaks down the polypeptide chains and releases the heme ring containing the iron. During digestion the heme ring stays intact and the iron is still secured in the middle. Fifty to sixty percent of the iron found in animal products is heme iron, the remaining iron is elemental or non-heme iron.[12] Animal products contain both forms of iron, but plants provide only non-heme iron. Dietary sources of heme and non-heme iron are listed in Table 4.

Animal Sources-Containing Heme and Non-Heme Iron	Iron (mg)	Plant Sources-Containing Non-Heme Iron	Iron (mg)
Oysters (3 oz)	5.7	Fortified Cereal (25% of DV)	4.5
Liver (3 oz)	4.1	Spinach (1/2 cup cooked)	3.2
Beef, round (3 oz)	2.3	Pumpkin seeds (1/4 cup)	2.4
Turkey leg (3 oz)	1.9	Black beans (1/2 cup)	1.8
Turkey breast (3 oz)	1.1	Dried Apricots (1/2 cup)	1.7
		Whole wheat bread (1 slice)	0.9
		Enriched bread (1 slice)	0.9
		Broccoli (1/2 cup cooked)	0.5

Table 4: Sources of iron

Absorption, transport and storage

The bioavailability of iron from food is dependent on a number of factors. Generally, iron is not a well absorbed mineral. In a mixed meal, iron absorption is estimated to be 14-18% and as low as 5% in vegetarian meals.[13] When iron is bound within heme, it is better absorbed than in the elemental form (non-heme). The digestive system has transporters that specialize in the absorption of heme iron. When there is a specific need to increase body iron levels, such as in iron deficiency anemia, animal products such as liver and red meats are often promoted by health professionals to help restore iron levels. But under normal circumstances plant products can provide good amounts of iron and are an important part of a healthy diet. It is important to be aware that the absorbability of iron from

Foods high in iron

plant products can either be enhanced or diminished depending of the presence of other compounds within the same food or food eaten at the same time. Some plants contain compounds such as phytates, oxalates, and polyphenols (such as tannins) that inhibit non-heme iron absorption. For example, black tea is rich in polyphenols and known to reduce iron absorption. While black tea isn't a significant source of iron, it can inhibit iron absorption when consumed with iron-containing foods or supplements.[13] In contrast, there are other food substances that can increase the absorption of non-heme iron. Vitamin C is recognized for its ability to increase non-heme iron absorption. For example, eating an orange with an iron-fortified cereal in the morning will increase the absorption of the non-heme iron in the cereal, or chopping up green and red peppers (high in vitamin C) in a spinach salad is another demonstration of the principle. The "meat factor" is also a means to increase non-heme iron absorption. While the mechanism has remained elusive, studies have shown that including meat, fish, or poultry with a non-heme iron source increases non-heme iron absorption.[13] For example, adding strips of chicken to a mixed green salad would not only increase the iron content of the salad by adding the meat, but also increase the absorption of the non-heme iron in the vegetables.

Once iron is absorbed into the intestinal cells, the amount of iron that leaves the intestinal cells will depend on body iron levels. If iron levels are good, much of the iron may stay in the intestinal cells as **ferritin**, a storage form of iron. If the iron has not been moved into the body from the intestinal cells within 3 days (3 days is the life span of an intestinal cell), it will be removed from the body as the dead intestinal cells slough off into the intestinal tract. When body iron levels are low, more of the iron will be moved into the blood stream and transported to areas of need such

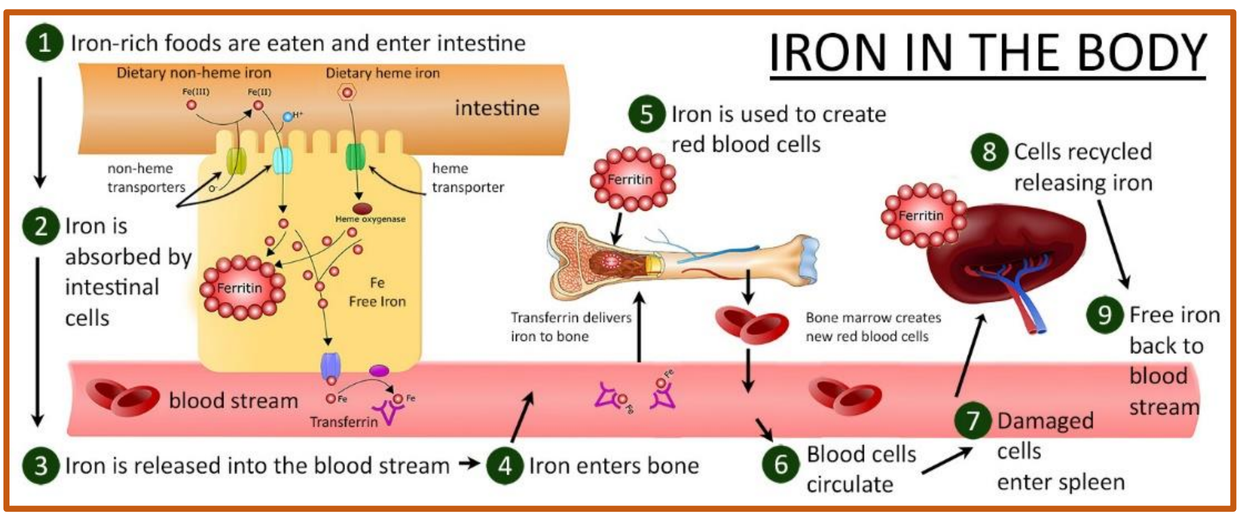


Figure 9: Movement of Iron in the body

as the bone marrow. Once it has been moved into the blood from the GI tract, iron is used and recycled very efficiently. For example, when blood cells die (roughly every 120 days), the body recycles the iron back to the bone marrow where red blood cells are made. The body also stores some iron in the bone marrow, liver, spleen, and skeletal muscle as ferritin. A relatively small amount of iron is lost when skin cells die and in blood loss, such as during menstrual bleeding. The lost iron must be replaced from dietary sources.

Iron-Deficiency and Recommendation

Iron deficiency affects over 2 billion people and is the most common nutritional disorder worldwide.[14,15] It can result from poor dietary intake, poor absorption, increased need or increased losses of iron.[15] In developing countries, the most common causes are poor intake and increased losses due to parasites. In developed countries, common causes would include poor iron intake due to diet preferences (vegetarianism), heavy menstruation, or disease states that affect iron levels such as celiac disease or ulcers.[15] Those at highest risk typically include young growing children, menstruating girls and women, pregnant women, and the elderly. Iron deficiency may be first noted by a reduction in the level of stored iron (ferritin). If the deficiency progresses, iron deficiency anemia can develop. Iron deficiency anemia (a microcytic anemia) is the presence of small, pale red blood cells due to insufficient iron levels in the bone marrow for proper blood cell production. Symptoms of iron deficiency include fatigue, weakness, pale skin, dizziness and pica. A logical connection between many of the symptoms of deficiency and iron's known roles in oxygen delivery and energy metabolism is apparent. Pica is an interesting side effect often associated with iron deficiency. It is characterized by strong cravings for generally non-nutritive substances such as ice, chalk, clay and dirt.

Symptoms of anemia include:

- Fatigue
- Weakness
- Pale Skin
- Dizziness
- And the presence of pica

Iron-deficiency anemia is diagnosed from characteristic signs and symptoms and confirmed with simple blood tests that count red blood cells and determine hemoglobin and iron content in blood. Iron-deficiency anemia is most often treated with iron supplements and increasing the consumption of foods that are higher in available iron. Iron supplements may have some adverse side effects including nausea, constipation, diarrhea, vomiting, and abdominal pain. Reducing the dose at first and then gradually increasing to the full dose often minimizes the side effects of iron supplements. Avoiding foods and beverages high in phytates and other binders and eating foods that increase iron absorption (such as those high in vitamin C), are important dietary strategies for people who have iron-deficiency anemia. Recommended iron intakes are listed in Table 5.

Age Range	RDA	UL
9-13 (male/female)	8 mg/day	40 mg/day
14-18 (male)	11 mg/day	45 mg/day
14-18 (female)	15 mg/day	45 mg/day
Older than 19 (male)	8 mg/day	45 mg/day
19-50 (female)	18 mg/day	45 mg/day
Older than 50	8 mg/day	45 mg/day
Pregnant women- all ages	27 mg/day	45 mg/day
19-50 (Lactating)	9 mg/day	45 mg/day

Table 5: Recommend iron intake levels[5]

Iron Toxicity

The body excretes little iron and therefore there is potential for accumulation of unhealthy amounts in tissues and organs. The body's mechanism to control iron levels in the body is to decrease iron absorption when the iron stores are full. However, iron toxicity can occur when large doses of iron are taken. Iron accumulation or iron overload in certain tissues and organs can cause a host of health problems in children and adults including extreme fatigue, arthritis, joint pain, and severe liver and heart damage. Iron supplements often look like candy to children and can be lethal. Symptoms of toxicity can occur at doses of only 10-20 mg/kg of body weight.[16] It is critical to keep iron supplements out of children's reach.

Iron supplements

There are also genetic disorders that lead to iron overload, even when iron intake is normal. **Hemochromatosis** is one of the more common and well known of these disorders. It occurs in about 1 in 150 people of northern European decent.[13] It is the result of a genetic mutation that leads to abnormal iron absorption and subsequent accumulation of iron in certain tissues such as the liver, pancreas, and heart. The signs and symptoms of hemochromatosis are similar to, but more severe than those of iron overload caused by high intake of iron. In men, hemochromatosis is typically observed by the age of 40, in women it may not be noticed until later in life (due to iron loses from menstruation). It may manifest as severe complications such as diabetes, scarring of the liver, cancer, arthritis or cardiac failure. Treatment for hemochromatosis includes regular blood removal, diet manipulations to reduce iron intake and absorption, and chelation therapy, which uses medications to remove excess iron from the body.[17]

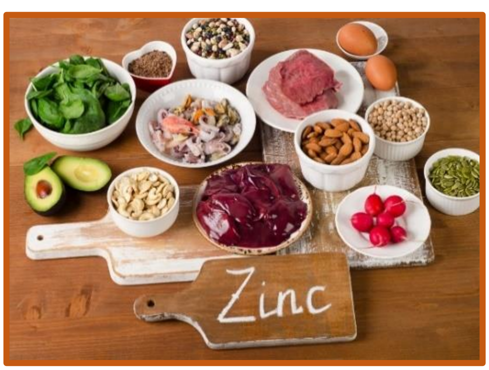
Zinc

Function

Zinc is a cofactor for roughly a hundred enzymes (possibly up to 200) and it is an important structural component of 1,000 or more transcription factors involved in gene expression.[18,19] With the diversity of zinc's functions, it is difficult to summarize the scope of its involvement in the human system. In brief, examples of zinc's involvement in the body include DNA and RNA synthesis, protein synthesis, immunity, carbohydrate metabolism, wound repair, hemoglobin synthesis and tissue and cell growth.

Food sources and bioavailability

Zinc is found in both animal and plant sources. It is more readily available from animal sources due to the common presence of binders in plant sources which decrease its bioavailability. One of the first observations that proved zinc was an essential mineral happened in 1958. A 21-year-old male from Iran presented with severe symptoms including dwarfism, delayed sexual maturation, dry rough skin, lethargy and an enlarged liver and spleen. His diet appeared to be adequate in calories and protein, but he ate little animal protein and all of his bread intake was unleavened bread. The phytates in the unleavened bread played a significant role in inhibiting the absorption of the zinc present in his food. He manifested with a fairly serious zinc deficiency. Once animal sources of zinc were included in his diet, all symptoms of the deficiency resolved.[20]



Foods high in zinc

Animal sources of zinc include: Seafood such as oysters, lobster and crab, red meat, poultry, fortified cereals and dairy products

Plant sources of zinc include: Whole wheat breads, oatmeal, legumes, nuts and seeds and many green veggies

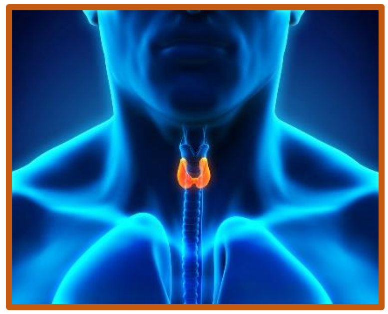
Deficiency and Toxicity

The effects of zinc deficiency are a worldwide concern, particularly in areas where the intake of red meat, seafood, and other animal sources of zinc is limited.[20] Considering the broad role of zinc in the human body, it is not surprising that the effects of zinc deficiency are varied. Symptoms such as impaired growth, diarrhea, delayed sexual maturation, and impaired immunity are common. Zinc deficiency may also manifest as skin lesions, poor fetal development, delayed wound healing, hair loss, poor appetite, and loss of taste.[19,21,22] Excessive intake of zinc can also be hazardous, causing significant intestinal distress such as cramping, nausea and vomiting, suppressed immunity, and interference with the proper function of copper and iron.[19,21]

Iodine

Function

Iodine is essential for the synthesis of thyroid hormones which regulate basal metabolism, growth, and development. The thyroid gland is located on the front of the neck just below the Adam's apple and in front of the trachea (windpipe). When dietary iodine is consumed, the majority is trapped within the thyroid gland. Seventy to eighty percent of the iodine in a human body is concentrated within the thyroid gland.[23]



Thyroid

Food sources and bioavailability

Most of the world's iodine is found in oceans. Over time it has been leached out of soils by flooding, erosion, and glacial action. Some of the iodine will vaporize from the oceans and be returned to the various land masses by rain fall, making coastal soils often richer in iodine.[2] The process of leaching and partial restoration of iodine from soils has left an uneven distribution of iodine in the world's soils, making plant foods an inconsistent source of iodine. Iodine levels can vary as much as 100 times, depending on the iodine content of the soil in which they were grown.[2] The presence of iodine in the oceans means that many types of seafood, such as seaweed and fish, are some of the richest sources of dietary iodine. In the United States, bread products and milk are the primary contributors of dietary iodine. In both cases, at least part of the iodine can be attributed to either an addition of iodine during processing or contamination. Iodine containing sanitizing agents are often used in the milk industry to clean cow udders before milking, and in other stages of the milk processing. This makes a significant contribution to the iodine content of milk. Because of

Sources of Iodine in the US

the issues of iodine distribution and the risk of deficiency globally, the iodization of salt has occurred in over 70 countries worldwide. It is a very inexpensive measure that has resulted in significant health benefits around the world. This practice was instituted in the United States in the 1920's and has been an important factor contributing to the low risk of iodine deficiency in the U.S.

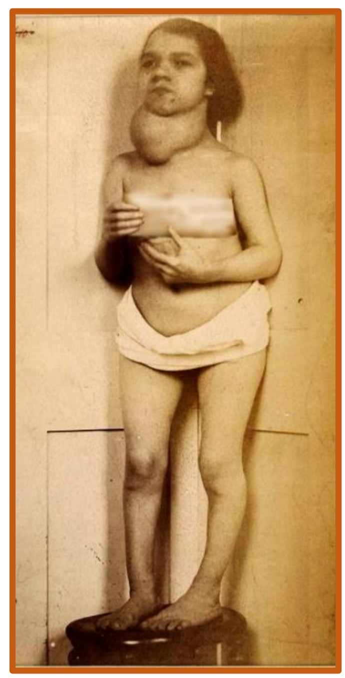

Cruciferous vegetables

Iodine is generally well absorbed, but there are substances that can interfere with the use of iodine in the body. These substances are called **goitrogens** and can be found in cassava, soy, and cruciferous vegetables such as kale, cabbage, broccoli, and cauliflower. While the consumption of these vegetables is certainly encouraged, it is also a reminder that moderation in all things is important.[2]

Deficiency and Toxicity

The World Health Organization (WHO) reports that the incidence of iodine deficiency has diminished by 50% in the last 10 years, but 54 countries are still iodine deficient, impacting more than 2 billion people.[25,26] Iodine deficiency and the resulting hypothyroidism has many signs and symptoms, including fatigue, impaired mental function, sensitivity to cold, weight gain, depression, dry, itchy skin, and paleness. The development of **goiter** (enlargement of the thyroid gland) may often be the most visible sign of chronic iodine deficiency. While these symptoms are concerning, the larger problem occurs in children born to iodine deficient women. Low iodine levels during pregnancy impacts neural development in the developing baby and in severe cases will result in mental retardation, deafness, mutism, and muscle spasticity. Collectively, the fetal effects of iodine deficiency are known as **cretinism**. Overall growth and life expectancy is also affected. World-wide iodine deficiency is one of the major


Women with a goiter


Cretinism and goiter in a female adult

causes of impaired mental development. Excess iodine intake can result in symptoms similar to iodine deficiency.

Fluoride

Fluoride is not considered an essential nutrient. There has not been a specific deficiency associated with a lack of fluoride intake, nor has a specific biochemical function for fluoride been identified.[27] It has gained a place in the DRI recommendations because of its known role in combating tooth decay. The primary way it combats tooth decay is by increasing the strength of the enamel on teeth, making it resistant to decay. It is also recognized that fluoride inhibits the formation of acid from bacteria, and promotes the re-mineralization of teeth.

Trace amounts of fluoride are present in the human body, but levels of fluoride in food are generally low in all the food groups. A few exceptions include some fish and shellfish, tea, and a few grain products. Some water sources are also naturally high in fluoride, but most are not. Reaching levels recommended for protection against dental caries has been achieved through topical applications of fluoridated tooth pastes and rinses, supplements, fluoridation of water, and the consumption of foods produced with fluoridated water. Fluoride was first added to drinking water in 1945 in Grand Rapids, Michigan. The reduction of the incidence in cavities was so apparent its popularity spread rapidly. Now, nearly 75% of the US population has access to fluoridated drinking water. The Centers for Disease Control and Prevention (CDC) reports that fluoridation of water prevents, on average, 25% of cavities in children and adults.[28] Recommended levels are at 0.7 parts per million, but should not greatly exceed that.[29]

In addition to strengthening teeth, research is being conducted to assess if fluoride will also strengthen bone and possibly protect against osteoporosis. No evidence clearly supports this connection at this time. As with most nutrients, fluoride intake must be kept within appropriate levels. Extremely high doses of fluoride taken in a short amount of time can cause symptoms anywhere from nausea and vomiting to death. The likelihood of this happening is remote. More commonly seen is the discoloration of teeth that is a result from a mild chronic overconsumption of fluoride in children called fluorosis. It can range from white flecks in the teeth that are largely unnoticeable to more severe yellow to dark brown stains with possible pitting of the enamel. The incidence of

Fluorosis

fluorosis has been increasing in the US and other parts of the world since fluoridation of water was instigated. This can be prevented by ensuring proper intake of fluoride. Parents should consult with health professionals when their children are young to correctly utilize fluoridated toothpastes and rinses and fluoride supplements in conjunction with the fluoride levels of the water in their community. Fluorosis can only develop in teeth before eruption from the gums, so primary prevention of fluorosis needs to be during the years of tooth development.

Additional essential trace minerals

Examples of function and food sources for the remaining trace minerals are summarized in Table 6. The listed information is by no means a comprehensive summary of each of the minerals, but is simply to demonstrate significant functions and food sources for these minerals. Generally, the functions of these minerals are carried out as cofactors to enzymes. Each of these minerals can be found in plant food, but the levels vary depending on the soil composition in which they were grown.

Trace mineral	Example of a function	Some food sources
Copper	Regulation of iron, antioxidant	Meats, shellfish, nuts, seeds, legumes
Molybdenum	Oxidation/reduction reactions	Meat, fish, poultry, legumes, grain products
Selenium	Antioxidant	Seafood
Chromium	Blood glucose regulation	Meat, fish and poultry, whole grains, dairy products
Manganese	Nutrient metabolism	Nuts, leafy vegetables, whole grains, legumes

Table 6: Functions and food sources of select trace minerals[30]

Chapter 10: Vitamins

10.1 Introduction to Vitamins

The identification and importance of carbohydrate, protein, lipids, and minerals in the dietary intake were established during the late 17th and early 18th century. However, the discovery of vitamins did not occur until the late 18th and early 19th century. During the end of the 1800's, scientists conducted deprivation studies where mixtures containing only carbohydrate, protein, lipids, and minerals were fed to animals. The animals did not survive on these diets which indicated the diets were lacking other substances that were essential to health. Referring to these studies, Gerrit Grijns in 1901 stated, "There occur in natural foods, substances, which cannot be absent without serious injury."[1]

In 1912, while Casimir Funk studied the disease beriberi and an antiberiberi factor, he found the factor contained an amine group. He hypothesized other conditions such as scurvy, rickets, and pellagra was caused by deficiencies of similar compounds containing amine groups. He thought these substances contained vital amines and coined the name "vitamines." After it was discovered not all the substances contained an amine group, the "e" was dropped and the term became vitamin.[2]

10.2 Characteristics of Vitamins

Vitamins are **organic compounds** that are needed by the body in very small amounts. Since the body cannot make them or makes them in insufficient amounts, vitamins are essential to consume. Vitamins are required to perform many functions in the body such as making red blood cells, synthesizing bone tissue, and playing a role in normal vision, nervous system function, and immune system function.

Organic compounds – a chemistry term for compounds containing carbon attached to other elements such as hydrogen, oxygen, and nitrogen. Carbohydrate, protein, lipids, and vitamins are organic compounds. This differs from organic food which refers to how the food was grown or raised.

Vitamins are classified by their biological functions, and some of the vitamins have more than one active chemical structure capable of meeting a nutritional requirement. The groups of chemically related compounds are referred to as **vitamers**.[3,4] For example, vitamers for vitamin B_6 include pyridoxine, pyridoxal, and pyridoxamine.

Water-Soluble and Fat-Soluble Vitamins

Vitamins can be categorized as either fat-soluble or water-soluble (see Table 1). Water-soluble vitamins readily disperse in a water solution, whereas the fat-soluble vitamins will not. These differences in solubility affect how they are absorbed, transported, stored, and excreted by the body. For example, water-soluble vitamins readily travel in the blood which is water-based, but fat-soluble vitamins need a transporter.

Water-soluble Vitamins
B-Vitamins
Thiamin
Riboflavin
Niacin
Biotin
Pantothenic acid
Vitamin B_6 (Pyridoxine)
Folate
Vitamin B_{12} (Cobalamin)
Vitamin C (Ascorbic acid)

Fat-soluble Vitamins
Vitamin A (Retinol)
Vitamin D (Cholecalciferol)
Vitamin E (Alpha-tocopherol)
Vitamin K

Table 1: Water-soluble and fat-soluble vitamins (most common vitamer listed for select vitamins)

Stability of Vitamins

The structure of certain vitamins often degrade the longer it is stored, the higher the temperature, and the greater amount of exposure the food has to light and air. After the vitamin structure has broken down, it will no longer be able to function as a vitamin. Since vitamin C, a water-soluble vitamin, is sensitive to heat, light, and oxygen, it is often used as an indicator of nutrient degradation (see Figure 1).[5]

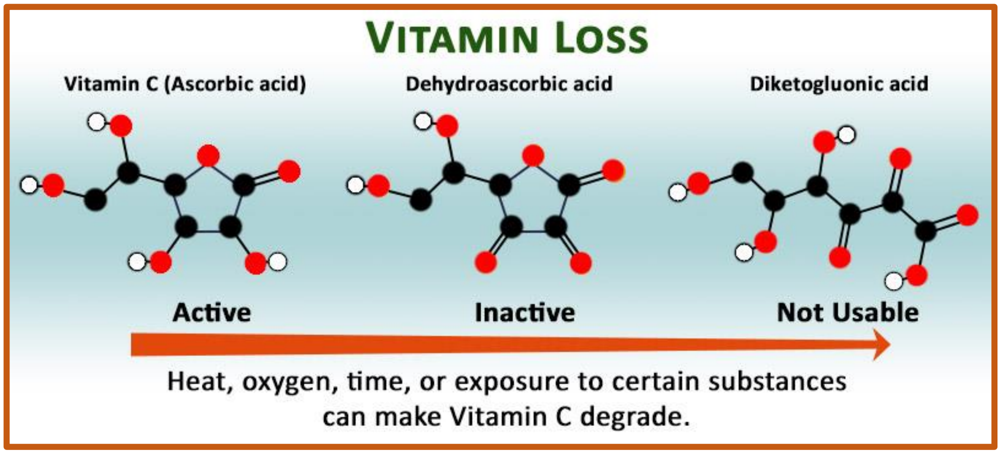


Figure 1: Vitamin C degradation

The highest amounts of vitamins in fruits and vegetables will be immediately post-harvest when the plant has reached peak maturity. Nutrient retention for fresh fruits and vegetables can be maximized if they are handled carefully and stored at cool temperatures. Surprisingly, commercially frozen vegetables have either the same or higher amounts of vitamin C as those found "market fresh" because the frozen vegetables are usually harvested, blanched, and quick-frozen within a day and "market fresh" vegetables typically spend 3 to 7 days in retail distribution and storage before they are bought.[6]

Recommendations to minimize vitamin loss in foods include:

- Cut vegetables and fruits close to cooking and serving times.
- Steam, microwave, or use small quantities of water to minimize the amount of water-soluble vitamins leaching out of the food.
- Do not overcook vegetables.
- Do not add baking soda when cooking vegetables or legumes because baking soda makes the water alkaline which can destroy certain vitamins (such as thiamin).
- Store canned goods at cool temperatures and use canned goods within a year.

Provitamins

A **provitamin** is a substance found in food that can be converted into a vitamin within the body. An example of a provitamin is beta-carotene, a pigment found in many fruits and vegetables, which can be converted to vitamin A (see Figure 2).

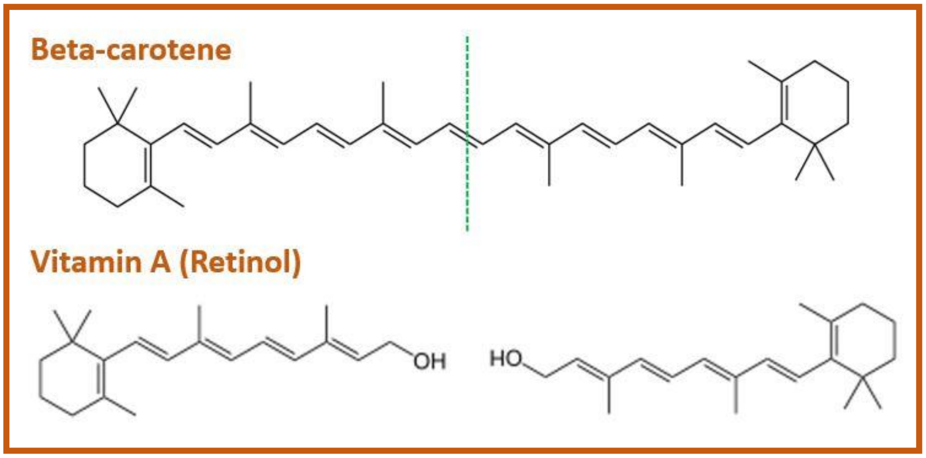


Figure 2: Beta-carotene can be converted by the body into vitamin A (retinols)

Antioxidant

Oxidation by free radicals in the body can cause cellular damage. A free radical is a molecule with an unpaired electron. The free radical's unbalanced "electrical field" makes the free radical highly unstable and it needs another electron to stabilize it. Stealing an electron (oxidizing) from another molecule stabilizes the free radical but damages the other molecule. An antioxidant can donate an electron to the free radical and remain stable, thus protecting the other molecules from oxidative damage (see Figure 3). Vitamin C, vitamin E, and beta-carotene (a provitamin for vitamin A) are antioxidants.

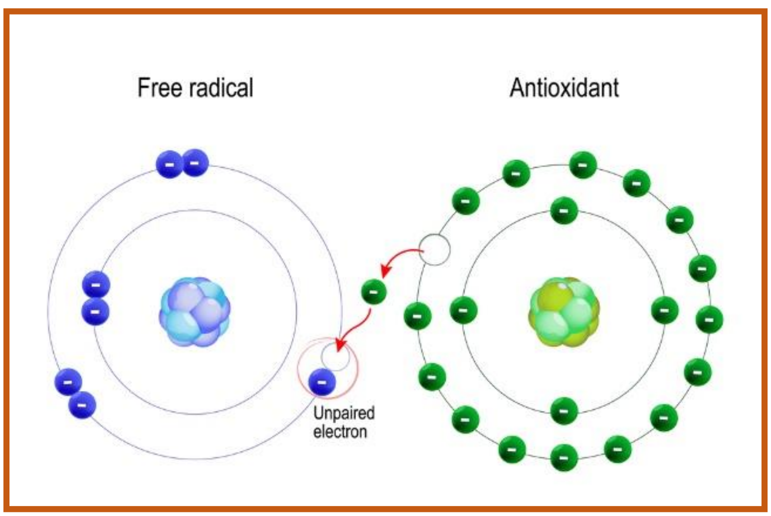


Figure 3: Antioxidants can donate an electron to neutralize free radicals

Coenzymes

A **coenzyme** is an organic non-protein compound that activates an enzyme so it can work (see Figure 4). The water-soluble vitamins and vitamin K can function as a coenzyme.

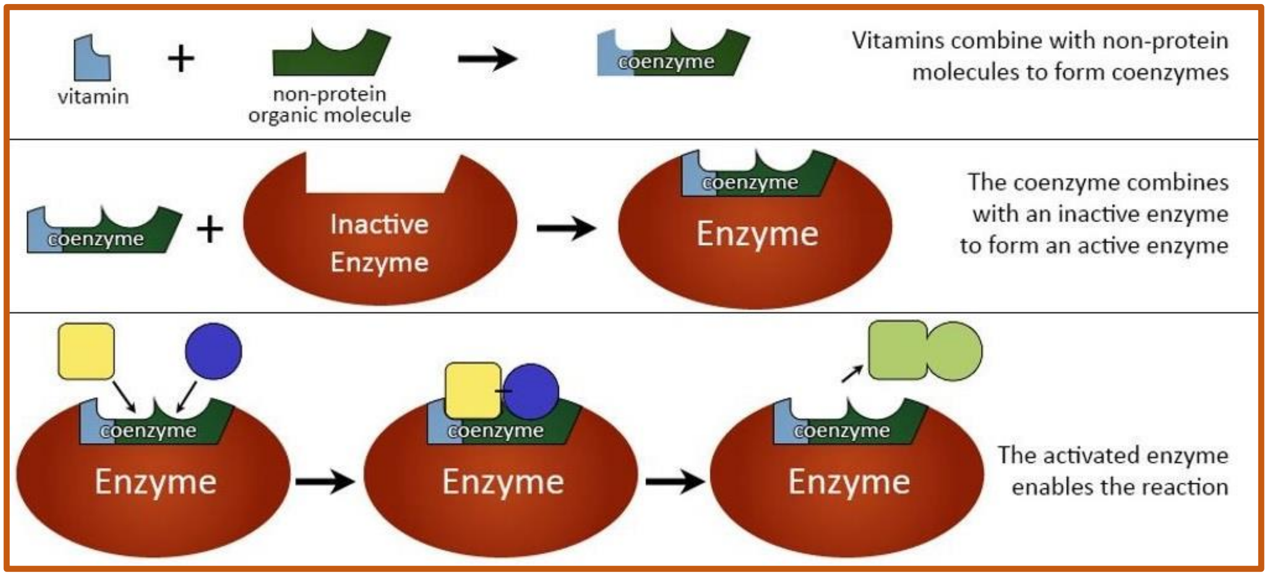


Figure 4: Coenzymes

Bioavailability

Bioavailability refers to the body's ability to absorb the nutrient into the digestive tract and utilize it. A number of factors can influence the bioavailability of vitamins. For example, fat-soluble vitamins have a higher bioavailability when there is at least a small amount of dietary fat consumed at the same time. A fat-free dietary intake lowers the bioavailability.[7,8,9,10] Another factor that may affect a vitamin's bioavailability is the amount that is consumed. For example, when 30 to 180 milligrams of vitamin C is consumed in a day, approximately 70 to 90% is absorbed. However, when doses of 1 gram (1,000 milligrams) or higher are consumed, absorption drops to less than 50%.[11]

10.3 Water-Soluble Vitamins

Thiamin

Thiamin, also known as vitamin B_1, has coenzyme and non-coenzyme functions in the body. Thiamin acts as a coenzyme in carbohydrate metabolism to help convert pyruvate to acetyl CoA. Thiamin also has a coenzyme role in the synthesis of components of RNA, DNA, and ATP. Thiamin has non-coenzyme roles in brain functions, muscle contraction, nerve tissue repair, and the immune system.[12]

Thiamin Sources

Thiamin food sources include whole grains, enriched grains, pork, and fish. Food groups that do not contain much thiamin include dairy and most fruits. Thiamin can be destroyed by excessive heat, and so minimizing cooking times is recommended.

Thiamin Recommendations

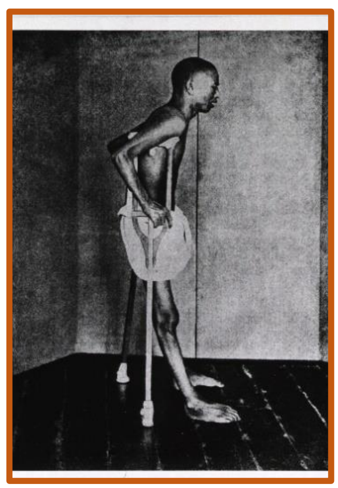
The RDA for thiamin increases as an infant grows, but once adulthood is reached, it remains constant at 1.2 milligrams per day for males and 1.1 milligrams per day for non-pregnant women (see Table 2).

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.2 mg*	0.2 mg*		
7-12 months	0.3 mg*	0.3 mg*		
1-3 years	**0.5 mg**	**0.5 mg**		
4-8 years	**0.6 mg**	**0.6 mg**		
9-13 years	**0.9 mg**	**0.9 mg**		
14-18 years	**1.2 mg**	**1.0 mg**	**1.4 mg**	**1.4 mg**
19-50 years	**1.2 mg**	**1.1 mg**	**1.4 mg**	**1.4 mg**
51+ years	**1.2 mg**	**1.1 mg**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations.

Table 2: Thiamin DRI recommended intakes[13]

Thiamin Deficiency and Toxicity



BeriBeri

Historically, the thiamin deficiency beriberi was prevalent in societies whose main dietary staple was polished white rice. During the harvesting of rice, the husk was taken off the rice, resulting in brown rice. Then the brown rice was polished to remove the bran layer which contained most of the thiamin. The resulting polished white rice was a poor dietary source of thiamin.

There are two types of beriberi: dry and wet. Symptoms of dry beriberi include a loss of muscle function or paralysis of the lower legs. Wet beriberi can cause an enlarged heart, edema in the lower legs, and shortness of breath.[14] Today beriberi is rare in the United States because thiamin is enriched (added back) to processed grains. However, beriberi still occurs in refugee camps where the primary source of food is polished rice that is not fortified.[15]

Alcoholics are at risk for a thiamin deficiency known as Wernicke-Korsakoff Syndrome. Up to 80% of people with chronic alcoholism have a thiamin deficiency.[15] Usually alcoholics have a low intake of thiamin due to alcohol displacing good food sources of thiamin. Also, alcohol decreases the absorption of thiamin and increases thiamin excretion. Symptoms of Wernicke-Korsakoff Syndrome include impaired muscle coordination, involuntary eye movements, memory loss, and confusion.[14]

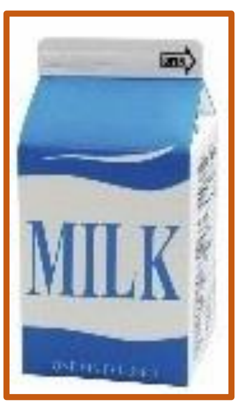
There are no reports of adverse effects from excessive thiamin intake by food and supplements. Hence, a UL has not been established for thiamin.[16]

Riboflavin

Riboflavin, also known as vitamin B_2, is an essential component of coenzymes FAD and FMN. These coenzymes play major roles in energy (ATP) production, cellular function, and growth. The riboflavin coenzymes have several other roles including the synthesis of niacin from the provitamin tryptophan and the activation of vitamin B6.

Riboflavin in water (notice the bright yellow color)

The "flavin" portion of riboflavin gives a bright yellow color to riboflavin, an attribute that helped lead to its discovery as a vitamin. When riboflavin is taken in excessive amounts, very little of it is stored in the body tissues. The majority of the excess riboflavin is excreted in the urine, giving the urine a bright yellow color.[17]



Milk packaged in an opaque container

Riboflavin Sources

Riboflavin food sources include milk, cheese, meat, eggs, whole grains, and enriched grains (riboflavin is one of the five nutrients added back to the enriched grains). Riboflavin is relatively stable during cooking but can rapidly break down when exposed to light. Milk is often packaged in opaque containers to protect the riboflavin from the light.

Riboflavin Recommendations

Similar to thiamin, the RDA for riboflavin increases as an infant grows, but once adulthood is reached, it remains constant at 1.3 milligrams per day for males and 1.1 milligrams per day for non-pregnant women (see Table 3).

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.3 mg*	0.2 mg*		
6-12 months	0.4 mg*	0.3 mg*		
1-3 years	**0.5 mg**	**0.5 mg**		
4-8 years	**0.6 mg**	**0.6 mg**		
9-13 years	**0.9 mg**	**0.9 mg**		
14-18 years	**1.3 mg**	**1.0 mg**	**1.4 mg**	**1.6 mg**
19-50 years	**1.3 mg**	**1.1 mg**	**1.4 mg**	**1.6 mg**
51+ years	**1.3 mg**	**1.1 mg**		

*Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations.

Table 3: Riboflavin DRI recommended intakes[13]

Riboflavin Deficiency and Toxicity

Riboflavin deficiency, ariboflavinosis, is often accompanied by other dietary deficiencies (most notably protein) and can be common in people that suffer from alcoholism. The signs of ariboflavinosis include dry, scaly skin, mouth inflammation and angular cheilitis, magenta tongue, and sore throat.[17]

Angular cheilitis

A UL has not been established for riboflavin because no adverse effects from riboflavin food and supplement intakes have been reported.[17] The excess riboflavin is rapidly excreted in the urine, giving the urine a bright yellow color.

Niacin

Niacin, also known as vitamin B_3, has two vitamers: niacinamide and nicotinic acid (not related to nicotine). Niacin is a component of the coenzymes NADH and NADPH, which are involved in the catabolism and anabolism of carbohydrates, lipids, and proteins. The NADH coenzyme is a carrier of the high energy electrons produced in glycolysis and the citric acid cycle and transfers them to the electron-transport chain to make ATP. NADPH is required for the anabolic pathways of fatty acid and cholesterol synthesis.[18]

Niacin Sources

Excellent food sources of niacin include chicken, tuna, turkey, beef, and fish. Other good sources include peanuts, whole grains, and enriched grains (niacin is one of the five nutrients added back to the enriched grains).

Although corn contains niacin, the niacin is bound by substances which drastically lower its bioavailability. If corn is treated in an alkaline solution, such as lime water, the bound niacin is released and its bioavailability is increased.

In humans, niacin can be synthesized from the essential amino acid tryptophan (see Figure 5). Tryptophan is the provitamin for niacin. The synthesis process requires riboflavin, vitamin B_6, and iron. It usually requires 60 milligrams of tryptophan to make 1 milligram of niacin. Since both niacin and tryptophan are considered sources of niacin, a unit of measure called niacin equivalents (NEs) was developed to account for the potential niacin from tryptophan. One niacin equivalent is equal to one milligram of niacin or 60 mg of tryptophan.[18]

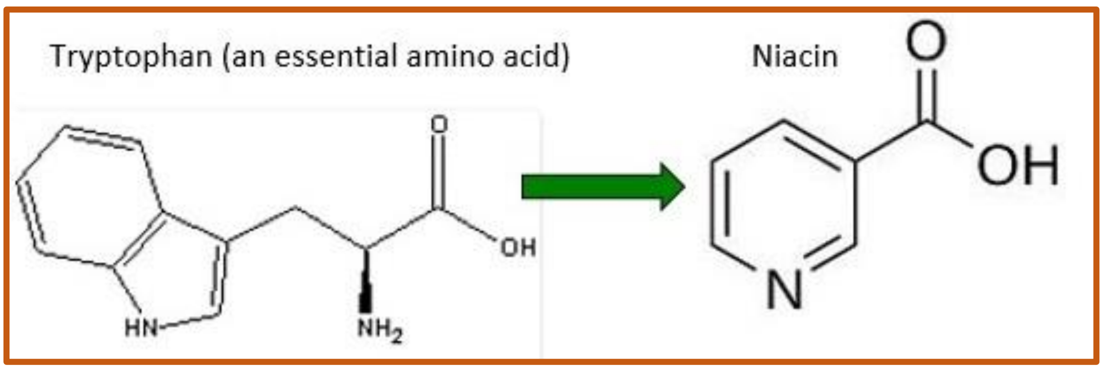


Figure 5: Conversion of tryptophan (an essential amino acid) to niacin

Niacin Recommendations

The recommendations for niacin are given in niacin equivalents (NE) to account for the niacin found in food as well as the niacin that can be synthesized from tryptophan.

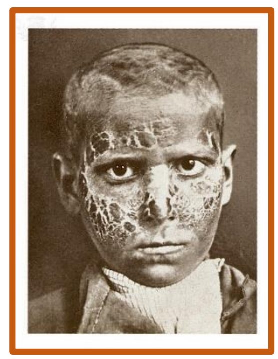
Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	2 mg NE*	2 mg NE*		
7-12 months	4 mg NE*	4 mg NE*		
1-3 years	**6 mg NE**	**6 mg NE**		
4-8 years	**8 mg NE**	**8 mg NE**		
9-13 years	**12 mg NE**	**12 mg NE**		
14-18 years	**16 mg NE**	**14 mg NE**	**18 mg NE**	**17 mg NE**
19-50 years	**16 mg NE**	**14 mg NE**	**18 mg NE**	**17 mg NE**
51+ years	**16 mg NE**	**14 mg NE**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations.
NE = niacin equivalent.

Table 4: Niacin DRI recommended intakes[13]

Niacin Deficiency and Toxicity

Pellagra is a disease resulting from severe niacin deficiency. During the early 1900s, pellagra was common in parts of Europe and the United States where corn was the dietary staple. Two factors contributed to this. First, the niacin in corn is bound and has a low bioavailability. Second, corn is a poor source of tryptophan, the provitamin for niacin.



A young boy suffering from pellagra

One of the characteristics of pellagra is a pigmented rash that develops in areas exposed to the sunlight. Other features included diarrhea, depression, fatigue, and loss of memory.[18] The symptoms of pellagra have been referred to as the three D’s: dermatitis, diarrhea, and dementia. Death, a fourth D, can occur if the pellagra is not treated.

There have been no adverse effects from consuming niacin in the quantities found naturally in foods. However, taking higher doses of nicotinic acid in supplements can cause flushing, a vasodilatory effect that causes a reddened flush on the face, arms, and chest often accompanied by a burning, itching sensation.[18] Other symptoms from high doses of nicotinic acid include gastrointestinal problems, liver dysfunction, and impaired glucose tolerance. Due to these adverse effects, a tolerable upper limit has been established. The adult UL is 35 mg/day.[18]

High doses of nicotinic acid (greater than 1000 milligrams per day) can lower total blood cholesterol and raise HDL cholesterol. The impact of using high doses of nicotinic acid on cardiovascular risk is not established.[19] Although nicotinic acid is considered a nutrient, it should be approached as if it were a medication and only used under the supervision of a qualified health care provider when high pharmacological doses are used.[20]

Biotin

Biotin acts as a coenzyme in several of the energy metabolism pathways. It is also needed for the synthesis of glucose.

Biotin Sources

Good food sources of biotin include peanuts, liver, eggs, and dairy foods. Meat and fruit are poor sources of biotin.

Another source of biotin is from bacteria in the large intestine. Although bacteria-produced biotin can be absorbed in the large intestine, the relative contribution of bacteria-produced biotin towards the body's need is not known.[21]

Biotin Recommendations

The research for biotin recommendations is limited, and RDA recommendations could not be established. The biotin recommendations for all age groups are Adequate Intakes (AIs).[23]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	5 mcg*	5 mcg*		
7-12 months	6 mcg*	6 mcg*		
1-3 years	8 mcg*	8 mcg*		
4-8 years	12 mcg*	12 mcg*		
9-13 years	20 mcg*	20 mcg*		
14-18 years	25 mcg*	25 mcg*	30 mcg*	35 mcg*
19-50 years	30 mcg*	30 mcg*	30 mcg*	35 mcg*
51+ years	30 mcg*	30 mcg*		

* Indicates Adequate Intake recommendation.

Table 5: Biotin DRI recommended intakes[13]

Biotin Deficiencies and Toxicities

Biotin deficiency is rare but can be caused by three situations. First, eating large amounts of raw egg whites over an extended period can cause a biotin deficiency. In raw egg whites, there is a protein called avidin which tightly binds to biotin and makes it unavailable for absorption. When the egg white is cooked, the protein is denatured and broken down, thus releasing the biotin. Experimentally it has been determined a dietary intake would need to provide 30% of its calories from raw eggs to produce a biotin deficiency.[22] For an individual that needs 2400 Calories per day, 30% would be 720 Calories, or 12 raw eggs. The second cause of biotin deficiency is a rare genetic condition that impairs intestinal biotin absorption. Third, biotin deficiency can be caused by prolonged intravenous (IV) feedings without biotin supplementation. Symptoms of biotin deficiency include hair loss, dermatitis, and depression.

A UL has not been established for biotin because no adverse effects from food and supplement intakes have been reported in humans.[23]

Pantothenic acid

Pantothenic acid is a part of coenzyme A (see Figure 6), which plays a key role in energy metabolism.

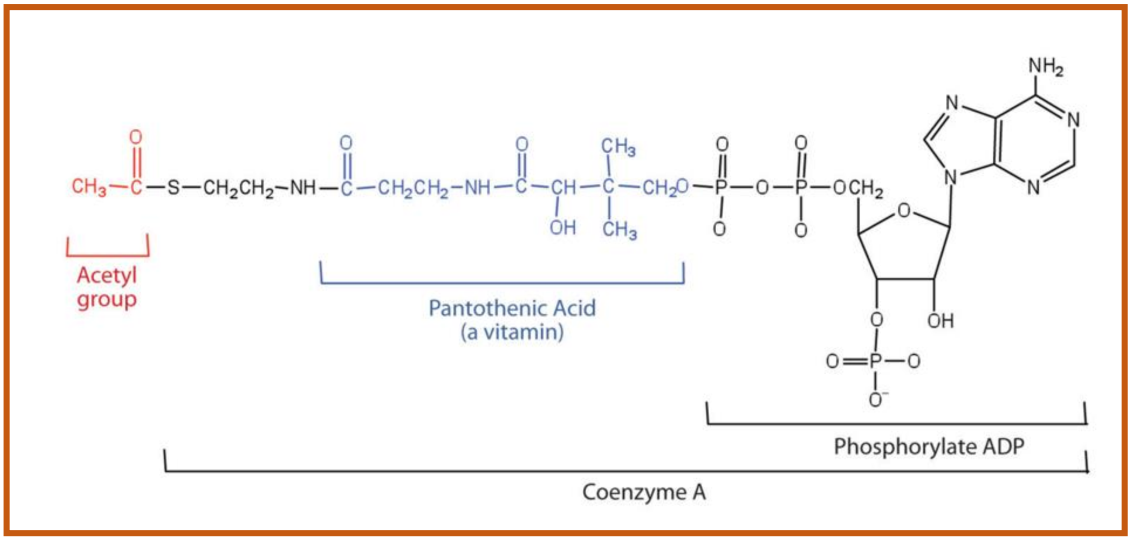


Figure 6: Acetyl-CoA = Coenzyme A and an acetyl group. Pantothenic acid is part of coenzyme A

Pantothenic Acid Recommendations

The research for pantothenic acid recommendations is limited, and RDA recommendations could not be established. The pantothenic acid intake recommendations for all age groups are Adequate Intakes (AIs).

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	1.7 mg*	1.7 mg*		
6-12 months	1.8 mg*	1.8 mg*		
1-3 years	2 mg*	2 mg*		
4-8 years	3 mg*	3 mg*		
9-13 years	4 mg*	4 mg*		
14-18 years	5 mg*	5 mg*	6 mg*	7 mg*
19-50 years	5 mg*	5 mg*	6 mg*	7 mg*
51+ years	5 mg*	5 mg*		

* Indicates Adequate Intake recommendation.

Table 6: Pantothenic acid DRI recommended intakes[13]

Pantothenic acid Sources

Pantothenic acid is found in most foods. The name pantothenic is based on the Greek word *pantothen* which means from all sides or everywhere.

Pantothenic acid Deficiencies and Toxicities

A pantothenic acid deficiency is rare. Symptoms include a sensation of burning in the feet, fatigue, irritability, numbness, muscle pain, and cramps.

A UL has not been established for pantothenic acid because no adverse effects from food and supplement intakes have been reported in humans or animals.[24]

Vitamin B_6

Vitamin B_6 is the generic name for six vitamers and plays a coenzyme role to over 100 enzymes. Most of vitamin B_6's coenzyme roles are involved with protein metabolism, two of which are facilitating deamination and transamination (discussed in the Protein chapter). Vitamin B_6 also plays a coenzyme role in the release of glucose from glycogen breakdown, the synthesis of multiple neurotransmitters, the conversion of tryptophan to niacin, and the synthesis of heme.[25,26]

Vitamin B_6 Sources

Vitamin B_6 is found in fish, organ meats, other meats, potatoes, and several non-citrus fruits such as bananas. Ready-to-eat fortified cereals provide a significant source of vitamin B_6 in the United States. Although there is vitamin B_6 in whole grains, significant amounts are lost in the refinement process and not added back in the enrichment process (refer to Chapter 5, Figure 18).

Vitamin B_6 Recommendations

The DRI recommendations for vitamin B6 are listed in Table 8.

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.1 mg*	0.1 mg*		
7-12 months	0.3 mg*	0.3 mg*		
1-3 years	**0.5 mg**	**0.5 mg**		
4-8 years	**0.6 mg**	**0.6 mg**		
9-13 years	**1.0 mg**	**1.0 mg**		
14-18 years	**1.3 mg**	**1.2 mg**	**1.9 mg**	**2.0 mg**
19-50 years	**1.3 mg**	**1.3 mg**	**1.9 mg**	**2.0 mg**
51+ years	**1.7 mg**	**1.5 mg**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations.

Table 7: Vitamin B_6 DRI recommended intakes[13]

Vitamin B_6 Deficiencies and Toxicities

A severe vitamin B_6 deficiency in the United States is relatively rare.[27, 28] The importance of vitamin B_6 in infant nutrition was illustrated during the 1950s when several infants fed an infant formula low in vitamin B_6 experienced convulsions. The formula company had used excessive heat treatments to sterilize the formula, which in turn, destroyed most of the vitamin B_6 in the formula.[29]

The groups at risk for a vitamin B_6 deficiency include alcoholics and the elderly with poor dietary intakes. One sign of a deficiency is microcytic anemia because vitamin B_6 is required for heme synthesis. Because the hemoglobin content is lower, the red blood cell has less capacity for carrying oxygen, resulting in muscle weakness, fatigue, and shortness of breath. Other signs include dermatitis, depression, and a weakened immune system.[28]

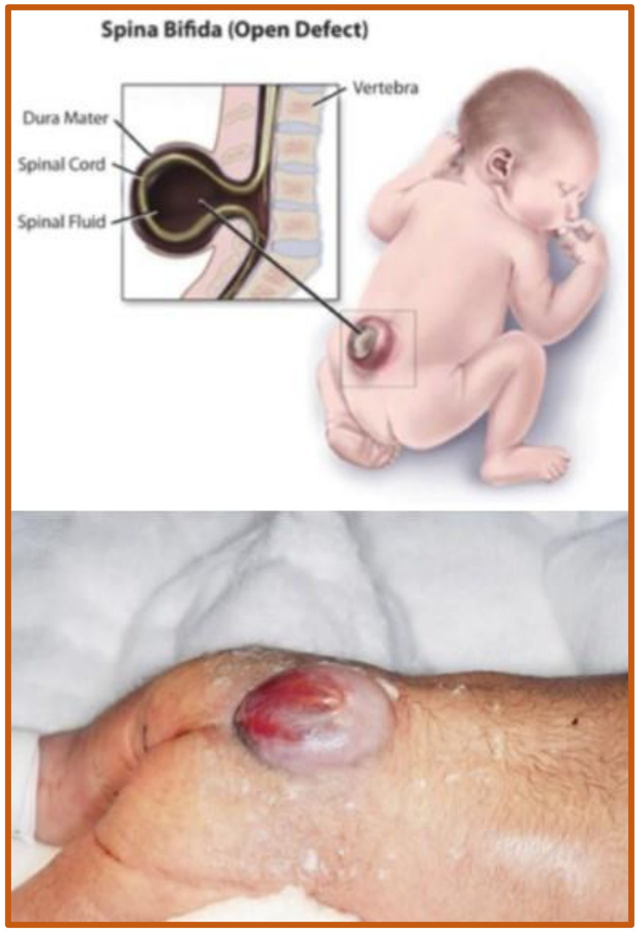
Although vitamin B_6 is a water-soluble vitamin and can be excreted in the urine, large supplementary doses (2000 to 6000 milligrams of vitamin B_6) over two to forty months can cause neuropathy and impaired motor control.[25] Supplemental doses greater than 500 milligrams per day taken over time can cause a sensory neuropathy (tingling in hands and feet). Adverse effects have not been found at doses under 200 mg per day. An adult UL of 100 mg per day has been established to prevent neuropathy problems.[27] No adverse effects have been reported with high intakes of vitamin B_6 from food sources.[25]

Folate

Folate, formerly known as vitamin B_9 or folacin, is a generic term for the folate vitamers naturally occurring in food and for folic acid, the synthetic form used in fortified foods and supplements.[30,31] Folate acts as a coenzyme in the synthesis of nucleic acids (DNA and RNA) and amino acid metabolism.

Folate and Health

Folate is essential for the growth and specialization of cells of the central nervous system. Adequate folate intake prior to and during pregnancy can lower the risk of the baby having serious neural tube defects. The two most common neural tube defects are spina bifida (incomplete closure of the neural tube in the spine) and anencephaly (missing parts of the brain and skull). Babies born with anencephaly cannot survive. Babies born with spina bifida often experience severe physical disabilities.[32]



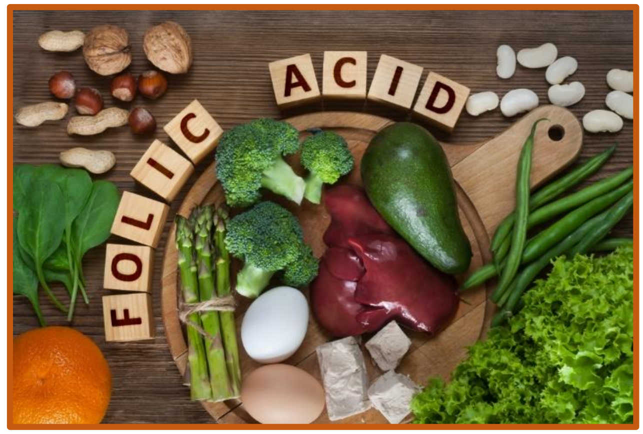
Spina bifida

Although the exact cause of neural tube defects has not been identified, adequate intake of folic acid has significantly lowered the incidence of neural tube defects. The Center for Disease Control and Prevention recommends all women consume 400 micrograms of folic acid every day. This is the adult woman's RDA for folate. In order for folic acid to help prevent neural tube defects, a woman needs to start getting 400 micrograms at least one month prior to getting pregnant.[32]

Folic acid has been added to several fortified foods, especially ready-to-eat cereals. In January 1998, the U.S. Food and Drug Administration required folate to be added to enriched grains to decrease the prevalence of neural tube defects in the United States. Since the fortification of grains in 1998, the prevalence of neural tube defects in the United States has decreased approximately 30%.[33,34] Other countries, such as Canada, Costa Rica, Chile, and South Africa have also established mandatory folic acid fortification programs.[30]

Folate Sources

Green leafy vegetables such as spinach are good sources of folate. The name folate came from the Latin word folium which means leaf or foliage. Folate is also found in liver, several vegetables, legumes, yeast, asparagus, and orange juice.



Foods high in folate

The bioavailability of folate occurring naturally in foods is variable. In general, the synthetic folic acid, found in supplements, fortified foods, and enriched grains, is approximately 1.7 times more bioavailable than the folates occurring naturally in foods. The Dietary Folate Equivalent (DFE) was devised to account for the difference in the bioavailability of folic acid and natural folates.[35]

Dietary Folate Equivalents = micrograms of food folate + (1.7 X micrograms of folic acid)

Folate Recommendations

The DRI recommendations for folate are given in dietary folate equivalents to account for the difference in bioavailability of folate found naturally in food and synthetic folic acid (see Table 9).[35]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	65 mcg DFE*	65 mcg DFE*		
7-12 months	80 mcg DFE*	80 mcg DFE*		
1-3 years	**150 mcg DFE**	**150 mcg DFE**		
4-8 years	**200 mcg DFE**	**200 mcg DFE**		
9-13 years	**300 mcg DFE**	**300 mcg DFE**		
14-18 years	**400 mcg DFE**	**400 mcg DFE**	**600 mcg DFE**	**500 mcg DFE**
19-50 years	**400 mcg DFE**	**400 mcg DFE**	**600 mcg DFE**	**500 mcg DFE**
51+ years	**400 mcg DFE**	**400 mcg DFE**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations.
DFE = Dietary Folate Equivalent.

Table 8: Folate DRI recommended intakes[13]

Folate Deficiencies and Toxicities

Folate plays an important role in the synthesis of DNA and RNA. Hence, rapidly dividing cells are most affected by folate deficiency. Red blood cells are continuously being synthesized in the bone marrow from dividing stem cells. A consequence of folate deficiency is macrocytic (large cell) anemia, also called megaloblastic anemia (see Figure 7). Without adequate folate, red blood cells are unable to produce DNA and RNA fast enough to divide properly. The result is fewer red blood cells that are large.

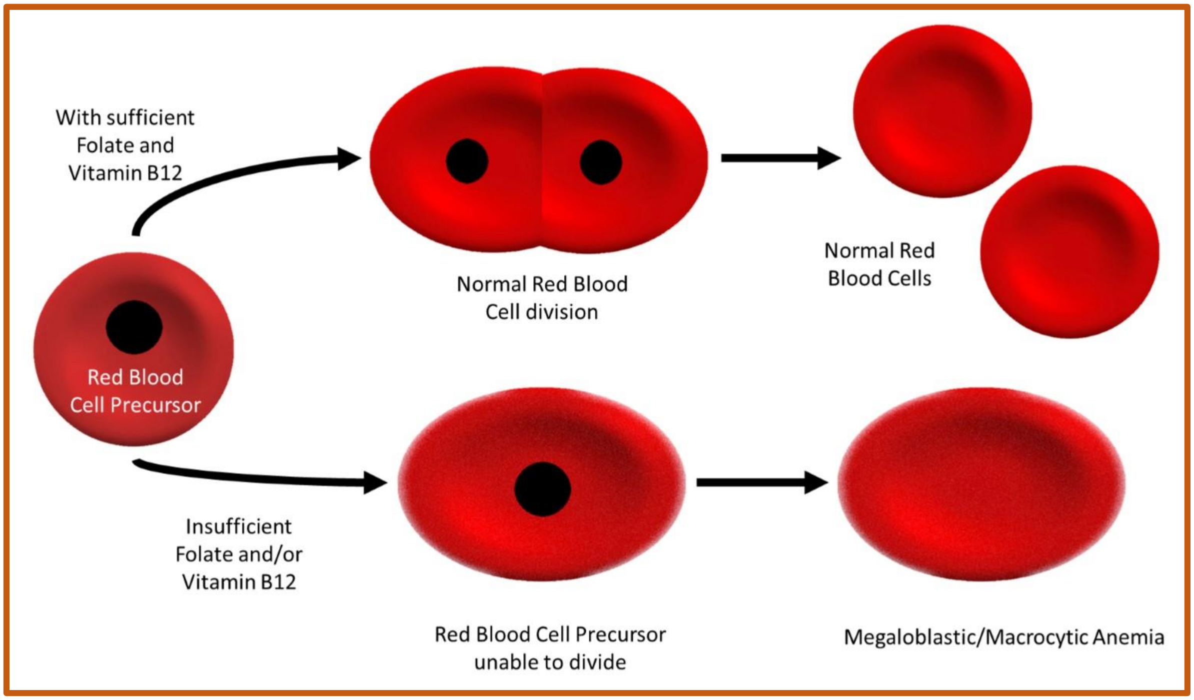


Figure 7: Megaloblastic/macrocytic anemia causes by insufficient folate and/or vitamin B12

Megaloblastic anemia is also an early symptom of a vitamin B_{12} deficiency. This is the same type of anemia that occurs with a folate deficiency. If a person takes large doses of folic acid, they will not develop megaloblastic anemia from a vitamin B_{12} deficiency. However, folic acid will not prevent the progressive damage to the neurological system that is caused by a more severe vitamin B_{12} deficiency. Hence, large doses of folic acid will hide or mask the early stages of a vitamin B_{12} deficiency. To avoid this, a UL for folic acid was established. No adverse effects have been associated with excess folate from food.[35]

Vitamin B_{12}

Vitamin B_{12}, also called cobalamin, is unique among the vitamins because it contains a mineral (cobalt). It also has the most complex structure of the vitamins. Vitamin B_{12} has several vitamers. The two vitamers actively used by humans are methylcobalamin and 5-deoxyandeosylcobalamin. Cyanocobalamin (the form of vitamin B_{12} usually found in supplements) and hydroxocobalamin can be readily converted by the body to these forms.[36]

Vitamin B_{12} functions as a coenzyme for two enzymes and plays a role in fat and protein catabolism, and maintaining the myelin sheath on nerve cells. Vitamin B_{12} also works with folate in the synthesis of methionine (an amino acid) from homocysteine, and the synthesis of DNA and RNA. These two vitamins depend on each other for activation in these functions. Early deficiency symptoms in vitamin B_{12} often has similar health consequences as a folate deficiency.

Vitamin B_{12} Absorption

The absorption of vitamin B_{12} is a complex process (see Figure 8). Vitamin B_{12} found naturally in animal products is bound by the food proteins and is not bioavailable for absorption. In the stomach, hydrochloric acid and pepsin (a protein digestive enzyme) digests the food proteins and releases vitamin B_{12}. While in the stomach, the freed vitamin B_{12} then binds with the R-protein (produced by the salivary glands). The stomach also produces **intrinsic factor**, a substance necessary for good vitamin B_{12} absorption.

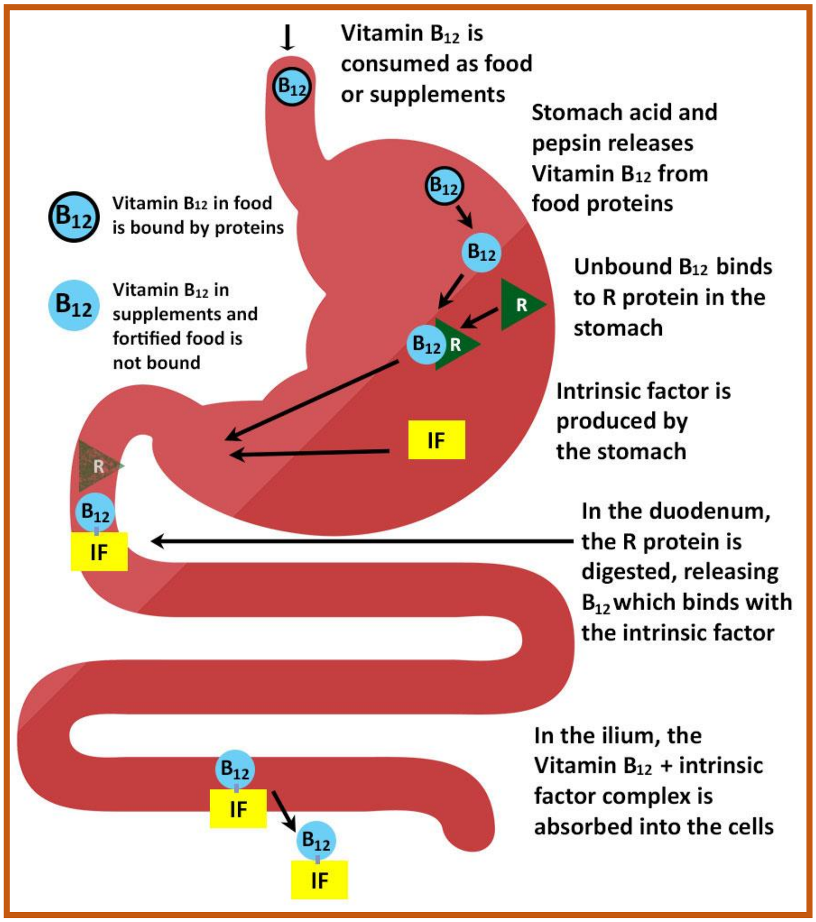


Figure 8: Absorption of Vitamin B_{12}

The vitamin B_{12}-R-protein complex then leaves the stomach and enters the duodenum. The pancreatic proteases cleave the R protein from vitamin B_{12} in the duodenum. Vitamin B_{12} then binds to the intrinsic factor and travels to the ilium. The vitamin B_{12}-intrinsic factor complex is then absorbed into the cells lining the ilium. Without the intrinsic factor, only one percent of the vitamin B_{12} can be absorbed.[37]

Vitamin B_{12} Sources

Plants and animals cannot synthesize vitamin B_{12}. Only certain bacteria can synthesize it. Hence, almost all plant foods do not provide a source for vitamin B_{12} naturally.[36] Reliable sources of vitamin B_{12} are found in meat and animal products. Animals consume vitamin B_{12} produced by bacteria in the soil. Also, ruminant animals can absorb vitamin B_{12} produced by bacteria within their digestive system.[38] Foods such as ready-to-eat cereals and soy milk are often fortified with vitamin B_{12}.

Vitamin B_{12} Recommendations

The vitamin B_{12} adult RDA is only 2.4 micrograms a day; this is the lowest quantity needed for all the vitamins (see Table 10 for recommended intakes). It is estimated that 10 to 30 percent of people over 50 years of age have atrophic gastritis (inflammation of the stomach lining) which results in low stomach acid secretion. Since this can increase the likelihood of food-bound vitamin B_{12} malabsorption, it is recommended for individuals over the age of 50 years to obtain their vitamin B_{12} from either a fortified food (such as ready-to-eat cereals) or a supplement.[37]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	0.4 mcg*	0.4 mcg*		
7-12 months	0.5 mcg*	0.5 mcg*		
1-3 years	**0.9 mcg**	**0.9 mcg**		
4-8 years	**1.2 mcg**	**1.2 mcg**		
9-13 years	**1.8 mcg**	**1.8 mcg**		
14-18 years	**2.4 mcg**	**2.4 mcg**	**2.6 mcg**	**2.8 mcg**
19-50 years	**2.4 mcg**	**2.4 mcg**	**2.6 mcg**	**2.8 mcg**
51+ years	**2.4 mcg**	**2.4 mcg**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations.

Table 9: Vitamin B_{12} DRI recommended intakes[13]

Vitamin B_{12} Deficiencies and Toxicities

Early stages of a vitamin B_{12} deficiency are characterized by tiredness, constipation, weight loss, and megaloblastic anemia (see Figure 9). As the severity of the deficiency continues, irreversible damage to the neurological system can cause numbness and tingling of the hands and feet, memory loss, disorientation, and dementia.

Three key groups are at risk of developing a vitamin B_{12} deficiency. First, individuals with atrophic gastritis, usually older adults, do not absorb vitamin B_{12} found naturally in foods because food proteins bind it. It is recommended individuals older than 50 years get their vitamin B_{12} from fortified foods or supplements. Second, people who no longer make intrinsic factor. The megaloblastic anemia caused by a lack of intrinsic factor is called **pernicious anemia**. These individuals may get their vitamin B_{12} either by an intramuscular injection or by taking a megadose vitamin B_{12} supplement (one percent of the vitamin B_{12} can be absorbed without the intrinsic factor). The third group at risk are vegan vegetarians. It is recommended they consume either fortified foods or take a vitamin B_{12} supplement.

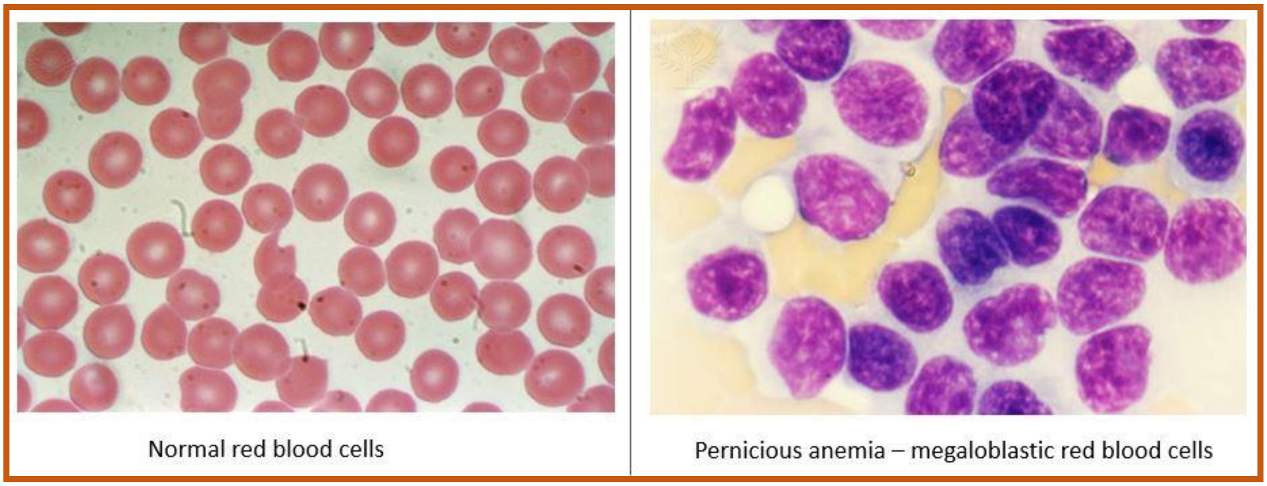


Figure 9: Comparison of normal and megaloblastic red blood cells

A UL has not been established for vitamin B_{12} because no adverse effects from excess vitamin B_{12} from food or supplements have been observed.[37]

Do B-Vitamin Supplements Provide an Energy Boost?

Although some marketers claim taking mega-doses of B-vitamins in a supplement boosts energy and performance, there is no evidence that supplementation with vitamins enhance performance except in cases where pre-existing deficiencies exists.[7] The perception of more energy from energy-boosting supplements usually comes from the high amount of caffeine, other herbal stimulants, and added sugars that accompany the high doses of B-vitamins. Although the B-vitamins are needed to support energy metabolism and growth, if a person has adequate amounts in their dietary intake, taking in more than required does not supply you with more energy. An analogy of this phenomenon is the gas in your car. Without gas, the car cannot operate. Will filling the tank until gas is running all over the ground improve your car's ability to operate at a faster speed? Similarly, depletion of B-vitamins will cause problems in energy metabolism, but having more than is required to run metabolism does not speed it up. Buyers of mega-dose B-vitamin supplements beware; B-vitamins are not stored in the body and all excess will be flushed down the toilet along with the extra money spent.

Vitamin C

Vitamin C, also known as ascorbic acid, is a water-soluble vitamin essential in the diet for humans, although most other mammals can readily synthesize it. It was the first vitamin to be scientifically studied. In 1747, James Lind was on a ship where sailors began to develop scurvy. He hypothesized scurvy was caused by the putrefaction of the body and could be cured by certain acids. To test his hypothesis, Lind divided twelve sailors with about the same degree of scurvy into six groups of two. They all were given the same basic diet. In addition, group one was given a quart of cider each day, group two received twenty-five drops of elixir vitriol (sulfuric acid) three times a day, group three two tablespoons of vinegar three times a day, group four half a pint of seawater, group five two oranges and one lemon, and group six a spicy paste plus barley water. The group receiving oranges and lemons recovered from the scurvy.[39] The name ascorbic acid comes from the prefix "a" meaning no and the word "scorbutus" meaning scurvy.

Functions

Antioxidant

Vitamin C's ability to easily donate electrons makes it an effective antioxidant to neutralize several free radicals in the body. It is the primary water-soluble, non-enzymatic antioxidant in plasma and the tissues. Vitamin C also helps protect lipids from oxidative damage by aiding in the regeneration of vitamin E, a fat-soluble vitamin that also functions as an antioxidant.[40]

Collagen Synthesis

Vitamin C is necessary for the synthesis of healthy collagen in the body. Collagen is the most abundant protein in the body and is an essential component of connective tissue. Cells are held together in part by the collagen that surrounds them. When a person has a wound, collagen helps bind the tissues together in the healing process. The thin capillary walls are supported by collagen.[28]

Collagen is made of three linear proteins that twist together to form a triple helix. Vitamin C plays a key role in adding hydroxyl (-OH groups) to the protein so crosslinks can form to stabilize the proteins (see Figure 10).

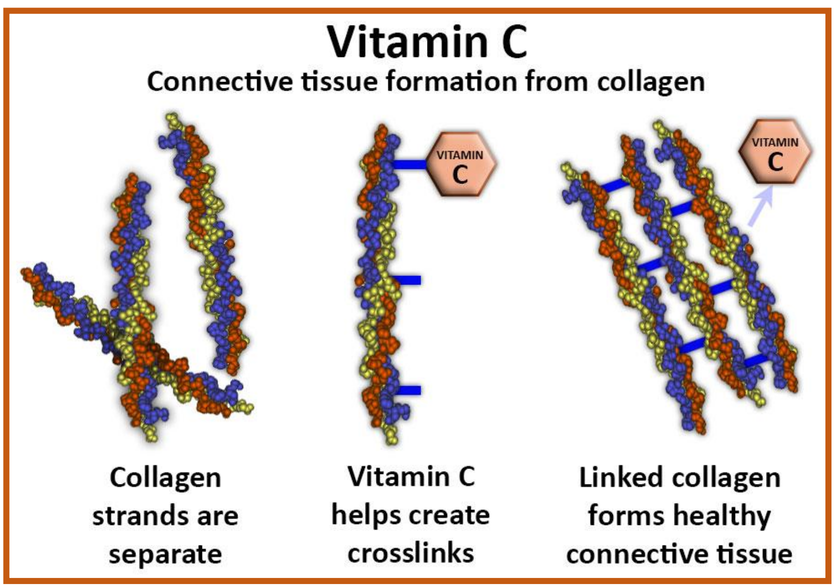


Figure 10: Vitamin C and healthy collagen synthesis

Iron Absorption

Non-heme iron absorption can increase by two- to threefold in the presence of 25 to 35 milligrams of vitamin C.[41] Vitamin C reduces the ferric iron (Fe^{3+}) to the more bioavailable ferrous iron (Fe^{2+}).

Vitamin C and Health

Cardiovascular Disease

Epidemiological studies indicate high intakes of fruits and vegetables are associated with a lower risk for cardiovascular disease. This association may be partly attributable to vitamin C, because vitamin C levels in the body have been shown to correlate well with fruit and vegetable intake, and higher plasma vitamin C levels are linked to reduced risk of some chronic diseases. However, most clinical trials have not shown a beneficial effect of vitamin C supplementation on the prevention of cardiovascular disease.[42]

Cancer

There is some evidence that a higher vitamin C intake is linked to a reduced risk of cancers of the mouth, throat, esophagus, stomach, colon, and lung, but not all studies confirm this is true.[69,70,71,72] As with the studies on cardiovascular disease, the reduced risk of cancer is the result of eating foods rich in vitamin C, such as fruits and vegetables, not from taking vitamin C supplements. In these studies, the specific protective effects of vitamin C cannot be separated from the many other beneficial chemicals in fruits and vegetables.

Common Cold

Many people increase vitamin C intake either from diet or supplements when they have a cold. Others take vitamin C supplements routinely to prevent colds. Contrary to these popular practices, there is no good evidence that vitamin C reduces the risk of developing a cold in the general population. However, in people undergoing heavy physical stress, such as marathon runners and soldiers in subarctic conditions, vitamin C supplementation ranging from 250 milligrams to 1000 milligrams per day reduced the cold incidence by 50%.[40, 42] Also, when people in the general population took vitamin C regularly prior to a cold, the duration of the cold was reduced 14% in children and 8% in adults. This reduction in duration was not observed when vitamin C was taken after the cold symptoms occurred.[40]

Vitamin C Sources

Fruits and vegetables are the best sources of vitamin C. Citrus fruits, tomatoes, and potatoes are major contributors of vitamin C in the United States. Vitamin C is not found in significant amounts in animal-based foods.

Foods high in vitamin C

Because vitamin C is water-soluble, it leaches away from foods considerably during cooking, freezing, thawing, and canning. Up to 50 percent of vitamin C can be destroyed. In order to maximize your vitamin C intake from foods, you can eat fruits and vegetables raw, microwaved, or lightly steamed.

There is a 70 to 90 percent absorption of vitamin C from food when consumed in amounts of 30 to 100 milligrams at a time. The absorption of vitamin C decreases to less than 50 percent when 1000 milligrams or more are consumed at one time.[28]

Vitamin C Recommendations

The DRI vitamin C recommended intakes are set to maintain near-maximal tissue concentrations of vitamin C and to provide antioxidant protection (see Table 10). Vitamin C's effectiveness as a free radical scavenger motivated the Institute of Medicine (IOM) to increase the RDA for smokers by 35 milligrams, as tobacco smoke is an environmental and behavioral contributor to free radicals in the body.[43]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	40 mg*	40 mg*		
7-12 months	50 mg*	50 mg*		
1-3 years	**15 mg**	**15 mg**		
4-8 years	**25 mg**	**25 mg**		
9-13 years	**45 mg**	**45 mg**		
14-18 years	**75 mg**	**65 mg**	**80 mg**	**115 mg**
19-50 years	**90 mg**	**75 mg**	**85 mg**	**120 mg**
51+ years	**90 mg**	**75 mg**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations

Table 10: Vitamin C DRI recommended intakes[13]

Vitamin C Deficiencies and Toxicities

A vitamin C deficiency causes scurvy. The symptoms of scurvy can appear after three months of a severe or total vitamin C-free diet.[42] Early symptoms include fatigue and aching limbs. Later symptoms are a result of defective collagen development and include bleeding gums, skin disorders, painful joints, petechiae (small red dots caused by capillary breakdown and bleeding), and corkscrew hair (see Figure 11). Other symptoms include weakness, depression, and increased susceptibility to infections.[43, 44]

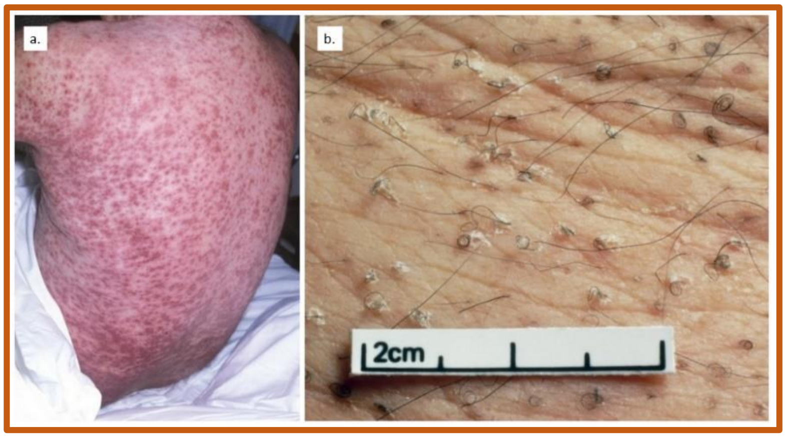


Figure 11: Scurvy symptoms include (a) petechiae (small red dots caused by ruptured capillaries) and (b) corkscrew hair.

Although current evidence indicates high doses of vitamin C (greater than 3000 milligrams per day) has low toxicity potential for the healthy person, there may be adverse gastrointestinal effects such as diarrhea, nausea, or cramping. The adverse effects are attributed to the decrease in vitamin C absorption when large doses are consumed. The unabsorbed vitamin C can cause an osmotic diarrhea. An adult UL of 2,000 milligrams per day of vitamin C has been established for healthy people based on the adverse intestinal effects.[43]

People at risk for iron-overload (such as those with hemochromatosis) are cautioned against taking high doses of vitamin C because of the potential for increased non-heme iron absorption and possible vitamin C pro-oxidant effects on the excessive iron stores in the body.[43]

10.4 Fat-Soluble Vitamins

Vitamin A

Although the vitamin A deficiency, night blindness, was described as early as 1500 BC by the Egyptians and was treated by dropping juice from liver (an excellent vitamin A source) onto the surface of the eye, it was not until 1913 that vitamin A was identified by McCollum and Davis.[2]

Vitamin A is found in food in both the active form of the vitamin and in a provitamin form which can be converted by the body to the active vitamin. The active vitamin A is referred to as the preformed vitamin A and has three vitamers (retinol, retinal and retinoic acid) that are collectively referred to as the retinoids. The vitamin A provitamins come from the carotenoid family. There are over 600 members of the carotenoid family, but not all of them can be converted by the body to vitamin A. The three most important members of the carotenoid family that are vitamin A provitamins are beta-carotene, alpha-carotene, and beta-cryptoxanthin.

Vitamin A Functions

Vitamin A has several roles in the body, which include maintaining vision, immunity, reproduction, growth and cellular differentiation (helping stem cells become specialized cells). The active forms of vitamin A (retinol, retinal and retinoic acid) are structurally similar but dissimilar enough to allow them to operate differently in the body.

Vision

Vitamin A can impact vision in two separate ways. The retinoids are needed by the retina (located at the back of the eye) to be able to see in dim light and by the cornea and surrounding membranes (located at the front of the eye) for normal cell differentiation and mucus production (see Figure 12).

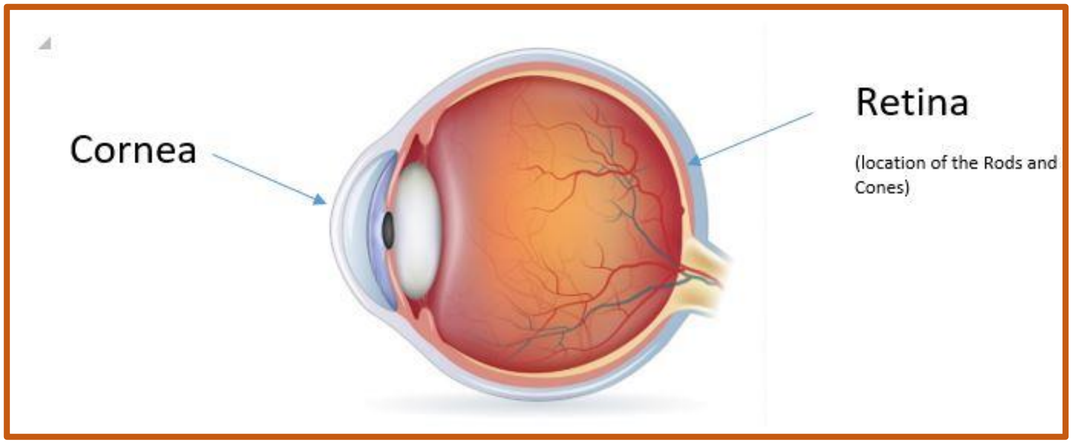


Figure 12: Structure of the eye

The retinal form of vitamin A is required by the eye to be able to see black and white vision. The eye's retina has two types of cells for vision, the rod cells for black and white vision in dim light and the cone cells for color vision. In the rod cells, a substance called rhodopsin plays an important role in black and white vision. Rhodopsin is made from the vitamin retinal and a protein called opsin. When light hits the rod cells, the retinal separates from the opsin and sends a visual signal to the optic nerve of the brain. To continue seeing in dim light, the rhodopsin needs to be reformed with new retinal which can take a few moments. You may have experienced this if you were in a low light setting and had a bright flash of light to your eyes. You were temporarily blinded until your eyes could make more rhodopsin.

Cell Growth and Differentiation

Retinoic acid plays a significant role in growth and development. At the genetic level, retinoic acid influences gene expression which in turn influences cell differentiation.

Immunity

During the 1970s, researchers conducting vitamin A studies in Indonesia noted that children with vitamin A deficiency died at much higher rates from infectious disease.[46] This observation led scientists to hypothesize that supplementing vitamin A in the diet of these children might reduce disease-related mortality. In subsequent studies, targeted populations of children were administered vitamin A supplements, and the death rates from measles and diarrhea declined by up to 54 percent.[46] Vitamin A supplementation in these deficient populations did not reduce the number of children who contracted these diseases, but it did decrease the severity of the diseases and the number of fatalities. Soon after the results of these studies were published, the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) commenced worldwide campaigns against vitamin A deficiency. UNICEF estimated that over a half of a billion vitamin A capsules have been distributed and have prevented over 350,000 childhood deaths each year. [46]

Vitamin A's role in the prevention of infectious disease is still being unraveled. It is apparent that through its interaction with cellular and nuclear receptors it affects the growth, development, and function of immune cells.[47] Vitamin A is also important in maintaining the integrity of epithelial tissues and in the production of mucus, both of which are essential for the maintenance of a barrier against infectious diseases. There are likely other ways adequate vitamin A protects against invaders, and while the exact mechanisms are not known yet, it is clear that low vitamin A intakes result in increased death rates from infection.

Carotenoid's Health Benefits

Since only a small portion of the provitamin A carotenoids are converted to vitamin A, much of those ingested stays intact in the body tissues. These carotenoids have health benefits independent of their vitamin A potential such as beta-carotene's antioxidant capabilities. The carotenoid family also has compounds such as lutein, lycopene, and zeaxanthin. These carotenoids are not provitamins for vitamin A but are recognized for their health-promoting properties.[48] Having elevated levels of these compounds in body tissues are associated with a reduced risk for eye problems with aging (such as cataracts) and chronic diseases such as cardiovascular disease and cancer.

Carotenoid	Food Source	Color
Beta-carotene	Carrots, Sweet Potatoes, Apricots	Orange
Lycopene	Tomatoes, Pink Grapefruit	Red
Lutein/Zeaxanthin	Spinach, Kale, Corn	Yellow*

* The yellow pigment of lutein may be masked by other pigments in spinach and kale such as chlorophyll

Table 11: Carotenoids food sources and color

Vitamin A Sources

The retinoids (preformed vitamin A) are found in animal products such as liver, fish oils, eggs, and milk. Most of the provitamin A carotenoids come from plant products such as bright orange/yellow and dark green vegetables such as carrots and spinach and some orange fruits such as apricots and cantaloupe.[49]

Animal products such as liver is the source for preformed vitamin A

Most of the provitamin A comes from plant products such as carrots

Both the preformed vitamin A (the retinoids) and provitamin A (carotenoids) in foods are considered vitamin A sources. A unit of measure called retinal activity equivalent (RAE) was developed to account for the potential vitamin A from the provitamins beta-carotene, alpha-carotene, and cryptoxanthin. The conversion units for these provitamins are:

- 12 micrograms of beta-carotene = 1 microgram of retinol activity equivalent (RAE)
- 24 micrograms of alpha-carotene = 1 microgram of retinol activity equivalent (RAE)
- 24 micrograms of cryptoxanthin = 1 microgram of retinol activity equivalent (RAE)[50]

The total amount of vitamin A in the meal is the actual vitamin A in the animal products plus the estimated amount that will be derived from converted provitamins (see Table 12).

Food	Retinol	Beta-carotene	Alpha-carotene	Crypto-xanthin	RAE
Beef liver, 3 oz raw	4948 mcg	232 mcg	11 mcg	13 mcg	4968 mcg
Cod liver oil, 1 Tablespoon	4080 mcg	0 mcg	0 mcg	0 mcg	4080 mcg
Cooked carrot, 1/2 cup	0 mcg	6499 mcg	2945 mcg	0 mcg	665 mcg
Apricots, 1 cup sliced	0 mcg	1805 mcg	31 mcg	172 mcg	158 mcg

Source: USDA Nutrient Database

Table 12: Dietary sources for Vitamin A

Vitamin A Recommendations

The Dietary Reference Intake recommendations for vitamin A are given in micrograms of retinol activity equivalents (RAE).[50] In the United States, older versions of the Food Label listed the amount of vitamin A in International Units which is a measure of the vitamin's biological activity. The conversion factor for vitamin A is 1 IU = 3.33 mcg retinol.

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	400 mcg RAE*	400 mcg RAE*		
7-12 months	500 mcg RAE*	500 mcg RAE*		
1-3 years	**300 mcg RAE**	**300 mcg RAE**		
4-8 years	**400 mcg RAE**	**400 mcg RAE**		
9-13 years	**600 mcg RAE**	**600 mcg RAE**		
14-18 years	**900 mcg RAE**	**700 mcg RAE**	**750 mcg RAE**	**1200 mcg RAE**
19-50 years	**900 mcg RAE**	**700 mcg RAE**	**770 mcg RAE**	**1300 mcg RAE**
51+ years	**900 mcg RAE**	**700 mcg RAE**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations. RAE = retinal activity equivalent.

Table 13: Vitamin A DRI recommended intakes[13]

Vitamin A Deficiency and Toxicity

Deficiency

A clinical vitamin A deficiency is rare in the United States. However, it is more common in many developing countries because of limited access to animal-based food sources (for preformed vitamin A) and not consuming plant foods with provitamin A (primarily beta-carotene).[49]

One of the first signs of a vitamin A deficiency is night-blindness, which is the inability to see in low light. Night-blindness is easily corrected by consuming adequate vitamin A. As the deficiency becomes more severe, there is a decrease in the production of mucus-secreting cells that lubricate the eye. This deficiency causes dryness of the eye which progresses to deterioration of the cornea, the appearance of white patches called Bitot's spots, and eventually leads to total blindness called xerophthalmia. Vitamin A deficiency is one of the leading causes of preventable blindness in children.[49, 51]

Xerophthalmia

In addition to impacting vision, a vitamin A deficiency can depress the immune system, decrease growth, impair reproduction, and lower bone mineral density. Furthermore, a deficiency can result in a condition called follicular hyperkeratosis, which is a buildup of the keratin (a fibrous protein) in hair follicles creating a bumpy, goose flesh appearance to the skin.

Toxicity

Vitamin A is well recognized as having a defined and serious toxicity. Symptoms may vary depending on if the toxicity is caused by extremely high amounts (over 15,000 micrograms) of vitamin A in a short period (acute toxicity) or intakes (over 2,700 micrograms) daily of vitamin A over an extending period (chronic toxicity).[52]

Up to this point, it has been clear that serious adverse effects do not arise until preformed vitamin A intakes are well over the UL. During pregnancy, adherence to the vitamin A guidelines is important. Doses above 3,000 micrograms per day (10,000 IU) have been linked to an increased incidence of birth defects. Pregnant women should check the amount of vitamin A contained in any prenatal or pregnancy multivitamin they are taking to assure the amount is below the UL, and be aware of the vitamin A content of foods. Because of this noted concern, most producers of prenatal supplements meet all or part of the vitamin A requirement by using beta-carotene instead of actual vitamin A in their supplement.[53]

Today, most vitamin A toxicity cases occur from excessive supplementation of vitamin A. Historically, there are cases of explorers consuming one meal with polar bear liver (or seal liver) and experiencing symptoms of irritability, vomiting, peeling skin, and death.[54] When analyzed it was found that raw polar bear liver contains up to 500,000 micrograms of vitamin A in a 3-ounce portion which drastically exceeds the current adult UL of 3,000 micrograms.[54] In comparison, 3-ounces of raw beef liver has only 4,000-5,000 micrograms of vitamin A. Consuming beef liver in moderation has not been associated with adverse side effects.

Interestingly, it is not possible to experience a vitamin A toxicity from any of the provitamins regardless of the level of intake. The body will stop the conversion of vitamin A from the provitamin when the body has adequate amounts of vitamin A. The most distressing problem that can occur with high intakes of carotenoids is the skin can take on an orange hue as the carotene deposits in the fat layers under the skin. When intake of carotenoids is decreased, the skin color will return to normal.[52]

Comparison of normal hand (left) with hand of person with carotenemia (right)

Vitamin D

Vitamin D, also known as calciferol, has two dietary vitamers, vitamin D_2 (ergocalciferol) found in a limited number of plants and vitamin D_3 (cholecalciferol) found in a small number of animal products. The human body can also make vitamin D_3 from cholesterol when the skin is exposed to the sun's ultraviolet B (UVB) rays.

Vitamin D is often referred to as a hormone because of the body's ability to synthesize it and because it has hormone-like functions when in its active form. The reason vitamin D is also classified as a vitamin is that the amount produced by the body may be inadequate under certain conditions. When this happens, it becomes essential to consume vitamin D either in food or a supplement.[55]

Vitamin D Activation and Functions

Vitamin D_2 and vitamin D_3 are not biologically active in the body. Activation of vitamin D requires two steps, first at the liver and then at the kidneys. Enzymes in the liver add a hydroxyl (OH) group to vitamin D's carbon number 25 to form 25 hydroxy-vitamin D (also known as calcidiol). Then the 25 hydroxyl vitamin D travels to the kidneys where another hydroxyl group is added to carbon number 1 to form the active vitamin, 1, 25 dihydroxy vitamin D (also known as calcitriol) (see Figure 13).[56]

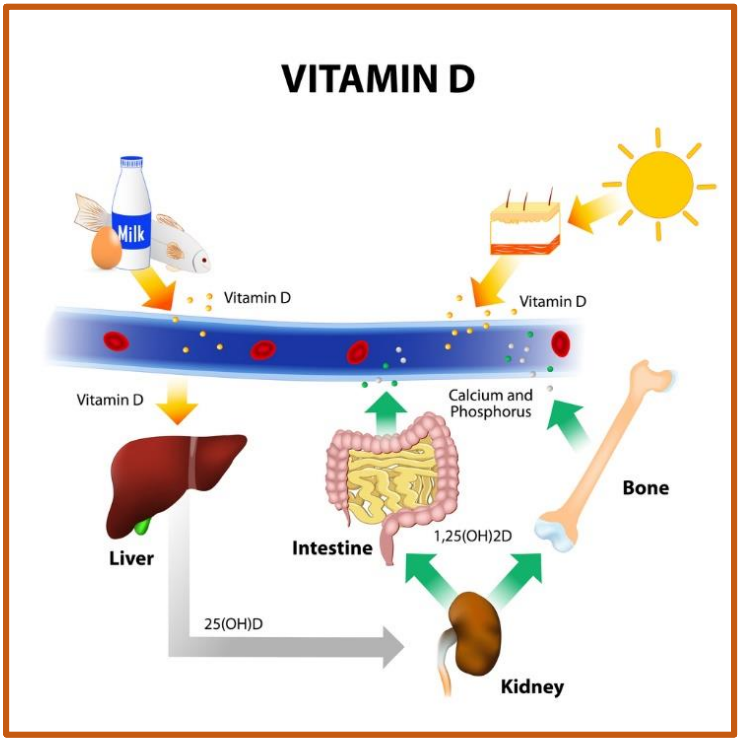


Figure 13. Activation of vitamin D

A key function of the activated vitamin D (calcitriol) is to regulate blood calcium levels. Calcitriol increases calcium absorption by promoting the synthesis of calcium transporter proteins in the cells lining the small intestine. When the blood levels of calcium are low, calcitriol and the parathyroid hormone will act to increase levels of calcium in the blood by decreasing the amount of calcium lost in the urine and promoting the bones to release calcium.

Calcitriol's action to increase calcium absorption from the small intestine is crucial for good bone health. When calcitriol levels are low, the absorption of calcium from food and supplements decreases from 25-33 percent to less than 10-15 percent.[57]

Other health benefits have been linked to having adequate vitamin D, from decreased cardiovascular disease to the prevention of infection. Furthermore, observational studies and evidence from laboratory studies conducted in cells, tissues, and animals suggest vitamin D inhibits the growth of certain colorectal and breast cancers, lowers risk for autoimmune diseases such as rheumatoid arthritis and multiple sclerosis, reverses atherosclerosis, lowers high blood pressure, and increases insulin secretion.[58]

Vitamin D Sources

Vitamin D is not found in very many foods naturally. Fatty fish, such as salmon, tuna, and mackerel, and fish liver oils are among the best sources. Lesser amounts of vitamin D_3 are found in egg yolks and beef liver. Mushrooms that have been exposed to UVB rays provide vitamin D_2.

Historically, cod liver oil (a rich source of vitamin D) was given to children to prevent rickets

In the United States, a milk fortification program was implemented in the 1930s as a public health intervention to lower the prevalence of rickets, a vitamin D deficiency in children. Other foods such as orange juice and ready-to-eat cereals are now fortified with vitamin D.[59]

Another source of vitamin D is the skin synthesis of vitamin D_3 when exposed to the sun's UVB rays. Anything that reduces your exposure to the sun's UVB rays decreases the amount of vitamin D_3 your skin synthesizes. The season of the year, latitude, altitude, cloud cover, time of day, and air pollution can affect the amount of UVB rays that reach the earth. Other factors that decrease vitamin D_3 synthesis include wearing sunscreen and darkly pigmented skin. [56, 59]

Vitamin D Recommendations

The Dietary Reference Intake recommendations for vitamin D is given in micrograms. Similar to vitamin A, older Food Supplement labels list vitamin D amounts in International Units (IU). The biological value of 40 IU of vitamin D is equal to 1 microgram.[57]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	**10 mcg**	**10 mcg**		
7-12 months	**10 mcg**	**10 mcg**		
1-3 years	**15 mcg**	**15 mcg**		
4-8 years	**15 mcg**	**15 mcg**		
9-13 years	**15 mcg**	**15 mcg**		
14-18 years	**15 mcg**	**15 mcg**	**15 mcg**	**15 mcg**
19-70 years	**15 mcg**	**15 mcg**	**15 mcg**	**15 mcg**
71+ years	**20 mcg**	**20 mcg**		

** Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations.*

Table 14: Vitamin D DRI recommended intakes[13]

Vitamin D Deficiency and Toxicity

A deficiency of vitamin D in children causes nutritional **rickets**, a bone disease. Rickets is characterized by soft, weak, deformed bones that are exceptionally susceptible to fracture.

Rickets, a severe vitamin D deficiency in children, causes malformation of the bones

In adults, vitamin D deficiency causes **osteomalacia**, which is characterized by poor bone mineralization. Osteomalacia differs from osteoporosis in that bone is still present but is not adequately mineralized with calcium. Osteoporosis has a loss of bone structure. Osteomalacia has the same symptoms and consequences as osteoporosis and often coexists with osteoporosis. Vitamin D deficiency is common, especially in the elderly population, dark-skinned populations, and in the many people who live in the northern latitudes where sunlight exposure is decreased during the long winter season.

Excessive vitamin D intake from supplements can cause adverse effects. Vitamin D toxicity has been observed in adults consuming over 1250 micrograms (50,000 IU) a day and can cause elevated levels of calcium in the blood and lead to calcium deposits in the kidneys and other organs of the body. Research suggests a vitamin D toxicity is unlikely in healthy people consuming under 250 micrograms (10,000 IU) a day.[58] An adult UL of 100 micrograms has been established.[56]

Excessive exposure to the sun will not cause a vitamin D toxicity. The skin production of vitamin D_3 is a regulated process, so when the body has adequate vitamin D the synthesis of vitamin D stops.

Vitamin E

Naturally occurring vitamin E has eight vitamers, four of which are tocopherols and four are tocotrienols. All the forms of vitamin E have varying levels of antioxidant properties; however, alpha-tocopherol is the only one that is recognized to meet human requirements.[60]

Unlike most other nutrients, vitamin E does not have a specific role in metabolism. The main function of alpha-tocopherol in the body is to act as a fat-soluble antioxidant and protect cell membranes against lipid destruction caused by free radicals.[60] After alpha-tocopherol interacts with a free radical, it is no longer capable of acting as an antioxidant unless it is enzymatically regenerated. Vitamin C helps to regenerate some of the alpha-tocopherol, but the remainder is eliminated from the body. Therefore, to maintain vitamin E levels, you ingest it as part of your diet.[61]

Other functions of vitamin E include regulation of gene expression, immune function, and cell signaling.[60] Despite vitamin E's numerous beneficial functions when taken in recommended amounts, large studies do not support the idea that taking higher doses of this vitamin will increase its power to prevent or reduce disease risk.

Examples of foods containing vitamin E. This includes healthy oils, nuts and seeds, and some vegetable sources.

Vitamin E Sources

The best food sources of vitamin E are oils and nuts. Wheat germ oil, sunflower oil, almonds, and canola oil are among the best sources for alpha-tocopherol.

Vitamin E Recommendations

The Dietary Reference Intake recommendations for vitamin E is alpha-tocopherol and is given in milligrams. Like vitamin A and D, older Food Supplement labels list vitamin E amounts in International Units (IU). The biological value of 1 IU of the natural form of alpha-tocopherol is equal to 0.67 milligrams of alpha-tocopherol. The biological value of 1 IU of synthetic alpha-tocopherol (often found in supplements) is 0.45 milligrams of alpha-tocopherol.[62]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	4 mg*	4 mg*		
7-12 months	5 mg*	5 mg*		
1-3 years	**6 mg**	**6 mg**		
4-8 years	**7 mg**	**7 mg**		
9-13 years	**15 mg**	**15 mg**		
14-18 years	**15 mg**	**15 mg**	**15 mg**	**19 mg**
19-70 years	**15 mg**	**15 mg**	**15 mg**	**19 mg**
71+ years	**15 mg**	**15 mg**		

* Indicates Adequate Intake recommendation. Bolded items indicate RDA recommendations

Table 15: Vitamin E (alpha-tocopherol) DRI recommended intakes[13]

Vitamin E Deficiency and Toxicity

A severe deficiency of vitamin E with clinical symptoms is rare in humans. Groups at risk for deficiency include premature infants with a very low birth weight and individuals with fat malabsorption. Clinical symptoms include hemolytic anemia and degeneration of nerve cells.[63]

No adverse effects have been found from consuming vitamin E in food. However, there have been reports of impaired blood coagulation when high doses of alpha-tocopherol supplements are taken. High doses of vitamin E can antagonize vitamin K-dependent clotting factors.[62] An adult UL of 1,000 mg of vitamin E from supplements has been established.[60]

Vitamin K

During the 1920s, Danish researcher H. Dam discovered a vitamin that was necessary for blood clotting and named it vitamin K after the Danish word *koagulation* which means coagulation.[64] Vitamin K vitamers can be categorized in the groups phylloquinone (vitamin K_1) which are found in plants, and menaquinone (vitamin K_2) most of which are synthesized by bacteria in the large intestine although some is found in fermented foods.[65]

Vitamin K functions as a coenzyme and has an essential role in blood coagulation. Without vitamin K, blood would not clot. Vitamin K is also required for maintaining bone health. It modifies proteins involved in the bone remodeling process. All the functions of the vitamin K-dependent proteins in bone tissue are not well understood and are under intense study. Some studies do show that people who have diets low in vitamin K also have an increased risk of bone fractures.

Vitamin K Sources

Vitamin K is present in many foods. It is found in highest concentrations in green vegetables such as broccoli, cabbage, kale, parsley, spinach, and lettuce. Additionally, vitamin K can be synthesized via bacteria in the large intestine. The exact amount of vitamin K synthesized by bacteria that is absorbed in the lower intestine is not known, it is believed to contribute to the vitamin K requirements but to a lesser amount than what was originally thought.[66]

Vitamin K Recommendations

An RDA could not be determined for vitamin K, and so the vitamin K recommendations for all age groups are Adequate Intakes and based on dietary reports of healthy population groups.[67]

Age	Male	Female	Pregnancy	Lactation
Birth to 6 months	2.0 mcg*	2.0 mcg*		
7-12 months	2.5 mcg*	2.5 mcg*		
1-3 years	30 mcg*	30 mcg*		
4-8 years	55 mcg*	55 mcg*		
9-13 years	60 mcg*	60 mcg*		
14-18 years	75 mcg*	75 mcg*	75 mcg*	75 mcg*
19-70 years	120 mcg*	90 mcg*	90 mcg*	90 mcg*
71+ years	120 mcg*	90 mcg*		

* Indicates Adequate Intake recommendation.

Table 16. Vitamin K DRI Recommended Intakes[13]

Vitamin K Deficiency and Toxicity

Vitamin K deficiencies are not common in healthy individuals. A deficiency may occur in adults with malabsorption disorders and results in poor blood clotting, hemorrhage, and low bone mineralization.

Newborns have low vitamin K stores because vitamin K transport across the placenta is poor. The American Academy of Pediatrics recommends newborns receive a single intramuscular dose of vitamin K.[26] This practice has greatly decreased vitamin K-dependent bleeding disorders in babies.

Vitamin K can interact with anticoagulants such as warfarin (Coumadin). People who take these medications need to maintain a consistent intake of vitamin K from food and supplements. Vitamin K is still essential to consume, but sudden changes with intakes may increase or decrease the anticoagulant effect.[68]

A UL for vitamin K has not been determined because no adverse effects have been associated with vitamin K consumption from food or supplements.[67]

Chapter 11: Energy Balance

11.1 Evaluating Body Weight

Weight and Health

Most people are working toward the goal of good health. Specifically, many people want to reach a healthy weight. Information in the media, however, often gives confusing messages about what constitutes a healthy weight. Social and cultural standards can influence the perception of "ideal" body weight. Also, reports of increasing obesity across the world highlight health concerns of too much body weight.[1] With all of this conflicting information, it can be hard to understand what is meant by the term "ideal weight".

The body is compared to a temple

The scriptures and modern-day revelation teach that the physical body is a gift from God.

1 Corinthians 3: 16-17 Know ye not that ye are the temple of God, and that the Spirit of God dwelleth in you… for the temple of God is holy, which temple ye are.[2]

Just as each temple is unique, physical bodies have many distinct attributes. A healthy weight is determined by more than just appearance or a number on a scale. Individual traits, such as height, gender, age, sex, frame size, and body composition[3] contribute to what constitutes a healthy weight for each individual.

There are many methods for assessing body weight and its impact on health and disease risk.

The major components of body weight are water weight, muscle mass, bone mass, and fat mass. Having more weight than is common for a particular height can be the result of water weight, muscle weight, or fat mass.[4] The terms **overweight** and **obesity** refer to an abnormal or excessive fat accumulation that may impair health.[5] Therefore, body weight can be a sign of obesity in many people. Having too much body fat can increase the risk of certain diseases (see Figure 1) and decrease quality of life.[1]

Too Much Body Fat Leads to Increased Risk of:

- High blood pressure
- High cholesterol
- Insulin resistance and type 2 diabetes
- Heart disease and stroke
- Gallbladder disease
- Osteoarthritis
- Sleep apnea and breathing problems
- Some types of cancer (breast, colon, liver, and others)
- Mental illness (depression, anxiety, and others)

Figure 1: Health consequences of too much body fat
Adapted from the Centers for Disease Control and Prevention[1]

Scientist have developed a variety of formulas that utilize measurements such as height, weight, age and waist and hip circumference to estimate a healthy weight for an individual. Health professionals use these types of equations to assess disease risk in individuals and populations. [6] In general, BMI is a good tool to use when looking at disease risk in populations. However, because BMI has some inherent problems, it is not a good tool to use to strictly define whether or not an individual person is at a healthy weight. However, because it only requires a height and weight, it is a quick and easy way to begin looking at a person's relative risk for some chronic diseases.

BMI

Body mass index (BMI) is calculated using height and weight measurements. BMI measurements are used to classify whether an individual may be **underweight**, at a **healthy weight**, **overweight**, or **obese**. Classification of these weight categories are determined differently for adults and children (see Table 1).[7,8] High BMI measurements can be warning signs of disease risks associated with too much body fat.[1] BMI-associated disease risks vary by race. For example, an Asian person with a BMI of 30 faces a greater disease risk than a Caucasian person with the same BMI. And a Caucasian person with a BMI of 30 faces a greater disease risk than an African American with a BMI of 30.

To calculate your BMI, divide your weight in kilograms by your height in meters squared. BMI can also be calculated using weight in pounds and height in inches with a conversion factor.[6]

Calculating BMI

BMI = [weight (kg)] ÷ height (m)^2

or

BMI = [weight (pounds) x 703] ÷ height (in)^2

BMI Category	Children & Adolescents (ages 2-19 years) (BMI-for-Age Percentile)	Adults (BMI)
Underweight	Less than the 5^{th} percentile	Less than 18.5 kg/m^2
Healthy Weight	5^{th} to < 85^{th} percentile	18.5-24.9 kg/m^2
Overweight	85^{th} to < 95^{th} percentile	25.0-29.9 kg/m^2
Obese	Greater than or equal to the 95^{th} percentile	30.0 kg/m^2
Extreme Obesity	-	40.0 kg/m^2 or greater

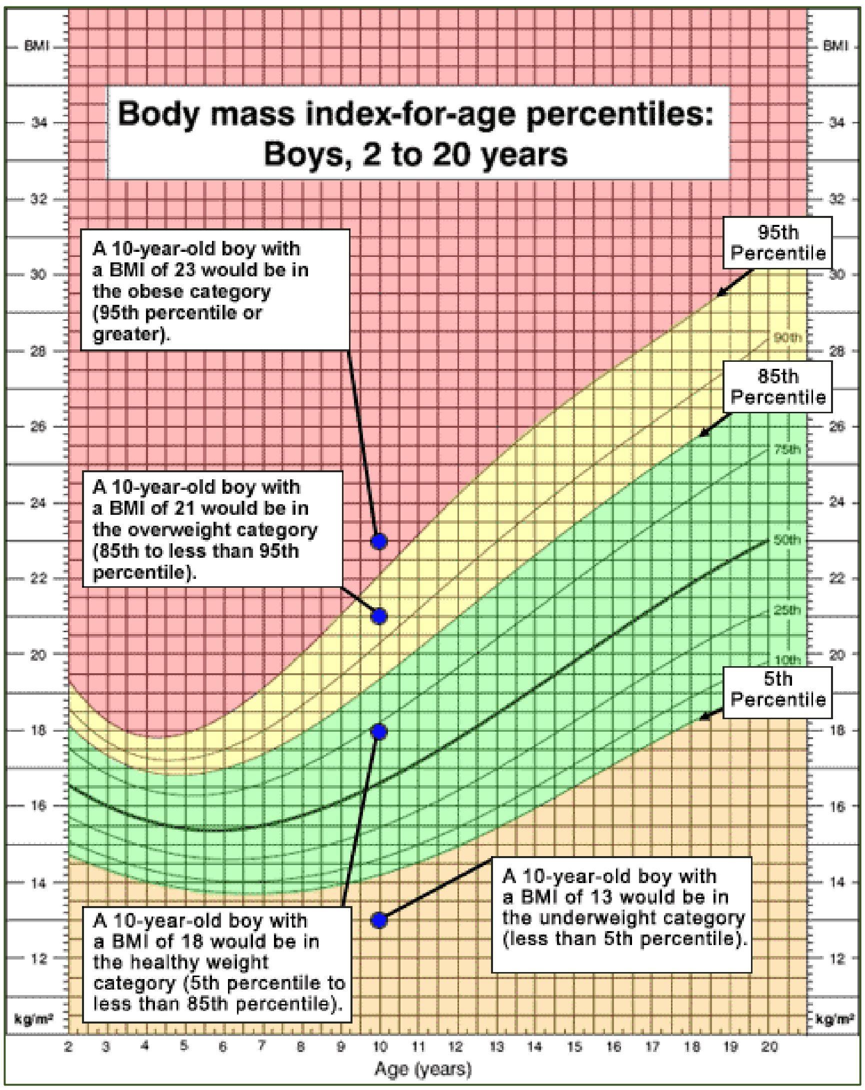
Table 1: BMI Categories[7,8]

BMI is a fairly simple measurement, but does not take into account fat mass or fat distribution in the body, both of which are predictors of disease risk. Contrary to popular belief, muscle does not weigh more than fat. One pound of muscle weighs exactly the same as one pound of fat, but they take up different amounts of space. The pound of fat takes up more space than the pound of muscle. For example, one pound of feathers and one pound of lead weigh exactly the same, but the pound of feathers takes up much more space than the pound of lead. Therefore, BMI can sometimes incorrectly categorize a person as overweight or obese.[9] For example, a muscular athlete will have more muscle mass (which is heavier than fat mass in the same volume area) than an inactive person with less muscle mass, of the same height. Based on their BMIs the muscular athlete may be categorized as more overweight or obese than the inactive person. Additionally, an older person with osteoporosis (decreased bone mass) will have a lower BMI than an older person of the same height without osteoporosis, even though the person with osteoporosis may have a greater fat mass.[9] Because BMI only requires height and weight it is an easy and inexpensive tool to use in public health to reflect a person's disease risk; however, other measurements are needed to more accurately assess health risk for the individual.

Weightlifters can have a high BMI for their weight

Monitoring Children's Weight

BMI charts were designed to help track weights of children. To calculate a BMI for a child, you would use height and weight as you would for adults. However, instead of using the calculated number by itself, you then need to plot the BMI on a chart to identify the percentile to assess their weight status.[27]



Obese: ≥95th percentile

Overweight: 85th to <95th percentile

Healthy: 5th to <85th percentile

Underweight: <5th percentile

Figure 2: Examples of how to use BMI for children and plotting on the BMI growth chart.[27]

Body Composition

Body composition includes the water, organs, bone, fat, and muscle tissue that make up a person's weight.[3] Having more fat mass may be a sign of disease risk, but fat mass also differs with sex, age, and physical activity level. Females have more fat mass than males, which is needed for reproduction and, in part, is a result of different levels of hormones.

Percent body fat is the amount of fat in the body compared to other tissues. Healthy body fat percentage for a female is considered to be between 20 and 30 percent of her total weight and for a male is between 12 and 20 percent.[10] Fat mass or percent body fat can be measured or estimated in a variety of ways, as outlined below.

Measuring skin with calipers

Skinfold Thickness

A health professional uses a caliper to measure the thickness of skin on the back, arm, and other parts of the body and compares it to standards to assess body fatness. This test measures **subcutaneous fat**, which is the layer of fat just beneath the skin. It is a simple and quick method of measuring fat mass in a specific area of the body, but it can be less precise than other methods in estimating total body fat.[11] Similar to BMI, skinfold thickness is compared to standards created from measurements of mostly young to middle-aged adults.

Air Displacement

Body composition can be measured using air displacement. A Bod Pod is a high tech piece of equipment that has a compartment big enough for a person to sit in. Once inside the compartment, computerized pressure sensors determine the amount of air displaced by the person's body.

A Bod Pod used to measure body composition

Water Displacement

Due to the fact that bone and muscle are denser than fat, underwater weighing can be used to determine a person's body composition. To obtain an underwater weight, a person is weighed on dry land, then placed into a large tank of water with a special scale. They are weighed again while submerged underwater. Fat is less dense and therefore more buoyant (able to float) than muscle and bone. Because of buoyancy, fat weighs less than muscle and bone underwater. Using a mathematical equation, the percent body fat of a person can be calculated by comparing their dry land weight and their underwater weight. Underwater weighing uses specialized equipment. The person being weighed must be able to hold their breath for an extended period of time.

For healthy adults, both underwater weighing and air displacement, rate high in accuracy and precision of determining body composition in comparison to other techniques. However, both are expensive and not readily available for most people. Given a choice, many people prefer air displacement to underwater weighing because they don't have to be submerged, or hold their breath.[11]

Bioelectric Impedance Analysis (BIA)

BIA assess body fat percentage by measuring resistance of tissues to a small electric current that is run through the body.[11] The amount of water in the body affects the flow of the current. Because certain tissues, such as fat and bone, contain very little water, they slow the flow of the electrical signal. When the small amount of electricity is passed through the body, the rate at which it travels is used to estimate body composition. Mathematical equations are used to estimate fat mass. These equations take into consideration individual characteristics such as age, height and disease state. Body composition scales, which incorporate BIA technology, are now available for home use. These devices make measuring body fat easy and inexpensive, However, accuracy and precision of this technique can be negatively affected by variations in food intake, hydration and other factors.[12]

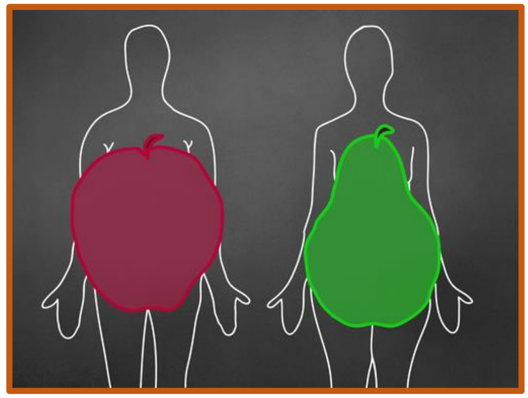
BIA Test

Dual-Energy X-Ray Absorptiometry (DEXA)

This method is commonly used to measure bone density, but it can determine fat content from a full body scan. Two low-dose x-ray beams are directed through the body and the amount of the energy absorbed from the beams is determined.[11] The amount of energy absorbed is dependent on the body's content of bone, muscle mass, and fat mass. Using standard mathematical formulas, fat content can be accurately estimated. While this tool is expensive and does expose subjects to a low dose of radiation, it is considered one of the most reliable ways to measure body fat composition.[11,13]

Doctor scanning patient using DEXA machine

Fat Distribution



"Apple" shape with weight in abdomen, and "pear" shape with weight on hips

Total body-fat mass is one predictor of health; another is body **fat distribution**. You may have heard that fat on the hips is healthier than fat in the belly—this is true. Observational studies have demonstrated that people with "apple-shaped" bodies, (those who carry more weight around the waist) have greater risks for chronic disease than those with "pear-shaped" bodies, (those who carry more weight around the hips).[3] Fat can be found in different areas of the body and it does not all act the same way. Fat is physiologically different, depending on its location. Fat deposited in the abdominal cavity is called **visceral fat** and it is a better predictor of disease risk than total fat mass.[3] Visceral fat releases hormones and inflammatory factors that contribute to disease risk. Waist measurement can be used to estimate visceral fat. The only tool required is a measuring tape. The measurement of waist circumference is taken just above the belly button. Men with a waist circumference greater than 40 inches (102 centimeters), and women with a waist circumference greater than 35 inches (88 centimeters), are predicted to face greater health risks.[14]

Extremely High Risk	Very High Risk	High Risk	Increased Risk	Low Risk
BMI ≥ 40.0 High waist circumference	BMI 30.0-39.9 High waist circumference	BMI 25.0-29.9 High waist circumference or BMI 30.0-34.9 Low waist circumference	BMI 25.0-29.9 Low waist circumference	BMI < 25.0

High waist circumference: Men>102 cm (40 in), Women>88 cm (35 in)
Low waist circumference: Men<102 cm (40 in), Women<88 cm (35 in)

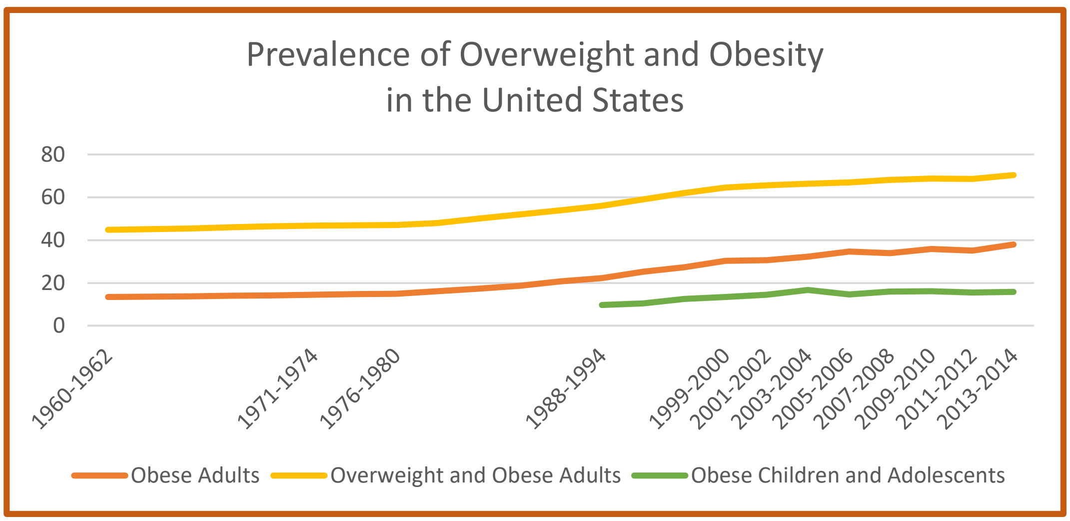
Figure 3: Health risk associated with BMI and waist circumference
Adapted for the National Institutes of Health[8]

An additional measure of fat distribution is the **waist-to-hip ratio**.[14] To calculate a waist-to-hip ratio, use a measuring tape to measure waist circumference and then measure **hip circumference** at its widest part. Next, divide the waist circumference by the hip circumference to arrive at the waist-to-hip ratio. Abdominal obesity, which can be predictive of disease risk, is defined by the World Health Organization (WHO) as having a waist-to-hip ratio above 0.90 for males and above 0.85 for females.[14]

11.2 The Energy Balance Principle

Obesity

According to the Dietary Guidelines for Americans, over the past 25 years over 50% of the U.S. adult population has been overweight or obese (See Figure 3).[7] Lifestyle behaviors related to poor eating habits and physical inactivity have resulted in 117 million adults with preventable chronic diseases in the United States.[7] The World Health Organization refers to obesity as a neglected public health problem and a global epidemic.[11] In 2016, almost 13% of adults across the world were obese and 39% were overweight.[18] Over the past 40 years, the incidence of obesity has more than doubled worldwide.[5] Additionally, over the past 30 years, there has been a rise in overweight and obesity in children and adolescents.[17]



Obese Adults: ≥ 20 years old, BMI ≥ 30 kg/m^2, Overweight and Obese Adults: ≥ 20 years old, BMI ≥ 25 kg/m^2, Obese Children and Adolescents: 2-19 years old, BMI ≥ 95th percentile for age and sex

Figure 4: Prevalence of Overweight and Obesity in the U.S.
Adapted from the Centers for Disease Control and Prevention (NHANES Data)[16,17]

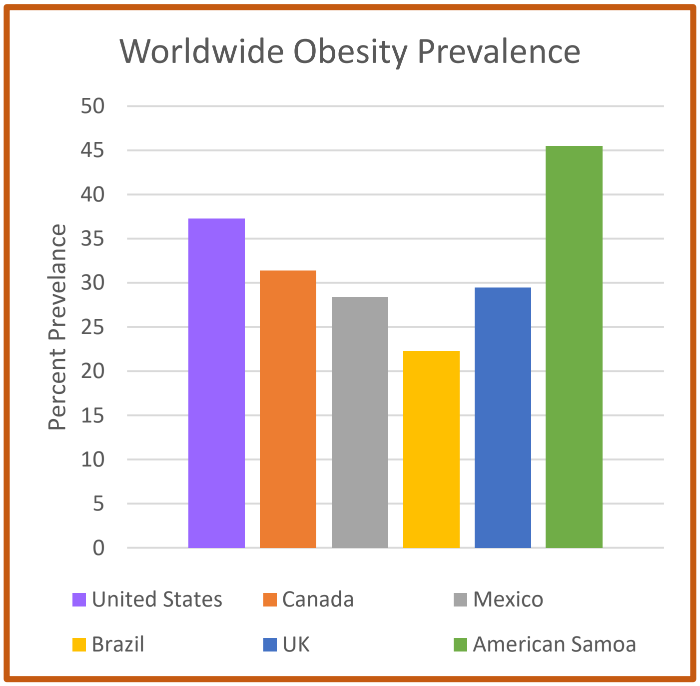


Figure 5: 2016 Obesity Prevalence – Adapted from the World Health Organization[16]

These trends are likely due to environmental and societal changes associated with modern development. Around the world, dietary habits have changed to include increased intake of processed foods that are high in fat, sugar, and calories. Advances in working conditions and modes of transportation have led to the development of a more sedentary lifestyle for many people.[5]

Over time as energy intake exceeds energy expenditure, weight gain occurs. This energy imbalance is often the cause of fat accumulation leading to the development of overweight and obesity.[5]

Energy Balance

People gain, maintain, or lose weight as a result of the balance of energy intake and energy expenditure. Energy is also known as calories. **Energy intake** includes calories consumed by eating and drinking. **Energy expenditure** includes calories burned through basal metabolism, physical activity, and the thermic effect of food.[7] **Energy balance** occurs when energy intake is equal to energy expenditure. Negative energy balance occurs when energy intake is less than what the body needs, leading to weight loss. Positive energy balance occurs when energy intake is more than what the body needs, leading to weight gain (see Figure 6). These weight changes do not happen overnight, but rather they occur in response to calorie imbalance over time.[19]

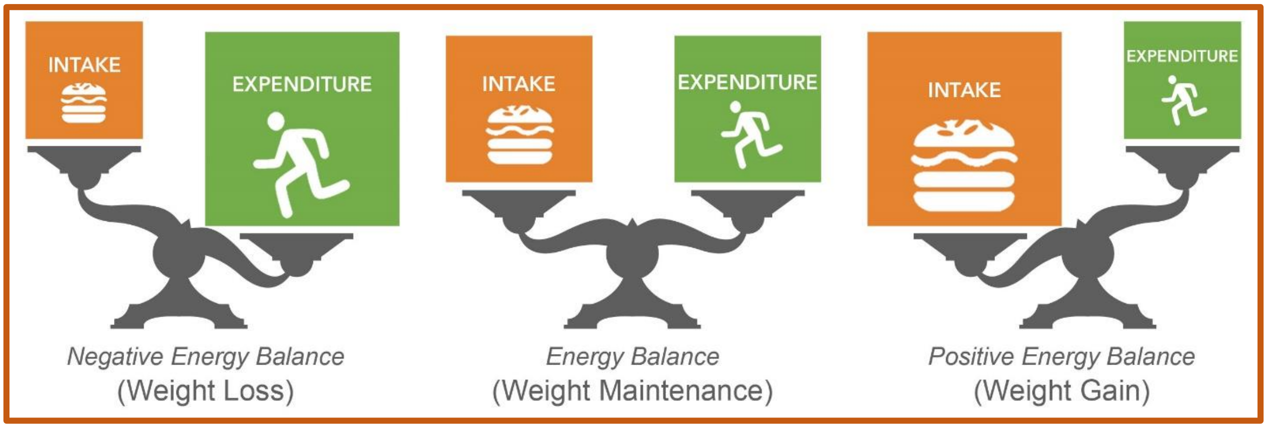


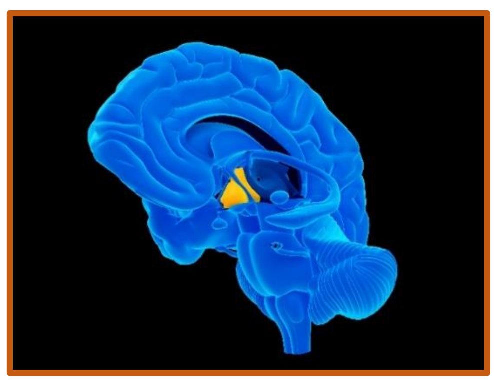
Figure 6: Energy Balance Concept[18]

Even small changes in energy balance, as little as 100 to 200 Calories per day, may be helpful in weight management.[20] For weight loss, cutting back 100 to 200 Calories could include reducing sugar sweetened beverage consumption, eating smaller portions at meals, or increasing physical activity by going for a walk or bike ride. Similarly, weight gain can be achieved by increasing food intake and decreasing activity.[19]

Energy Intake

The **estimated energy requirement** (EER) approximates the recommended amount of calories that should be consumed on a daily basis to maintain a healthy body weight. To calculate EER, equations are used that factor in gender, age, height, weight, and activity level, all of which affect a person's energy needs.

Energy intake is influenced by individual desires, physiological needs, and even genetics. The hypothalamus in the brain is responsible for controlling energy balance.[21] **Hunger** is a signal the body sends to promote eating. This signal is triggered by emptiness of the stomach, changes of blood nutrient levels and other physiological changes, which stimulates the release of hormones and stomach contractions. These stomach contractions often result in the familiar "growling" stomach. **Appetite** is a desire for food that is independent of hunger.[21] For example after a large meal, we may still have an interest in a favorite dessert



The hypothalamus controls energy balance despite the lack of any physical signals indicating the presence of hunger. The desire to eat when we are not hungry is referred to as appetite.

Energy Expenditure

Energy expenditure is made up of basal metabolism, physical activity, non-exercise activity thermogenesis (NEAT), and the thermic effect of food.[3] **Basal metabolism** includes the energy for basic needs, specifically involuntary functions such as blood circulation, breathing, maintenance of body temperature, cell/tissue growth, and other body functions. On average, energy needed for these processes makes up 60% of total energy expenditure. The basal metabolic rate (BMR) can be affected by age, gender, genetics, and body composition. This is why two people of the same age, height, and activity levels can have significantly different experiences with weight management.[3]

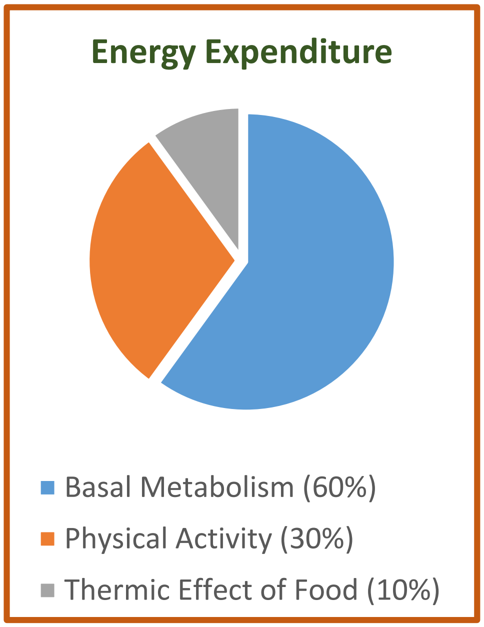


Figure 7: Energy Expenditure - Adapted from the Academy of Nutrition and Dietetics[3]

Physical activity includes any movement, as small as blinking or as large as jogging around the block, that uses energy. About 30% of energy expenditure on average is used for movement. This estimate varies significantly with activity level. A more active person will have a higher percent of energy expenditure from physical activity than an inactive person.[3] This is the easiest component of energy expenditure to modify.

NEAT is the abbreviation for non-exercise activity thermogenesis. It includes activity that is not formal exercise (playing basketball) or resistance training activities (working out at the gym etc.). For many people, NEAT is a significant contributor to their daily energy expenditure above the basal rate.[22,23] NEAT includes common activities such as walking around the house (or store or office), climbing stairs, cleaning, standing (rather than sitting) and even fidgeting and gum chewing. Energy expenditure from NEAT can add up to significant amounts. Sedentary individuals may only expend 15%

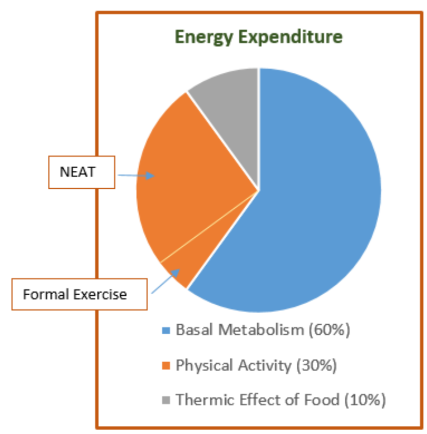


Figure 8: Energy expenditure from NEAT

of their total daily energy expenditure as NEAT, whereas active individuals may exceed 50%.[2] This type of energy expenditure has gained interest in the scientific community. Research has shown increased NEAT expenditure has positive effects on weight maintenance, successful weight loss, as well as reduced risk for chronic disease.[22,23] Small changes in daily routines can enhance energy expenditures and can positively impact health. The benefits of regularly planned formal exercise is well documented. NEAT activities are not a replacement for formal exercise or resistance training, but instead are an additional source of energy expenditure.

The energy needed to digest food and absorb nutrients is called the **thermic effect of food.** Eating and digestion makes up about 10% of daily energy use.[3]

11.3 Additional Factors

After considering the role that energy intake and energy expenditure play in weight management, it is important to consider other factors that may contribute to the development of obesity.

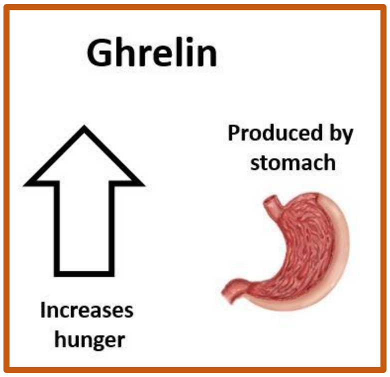
Genes

Genetics certainly play a role in the development of body fatness and weight. It is estimated that genes are responsible for 40-70% of variation in BMI of the population.[24] Evidence of this fact can be seen in children who have been adopted. Typically, the BMI of an adopted child more closely resembles the BMI of their biological parents than their adoptive parents.[24] Moreover, identical twins are twice as likely to be of similar weights as compared to fraternal twins.[24] Specific genes have been identified that increase a person's risk for obesity. Typically, these genes are associated with an increased intake of food. For example, errors in the production of the hormone leptin due to genetic variation increases hunger.[24] As our understanding of the relationship between genes and obesity has increased it has become apparent that obesity cannot be attributed to one or even a few genes, but is rather the interaction of hundreds of genes with the environment.[24] Fortunately, even if a person has obesity related genes, obesity can be prevented if their environment is managed well.

Obesity has a genetic component

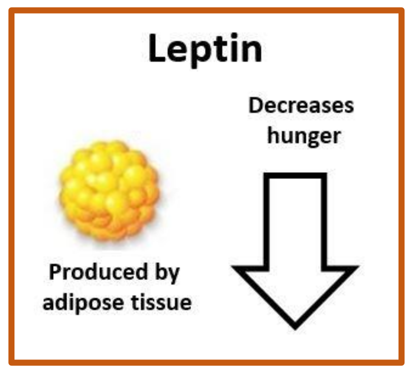
Hormones

Hormones are clearly linked to hunger and satiety which can affect weight status. The levels of certain hormones influence when a person desires food or feels satiated (feels full).



Ghrelin is often referred to as the hunger hormone. It is produced and secreted by the stomach. Ghrelin travels through the bloodstream to the brain and signals the hypothalamus to increases hunger signals. When a person hasn't eaten, ghrelin levels will increase and stimulate hunger. After a person eats, levels of the ghrelin hormone will decrease.[25]

Leptin is a hormone produced by the adipose tissue. Leptin travels through the bloodstream to the brain and signals the hypothalamus to decrease hunger signals. When the adipose stores are full, increased amounts of leptin are produced, which sends a message to the hypothalamus the body energy stores are full and to lower hunger signals.[25] With obesity, a person may develop leptin resistance. When this happens, an increase in leptin production does not cause a corresponding decrease in hunger.[26]



When ghrelin levels are abnormally high and/or leptin levels are abnormally low, a person can experience increased hunger and decreased satiety. Over the long term, these errors in signaling can contribute to increased caloric intake and weight gain.

Chapter 12: Promoting Healthy Weight

12.1 Healthy Weight Loss

Tools of healthy weight loss include diet, exercise, and more.

A quick search on the internet may lead you to believe that everyone is trying to lose weight, but healthy weight loss does not come easily. It requires changes in a person's daily habits and lifestyle, including decreasing calories consumed through food and beverages and increasing calories expended through physical activity and exercise.

Recommendations

While the recommendation to have a healthy weight to minimize health risks applies to all, not everyone needs to lose weight. Weight loss is recommended when health risks are increased due to an individual's weight. Health risks increase with a BMI greater than or equal to 30 kg/m^2 or being overweight (BMI of 25-29.9 kg/m^2) with two or more risk factors.[1] Risk factors include high blood pressure, high blood cholesterol, high triglycerides, high blood sugar, family history of heart disease, or physical inactivity.[1] In each of these circumstances, health professionals recommend weight loss.

Weight loss is recommended with:

- BMI greater than or equal to 30 kg/m^2
- Overweight or high waist circumference and two or more risk factors

Exercise improves weight loss

In overweight and obese persons, weight loss of 5% to 10% of their body weight is recommended to reduce risk factors of chronic disease such as a reduction in triglyceride levels, lipoprotein blood cholesterol levels, blood pressure, blood glucose levels, and the development of type 2 diabetes.[2] Healthy weight loss should be gradual and steady. People who experience and maintain successful weight loss make ongoing lifestyle changes regarding diet and physical activity. The recommended rate of weight loss is up to 2 pounds per week.[3] To achieve this goal, calories expended should be greater than calories consumed in food and beverages. One pound of adipose tissue provides 3500 Calories. In order to lose one pound of adipose tissue per week, a person would need to expend 500 more Calories per day than were consumed.[3]

Recommended weight loss:

Up to 2 pounds per week

Dieting

Many diet and exercise plans claim to help people lose large amounts of weight very quickly. Seeking quick results can lead to patterns of weight cycling, also known as yo-yo dieting.[4] **Weight cycling** happens when an individual makes short-term changes to lose weight. After losing weight, the individual often returns to their previous food and activity habits, causing them to regain the weight. Over the years, a person may gain and lose the same 10, 20, or even 30 pounds over and over again. Often, weight cycling eventually results in the person weighing more than before they began to diet. This weight cycling can be frustrating and discouraging and usually occurs as a result of making temporary changes in diet and exercise rather than permanent lifestyle changes.[4]

To prevent weight cycling, avoid **fad diets**, which gain popularity due to their claims of quick, easy weight loss.[4] Fad diets often promote rapid weight loss, no need to exercise, strict meal plans, or extreme restriction of certain foods.[4] These types of diets are often very difficult to follow long-term and the weight loss is often quickly regained. **Very low-calorie diets** (800 Calories or less per day) are often popular because they can contribute to rapid weight loss.[5] It is difficult to meet nutrient needs when caloric intake is less than 1200 Calories per day. Very low-calorie diets and dramatic changes in weight are often associated with loss of muscle mass, a slowing of basal metabolism, and increased risk of gallstones.[4,5]

Diets that contribute to successful long-term weight loss focus on eating a variety of natural, unprocessed foods, limiting added sugar and processed foods, and appropriate portion sizes. [4]

For those trying to lose weight, a good place to start is to identify specific eating behaviors that may contribute to weight gain. These may include: eating foods high in added sugars and unhealthy fats; skipping meals; eating fast food, pre-prepared foods or restaurant foods; eating mostly refined grains; snacking when not hungry; drinking beverages with added sugars; emotional eating, or distracted eating. [6]

Dieting should include healthy foods

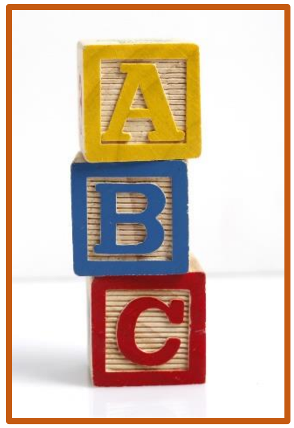
Making small changes in diet, which are focused on meeting the body's nutrient needs, can lead to changes that will contribute to a lifelong healthy weight. [4]

Physical Activity Guidelines

Control of energy intake is central to achieving and maintaining a healthy weight. Including physical activity as a part of weight control program can enhance weight loss efforts and increase health benefits.[7] The American College of Sports Medicine recommends a person participate in 150-250 minutes of moderate-intense physical activity per week to prevent weight gain or promote modest weight loss and gain substantial health benefits.[7] This can be achieved by participating in 30 minutes of moderate activity 5 days a week. Examples of moderate activity include brisk walking, biking on level terrain or swimming.[8] Greater than 250 minutes of exercise per week may result in increased weight loss and increased health benefits. The American College of Sports Medicine recommends including resistance training at least twice a week to increase muscle mass and promote the loss of fat.

12.2 Behavior Modification

The ABCs of Behavior Modification


ABCs of behavior modification

In order to achieve a healthy weight, lifestyle changes are required. When it comes to daily habits, such as eating and exercise, change can be difficult. Even though this change is hard, it is not impossible. Changes toward a healthy lifestyle take place over time. There are strategies and theories that can help make behavior change successful. Successful behavior change is rarely as simple as starting or stopping something new. It requires understanding what leads to or motivates the behavior. One model that can assist in behavior change is called **the ABCs of Behavior modification**.[9] This model considers the cause and effect of a specific behavior. A is for **antecedent**, which is the action that comes before a behavior. B is for **behavior**, which is the action or habit to be changed. C is for **consequence**, which is the result of the action or behavior if it remains unchanged.[9] Sometimes understanding the consequences of a behavior can be motivation to change; however, it is often the antecedent of the behavior that must be changed. For example, Miguel has early classes and usually wakes up just in time to get to school. He realizes that he always misses breakfast. During class, Miguel gets distracted by his feelings of hunger. The antecedent in this situation is sleeping in. The behavior is missing breakfast. And the consequence is feeling hungry and distracted during class. Miguel decides to get up earlier in the mornings, changing the antecedent and then changing the behavior. When Miguel gets up earlier, he has time to eat breakfast and is more focused throughout his classes.

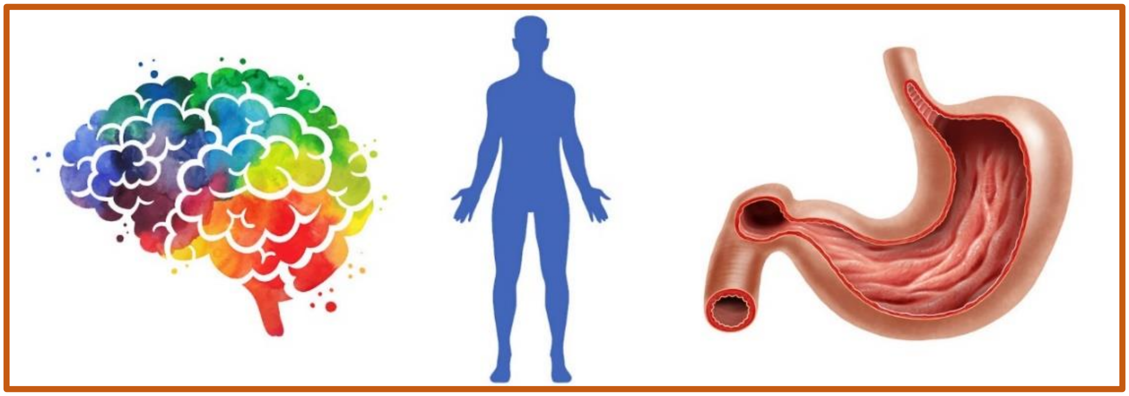
Antecedent	Behavior	Consequence
Action that comes before the behavior	The action or habit to be changed	Result of the action or behavior

Figure 1: The ABCs of behavior modification[9]

Effective Weight Loss

"You'll never change your life until you change something you do daily. The secret of your success is found in your daily routine."
-John C. Maxwell[10]

Achieving a healthy weight involves making changes regarding the mind, the body, and the stomach.[4] The true test of an effective weight loss plan is whether a healthy weight change can be maintained over time.



Weight loss involves the brain, body, and appetites.

Successful weight loss requires realistic expectations. By setting small, achievable goals, individuals can develop a healthy lifestyle. Rather than focusing on weight, improved health should be the central goal of any weight loss plan.[4] Next, an individual who desires weight loss should strive to live an active lifestyle. A physically active lifestyle can contribute to heart health, bone strength, and even stress management.[4] Finally, making healthy food choices is essential for sustaining a healthy weight loss. The Dietary Guidelines for Americans 2015 recommends eating more vegetables, fruits, whole grains, low-fat dairy, and lean protein and consuming less saturated and trans-fats, added sugars, and sodium.[11]

12.3 Treatment for Obesity

Medication

For some individuals, changing lifestyle habits, eating healthier, and increased physical activity may not be enough to help them lose weight long term.[12] If this is the case, a doctor may prescribe medication or further treatment as part of a weight management program. These treatments are not recommended for everyone. A doctor is more likely to prescribe weight loss medications to an adult with a BMI equal to or greater than 30 kg/m^2 or a BMI equal to or greater than 27 kg/m^2 with weight-related health problems, such as type 2 diabetes or high blood pressure.[12]

Prescription weight-loss medications work to treat obesity in different ways. One oral weight-loss medication, phentermine, stimulates satiety in the hypothalamus resulting in suppressed appetite and decreased food intake.[12,13] Common side effects may include dizziness, change of taste, insomnia, constipation, or dry mouth.[2] Another medication, Orlistat, also known as Xenical or Alli, acts to block dietary fat absorption.[14] Some common adverse effects of Orlistat include decreased absorption of fat-soluble vitamins and fat excretion in stool, especially with a high-fat diet.[2] Weight loss medications should be used in combination with lifestyle changes, such as a reduced calorie diet and increased exercise.[12] A major disadvantage of drug treatment to promote weight loss is that weight regain often occurs when the medication is stopped.[12]

Weight loss medication

There are also some **dietary supplements** that are believed to promote weight loss.[15] These supplements are often sold with unproven marketing claims of fat burning or appetite suppression. While these supplements may contribute to short term changes in weight, they may also cause dangerous side effects, and are not effective for long-term weight change.[15] Guarana, also known as Brazilian cocoa, is marketed as a weight loss supplement and is claimed to aid in weight loss. However, evidence shows that the caffeine content of guarana may cause side effects, such as increased heart rate and abnormal heart rhythms, that are similar to side effects seen in banned supplements.[15] Guarana is often found in energy drinks.[16] Green tea

Green tea has several side effects and may not be effective in promoting weight loss.

and green tea extract are sometimes used to promote weight loss, but there is no evidence to support that it contributes to weight loss or maintenance of weight loss.[17] Because of the high caffeine content, green tea can cause poor sleep and headaches. In high concentrations, green tea has also been found to cause liver problems.[17] For many supplements, such as guarana and green tea, research does not support the claim that they are effective in promoting weight loss.[15]

Weight-Loss Surgery

When efforts for weight loss have been unsuccessful with diet and exercise, weight loss surgery may be beneficial for individuals with extreme obesity, defined as a BMI greater than or equal to 40 kg/m^2, or individuals with a BMI of 35 kg/m^2 with obesity-related health problems such as type 2 diabetes, heart disease, and sleep apnea.[2, 18] Possible benefits of weight loss surgery include improvements of these obesity-related health problems. Weight loss surgery may allow some individuals greater physical function and improved quality of life.[18]

Roux-en-Y gastric bypass, more commonly known as **gastric bypass surgery**, involves permanently changing the pathway of food through the digestive system (see Figure 2).[2] In this procedure, the top of the stomach is stapled to create a small pouch. Then, the small intestine is cut between the duodenum and jejunum and reattached to the small pouch. The bypassed section of the duodenum is reattached to the lower part of the jejunum to provide passage for the gastric juice, bile, and pancreatic secretions. [18]

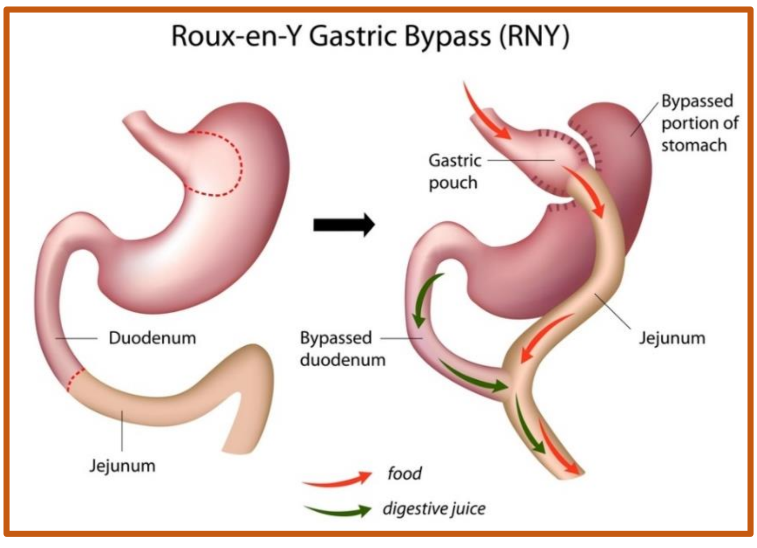


Figure 2: Gastric bypass surgery permanently re-routs the pathway of food

This smaller stomach helps people experience feelings of fullness, causing them to eat less. Gastric bypass surgery typically results in a 35% weight loss over 1 to 2 years and a 30% weight loss maintained over 10 years.[18] Common complications of weight loss surgery include bleeding, infection, leaking at the surgical site, diarrhea, blood clots, or nutrient deficiencies.[29]

Weight loss surgery does not eliminate the need for lifestyle changes. Healthy habits are necessary for long term success.[18] With the help of weight loss surgery, eating less and being more physically active may be easier. For long-term health improvements, individuals considering weight loss surgery should be ready to commit to healthy lifestyle habits for the rest of their life.[18]

Potential Complications of Weight Loss Surgery[18, 29]:

- Bleeding
- Infection
- Leaking at surgical site
- Diarrhea
- Blood clots
- Nutrient deficiencies

12.4 Promoting Healthy Weights during the Lifecycle

Weight Gain during Pregnancy

During pregnancy, a mother's body changes in many ways. One of the most notable and significant changes is weight gain. BMI can be used to determine body size. A woman's pre-pregnancy BMI can be used to determine a healthy amount of weight to gain during pregnancy (see Table 1). Poor weight gain, especially in the third trimester, could result not only in low birth weight but also infant mortality and intellectual disabilities. The mother may also deliver a preterm baby (born before 36 weeks gestation). Preterm babies are usually born small and are at risk for other concerns such as difficulty breathing, difficulty eating and difficulty maintaining their body temperature.

Pre-pregnancy BMI	Weight Category	Recommended Weight Gain
Below 18.5	Underweight	28–40 lbs.
18.5–24.9	Normal	25–35 lbs.
25.0–29.9	Overweight	15–25 lbs.
Above 30.0	Obese	11–20 lbs.

Table 1: Weight Gain Recommendations for Pregnancy[19]

Starting weight below or above the normal range can lead to different complications. Pregnant women with a pre-pregnancy BMI below twenty are at higher risk of a preterm delivery and an underweight infant. Pregnant women with a pre-pregnancy BMI above thirty have an increased risk of the need for a cesarean section during delivery. Therefore, it is optimal to have a BMI in the normal range prior to pregnancy.

Generally, women gain 2 to 5 pounds in the first trimester. After that, it is recommended to gain approximately one pound per week during the second and third trimesters. Some of the new weight is due to the growth of the fetus, while some is due to changes in the mother's body that support the pregnancy. Weight gain often breaks down in the following manner (see Figure 3):

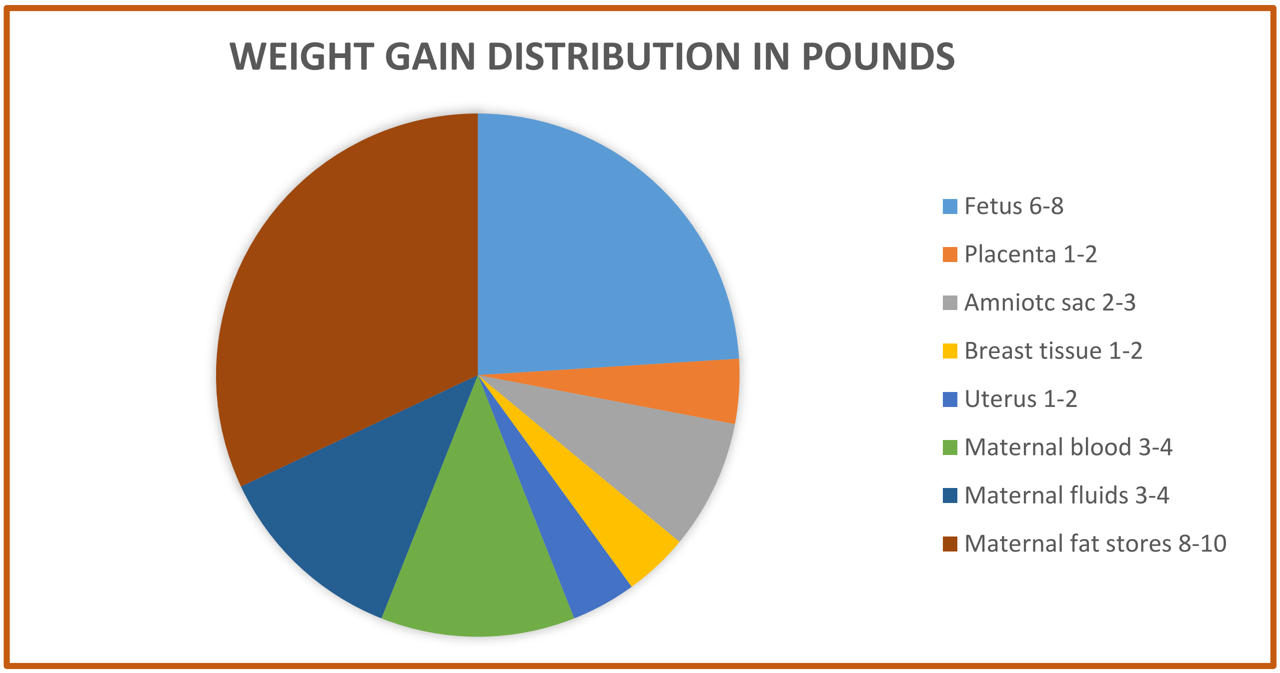


Figure 3: Distribution of recommended weight gain during pregnancy[19]

Women who are pregnant with more than one fetus are advised to gain even more weight to ensure the health of their unborn babies.

The pace of weight gain is also important. If a woman puts on weight too slowly, her physician may recommend nutrition counseling because inadequate weight gain can increase the risk of delivering a baby early or having a baby that does not have sufficient stores. If she gains weight too quickly, especially in the third trimester, it may be the result of edema, or swelling due to excess fluid accumulation. Rapid weight gain may also result from increased calorie consumption or a lack of exercise. A baby's birthweight can help assess how well the pregnancy went. An infant's weight can be categorized as **Small for Gestational Age** (SGA), **Average for Gestational Age** (AGA) or **Large for Gestational Age** (LGA).

Category	Weight Range
SGA	Weight below the 10th percentile
AGA	Weight between the 10th and 90th percentile
LGA	Weight above the 90th percentile

Table 2: Birthweight Categories[20]

Assessing Growth in Infants

Healthy infants grow steadily but not always at an even pace. For example, during the first year of life, height increases by 50 percent, while weight triples. Physicians and other health professionals can use growth charts to track a baby's development process. Because infants cannot stand, the length is used instead of height to determine the rate of a child's growth. Other important developmental measurements include head circumference and weight. All of these must be tracked and compared against standard measurements for an infant's age. Nationally-accepted growth charts are based on data collected by the National Center for Health Statistics.[21] These charts allow for tracking trends over time and comparing with other infants among percentiles within the United States. Growth charts may provide warnings that a child has a medical problem or is malnourished. Insufficient weight or height gain during infancy may indicate a condition known as failure-to-thrive (FTT), which is characterized by poor growth. FTT can happen at any age, but in infancy, it typically occurs after six months. Some causes include poverty, lack of enough food, feeding inappropriate foods, and excessive intake of fruit juice.

Measuring and tracking an infant's growth is one of the best ways to monitor if the child is receiving adequate nutrition. Common measurements during the first year of life are length-for-age, weight-for-age, length-for-weight and head circumference-for-age. To best identify proper growth, it is best to plot these measurements on a growth chart. For infants, the charts that are recommended to use are the World Health Organization (WHO) growth charts. These charts were developed using infants that were exclusively breastfed for at least 4 months. The **percentiles** in the WHO growth charts better reflect the pattern set by following recommendations regarding breastfeeding. The Centers for Disease Control (CDC) charts were developed tracking the growth of infants that were not necessarily breastfed for the recommended amount of time. It is recommended to use the WHO growth charts until the age of two.[21] Percentiles reflect how children grow compared to children of the same age and gender. For example, a 3-month-old baby girl plotted at the 30th percentile indicates that out of 100 3-month-old baby girls, 30 would be smaller and 70 would be larger. The goal is to have a child follow their growth curve or percentile. Without using growth charts, two "checkpoints" can be monitored to do a less detailed assessment of weight and nutritional status. Normal growth would be indicated by the baby's weight doubling by about 5 months and tripling by one year of age.[22]

Healthy Weights in Childhood

The percentage of children with obesity in the United States has more than tripled since the 1970's.[23] There are several contributing factors for the increase in obesity in children. Some factors that may contribute include:[24-26]

- Genetics
- Metabolism—how your body changes food and oxygen into the energy it can use
- Eating and physical activity behaviors
- Environmental factors
- Social and individual psychology

Family exercise is a good way to promote healthy weights and lifestyles to children.

There are recommendations regarding both food intake and physical activity to help promote healthy weights and lifestyles in children. It is very effective to teach children to eat healthily and be active by example. Incorporating activity into daily life is a good way to increase movement throughout the day to help build good habits. The diet and activity recommendations are summarized in Table 3.

Dietary Modifications	Physical Activity Recommendations
Eat more fresh fruits and vegetables Decrease intake of added sugars (soda, candy) Decrease intake of solid fats Eat meals at a table instead of in front of TV Parents provide appropriate portion sizes	At least 60 minutes of physical activity daily Watch less television (less screen time) Parents encourage games, walks, hikes together

Table 3: Diet and activity recommendations to promote healthy weights in children[27]

Research on the topic of childhood obesity has revealed relationships with immediate effects on their health, not only physical but emotional and social health as well. Children with obesity are impacted in the following ways (see Table 4):

Physical Health	Emotional Health	Social Health
Asthma Sleep apnea Bone and joint pain Type 2 diabetes Risk factors for heart disease	Depression Low self-esteem	Bullied and teased more often than healthy weight peers Social isolation

Table 4: Immediate effects of obesity on children's health[28]

In addition to immediate effects, children with obesity also have higher risk factors for diseases as adults such as obesity, Type 2 diabetes, heart disease, metabolic syndrome and several types of cancer.

Chapter 13: Life Cycle

13.1 Nutrition and Pregnancy

Introduction

Human bodies change significantly over time, and food is the fuel for those changes. People of all ages need the same basic nutrients—essential amino acids, carbohydrates, essential fatty acids, and twenty-eight vitamins and minerals—to sustain life and health. However, the amounts of nutrients needed differ. Throughout the human life cycle, the body constantly changes and goes through different periods known as stages. One stage that requires different nutrient needs is pregnancy.

Healthy habits during pregnancy will help the health of the unborn child

For medical purposes, **pregnancy** is measured from the first day of a woman's last menstrual period until childbirth, and typically lasts about forty weeks. These forty weeks are then broken down into trimesters which are approximately 13 weeks each. Major changes begin to occur in the earliest days of pregnancy, often weeks before a woman even knows she is pregnant. During this period, adequate nutrition supports cell division, tissue differentiation, and organ development. As each week passes, new milestones are reached. Therefore, women who are trying to conceive should make proper dietary choices to ensure the delivery of a healthy baby. Fathers-to-be should also consider their eating habits. A sedentary lifestyle and a diet low in fresh fruits and vegetables may affect male fertility. Men who drink too much alcohol may also damage the quantity and quality of their sperm.[1] For both men and women, adopting healthy habits also boosts general well-being and makes it possible to meet the demands of parenting.

During pregnancy, a **placenta** is also developed in the uterus. The placenta plays a critical role during pregnancy in the nutrition of the fetus. Its role is to deliver nutrients and oxygen to the baby and remove waste products from the baby's blood.

Knowing that nutrition during pregnancy is so vital, The Church of Jesus Christ has even published a statement in *The Latter-Day Saint Woman* which says, "It is important that a pregnant woman eat a healthful variety of foods. Eating properly has a great influence on the unborn baby. Eating well is so important that all potential mothers need to prepare their bodies by carefully choosing what they eat. When they do so, they will have a better chance of having good health and bearing healthy children. When a young woman makes a habit of eating a variety of healthful foods in sufficient amounts, her ability to give birth to healthy children is improved. Because these established good eating habits will go with her into marriage and pregnancy, she will continue eating the right foods and teach the same good habits of nutrition to her children."[2]

Discomforts and Complications of Pregnancy

Pregnancy can lead to certain discomforts, from back strain to swollen ankles. Pregnant women are also likely to experience constipation because increased hormone levels can slow digestion and relax muscles in the bowels. Constipation and pressure from growth of the uterus can result in hemorrhoids, which are another common discomfort.[3] Getting mild to moderate exercise and drinking enough fluids can help prevent both conditions. Also, eating a high-fiber diet softens the stools and reduces the pressure on hemorrhoids.

Heartburn can occur during the early months of pregnancy due to an increase in the hormone progesterone, and during the later months due to the expanding size of the fetus, which limits stomach contraction. Avoiding chocolate, mint, and greasy foods, and remaining upright for three hours after meals can help pregnant women avoid heartburn. In addition, it can be helpful to drink fluids between meals, instead of with food.

Pregnant woman suffering from nausea

Other common complaints can include leg cramps and bloating. Regular exercise can help to alleviate these discomforts. A majority of pregnant women develop gastrointestinal issues, such as nausea and vomiting. Many also experience food cravings and aversions. All of these can impact a pregnant woman's nutritional intake and it is important to protect against adverse effects.

Nausea and Vomiting

Nausea and vomiting are gastrointestinal issues that affect many pregnant women, typically in the first trimester. Nausea tends to occur more frequently than vomiting. These conditions are often referred to as "morning sickness," although that's something of a misnomer because nausea and vomiting can occur all day long, although it is often worst in the first part of the day.

Increased levels of the pregnancy hormone human chorionic gonadotropin may cause nausea and vomiting, although that is speculative. Another major suspect is estrogen because levels of this hormone also rise and remain high during pregnancy. Given that a common side effect of estrogen-containing oral contraceptives is nausea this hormone likely has a role. Nausea usually subsides after sixteen weeks, possibly because the body becomes adjusted to higher estrogen levels.

It can be useful for pregnant women to keep a food diary to discover which foods trigger nausea, so they can avoid them in the future. Other tips to help avoid or treat nausea and vomiting include the following:

- Avoid spicy foods
- Avoid strong or unusual odors
- Eat dry cereal, toast, or crackers
- Eat frequent, small meals
- Get moderate aerobic exercise
- Drink ginger ale or ginger tea, which helps aids in stomach upset
- Seek fresh air when a bout of nausea comes on

A severe form of nausea and vomiting is a condition known as **hyperemesis gravidarum**. It is marked by prolonged vomiting, which can result in dehydration and require hospitalization. This disorder is relatively rare and impacts only 0.3 to 2 percent of all pregnant women.[4]

Food Cravings and Aversions

Food aversions and cravings do not have a major impact unless food choices are extremely limited. The most common food aversions are milk, meats, pork, and liver. For most women, it is not harmful to indulge in the occasional craving, such as the desire for pickles and ice cream. However, a medical disorder known as pica is willingly consuming foods with little or no nutritive value, such as dirt, clay, and laundry starch. In some places this is a culturally accepted practice. However, it can be harmful if these substances take the place of nutritious foods or contain toxins.

Gestational Diabetes

Pregnant women who never had diabetes before and experience high blood sugar levels during pregnancy are diagnosed with **gestational diabetes**. The prevalence of gestational diabetes is estimated as high as 9.2%.[5] The body becomes resistant to the hormone insulin, which enables cells to transport glucose from the blood. Gestational diabetes is usually diagnosed around twenty-four to twenty-six weeks, although it is possible for the condition to develop later into a pregnancy. Most women are given a test around this time of pregnancy to identify gestational diabetes. If blood sugar levels are not properly monitored and treated, the baby might gain too much weight and require a cesarean delivery. Diet and regular physical activity can help to manage this condition. Gestational diabetes usually resolves after childbirth, although some women who suffer from this condition develop Type 2 diabetes later in life, particularly if they are overweight. A previous diagnosis of gestational diabetes increases the risk of getting Type 2 Diabetes by up to 60%.[6]

Gestational Hypertension

Elevated blood pressure that begins in the second half of pregnancy is referred to as **gestational hypertension**. Approximately 5-8% of pregnant women worldwide experience hypertensive disorders.[7] First-time mothers are at a greater risk, along with women who have mothers or sisters who had gestational hypertension, women carrying multiple fetuses, women with a prior history of high blood pressure or kidney disease, and women who are overweight or obese when they become pregnant.

Pregnant woman having blood pressure measured

Hypertension can prevent the placenta from getting enough blood, which would result in the baby getting less oxygen and nutrients. This can result in low birth weight, although most women with gestational hypertension can still deliver a healthy baby if the condition is detected and treated early. Some risk factors can be controlled, such as diet, while others cannot, such as family history. If left untreated, gestational hypertension can lead to a serious complication called preeclampsia, which is sometimes referred to as toxemia. This disorder is marked by elevated blood pressure and protein in the urine and is associated with swelling, or edema. Because this condition is so serious, it is recommended that all women regularly attend their prenatal checkups to monitor for this and overall health of the mother and baby during pregnancy.[8]

13.2 Nutrition Recommendations for Pregnancy

As a female's body changes during pregnancy, so do her nutritional needs. Pregnant women must consume more calories and nutrients in the second and third trimesters than other adult women. However, the average recommended daily caloric intake can vary depending on activity level and the mother's normal weight. Also, pregnant women should choose a high-quality, varied diet, consume fresh foods, and prepare nutrient-rich meals. Although it is possible to consume adequate nutrients with a well-balanced diet, it can be difficult; for that reason, supplementation during pregnancy is generally recommended.

Energy

During the first trimester, a pregnant woman has the same energy requirements as prior to pregnancy. However, as the pregnancy progresses, a woman needs to increase her caloric intake. According to the Centers for Disease Control and Prevention,[9] the caloric recommendation for the second trimester is to consume an additional 340 Calories per day above the caloric needs prior to pregnancy. During the third trimester the recommendation is an additional 450 Calories per day above the pre-pregnant caloric needs. The increased calories go toward the increased maternal metabolism, the baby's development, and building fat stores to support lactation after pregnancy. A woman can easily meet these increased needs by consuming more nutrient-dense foods. For example, **Figure 1** shows food that would increase intake by about 340 Calories.

		
1 medium-sized banana	6 ounces low-fat vanilla yogurt	1 slice whole-wheat toast with 1 teaspoon jam
100 Calories	140 Calories	75 Calories (toast) 25 Calories (jam)
		Total: 340 Calories

Figure 1: Additional calories required by pregnancy in second trimester

Carbohydrates

The recommended daily allowance, or RDA, for carbohydrates during pregnancy is a minimum of 175 grams per day to fuel maternal and fetal brain development.[10] The best carbohydrate food sources for pregnant women include whole-grain breads and cereals, brown rice, root vegetables, legumes, and fruits. These and other unrefined carbohydrates provide energy, nutrients, phytochemicals, antioxidants, and fiber. These foods also help to build the placenta and supply energy for the growth of the unborn baby. Refined carbohydrates, such as white bread, cookies and other baked desserts, pretzels, and chips are still a source of carbohydrates, however, they have low nutrient density and should be eaten in moderation.

Protein

During pregnancy, extra protein is needed for the synthesis of new maternal and fetal tissues. Proteins build muscle and other tissues, enzymes, antibodies, and hormones in both the mother and the unborn baby. Additional protein also supports increased blood volume and the production of amniotic fluid. The RDA for protein during the second and third trimesters of pregnancy is 25 grams above the recommendation for non-pregnant women.[10] However, in most instances, there is no need for a pregnant woman to make a focused effort to increase protein intake as long as she has a normal appetite. Protein should be derived from healthy sources, such as lean red meat, white-meat poultry, legumes, nuts, seeds, eggs, and fish. Low-fat milk and other dairy products also provide protein, along with calcium and other nutrients.

Pregnant woman with healthy snacks

Fat

There are no specific recommendations for fats during pregnancy, apart from following normal dietary guidelines. Fats should make up 20 to 35 percent of daily calories, and those calories should come from healthy fats, such as avocados, nuts and oils. It is not recommended for pregnant women to be on a very low-fat diet, since it would be hard to meet the needs of essential fatty acids and fat-soluble vitamins. Fatty acids are important during pregnancy because they support the baby's brain and eye development. In particular, the brain depends on omega-3 (DHA) and omega-6 fatty acids for function, structure, and growth. Fats can also help the placenta grow and may help to prevent premature birth and low birth weight. There are several healthy sources of dietary fat. It is recommended that women eat a variety of these sources, including fish. Cold-water fish such as salmon, and even tuna, are good sources of the omega-3 fatty acids EPA and DHA. It is recommended that pregnant women avoid shark, king mackerel, swordfish and tilefish due to the high level of mercury in these fish. Other than avoiding these fish high in mercury, it is recommended that pregnant women eat 8-12 ounces of a variety of fish per week.[11]

Sources of healthy fats

Fiber

The recommendation for fiber for pregnant women is 28 grams of dietary fiber per day.[10] Pregnant women should consume both soluble and insoluble fiber. Insoluble fiber helps soften stools and speeds the elimination of waste material through the colon to avoid constipation. Soluble fiber helps to lower blood-cholesterol levels and regulate blood glucose. Sources of fiber include whole grains, fruits, vegetables, dried peas, and beans.

Fluids

According to the Institutes of Medicine, pregnant women should drink 2.3 liters (about 10 cups) of liquids per day to provide enough fluid for blood production. It is also important to drink liquids during physical activity or when it is hot and humid outside, to replace fluids lost through perspiration. The combination of a high-fiber diet and lots of liquids also helps to prevent constipation.[12]

Vitamins and Minerals

Recommendations for most vitamins and minerals increase slightly during pregnancy. Most of these requirements can be fulfilled with a healthy diet. However, taking a daily prenatal supplement or multivitamin is often recommended to help meet many nutritional needs. **Table 1** (see below) shows the vitamin and mineral recommendations for non-pregnant and pregnant women.

The micronutrients involved with building the skeleton—vitamin D, calcium, phosphorus, and magnesium—are crucial during pregnancy to support fetal bone development. Although the levels are the same as those for non-pregnant women, many women do not typically consume adequate amounts of these nutrients and should make an extra effort to meet those needs during pregnancy. Even though the amount of calcium absorption doubles, the intake of calcium needs to remain at the recommended level to meet the extra demands of pregnancy for this nutrient.[13]

Additional iron intake is important because of the increase in blood volume during pregnancy required to support the fetus and placenta. Iron-deficiency anemia during pregnancy has been linked to the risk of preterm delivery and low-birthweight infants by two to three times. It is possible this is related to the decreased oxygen supply to the fetus and placenta, increased rates of infection or adverse effects on brain development that may occur with low iron stores in the mother.[14] It is optimal to have a female enter pregnancy with adequate iron stores to better meet her needs as it is difficult to make up low iron levels and also meet the increased demands of pregnancy. Obtaining the increased recommendation for iron is very difficult for many women.

Oftentimes, even if a pregnant woman consumes a healthy diet, there still is a need to take an iron supplement.

Vitamin	Non-Pregnant Females	Pregnant Females
Vitamin A (mcg)	700	770
Vitamin B_6 (mg)	1.3	1.9
Vitamin B_{12} (mcg)	2.4	2.6
Vitamin C (mg)	75	85
Vitamin D (mcg)	15	15
Vitamin E (mg)	15	15
Calcium (mg)	1000	1000
Folate (mcg)	400	600
Iron (mg)	18	27
Magnesium (mg)	310	350
Niacin (mg)	14	18
Phosphorus (mg)	700	700
Riboflavin (mg)	1.1	1.4
Thiamine (mg)	1.1	1.4
Zinc (mg)	8	11

Table 1: RDA values for vitamins and minerals of non-pregnant and pregnant females[10]

Folate needs increase during pregnancy from 400 micrograms to 600 micrograms per day to prevent neural tube defects. Neural tube defects are conditions associated with the development of the brain, spine, or spinal cord. These defects occur early in pregnancy, prior to day 28, usually before the woman even knows she is pregnant. The two most common neural tube defects are spina bifida and anencephaly.[15] These conditions vary in severity from some paralysis in the lower limbs in spina bifida to an undeveloped brain or skull (anencephaly). Babies born with anencephaly are usually either stillborn or die shortly after birth. Folate is also crucial for fetal development because it helps produce the extra blood a woman's body requires throughout pregnancy. Low folate intake is associated with fetal growth restriction, premature and low-birth-weight infants.[16]

For most other micronutrients, recommended intakes are similar to those for non-pregnant women, although it is crucial for pregnant women to make sure to meet the RDAs to help with proper development. In addition, pregnant mothers should avoid exceeding any recommendations. Taking mega-doses of supplements can lead to excessive intake of certain micronutrients, such as vitamin A and zinc, which may produce toxic effects that can also result in birth defects.

Teratogens

Teratogens are substances that can be harmful to the fetus if they are present during pregnancy.[17] Examples of teratogens that may cause harm to the fetus include mercury, alcohol, marijuana, prescription and illegal drugs and harmful levels of Vitamin A. These substances may cause physical and/or mental abnormalities for the developing fetus. When alcohol is ingested by a pregnant woman, it readily passes through the placenta to the developing fetus. Negative effects of alcohol intake during pregnancy may include abnormal mental development and growth of the fetus. Therefore, it is advised that women that are or may become pregnant do not drink alcohol.[51]

Physical Activity during Pregnancy

Pregnant woman exercising

For most pregnant women, physical activity is important and is recommended in the *2018 Physical Activity Guidelines for Americans*.[18] Unless women has medical reasons to avoid physical activity during pregnancy it is recommended to have 150 minutes of regular moderate-intensity aerobic activity. This can be met with 30 minutes of activity per day most days of the week. Regular activity keeps the heart and lungs healthy and helps improve sleep, boosts mood and energy levels. In addition, women who participate in regular physical activity during pregnancy report fewer discomforts and may have an easier time losing excess weight after childbirth. Brisk walking, swimming, or an aerobics class geared toward expectant mothers are all great ways to get physical activity during pregnancy. Healthy women who already participate in vigorous activities, such as running, can continue doing so during pregnancy if they discuss an exercise plan with their physician.[19]

However, pregnant women should avoid pastimes that could cause injury, such as soccer, football, and other contact sports, or activities that could lead to falls, such as horseback riding and downhill skiing. It may be best for pregnant women not to participate in certain sports that require you to jump or change direction quickly, or laying on their back after the first trimester. Scuba diving should also be avoided because it might result in the fetus developing decompression sickness. This potentially fatal condition results from a rapid decrease in pressure when a diver ascends too quickly.

13.3 Lactation

New mothers will need to decide if they will breastfeed

After the birth of the baby, nutritional needs must be met to ensure that an infant not only survives, but thrives from infancy into childhood. Breastfeeding provides the fuel newborns need for rapid growth and development. As a result, the World Health Organization (WHO) recommends that breastfeeding be done exclusively for the first six months of an infant's life.[20] New mothers must also consider their own nutritional requirements to help their bodies recover from pregnancy. This is particularly true for women who breastfeed their babies, which calls for an increased need in certain nutrients.

Lactation is the process that makes breastfeeding possible, and is the synthesis and secretion of breast milk. Early in a woman's pregnancy, her mammary glands begin to prepare for milk production. Hormones play a major role in this, particularly during the second and third trimesters. At that point, levels of the hormone **prolactin** increase to stimulate the growth of the milk duct system, which initiates and maintains milk production. Levels of the hormone **oxytocin** also rise to promote the release of breast milk when the infant suckles, which is known as the milk ejection reflex, or letdown. However, levels of the hormone progesterone need to decrease for successful milk production, because progesterone inhibits milk secretion. Shortly after birth, the expulsion of the placenta triggers progesterone levels to fall, which activates lactation.[21]

Nutrition Recommendations

New mothers need to adjust their caloric and fluid intake to make breastfeeding possible. The RDA is an additional 330 Calories from baseline caloric needs during the first six months of lactation and an additional 400 Calories from baseline caloric needs during the second six months of lactation. The energy needed to support breastfeeding comes from both increased intake and from maternal fat stores. For example, during the first six months after her baby is born, the daily caloric cost for a lactating mother is 500 Calories, with 330 Calories derived from increased intake and 170 Calories derived from maternal fat stores. This helps explain why breastfeeding may promote weight loss in new mothers. Lactating women should also drink 3.1 liters of liquids per day (about 13 cups) to maintain milk production, according to the Institutes of Medicine (IOM). As is the case during pregnancy, the RDA of nearly all vitamins and minerals increases for women who are breastfeeding their babies. The protein RDA for women who are lactating is also an additional 25 grams of protein above non-pregnant/non-lactating needs, just as in the second and third trimesters of pregnancy.[10]

Benefits of breastfeeding

Breastfeeding has a number of benefits, both for the mother and for the child. Breast milk contains immunoglobulins, enzymes, immune factors, and white blood cells. As a result, breastfeeding boosts the baby's immune system and lowers the incidence of diarrhea, along with respiratory diseases, gastrointestinal problems, and ear infections. Breastfed babies also are less likely to develop asthma and allergies. Breastfeeding lowers the risk of sudden infant death syndrome. In addition, human milk encourages the growth of healthy bacteria in an infant's intestinal tract. All of these benefits remain in place after an infant has been weaned from breast milk. Studies also report other possible long-term effects. For example, breast milk may improve an infant's intelligence and protect against Type 1 Diabetes, Type 2 Diabetes, celiac disease and obesity.[22]

Breastfeeding has several other important benefits. It is easier for babies to digest breast milk than bottle formula, which contains proteins made from cow's milk that is harder for the infant's immature digestive tract to handle.[23] For that reason, it is recommended that cow's milk be avoided during the first year of life. Breastfeeding is more sustainable and results in less plastic waste and other trash. Breastfeeding can also save families money because it does not incur the same cost as purchasing formula. Another benefit is that breast milk is always ready. It does not have to be mixed, heated, or prepared. Also, breast milk is sterile and is always at the right temperature.

In addition, the skin-to-skin contact of breastfeeding promotes a close bond between mother and baby, which is an important emotional and psychological benefit. The practice also provides health benefits for the mother. Breastfeeding releases hormones that helps the uterus shrink back to its normal size and helps a woman's bones stay strong, which protects against fractures later in life. Studies have also shown that breastfeeding reduces the risk of type 2 diabetes and breast and ovarian cancers.[24]

Barriers to breastfeeding

Although breast milk is ideal for almost all infants, there are some challenges that nursing mothers may face when starting and continuing to breastfeed their infants. Possible obstacles may include painful engorgement or fullness in the breasts, sore and tender nipples, little support from family and peers, low levels of comfort or confidence in public, and lack of accommodation to breastfeed or express milk in the workplace.

One of the first challenges nursing mothers face is learning the correct technique. It may take a little time for a new mother to help her baby properly latch on to her breast. Improper latching can result in inadequate intake, which could slow growth and development. However, International Board Certified Lactation Consultants (IBCLCs), trained OB nurses, and trained registered dietitians are qualified to help new mothers learn the proper technique. Education, the length of maternity leave, and laws to protect public breastfeeding, among other measures, can all help to facilitate breastfeeding for many lactating women and their newborns.

Contraindications to breastfeeding

Although there are numerous benefits to breastfeeding, in some cases there are also risks that must be considered. In the developed world, a new mother with HIV should not breastfeed, because the infection can be transmitted through breast milk. These women typically have access to bottle formula that is safe, and can be used as a replacement for breast milk. However, in developing nations where HIV infection rates are high and acceptable infant formula can be difficult to come by, many newborns would be deprived of the nutrients they need to develop and grow. Also, inappropriate or contaminated bottle formulas cause 1.5 million infant deaths each year. As a result, the WHO recommends that women infected with HIV in the developing world should nurse their infants while taking antiretroviral medications to lower the risk of transmission.[25]

Breastfeeding also is not recommended for women undergoing radiation or chemotherapy treatment for cancer. Additionally, if an infant is diagnosed with **galactosemia**, meaning an inability to process the simple sugar galactose, the child must be on a galactose-free diet, which excludes breast milk. This genetic disorder is a very rare condition, however, and only affects 1 in thirty- to sixty thousand newborns.[26] When breastfeeding is contraindicated for any reason, formula enables parents and caregivers to meet their newborn’s nutritional needs.

13.4 Nutrition Recommendations for Infants

Diet and nutrition have a major impact on a child’s development from infancy into the adolescent years. A healthy diet not only affects growth, but also immunity, intellectual capabilities, and emotional well-being. One of the most important jobs of parenting is making sure that children receive an adequate amount of needed nutrients to provide a strong foundation for the rest of their lives.

Nutritional Requirements

Mother feeds infant

Requirements for macronutrients and micronutrients on a per-kilogram basis are higher during infancy than at any other stage in the human life cycle. These needs are affected by the rapid cell division that occurs during growth, which requires energy and protein, along with the nutrients that are involved in DNA synthesis. During this period, children are entirely dependent on their parents or other caregivers to meet these needs. For almost all infants six months or younger, breast milk is the best source to fulfill nutritional requirements. An infant may require feedings eight to twelve times a day or more in the beginning. After six months, infants can gradually begin to consume solid foods to help meet nutrient needs.

Energy

Energy needs relative to size are much greater in an infant than an adult. The RDA to meet energy needs changes as an infant matures and puts on more weight. For example, the equation for the first three months of life is *(89 x weight [kg] −100) + 175 kcal*. Based on these equations, the estimated energy requirement for infants from zero to six months of age is 472 to 645 Calories per day for boys and 438 to 593 Calories per day for girls. For infants ages six to twelve months, the estimated requirement is 645 to 844 Calories per day for boys and 593 to 768 Calories per day for girls.[27] How often infants want to eat will also change over time due to growth spurts, which typically occur at about two weeks and six weeks of age, and again at about three months and six months of age.

Macronutrients

The dietary recommendations for infants are based on the nutritional content of human breast milk. Almost all of the carbohydrate in human milk is lactose, which infants digest and tolerate well. Between four to six months, it is appropriate to start introducing additional food sources of carbohydrates such as cereal grains, fruits and vegetables. Added sugars are not recommended. The protein DRI recommendation for infants ages two to six months is 1.52 g/kg/day and for infants seven to twelve (12) months is 1.2 g/kg/day compared to the adult RDA of 0.8 g/kg/day.[28] Pureed or ground meat and beans may be added at 6 months to provide protein and iron.

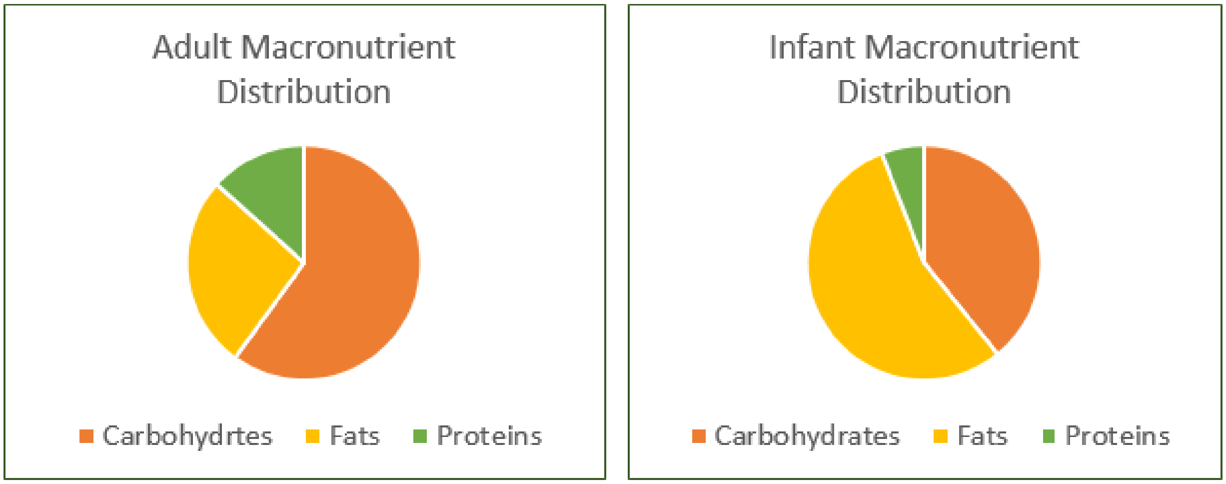


Figure 2: Comparison of adult and infant macronutrient distribution. Adults' needs are very different than that of an infant. An infant's diet is very energy dense to ensure adequate intake of calories in a smaller volume

Fat is the major source of calories for infants fed human breast milk. The energy density fat provides for the infant is important for the rapid growth and development that occurs during infancy. The recommendation of fat is based on the average composition of breastmilk, which is approximately 55% of calories consumed in a day. Breast milk also contains the essential fatty acid, DHA. Increasing evidence shows that infants fed breast milk with a higher content of DHA have better eye and brain development. For this reason, it is important for lactating mothers to consume adequate amounts of DHA.[29]

Fluids

Infant's needs for fluids are higher than adults because of their increased surface area for size and they also excrete more urine because their kidneys are not fully mature. However, infants that are exclusively breastfed do not require additional water. If water losses are increased due to diarrhea or vomiting, additional fluids may be needed.[30]

Micronutrients

Almost all of the nutrients that infants require can be met if they consume an adequate amount of breast milk. There are a few exceptions, though. Human milk is low in vitamin D, which is needed for calcium absorption and building bone, among other things. Therefore, breastfed children often need to take a vitamin D supplement in the form of drops. Infants at the highest risk for vitamin D deficiency are those with darker skin and no exposure to sunlight.

Breast milk is also low in vitamin K, which is required for blood clotting, and deficits could lead to bleeding or hemorrhagic disease. Babies are born with limited vitamin K, so some states require a vitamin K injection after birth.

Breast milk is not a good source of iron, but the iron in breast milk is well absorbed by infants. Although formula has more iron than breast milk, the iron in breast milk is more bioavailable. Nearly 80% of the iron a healthy term infant is born with was transferred to the baby during the third trimester of pregnancy. While this storage of iron may be sufficient for about four to six months, an infant needs an additional source of iron other than breast milk after that age.[31] After that point, the RDA for iron is 11 mg/day.[10]

Current recommendations by the American Academy of Pediatrics states that infants under six months of age should not receive fluoride supplements whether they are breast-fed or formula-fed. Older infants and children then should have appropriate supplementation if the local water provides less than 30 parts per million of fluoride.[32] Toothpaste with fluoride is generally recommended as well. A smear, or size of a grain of rice, should be used up to age three. Older children should limit the size of their toothpaste to the size of a pea.[33]

Introducing solid foods

Infants should be breastfed or bottle-fed exclusively for the first six months of life according to the WHO. (The American Academy of Pediatrics recommends breast milk or bottle formula exclusively for at least the first four months, but ideally for six months.) Infants should not consume solid foods prior to six months because there is a risk of choking and solids do not contain the right composition of nutrients infants need. Also, eating solids may mean drinking less breast milk or bottle formula. If that occurs, an infant may become malnourished.

Is my baby ready for solid foods?
• Can he hold his head up? • Does he open his mouth when food comes his way? • Can he move food from the spoon into his throat? • Is he big enough? (generally double birth weight or 13 pounds)

Table 2: Signs a baby is ready for solid

If parents try to feed an infant who is too young or is not ready, their tongue will push the food out, which is called an extrusion reflex. After six months, the suck-swallow reflexes are not as strong, and infants can hold up their heads and move them around, both of which make eating solid foods more feasible.

Baby food can be pre-prepared or made at home

Solid baby foods can be bought commercially or prepared from regular food using a food processor, blender, food mill, or grinder at home. Usually, an infant cereal can be offered from a spoon at six months. By nine months to a year, infants are able to chew soft foods and can eat solids that are well chopped or mashed.

Infants who are fed solid foods too soon are susceptible to developing food allergies. Therefore, as parents and caregivers introduce solids, they should feed their child only one new food at a time (starting with rice cereal, followed by fruits or vegetables), to help identify allergic responses or food intolerances. An iron supplement or iron-fortified cereal is also recommended at this time.

Feeding problems in infancy

Parents and caregivers should be mindful of certain diet-related problems that may arise during infancy. Certain foods are choking hazards, including foods with skins or foods that are very small, such as grapes. Other examples of potential choking hazards include raw carrots and apples, raisins, and hard candy. Parents should also avoid adding salt or seasonings to an infant's food.

Heating an infant's food presents a risk of accidental injury or burns, which may occur if the food is heated unevenly or excessively. Keep in mind that an infant cannot communicate that the food is too hot. Also, parents and caregivers should never leave a baby alone at mealtime, because an infant can accidentally choke on pieces of food that are too big or have not been adequately chewed. Honey has been identified as a source of a specific spore which is called *Clostridium botulinum*. The spores can produce a poisonous toxin in a baby's immature intestines which can cause **infantile botulism** causing the baby to become very weak and sick. For this reason, it is recommended to not provide honey to an infant before age one.[35] However, honey as an ingredient in food, such as in cereal, is safe for all ages because it has been adequately heat treated. It is important to note that botulinum exists in the environment and has been

Washing produce helps prevent foodborne illnesses such as infantile botulism.

found on fresh fruits and vegetables. This is a good reminder that using good food safety practices such as washing fruits and vegetables is also important.[36]

Assessing Growth

Healthy infants grow steadily, but not always at an even pace. For example, during the first year of life, height increases by 50 percent, while weight triples. Physicians and other health professionals can use growth charts to track a baby's development process. Because infants cannot stand, length is used instead of height to determine the rate of a child's growth. Other important developmental measurements include head circumference and weight. All of these must be tracked and compared against standard measurements for an infant's age. Nationally-accepted growth charts are based on data collected by the National Center for Health Statistics.[37] These charts allow for tracking trends over time and comparing with other infants among percentiles within the United States. Growth charts may provide warnings that a child has a medical problem or is malnourished. Insufficient weight or height gain during infancy may indicate a condition known as failure-to-thrive (FTT), which is characterized by poor growth. FTT can happen at any age, but in infancy, it typically occurs after six months. Some causes include poverty, lack of enough food, feeding inappropriate foods, and excessive intake of fruit juice.

Measuring and tracking an infant's growth is one of the best ways to monitor if the child is receiving adequate nutrition. Common measurements during the first year of life are length-for-age, weight-for-age, length-for-weight and head circumference-for-age. To best identify proper growth, it is best to plot these measurements on a growth chart. For infants, the charts that are recommended to use are the World Health Organization (WHO) growth charts. These charts were developed using infants that were exclusively breastfed for at least 4 months. The **percentiles** in the WHO growth charts better reflect the pattern set by following recommendations regarding breastfeeding. The Centers for Disease Control (CDC) charts were developed tracking growth of infants that were not necessarily breastfed for the recommended amount of time. It is recommended to use the WHO growth charts until the age of two.[37] Percentiles reflect how children grow compared to children with the same age and gender. For example, a 3-month-old baby girl plotted at the 30th percentile indicates that out of 100 3-month-old baby girls, 30 would be smaller and 70 would be larger. The goal is to have a child follow their growth curve or percentile. Without using growth charts, two "checkpoints" can be monitored to do a less detailed assessment of weight and nutritional status. Normal growth would be indicated by the baby's weight doubling by about 5 months and tripling by one year of age.[38]

13.5 Nutrition Recommendations for Young Children

By the age of two, children have advanced from infancy and are on their way to becoming school-aged children. Their physical growth and motor development slows compared to the progress they made as infants. However, toddlers experience enormous intellectual, emotional, and social changes. Of course, food and nutrition continue to play an important role in a child's development. During this stage, the diet completely shifts from breastfeeding or bottle-feeding to solid foods along with healthy juices and other liquids. Parents of toddlers also need to be mindful of certain nutrition-related issues that may occur during this stage of the human life cycle.

Young children preparing a healthy snack

During this phase of human development, children are mobile and grow more slowly than infants, but are much more active. The toddler years pose interesting challenges for parents or other caregivers, as children learn how to eat on their own and begin to develop personal preferences. However, with the proper diet and guidance, toddlers can continue to grow and develop at a healthy rate.

Energy

The energy requirements for children from ages two to three are about 1,000 to 1,400 Calories a day. In general, a toddler needs to consume about 40 Calories for every inch of height. For example, a young child who measures 32 inches should take in an average of 1,300 Calories a day. However, the recommended caloric intake varies with each child's level of activity. Toddlers require small, frequent, nutritious snacks and meals to satisfy energy requirements. The amount of food a toddler needs from each food group depends on daily caloric needs. The following figure (Figure 3) describes how a 1000 Calorie meal pattern could be arranged to provide the needs for a child of this age.[39]

Meal and Snack Pattern A

These patterns show one way a **1000 calorie Daily Food Plan** can be divided into meals and snacks for a preschooler. Sample food choices are shown for each meal or snack.

Notes for using the Meal and Snack Ideas.

Breakfast	Breakfast Ideas		
1 ounce Grains ½ cup Fruit ½ cup Dairy*	Cereal and Banana *1 cup crispy rice cereal* *½ cup sliced banana* ½ cup milk*	Yogurt and Strawberries *½ cup plain yogurt** *4 sliced strawberries* 1 slice whole wheat toast	Applesauce Topped Pancake *1 small pancake* *¼ cup applesauce* ¼ cup blueberries ½ cup milk*

Morning Snack	Morning Snack Ideas		
½ ounce Grains ½ cup Fruit	½ slice cinnamon bread ½ large orange	½ cup toasted oat cereal ½ cup diced pineapple	Frozen Graham Cracker Sandwich *1 graham cracker (2 squares)* *¼ cup mashed banana* ¼ cup apple juice

Lunch	Lunch Ideas		
1 ounce Grains ¼ cup Vegetables ½ cup Dairy* 1 ounce Protein Foods	Open-faced Chicken Sandwich and Salad *1 slice whole wheat bread* *1 slice American cheese** *1 ounce sliced chicken* ¼ cup baby spinach (raw) 2 Tbsp grated carrots	Soft Taco (meat or veggie) *1 small tortilla* *¼ cup salad greens* *2 Tbsp chopped tomatoes* *3 Tbsp shredded cheese** *1 ounce cooked ground beef or ¼ cup refried beans*	Bagel Snake *1 mini whole grain bagel* *¼ cup sliced cherry tomatoes* *¼ cup diced celery* *1 ounce tuna* ½ cup milk*

Afternoon Snack	Afternoon Snack Ideas		
¼ cup Vegetables ½ cup Dairy*	¼ cup sugar snap peas ½ cup yogurt*	¼ cup carrot "matchsticks" ½ cup milk*	¼ cup tomato juice 1 string cheese*

Dinner	Dinner Ideas		
½ ounce Grains ½ cup Vegetables ½ cup Dairy* 1 ounce Protein Foods	Chicken & Potatoes *1 ounce chicken breast* *¼ cup mashed potato* ¼ cup green peas ½ small whole wheat roll ½ cup milk*	Spaghetti & Meatballs *¼ cup cooked pasta* *2 Tsbp tomato sauce* *1 meatball (1 ounce)* ½ medium ear corn on the cob ½ cup milk*	Rice & Beans *¼ cup cooked brown rice* *¼ cup black beans* *¼ cup bell pepper* ¼ cup broccoli ½ cup milk*

*Offer your child fat-free or low-fat milk, yogurt, and cheese.

Figure 3: 1000 Calorie meal and snack pattern for preschoolers[39]

Macronutrients

Children eating a healthy breakfast

For carbohydrate intake, the Acceptable Macronutrient Distribution Range (AMDR) is 45 to 65 percent of daily calories (113 to 163 grams of carbohydrate per 1,000 Calories). Toddlers' needs increase to support their body and brain development. Brightly-colored unrefined carbohydrates, such as peas, orange slices, tomatoes, and bananas are not only nutrient-dense, they also make a plate look more appetizing and appealing to a young child. The AMDR for protein is 5 to 20 percent of daily calories (13 to 50 grams of protein per 1,000 Calories). The AMDR for fat for toddlers is 30 to 40 percent of daily calories (33 to 44 grams of fat per 1,000 Calories). Essential fatty acids are vital for the development of the eyes, along with nerve and other types of tissue.[10]

Micronutrients

As a child grows bigger, the demands for micronutrients increase. These needs for vitamins and minerals can be met with a balanced diet, with a few exceptions. The RDA for toddlers is 15 micrograms of vitamin D per day.[10] Vitamin D-fortified milk can help to meet this need. However, toddlers who do not get enough of this micronutrient may be advised to take a supplement. Along with Vitamin D, calcium plays an important role in the development of healthy bones and to help children achieve their optimal peak bone mass.[40] Pediatricians may also prescribe a fluoride supplement for toddlers who live in areas with fluoride-poor water.

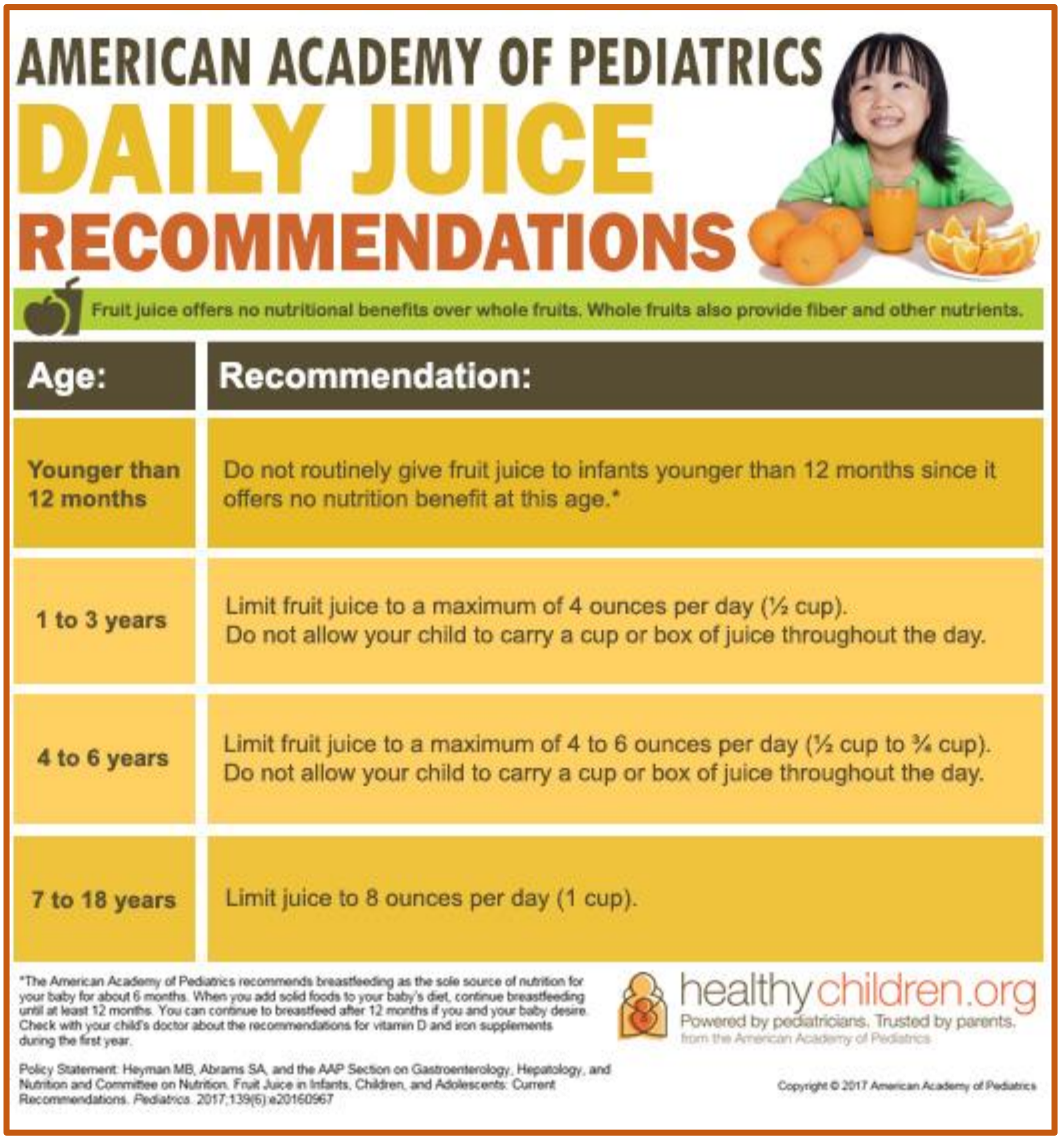
Iron deficiency is also a major concern for children between the ages of two and three. An infant who switches to solid foods, but does not eat enough iron-rich foods, can develop iron-deficiency anemia. This condition occurs when an iron-deprived body cannot produce enough hemoglobin, a protein in red blood cells that transports oxygen throughout the body. The inadequate supply of hemoglobin for new blood cells results in anemia. Iron-deficiency anemia causes a number of problems including weakness, pale skin, shortness of breath, and irritability. It can also result in intellectual, behavioral, or motor problems. In infants and toddlers, iron-deficiency anemia can occur when older babies are weaned from breast milk and iron-fortified formula and not given good sources of iron in foods. As a result, their iron stores become diminished at a time when this nutrient is critical for brain growth and development.[41]

Examples of iron sources

There are steps that parents and caregivers can take to prevent iron-deficiency anemia, such as adding more iron-rich foods to a child's diet, including lean meats, fish, poultry, eggs, legumes, and iron-enriched whole-grain breads and cereals. A toddler's diet should provide 7 to 10 milligrams of iron daily. Milk is a poor source of iron but provides an excellent source of calcium. It is recommended for children to consume 16 fluid ounces (470 milliners) but not exceed 24 fluid ounces (710 milliliters) of milk per day to provide calcium but avoid displacing foods rich with iron.[40, 41, 42] Children may also be given a daily supplement, using infant vitamin drops with iron or ferrous sulfate drops if advised by a doctor. Consuming vitamin C, such as orange juice, can also help to improve iron absorption.[43]

Toddler Diarrhea

A variety of conditions or circumstances may give a toddler diarrhea. Possible causes include bacterial or viral infections, food allergies, or lactose intolerance, among other medical conditions. Excessive fruit juice consumption (more than one 6-ounce cup per day) can also lead to diarrhea.[43] Diarrhea presents a special concern in young children because their small size makes them more vulnerable to dehydration. Parents should contact a pediatrician if a toddler has had diarrhea for more than twenty-four hours, if a child is also vomiting, or if they exhibit signs of dehydration, such as a dry mouth or tongue, or sunken eyes, cheeks, or abdomen. Preventing or treating dehydration in toddlers includes the replacement of lost fluids and electrolytes (sodium and potassium). Oral rehydration therapy, or giving special fluids by mouth, is the most effective measure. Figure 4 describes the recommendations from the American Academy of Pediatrics for juice consumption for children of all ages.



AMERICAN ACADEMY OF PEDIATRICS
DAILY JUICE
RECOMMENDATIONS

Fruit juice offers no nutritional benefits over whole fruits. Whole fruits also provide fiber and other nutrients.

Age:	Recommendation:
Younger than 12 months	Do not routinely give fruit juice to infants younger than 12 months since it offers no nutrition benefit at this age.*
1 to 3 years	Limit fruit juice to a maximum of 4 ounces per day (½ cup). Do not allow your child to carry a cup or box of juice throughout the day.
4 to 6 years	Limit fruit juice to a maximum of 4 to 6 ounces per day (½ cup to ¾ cup). Do not allow your child to carry a cup or box of juice throughout the day.
7 to 18 years	Limit juice to 8 ounces per day (1 cup).

*The American Academy of Pediatrics recommends breastfeeding as the sole source of nutrition for your baby for about 6 months. When you add solid foods to your baby's diet, continue breastfeeding until at least 12 months. You can continue to breastfeed after 12 months if you and your baby desire. Check with your child's doctor about the recommendations for vitamin D and iron supplements during the first year.

healthychildren.org
Powered by pediatricians. Trusted by parents.
from the American Academy of Pediatrics

Policy Statement: Heyman MB, Abrams SA, and the AAP Section on Gastroenterology, Hepatology, and Nutrition and Committee on Nutrition. Fruit Juice in Infants, Children, and Adolescents: Current Recommendations. *Pediatrics*. 2017;139(6):e20160967

Copyright © 2017 American Academy of Pediatrics

Figure 4: Juice Recommendations from the Academy of Pediatrics[42]

Food Jags

For weeks, toddlers may go on a **food jag** and eat one or two preferred foods—and nothing else. It is important to understand that preferences will be inconsistent as a toddler develops eating habits. This is one way that young children can assert their individuality and independence. However, parents and caregivers should be concerned if the same food jag persists for several months, instead of several weeks. Options for addressing this problem include rotating acceptable foods while continuing to offer diverse foods, remaining low-key to avoid exacerbating the problem, and discussing the issue with a pediatrician. Also, children should not be forced to eat foods that they do not want. It is important to remember that food jags do not have a long-term effect on a toddler's health, and are usually temporary situations that will resolve themselves.[44]

Dental Caries

Early childhood caries remains a potential problem during the toddler years. The risk of early childhood caries continues as children begin to consume more foods with a high sugar content. According to the National Health and Nutrition Examination Survey, children between ages of two and five consume about 200 Calories of added sugar per day.[45] Therefore, parents with toddlers should avoid processed foods, such as snacks from vending machines, and sugary beverages, such as soda. Parents also need to instruct a child on brushing their teeth at this time to help a toddler develop healthy habits and avoid tooth decay.

Choking Hazards

Certain foods are difficult for toddlers to manage and pose a high risk of choking. Big chunks of food should not be given to children under the age of four. Also, globs of peanut butter can stick to a younger child's palate and choke them. Popcorn and nuts should be avoided as well, because toddlers are not able to grind food and reduce it to a consistency that is safe for swallowing. Certain raw vegetables, such as baby carrots, whole cherry tomatoes, whole green beans, and celery are also choking hazards. However, there is no reason that a toddler cannot enjoy well-cooked vegetables cut into bite-size pieces.

Developing Healthy Habits

During the toddler years, parents may face a number of problems related to food and nutrition. Possible obstacles include difficulty helping a young child overcome a fear of new foods, or fights over messy habits at the dinner table. It may take a child being exposed to a new food 8-10 times before it is accepted.[46,47] Even in the face of problems and confrontations, parents and other caregivers must make sure their preschooler has nutritious choices at every meal. For example, even if a child stubbornly resists eating vegetables, parents should continue to provide them. Before long, the child may change their mind, and develop a taste for foods once abhorred. It is important to remember this is the time to establish or reinforce healthy habits.

Eating habits develop early in life. They are typically formed within the first few years and it is believed that they persist for years, if not for life. So it is important for parents and other caregivers to help children establish healthy habits and avoid problematic ones. Children begin expressing their preferences at an early age. Parents must find a balance between providing a child with an opportunity for self-expression, helping a child develop healthy habits, and making sure that a child meets all of their nutritional needs.

Registered Dietitian Nutritionist Ellyn Satter states that feeding is a responsibility that is split between parent and child.[47] The **division of responsibility** is outline in the following table:

Parent's Responsibility	Child's responsibility
What children eat	*How much* they eat
When children eat	*Whether* they eat
Where children eat	

Table 4: Division of Responsibility of eating as described by Ellyn Satter, RDN[47]

Satter states the role of the parent or caregiver in feeding includes:

- selecting and preparing food
- providing regular meals and snacks
- making mealtimes pleasant
- showing children what they must learn about mealtime behavior
- avoiding letting children eat in between meal- or snack-times[48]

Following Satter's division of responsibility in feeding can help a child eat the right amount of food, learn mealtime behavior, and grow at a healthy and predictable rate.

The Family: A Proclamation to the World describes the **stewardship** of parents by stating, "Parents have a sacred duty to rear their children in love and righteousness, to provide for their physical and spiritual needs, and to teach them to love and serve one another, observe the commandments of God, and be law-abiding citizens wherever they live."[49] Parents are encouraged to provide a loving environment and learning opportunities for their children to help them grow and learn. We learn from the same revelation that [we accepted] "His plan by which His children could obtain a physical body and gain earthly experience to progress toward perfection and ultimately realize their divine destiny as heirs of eternal life."[49] God has given us the gift of **agency**, or the ability and privilege to choose and act for ourselves, to help us grow. Agency is essential in the plan of salvation. Without agency, we would not be able to learn or progress or follow the Savior.[49] When parents apply this council to the feeding process, children can learn at an early age how to make choices. The following table compares these two ideas and how to implement the feeding relationship process to teach children in a loving environment.

	Satter's Division of Responsibility in Eating	The Family: A Proclamation to the World
Parents	Provide *what* children eat Decide *when* children eat (meal and snack times) Determine *where* children will eat	Stewardship: Provide choices Teach correct principles Loving environment
Children	Decide *how much* to eat Determine *whether* to eat (hungry or not?)	Agency: Make choices Learn from experience Be respectful

Table 5: Satter's Division of Responsibility of eating compared to principles outlined in The Family: A Proclamation to the World[48, 49]

Providing learning opportunities in a safe environment allows children to make choices when the consequences are not high. This can teach them the skill of decision making and can be valuable as children make more and more difficult decisions. Bad habits and poor nutrition have an accrual effect. However, the opposite is also true. Forming good habits at a young age will also have an effect as children grow. The foods you consume in your younger years will impact your health as you age, from childhood into the later stages of life. As a result, good nutrition today means optimal health tomorrow.

References

General

Principles of Nutrition is based on 'An Introduction to Nutrition' available at http://2012books.lardbucket.org/books/an-introduction-to-nutrition. Licensed under a Creative Commons Attribution-Noncommercial-Share Alike 3.0, http://creativecommons.org/licenses/by-nc-sa/3.0

*All **text** from "Principles of Nutrition" is licensed under the Creative Commons Attribution-Noncommercial-Share Alike 4.0 International License. To view a copy of this license, visit Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License/.*

All images used in this text are all rights reserved, and you must request permission from the copyright owner to use this material

Only the text of this work, "Principles of Nutrition" is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License. All images are all rights reserved, and you must request permission from the copyright owner to use this material

Additions made to the text were don't at BYU-Idaho, BYU-Provo, and from the following sources noted below.

Chapter 1

1. The Holy Bible, KJV. Salt Lake City, UT: Intellectual Reserve, Inc; 1979.
2. Doctrine and Covenants. Salt Lake City, UT: Intellectual Reserve, Inc; 1981:176.
3. Wolf G. A history of vitamin A and retinoids. *FAESB J.* 1996; 10(9): 1102-1107.
4. Baron J. Sailors' scurvy before and after James Lind - a reassessment. *Nutr Rev.* 2009; 67(6): 315-332.
5. Carpenter KJ. A short history of Nutritional Science: Part 1. *J Nutr.* 2003; 133(3): 638-645.
6. Carpenter KJ. A short history of Nutritional Science: Part 2. *J Nutr.* 2003; 133(4): 975-984.
7. Carpenter, KJ. A short history of Nutritional Science: Part 3. *J Nutr.* 2003; 133(10): 3023-3032.
8. Collier R. Legumes, lemons and streptomycin: A short history of the clinical trial. *CMAJ.* 2009; 180(1): 23-24.
9. Overnutrition. Unite for Sight website. http://www.uniteforsight.org/hunger/module4. Accessed December 22, 2016.
10. Malnutrition. World Health Organization website. https://www.who.int/news-room/fact-sheets/detail/malnutrition#:~:text=forms%20of%20malnutrition-,Undernutrition,vulnerable%20to%20disease%20and%20death.&text=A%20child%20who%20is%20underweight,stunted%2C%20wasted%2C%20or%20both. Accessed September 8, 2020.
11. The faces of malnutrition. UNICEF. http://www.unicef.org/nutrition/ index_faces-of-malnutrition.html. Updated July 20, 2016. Accessed December 22, 2016.
12. Drake F, Tawiah E, Badasu D. Sociodemographic correlates of obesity among Ghanaian women. *Public Health Nutr.* 2010; 14(7): 1285-1291.
13. Popkin B. An overview on the nutrition transition and its health implications: The Bellagio meeting. *Public Health Nutr.* 2002; 5(1A): 93-103.
14. Uusitalo UP. Dietary transition in developing countries: Challenges for chronic disease prevention. In: *Globalization, Diets, and Noncommunicable Diseases.* Switzerland: World Health Organization Publication; 2002: 6-31.
15. Popkin B. The nutrition transition in the developing world. *Dev Policy Rev*. 2003; 21(5-6): 581-597.
16. Jaacks LM, Slining MM, Popkin BM. Recent underweight and overweight trends by rural-urban residence among women in low- and middle-income countries. *J Nutr*. 2015; 145(2): 352-357.
17. Vorster H, Kruger A, Margetts B. The nutrition transition in Africa: Can it be steered into a more positive direction? *Nutrients*. 2011; 3(4): 429--441. doi:10.3390/nu3040429

18. Hampl JS, Johnston CS, Mills RA. Scourge of black-leg (scurvy) on the Mormon Trail. *Nutrition*, 2001; 17(5): 416-418.
19. WHO. *Global prevalence of vitamin A deficiency in populations at risk 1995-2005.* Geneva: World Health Organization; 2009. http://apps.who.int/iris/bitstream/10665/44110/1/9789241598019_eng.pdf. Accessed December 21, 2016.
20. Kochanek KD, Murphy SL, Xu J, Arias E. Deaths: final data for 2017. *Natl Vital Stat Reports*. June 24, 2019; 68(9): 1-76. https://www.cdc.gov/nchs/data/nvsr/nvsr68/nvsr68_06-508.pdf.
21. Wang X, Ouyang Y, Liu J, Zhu M, Zhao G, Bao W, et al. Fruit and vegetable consumption and mortality from all causes, cardiovascular disease, and cancer: Systematic review and dose-response meta-analysis of prospective cohort studies. *Br Med J.* 2014; 349: 4490. doi: http://dx.doi.org/10.1136/bmj.g4490
22. Loef M, Walach H. Fruit, vegetables and prevention of cognitive decline or dementia: A systematic review of cohort studies. *J Nutr Health Aging.* 2012; 16: 626-630.
23. Liu R. Health benefits of fruit and vegetables are from additive and. *Am J Clin Nutr.* 2003; 78S: 517S-520S.
24. El Gharris H. Polyphenols: food sources, properties and applications – a review. *Int J Food Sci Technol.* 2009; 44: 2512-2518.
25. Book of Mormon. Salt Lake City, UT: Intellectual Reserve, Inc; 1981:325.
26. Horacek TM, Betts NM. Students cluster into 4 groups according to the factors influencing their dietary intake. *J Acad Nutr Diet.* 1998; 98(12): 1464-1467. doi: http://dx.doi.org/10.1016/S0002-8223(98)00333-2
27. Birch LL, Fisher JO. Development of eating behaviors among children and adolescents. Pediatrics. 1998; 101(2S): 539S-449S.
28. Wansink B, Sobal J. Mindless eating: the 200 daily food decisions we overlook. *Environ Behav.* 2007; 39(1): 106-123.
29. Prochaska JO, DiClemente CC, Norcross JC. In Search of the Structure of Change. In: Klar Y, Fisher JD, Chinsky, JM, Nadler A, eds. *Self Change.* New York, NY: Springer; 1992: 87-114.
30. Doctrine and Covenants. Salt Lake City, UT: Intellectual Reserve, Inc; 1981:105.

Images – Ch1

1. Adam and Eve Kneeling at an Altar, by Del Parson, courtesy of lds.org.
2. Scurvy: a male figure showing skin eruptions, back view. Wellcome Images, By http://wellcomeimages.org/indexplus/obf_images/81/d6/fe3038ea32f81e4ce20503281ea2.jpgGallery: http://wellcomeimages.org/indexplus/image/M0002829.html, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=36314042
3. A local man in an open market in Ghana, Africa chopping fresh chicken on an old stump with a machete. Property of BYU-Idaho.
4. School lunch in Ghana. Property of BYU-Idaho.
5. Winter Quarters, by Jonathan Leo Fairbanks, courtesy of lds.org
6. Keratomalacia from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3936686/.
7. *Collage of Pima/Papago Native Americans*, By Rob Ferguson Jr - Public Domain, https://commons.wikimedia.org/w/index.php?curid=6337525.
8. DNA with nutrition and lifestyle elements. Original found at RGBStock.
9. A free range Guinea Pig eating apple. By Jg4817 (own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons from Wikimedia Commons, https://commons.wikimedia.org/wiki/File%3AGuinea_Pig_eating_apple.JPG
10. Peanut butter and jelly whole meal sandwich, by bhofack2. Courtesy of Thinkstock #186260936.
11. Potatoes. Property of BYU-Idaho.

12. French fries. Property of BYU-Idaho.
13. Pasta pictures. Property of BYU-Idaho
14. Types of Milk. Created by at BYU-Idaho, 2016.
15. Mid-adult man holding pastry, by moodboard. Courtesy of Thinkstock #85446908.
16. Woman eating fried insects, by Marcel Braendli. Courtesy of Thinkstock #119452488.

Figures – Ch1

1. Nutrition transition: Created at BYU-Idaho, 2016.
2. Percent of total deaths: Data derived from the 2013 Final Vital Statistic report provided by the Center for Disease Control (CDC): Created at BYU-Idaho, 2016.
3. Nutrigenomics: Created at BYU-Idaho, 2016.
4. The Six Classes of Nutrients Required for Normal Bodily Functions: Created at BYU-Idaho, 2016.
5. The Macronutrients and their primary functions: Created at BYU-Idaho, 2016.
6. Micronutrient categories: Created at BYU-Idaho, 2016.
7. Calorie content of the energy containing nutrients. Created at BYU-Idaho 2016.
8. Where phytochemicals fit in food. Created at BYUI-Idaho 2016.
9. Some common phytochemicals found in foods: modified at BYU-Idaho from, Eat a rainbow, by elenabs. Courtesy of Thinkstock #477795394.
10. The Amount of the selected nutrients provided in a 150-Calorie serving of a baked potato with butter and French fries in relation to the daily value: Created at BYU-Idaho 2016.
11. The Amount of the selected nutrients provided in a 150-Calorie serving of a baked potato with butter and French fries in relation to the daily value: Created at BYU-Idaho 2016.
12. The amount of the selected nutrients provided in a 320-Calorie serving of a pasta with alfredo or marinara in relation to the daily value: Created at BYU-Idaho 2016.
13. The amount of the selected nutrients provided in an 83-Calorie serving of milk products in relation to the daily value: Created at BYU-Idaho 2016.
14. Stages of change: Created by BYU-Idaho, based on information from Prochaska, DiClemente, & Norcross.

Chapter 2

1. Widtsoe J. *Discourses of Brigham Young.* Salt Lake City, UT: Deseret Book Company; 1925: 380.
2. How science works. Understanding Science website. http://undsci.berkeley.edu/article/howscienceworks_01. Accessed December 5, 2016.
3. What is peer review? Elsevier website. https://www.elsevier.com/reviewers/what-is-peer-review. Accessed November 30, 2016.
4. What is epidemiology? Centers for Disease Control and Prevention website. https://www.cdc.gov/careerpaths/k12teacherroadmap/epidemiology.html. Accessed November 29, 2016.
5. Placebo Effect. American Cancer Society website. http://www.cancer.org/treatment/treatmentsandsideeffects/treatmenttypes/placebo-effect. Accessed November 20, 2016.
6. Interpreting Research Studies. Unite for Sight website. http://www.uniteforsight.org/public-health-management/interpret-research-studies. Accessed April 3, 2017.
7. Bassett WM. For our spiritual development and learning.The Church of Jesus Christ of Latter-Day Saints website. https://www.lds.org/general-conference/2016/10/for-our-spiritual-development-and-learning?lang=eng&_r=1. Accessed October 28, 2016.
8. Fox S, Duggan M. Health Online 2013. Pew Research Center's Internet and American Life Project website. http://www.pewinternet.org/2013/01/15/health-online-2013/. Accessed December 8, 2016.
9. Ansel K. What an RDN can do for you. Academy of Nutrition and Dietetics website. http://www.eatright.org/resource/food/resources/learn-more-about-rdns/what-an-rdn-can-do-for-you. Accessed December 7, 2016.
10. Fontenot, B. Nutrition 101: Finding good help and information. The Doctor Will See You Now website. http://www.thedoctorwillseeyounow.com/content/nutrition/art3786.html. Accessed December 7, 2016.

Images - Ch2

1. Vector placebo pill by VectorHotShot. Courtesy of Thinkstock #478528122.
2. Mouse by artisteer. Courtesy of Thinkstock #618556680.
3. Graduation women by aodaodaod. Courtesy of Thinkstock #450121801.
4. Visit to a nutritionist doctor by razyph. Courtesy of Thinkstock #508669134.

Figures – Ch2

1. The scientific method: Created at BYUI 2017
2. Evaluating the strength of evidence: Created at BYUI 2017
3. Evaluating internet sources: Created at BYUI 2017

Chapter 3

1. U.S. Food and Drug Administration. Changes to the Nutrition Facts Label. U.S. Department of Health and Human Services website. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm. Published May 20, 2016.
2. Industry Resources on the Changes to the Nutrition Facts Label: Updated Daily Values Final Rule. U.S. Food and Drug Administration Website. https://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm513734.htm. Updated March 1, 2018
3. Liptak, A. Coke Can Be Sued by Rival Over Juice Claim, Court Says. The New York Times. June 12, 2014. http://www.nytimes.com/2014/06/13/business/supreme-court-says-coca-cola-can-be-sued-by-Pom-Wonderful.html?_r=0.
4. Guidance for Industry: A Food Labeling Guide. U.S. Food and Drug Administration Website. http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm2006828.htm. Published January 2013. Updated November 14, 2017.
5. National Academy of Sciences. Institute of Medicine. Food and Nutrition Board. Dietary Reference Intakes for Vitamin D and Calcium. United States Department of Agriculture website. https://fnic.nal.usda.gov/dietary-guidance/dietary-reference-intakes/dri-nutrient-reports. Published 2011.
6. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans, 8th Edition. Office of Disease Prevention and Health Promotion website. http://health.gov/dietaryguidelines/2015/guidelines/. Published December 2015.
7. Britten P, Cleveland LE, Koegel KL, Kuczynski KJ, Nickols-Richardson SM. Impact of Typical Rather than Nutrient-Dense Food Choices in the US Department of Agriculture Food Patterns. J Acad Nutr Diet. 2012; 112(10): 1560-1569.
8. United States Department of Agriculture. ChooseMyPlate.gov. ChooseMyPlate.gov website. https://www.choosemyplate.gov/. Updated March 20, 2017.

Images – Ch3

1. Orange mushrooms. Lactarious section Deliciosi, by Grape_vein. Courtesy of Thinkstock #609825656.
2. Young woman reading label on food can in a grocery store by Jack Hollingsworth. Courtesy of Thinkstock #200330988-001.
3. Collection of fruits and vegetables by egal. From Thinkstock.com, #153517627.
4. Composite images made at BYU-Idaho - originals from Thinkstock.com. Fitness salad and measuring tape on wooden table by scyther5, Thinkstock.com #482658270; and Cheeseburger and French fries by draghicich, Thinkstock.com #185916134.
5. Vegetables vegetarian with wild rice by Dar1930. Courtesy of Thinkstock #481267703.
6. Pasta salad by isantilli. Courtesy of Thinkstock #177848364.
7. Deli tortilla wrap cut in half, by Monkey Business Images. Courtesy of Thinkstock #84467151.
8. Composite image made at BYU-Idaho – originals from Thinkstock.com. Cup of Milk by Kvkirilov #488243691; Sharp cheddar cheese by BWFolsom #490311335; and American Cheese Slices by wisan224 #520616404.
9. Cherries in a stainless steel measuring cup by Dirk Becker. Courtesy of Thinkstock #501951137.

10. Boy (5-7) holding baseball, close-up of hand by Thomas Northcut. Courtesy of Thinkstock #200549006-001
11. Multigrain bread slice by Canadapanda. Courtesy of Thinkstock #157604392.
12. Pancake by Hong Vo. Courtesy of Thinkstock #527740945.
13. Peanut butter by baibaz. Courtesy of Thinkstock #465696297.
14. White golf ball on a tee on a white background by Askold Romanov. Courtesy of Thinkstock #450449623.
15. Cheese cubes by RusN. Courtesy of Thinkstock #450540393.
16. Human hand ready to roll the dice on white isolated by twinsterphoto. Courtesy of Thinkstock #531613872.
17. Steak with potatoes and vegetables. Courtesy of Thinkstock #78036796.
18. Deck of playing cards by Zoonar. Courtesy of Thinkstock #126877298.

Figures – Ch3

1. Granola food label. Retrieved from http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm
2. 20 oz of soda. Adapted from a sample label http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm
3. Products containing 2-3 servings, Vanilla Ice Cream. Adapted from sample label at https://www.federalregister.gov/articles/2016/05/27/2016-11867/food-labeling-revision-of-the-nutrition-and-supplement-facts-labels
4. Dietary Reference Intakes: Created at BYUI-Idaho 2016.
5. A hypothetical representation of vitamin A needs of a group of women 19-30: Created at BYU-Idaho 2016.
6. Setting RDA's: Created at BYU-Idaho 2016.
7. Setting the Tolerable Upper Intake Level: Created at BYUI-Idaho 2016.
8. The United States Department of Agriculture's MyPlate Eating Pattern. Retrieved from http://www.choosemyplate.gov/sites/default/files/printablematerials/MyPlateOnePageGraphic.pdf
9. Components of a healthy eating pattern. Retrieved from U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015 –2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at http://health.gov/dietaryguidelines/2015/guidelines/
10. Example of how a thoughtfully selected meal can provide nutrients from each of the food groups: Retrieved from U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at http://health.gov/dietaryguidelines/2015/guidelines/
11. Healthy food combinations consistent with different eating patterns. Created at BYU-Idaho 2016. Images courtesy of Thinkstock.
12. Current eating patterns in the United States. Retrieved from U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at https://health.gov/dietaryguidelines/2015/guidelines/chapter-2/current-eating-patterns-in-the-united-states/
13. Saturated fat intake in America. Retrieved from U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at http://health.gov/dietaryguidelines/2015/guidelines/executive-summary/#callout-terms
14. Sodium intake in America. Retrieved from U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015 – 2020 Dietary Guidelines for Americans. 8th Edition. December 2015. Available at http://health.gov/dietaryguidelines/2015/guidelines/executive-summary/#callout-terms
15. Choose MyPlate Visual. Retrieved from http://www.choosemyplate.gov/sites/default/files/printablematerials/MyPlateGraphicsStandards.pdf
16. Establishing diary cup equivalents: Created at BYU-Idaho 2016.
17. Measuring serving sizes. Created at BYUI-Idaho 2016. Images courtesy of Thinkstock.
18. Suggested cup and ounce equivalents for a 2000 Calorie diet. Retrieved from

http://www.choosemyplate.gov/sites/default/files/myplate/checklists/MyPlateDailyChecklist_2000cals_Age14plus.pdf
19. Sample menus for a 2000 Kcal meal plan. Retrieved from http://www.choosemyplate.gov/sites/default/files/printablematerials/Sample_Menus-2000Cals-DG2010.pdf

Chapter 4

1. The Digestive System and How it Works. National Institute of Diabetes and Digestive and Kidney Disease website https://www.niddk.nih.gov/health-information/digestive-diseases/digestive-system-how-it-works. Published September 2013. Accessed April 2017.
2. The Role of HCL in Gastric Function and Health. Clinical Education website https://www.clinicaleducation.org/resources/reviews/the-role-of-hcl-in-gastric-function-and-health/. Published January 2011. Accessed May 2017.
3. Amylases. Encyclopedia Britannica website https://www.britannica.com/science/amylase. Updated July 2013. Accessed May 2017.
4. Lipases. University of Maryland Medical Center website http://www.umm.edu/health/medical/altmed/supplement/lipase. Updated June 2015. Accessed May 2017.
5. Walsh JH. Gastrin. Digestion. 1990; 47 Suppl 1: 11-16.
6. Secretin. Medical dictionary website http://medical-dictionary.thefreedictionary.com/secretin. Accessed May 2017.
7. Cholecystokinin. Encyclopedia Britannica website https://www.britannica.com/science/cholecystokinin. Updated July 2015. Accessed May 2017.
8. Tiwari M. Science behind human saliva. J Nat Sci Biol Med. 2011; 2(1): 53-58.
9. Mucus. Encyclopedia Britannica website https://www.britannica.com/science/mucus. Updated September 2010. Accessed May 2017.
10. Pancreas and digestion. Baseline of Health Foundation website. https://jonbarron.org/article/pancreas-and-digestion. December 2009.
11. Picture of the intestines. WebMD website http://www.webmd.com/digestive-disorders/picture-of-the-intestines. Published March 2017. Accessed May 2017.
12. What is Bile? Production, Function, Salts, Storage, Secretion. Health Hype website http://www.healthhype.com/what-is-bile-production-function-salts-storage-secretion.html. Accessed June 2017.
13. Bile and Fat Digestion. Livestrong.com website http://www.livestrong.com/article/484996-bile-and-fat-digestion/. Updated August 2017.
14. Secretion of Bile and the Role of Bile Acids in Digestion. Colorado State University website http://www.vivo.colostate.edu/hbooks/pathphys/digestion/liver/bile.html. Accessed August 2017.
15. Capillary. Encyclopedia Britannica website https://www.britannica.com/science/capillary. Updated August 2014. Accessed June 2017.
16. ATP. The True Orgin website https://www.trueorigin.org/atp.php. Accessed July 2017.
17. Prevalence of food allergies. University of Nebraska-Lincoln Institute of Agriculture and Natural Resources Food Allergy Research and Resource Program website http://farrp.unl.edu/resources/gi-fas/prevalence-of-food-allergies. Accessed August 2017.
18. Celiac disease. U.S. National Library of Medicine Genetics Home Reference website https://ghr.nlm.nih.gov/condition/celiac-disease#genes. Published September 2015. Updated August 2017. Accessed August 2017.
19. El-Serag HB, Petersen NJ, Carter J, et al. Gastroesophageal reflux among different racial groups in the United States. *Gastroenterology*. 2004; 126: 1692-1699.
20. Peptic ulcers (stomach ulcers). National Institute of Diabetes and Digestive and Kidney Diseases website https://www.niddk.nih.gov/health-information/digestive-diseases/peptic-ulcers-stomach-ulcers. Accessed July 2017.

21. Gallstones. National Institute of Diabetes and Digestive and Kidney Diseases website https://www.niddk.nih.gov/health-information/digestive-diseases/gallstones. Published November 2013. Accessed July 2017.
22. Andrews EB, Eaton SC, Hollis KA, et al. Prevalence and demographics of irritable bowel syndrome: results from large web-based survey. *Aliment Pharmacol Ther* 2005; 22(10): 935-942.
23. Anastasi JK, Capili B. Chang M. Managing irritable bowel syndrome. *Am J Nurs*. 2013; 113(7): 42-52.
24. Catassi G, Lionetti E, Gatti S, Catassi C. The low FODMAP diet: Many question marks for a catchy acronym. *Nutrients.* 2017; 9(3): 292.
25. Hill P, Muir JG, Gibson PR. Controversies and recent developments of the low-FODMAP diet. *Gastroenterol Hepatol.* 2017; 13(1): 36-45.
26. Marsh A, Eslick EM, Eslick GD. Does a diet low in FODMAPs reduce symptoms associated with functional gastrointestinal disorders? A comprehensive systematic review and meta-analysis. *Eur J Nutr.* 2016; 55(3): 897-906.
27. Probiotics: In Depth. National Center for Complementary and Integrative Health website https://nccih.nih.gov/health/probiotics/introduction.htm. Published October 2016. Accessed July 2017.
28. Cummings JH, Macfarlane GT. Role of intestinal bacteria in nutrient metabolism. *JPEN J Parenter Enteral Nutr.* 1997; 21(6): 357-365.
29. Caricilli AM, Castoldi A, Camara NO. Intestinal barrier: A gentlemen's agreement between microbiota and immunity. *World J Gastrointest Pathophysiol.* 2014; 5: 18-32.
30. Hill C, Guarner F, Reid G, et al. Expert consensus document: The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. *Nat Rev Gastroenterol Hepatol.* 2014; 11(8): 506-514.
31. Hempel S, Newberry SJ, Maher AR, et al. Probiotics for the prevention and treatment of antibiotic-associated diarrhea: a systematic review and meta-analysis. *JAMA*. 2012; 307: 1959-1969.
32. Hungin AP, Mulligan C, Pot B, et al. Systematic review: probiotics in the management of lower gastrointestinal symptoms in clinical practice—an evidence-based international guide. *Aliment Pharmacol Ther.* 2013; 38: 864-886.
33. Guarner F, Malagelada JR. Gut flora in health and disease. *Lancet*. 2003; 361: 512-519.
34. https://www.eatright.org/food/vitamins-and-supplements/nutrient-rich-foods/prebiotics-and-probiotics-creating-a-healthier-you

Images – Ch4

1. A human cell modified at BYU-Idaho from Animal cell cut-away by Designua. Courtesy of Shutterstock #215726599.
2. Diagram of common cell types illustration modified at BYU-Idaho from GraphicsRF. Courtesy of Shutterstock #445796869.
3. Epithelium by sciencepics. Courtesy of Shutterstock #229448149.
4. Stomach icon. Human internal organs symbol. Digestive system anatomy. Vector illustration in flat style isolated on white background by egudinKa. Courtesy of Shutterstock #585073270.
5. Human digestive system vector illustration by La Gorda. Courtesy of Shutterstock #153338039.
6. Portrait of a fitness man doing planking exercise in gym by ESB Professional. Courtesy of Shutterstock #314439998.
7. Human digestive system tract alimentary canal by Christos Georghiou. Courtesy of Shutterstock #367631687.
8. Layers of the gi tract. Human anatomy by logika600. Courtesy of Shutterstock #497693974.
9. Swallowing (Deglutition) Labeled Diagram by joshya. Courtesy of Shutterstock #245355817.
10. Illustration of Human Digestive System by Teguh Mujiono. Courtesy of Shutterstock # 407974276.
11. Stomach anatomy diagram of the human digestive organ with a medical cross section inside the body part that digests as a health care icon and illustration on old beige grunge parchment paper modified at BYU-Idaho from Lightspring. Courtesy of Shutterstock #100317938.

12. Gastrointestinal tract. Stomach, small intestine and colon by Tefi. Courtesy of Shutterstock #420416893.
13. A fold of the intestinal lining on a white background modified at BYU-Idaho from Tefi. Courtesy of Shutterstock #386649352.
14. Intestinal villi anatomy, small intestine lining modified at BYU-Idaho from Tefi. Courtesy of Shutterstock #387747391.
15. Intestinal epithelial cell with microvilli, detailed illustration modified at BYU-Idaho from Tefi. Courtesy of Shutterstock #373124563.
16. Medically accurate illustration of the colon modified at BYU-Idaho from Sebastian Kaulitzki. Courtesy of Shutterstock.
17. Liver, stomach, pancreas, gallbladder and spleen detailed anatomy drawing on a white background modified at BYU-Idaho from Tefi. Courtesy of Shutterstock.
18. Ligand-gated ion channel, channel proteins which open to ions Na, K, Ca, or Cl modified at BYU-Idaho from Designua. Courtesy of Shutterstock #478999153.
19. Human bloodstream – didactic board of anatomy of blood system of human circulation, sanguine, and cardiovascular system modified at BYU-Idaho from stihii. Courtesy of Shutterstock #135275144.
20. Cellular respiration: a set of metabolic reactions to produce biochemical energy from nutrients modified at BYU-Idaho from ellepigrafica. Courtesy of Shutterstock #603031976.
21. Hearburn and gastroesophageal reflux disease (GERD). If the esophageal sphincter does not close tight enough, stomach acid seep back into the esophagus, damaging it and causing the heartburn by Designua. Courtesy of Shutterstock #266699561.
22. Celiac disease affected small intestine lining on a white background. Healthy and damaged villi by Tefi. Courtesy of Shutterstock #390572875.

Figures – Ch4

1. Organization of an organism: created at BYU-Idaho, 2017 from Diagram of common cell types illustration by GraphicsRF, Epithelium by sciencepics, Stomach icon. Human internal organs symbol. Digestive system anatomy. Vector illustration in flat style isolated on white background by egudinKa, Human digestive system vector illustration by La Gorda and Portrait of a fitness man doing planking exercise in gym by ESB Professional. Courtesy of Shutterstock #445796869, #229448149, #585073270, #153338039, and #314439998.
2. The digestive tract organs and close up of the layers of the intestinal tract wall: created at BYU-Idaho, 2017 from Human digestive system tract alimentary canal by Christos Georghiou and Layers of the gi tract. Human anatomy by logika600. Courtesy of Shutterstock #367631687 and #497693974.
3. Swallowing (Deglutition) Labeled Diagram by joshya. Courtesy of Shutterstock #245355817.
4. Illustration of Human Digestive System by Teguh Mujiono. Courtesy of Shutterstock #407974276.
5. Stomach anatomy diagram of the human digestive organ with a medical cross section inside the body part that digests as a health care icon and illustration on old beige grunge parchment paper modified at BYU-Idaho, 2017 from Lightspring. Courtesy of Shutterstock #100317938.
6. The intestinal folding, villi, and microvilli: created at BYU-Idaho, 2017 from A fold of the intestinal lining on a white background by Tefi, Intestinal villi anatomy, small intestine lining by Tefi, and Intestinal epithelial cell with microvilli, detailed illustration by Tefi. Courtesy of Shutterstock #386649352, #387747391, and #373124563.
7. Small intestine absorption methods: created at BYU-Idaho, 2017 from Ligand-gated ion channel, channel proteins which open to ions Na, K, Ca, or Cl by Designua. Courtesy of Shutterstock #478999153.
8. Blood circulation through the body modified at BYU-Idaho from Human bloodstream – didactic board of anatomy of blood system of human circulation, sanguine, and cardiovascular system by stihii. Courtesy of Shutterstock #135275144.
9. Villi containing both blood and lymph vessels for nutrient absorption modified at BYU-Idaho from A fold of the intestinal lining on a white

background by Tefi. Courtesy of Shutterstock #386649352.

10. Cellular respiration modified at BYU-Idaho from Cellular respiration: a set of metabolic reactions to produce biochemical energy from nutrients by ellepigrafica. Courtesy of Shutterstock #603031976.
11. Celiac disease affected small intestine lining on a white background. Healthy and damaged villi by Tefi. Courtesy of Shutterstock #390572875.
12. Heartburn and gastroesophageal reflux disease (GERD). If the esophageal sphincter does not close tight enough, stomach acid seep back into the esophagus, damaging it and causing the heartburn by Designua. Courtesy of Shutterstock #266699561.

Chapter 5

1. The Holy Bible, KJV. Salt Lake City, UT: Intellectual Reserve, Inc; 1979..
2. Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Office of Disease Prevention and Health Promotion website. http://health.gov/dietaryguidelines/2015-scientific-report/06-chapter-1/d1-2.asp. Accessed December 15, 2016.
3. Fields L. How Fiber Helps Your Digestive Health. Available at http://www.webmd.com/diet/features/fiber-digestion. Accessed July 24, 2016.
4. American Dietetic Association. Position of the American Dietetic Association: Health Implications of Dietary Fiber. JADA. 2008;108: 1716-1731.
5. Aune D., Keum N., Giovannucci E., Fadnes L.T., Boffett P., Greenwood, D. C., Valtten, L. J. (2006). Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. BMJ. 2016; 353: i2716.
6. Lactose Intolerance. National Institute of Diabetes and Digestive and Kidney Disease website https://www.niddk.nih.gov/health-information/health-topics/digestive-diseases/lactose-intolerance/Pages/facts.aspx#who Published June 2014. Retrieved July 2016.
7. Livesey G, T. R. (2008). Glycemic response and health--a systematic review and meta-analysis: relations between dietary glycemic properties and health outcomes. American Journal of Clinical Nutrition, 87(1), 258S-268S.
8. Aune D, Keum N, Giovannucci E, et al. Whole grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: systematic review and dose-response meta-analysis of prospective studies. BMJ. 2016; 353: i2716.
9. Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Office of Disease Prevention and Health Promotion website. https://health.gov/sites/default/files/2019-09/Scientific-Report-of-the-2015-Dietary-Guidelines-Advisory-Committee.pdf
10. Whole Grains and Fiber. American Heart Association website. http://www.heart.org/HEARTORG/HealthyLiving/HealthyEating/HealthyDietGoals/Whole-Grains-and-Fiber_UCM_303249_Article.jsp#.V5ZDvbgrLIU. Retrieved 2016.
11. ACS Guidelines on Nutrition and Physical Activity for Cancer Prevention. American Cancer Society website. http://www.cancer.org/healthy/eathealthygetactive/acsguidelinesonnutritionphysicalactivityforcancerprevention/acs-guidelines-on-nutrition-and-physical-activity-for-cancer-prevention-summary. Retrieved February 5, 2016.
12. Margolin, D. A. (2009). Epidemiology and Pathophysiology of Diverticular Disease. Clinics and Colon and Rectal Surgery, 22(3), 141-146.
13. Johnson RK, Appel LJ, Brands M, et al. Dietary Sugars Intake and Cardiovascular Health. Circulation. 2009; 120: 1011-1020.
14. 2015-2020 Dietary Guidelines for Americans. Office of Disease Prevention and Health Promotion website. https://health.gov/dietaryguidelines/2015/guidelines/. Accessed 2016.
15. Dietary Reference Intakes Summary Table. USDA National Agricultural Library website. http://www.nationalacademies.org/hmd/~/media/Files/Activity%20Files/Nutrition/DRI-Tables/5Summary%20TableTables%2014.pdf?la=en. Accessed 2016.
16. Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrates, Fiber, Fat, Fatty

Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: The National Academies Press; 2005. Available at https://doi.org/10.17226/10490.
17. U.S. Food and Drug Administration. Additional Information about High-Intensity Sweeteners Permitted for use in Food in the United States. U.S. Department of health and Human Services website. https://www.fda.gov/food/ingredientspackaginglabeling/foodadditivesingredients/ucm397725.htm Last updated 05/26/2015

Images – Ch5

1. Daniel refusing the King's Meat and Wine by Del Parson. Found at lds.org.
2. Healthy breakfast by AnaitBoyajyan. Courtesy of Thinkstock #479453543
3. Making flour in a traditional way for the Neolithic era, by SimeonDonov, courtesy of Thinkstock. Item number 505258420
4. Epithelium by ClusterX, courtesy of Thinkstock Item #: 487780062, modified at BYUI
5. Close up of woman's hand setting temperature control on oven by djedzura. Courtesy of Thinkstock #469777200
6. Body Art. Courtesy of Cliparts.co at http://cliparts.co/cliparts/kiK/By8/kiKBy8zrT.jpg
7. Coins at. Courtesy of istockimg.com at http://i.istockimg.com/file_thumbview_approve/36226786/5/stock-illustration-36226786-three-coins-cartoon.jpg
8. Dollar Bill. Courtesy of Clipartbest.com at http://www.clipartbest.com/cliparts/KTj/o5n/KTjo5n8Lc.gif
9. Sun. Courtesy of Cliparts.com at: http://cliparts.co/cliparts/qTB/X45/qTBX45p9c.jpg
10. Tomato. Courtesy of Free Vectors at http://all-free-download.com/free-vector/download/tomato_310436.html
11. Tomato Plant. Courtesy of Cliparts 101 at http://www.cliparts101.com/files/661/034DEB997B478CDFF9EBB5FE00DC6A8D/tomato_plant.png
12. Animal cell by 7activestudio. Courtesy of Thinkstock.com #509515223.
13. Slice view of a Mitochondrion by ttsz. Courtesy of Thinkstock.com #466190268.
14. Various types of cereal grains by Magone. Courtesy of Thinkstock #526258625
15. Diverticulosis and Diverticulitis created by ttsz, found at Thinkstock.com, #534107411.
16. Diverticulitis created by selvanegra, found at Thinkstock.com, #532868591.
17. Whole wheat bread. Courtesy of Fran Hogan, https://commons.wikimedia.org/wiki/File:Fresh_made_bread_05.jpg
18. Red disposable cup with drinking straw by karandaev. Courtesy of Thinkstock.com #179024995
19. White sugar by ajafoto. Courtesy of Thinkstock.com #495650076.

Figures – Ch5

1. Types of carbohydrates: Created at BYU-Idaho, 2016
2. Monosaccharides: Created by Mike Grosbeck at BYU-Idaho, 2013
3. Disaccharides: Created by Mike Grosbeck at BYU-Idaho, 2013
4. Relative sweetness of sugars- Data take from McWillliams, Margaret Monosaccharides, Disaccharides and Sweeteners. In: Foods Experimental Perspectives. 5th ed. Upper Saddle River, NJ:Pearson/Prentice Hall;2005:151-177.
5. Starch: Created at BYU-Idaho, 2017
6. Glycogen: Created at BYU-Idaho, 2017
7. Components of a whole grain: Created at BYU-Idaho, 2016
8. Effects of refinement and enrichment on nutrient content of wheat flour: Created at BYU-Idaho, 2016
9. Breakdown of lactose by lactase at the small intestine brush border. Created at BYU-Idaho, 2016
10. Worldwide incidence of lactose intolerance: Image downloaded from Wikimedia commons Dec, 2013 Author: NmiPortal; License: Creative Commons Attribution-Share Alike 3.0 Unported- obtained from Jason Shaw
11. The conversion of fructose and galactose to glucose in the liver. Modified image from: Hukman Digestive System by blueringmedia, courtesy of Thinkstock Item #: 480839163

12. Blood glucose levels influenced by hormones. Created by Jay Keller, BYUI, glycogen by Jason Shaw
13. High vs. low glycemic index foods. Based on the lardbucket open-source text, created at BYU-Idaho.
14. The conversion of complex energy forms to simple usable forms: Created at BYU-Idaho, 2016 as a composite of images from various sources.
15. Glucose splits into pyruvates. Created at BYU-Idaho, 2016 including Thinkstock image #509515223, Animal cell from 7activestudio.
16. Cell respiration. Created at BYU-Idaho including Thinkstock image #466190268, Splice view of a Mitochondrion by ttsz, and #509515223, Animal cell from 7activestudio.
17. Glycogen: Created at BYU-Idaho, 2017
18. Percent of Americans meeting the whole grain recommendations: Taken from- Office of Disease Prevention and Health Promotion. (2016, July 25). Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Retrieved from Health.gov: https://health.gov/dietaryguidelines/2015-scientific-report/06-chapter-1/d1-3.asp
19. Diverticulosis and diverticulitis: Created at BYU-Idaho, 2016, taken from: Office of Disease Prevention and Health Promotion. (2016, July 25). Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Retrieved from Health.gov: https://health.gov/dietaryguidelines/2015-scientific-report/06-chapter-1/d1-3.asp
20. Identification of added sugars: Label adapted from the sample label on the FDA website
21. Created at BYU-Idaho, 2016 Label adapted from a sample label at http://www.fda.gov/Food/GuidanceRegulation/GuidanceDocumentsRegulatoryInformation/LabelingNutrition/ucm385663.htm.
22. Sources of added sugar in the American diet: Created at BYU-Idaho, 2016. Taken from the Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Office of Disease Prevention and Health Promotion website. http://health.gov/dietaryguidelines/2015-scientific-report/06-chapter-1/d1-2.asp

Chapter 6

1. Huis AV. Potential of insects as food and feed in assuring food security. *Annu. Rev. Entomol*. 2013; 58: 563-583.
2. Williams RA, Mamotte C, Burnett JR. Phenylketonuria: An inborn error of phenylalanine metabolism. *Clin Biochem Rev.* 2008; 29: 31-41.
3. Welle S, Nair K. Relationship of resting metabolic rate to body composition and protein turnover. *Am J Physiol*. 1990; 258: 990-98.
4. Shoulders M, Rains R. Collagen Structure and Stability. Annu Rev Biochem. 2009; 78: 929–958.
5. Stanton J. Listening to the Ga: Cicely Williams' Discovery of Kwashiorkor on the Gold Coast. Clio Med. 2001; 71: 149–171.
6. Appleton V. *Metabolism and Nutrition.* In: Horton-Szar D, ed. Crash Course: Metabolism and Nutrition. 4th ed. New York, NY: Elsevier; 2013.
7. Academy of Nutrition and Dietetics. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *J. Acad Nutr Diet.* 2016; 116(3): 501-528.
8. Titi-Lartey, O.A., Gupta, V. Marasmum. Treasure Island, Florida. StatPearls LLC, 2020 Accessed at https://www.ncbi.nlm.nih.gov/books/NBK559224/
9. World Health Organization. "Malnutrition." April 2020. https://www.who.int/news-room/fact-sheets/detail/malnutrition

Images – Ch6

1. Raw meat by margouillat photo. Courtesy of Shutterstock #236721610.
2. Fried insect by Zanuda. Courtesy of Thinkstock #501863629.
3. Natural products containing plant and animal proteins by morisfoto. Courtesy of Thinkstock #545444372
4. Gross edema of leg and foot by Amawasri. Courtesy of Thinkstock #483285464
5. Child with Kwashiorkor: By Nelson Bastidas – Courtesy of Shutterstock #176895957
6. Pvt. Jackson O. Broshears: By Unknown - http://hdl.loc.gov/loc.pnp/ppmsca.34520, Public Domain,

https://commons.wikimedia.org/w/index.php?curid=28356891
7. Young woman holding textbooks by Paffy69. Courtesy of Thinkstock # 508420146.
8. Extreme Sports in Japan by kumikomini. Courtesy of Thinkstock # 612508600.
9. College student sitting outside by BananaStock. Courtesy of Thinkstock # 78184025.
10. Close-up of a male doctor giving medicines to a patient by Purestock. Courtesy of Thinkstock #79077307.
11. An adult Caucasian male marathon runner in red shorts and a white tank stands smiling with hands on hips by Photodisc. Courtesy Thinkstock #rbrb_0241.
12. Heap of raw Quinoa seeds by PicturePartners. Courtesy of Thinkstock #485130848.
13. Amaranth Seeds by Magone. Courtesy of Thinkstock #466216574.
14. Soybean on white background by artphotoclub. Courtesy of Thinkstock #488270540.
15. Legumes in wooden bowels by Andrii Gorulko. Courtesy of Shutterstock #100628686

Figures – Ch6

1. Structure of an amino acid: Created at BYU-Idaho, 2016.
2. Amino acids: Created at BYU-Idaho, 2016.
3. Transamination: Created at BYU-Idaho, 2016.
4. Conversion of phenylalanine to tyrosine is blocked in PKU: Created at BYU-Idaho, 2016.
5. Formation of a peptide bond: Created at BYU-Idaho, 2016.
6. Folded protein: Created at BYU-Idaho, 2016.
7. Denaturation: Created at BYU-Idaho, 2016.
8. Denaturation in the cooking process of an egg: Created at BYU-Idaho, 2016.
9. Action of pepsin: Created at BYU-Idaho, 2016.
10. Protein synthesis: Created at BYU-Idaho, 2016.
11. Amino acid pool: Created at BYU-Idaho, 2016.
12. A closer look at deamination: Created at BYU-Idaho, 2016.
13. Function of an enzyme: Created at BYU-Idaho, 2016.

Chapter 7

1. Vannice G and Rasmussen H. Position of the Academy of Nutrition and Dietetics: Dietary fatty acids for healthy adults. J Acad Nutr Diet. 2014;114:136-153
2. Mozaffarian D, Katan MB, Ascherio A and Stampfer MJ. *Trans* fatty acids and cardiovascular disease. *N Engl J Med*. 2006; 354: 1601-1613
3. Surrette ME. The science behind dietary omega-3 fatty acids. *CMAJ.* 2008; 178: 177-180.
4. Shaghaghi MA, Abumweis SS Jones PJH. Cholesterol-lowering efficacy of plant sterols/stanols provided in capsule and tablet formats: Results of a systematic review and meta-analysis. *J Acad Nutr Diet*. 2013; 113: 1494-1503.
5. Jong AD, Plat J, Mensink RP. Metabolic effects of plant sterols and stanols. *J Nutr Biochem*. 2003: 362-369.
6. Centers for Disease Control and Prevention. (2016, October 7). *Leading Causes of Death*. Retrieved from National Center for Health Statitics: http://www.cdc.gov/nchs/fastats/leading-causes-of-death.htm
7. Centers for Disease Control and Prevention. (2015, August 10). *Heart Disease Risk Factors*. Retrieved from Heart Disease: http://www.cdc.gov/heartdisease/risk_factors.htm
8. US Department of Health and Human Services. (2005, June). *High Blood Cholesterol: What You Need To Know*. Retrieved from National Heart Lung and Blood Institute: https://www.nhlbi.nih.gov/health-topics/all-publications-and-resources/high-blood-cholesterol-what-you-need-know
9. National Institue of Health. (October, 2016). *What is a standard drink*. Retrieved from National institue of alcohol abuse and alcoholism. https://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/what-standard-drink
10. U.S. Department of Health and Human Services and U.S. Department of Agriculture. *2015 – 2020 Dietary Guidelines for Americans*. 8th Edition. December 2015. Available

athttp://health.gov/dietaryguidelines/2015/guidelines/.
11. National Institue of Health. (October, 2016). *Binge Drinking Defined*. Retrieved from National institue of alcohol abuse and alcoholism. https://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/moderate-binge-drinking
12. World Health Organization. (2015, January). *Alcohol*. Retrieved from World Health Organization: http://www.who.int/mediacentre/factsheets/fs349/en/
13. Center for Disease Control and Prevention. (2016, August). *Alcohol and Public Health*. Retrieved from Center for Disease Control and Prevention: http://www.cdc.gov/alcohol/faqs.htm
14. Association of Alcohol Consumption with Selected Cardiovascular Disease Outcomes: A Systematic Review and Meta-Analysis." *BMJ* 342, no. d671 (2011). Doi
15. Holms MV, Dale CE, Zuccolo E. Association between alcohol and cardiovascular disease: Mendelian randomization analysis based on individual participation data. *BMJ*. 2014;349:4164
16. Nelson DE, Jaman DW, Rehm J. et al. Alcohol-attributable cancer deaths and years of potential life lost in the United States. *Am J Public Health*. 2013; 103(4) :641-648.
17. National Cancer Institute. (2013, June). *Alcohol and Cancer Risk*. Retrieved from National Cancer Institute: https://www.cancer.gov/about-cancer/causes-prevention/risk/alcohol/alcohol-fact-sheet#q2
18. American Heart Association. (2015, January). *Alcohol and Heart Health*. Retrieved from American Heart Association: http://www.heart.org/HEARTORG/HealthyLiving/HealthyEating/Nutrition/Alcohol-and-Heart-Health_UCM_305173_Article.jsp#.WAZC5OArLIU
19. U.S. Department of Health and Human Services and U.S. Department of Agriculture. *2015 – 2020 Dietary Guidelines for Americans*. 8th Edition. December 2015. Available at http://health.gov
20. Michas G, Micha R, Zamelas A. Dietary fats and cardiovascular disease: Putting together the pieces of a complicated puzzle. Atherosclerosis. 2014; 234: 320-328.
21. Aune D, Keum N, Giovannucci E, et al. Whole-grain consumption and risk of cardiovascular disease, cancer, and all cause and cause specific mortality: Systematic review and dose-response meta-analysis of prospective studies. BMJ. 2016; 353-367.
22. American Heart Association. (2015, August). *The American Heart Association's Diet and Lifestyle Recommendations*. Retrieved from: http://www.heart.org/HEARTORG/HealthyLiving/HealthyEating/Nutrition/The-American-Heart-Associations-Diet-and-Lifestyle-Recommendations_UCM_305855_Article.jsp#

Images – Ch7

1. Jar of coconut oil and fresh coconuts by Magone. Courtesy of Thinkstock #466830406.
2. Yellow oil by PumpizoidA. Courtesy of Thinkstock #590281788.
3. Olives with leaves by ValentynVolkov. Courtesy of Thinkstock #468461322.
4. Sunflower seeds, peanuts, and oil by Serg_Velusceac. Courtesy of Thinkstock #179089934.
5. Curls of fresh butter with basil, isolated on white by belchonock. Courtesy of Thinkstock #481054395.
6. Butter Sticks by Tomas_Mina. Courtesy of Thinkstock #513315099.
7. Bottle of linseed oil by egal. Courtesy of Thinkstock #134388311.
8. Peanut butter by Marcio Silva. Courtesy of Thinkstock #463889795.
9. Flax flowers isolated on white by Olga Kashubin. Courtesy of Thinkstock #472916146.
10. Fish jumping out of the water, with some splashes by leonello. Courtesy of Thinkstock #178016426.
11. Sunflower by WesAbrams. Courtesy of Thinkstock #490878338.
12. Brown chicken isolated white by suriya silsaksom. Courtesy of Thinkstock #472159798.
13. Omega-3 phospholipid by ClusterX, modified at BYU-Idaho. Courtesy of Thinkstock #469896333.
14. Structural chemical formulas of cholesterol molecule by chromatos. Courtesy of Thinkstock #475632162.

15. Cholesterols modified at BYU-Idaho from Cell membrane by ttsz. Courtesy of Thinkstock #509862902.
16. Lineman in skull cap by 63alfred. Courtesy of Thinkstock.com #139972692.
17. Helping the Martin Handcart Company across the Sweetwater River, by Clark Kelley Price, courtesy of lds.org.
18. Portrait of a smiling woman falling down on a ski slope by Digital Vision. Courtesy of Thinkstock #dv1448026.
19. Vinegar pouring into salad bowl by Pat_Hastings. Courtesy of Thinkstock #509733262.
20. Close-up of baked stuffed pastry by Medioimages/Photodisc. Courtesy of Thinkstock #med321082.
21. Atherosclerosis by Judith Glick Ehrenthal. Courtesy of Thinkstock #521550868.
22. Aterosclerose1 by JFalcetti Courtesy of Thinkstock # 539166207.
23. Atherosclerosis by Diamond_Images. Courtesy of Thinkstock #153442838.
24. Selection of food that is good for the heart by a_namenko. Courtesy of Thinkstock #509858008.
25. Frying bacon in the pan, food concept by Gumpanat. Courtesy of Thinkstock #598814952.
26. Assorted dessert bars by Jupiterimages. Courtesy of Thinkstock #86495616.
27. Fast food items like hot dogs, hamburgers, fries and pizza by wildpixel. Courtesy of Thinkstock #180258510.
28. Natural organic bread made from whole wheat flour by olgakr. Courtesy of Thinkstock #618765476.
29. Close-up of various fruits and vegetables by Purestock. Courtesy of Thinkstock #57575899.

Figures – Ch7

1. Categories of lipids: Created at BYU-Idaho, 2016.
2. Elements found in glycerides: Created at BYU-Idaho, 2016.
3. Formation of a triglyceride: Created at BYU-Idaho, 2016.
4. Mono and di-glycerides: Created at BYU-Idaho, 2016.
5. Fatty acids of varying chain lengths: Created at BYU-Idaho, 2016.
6. Mono and poly-unsaturated fatty acids: Created at BYU-Idaho, 2016.
7. Example of a cis double bond: Created at BYU-Idaho, 2016.
8. Example of a trans double bond: Created at BYU-Idaho, 2016.
9. An example of a cis bond shifting to a trans bond during partial hydrogenation: Created at BYU-Idaho, 2016.
10. Strategies used to eliminate *trans* fats in food products: Created at BYU-Idaho, 2016.
11. The process of full hydrogenation: Created at BYU-Idaho, 2016.
12. Example of an omega-3 fatty acid: Created at BYU-Idaho, 2016.
13. Omega-6 and omega-3 fatty acid families: Created at BYU-Idaho, 2016.
14. Dietary sources of omega-3 and omega-6 fatty acids: Created at BYU-Idaho, 2016.
15. Structure of a phospholipid: Created by BYU-Idaho, 2016.
16. Structure of a triglyceride compared to a phospholipid: Created at BYU-Idaho, 2016.
17. Lipid droplets surrounded by phospholipids comfortably suspended in water: Created at BYU-Idaho, 2016.
18. Role of phospholipids in cellular membranes: Cholesterols modified at BYU-Idaho from Cell membrane by ttsz. Courtesy of Thinkstock #509862902.
19. Structural chemical formulas of cholesterol molecule by chromatos. Courtesy of Thinkstock #475632162.
20. Cholesterols place in the cellular membrane cholesterols modified at BYU-Idaho from Cell membrane by ttsz. Courtesy of Thinkstock #509862902.
21. The accessory organs and digestion: modified at BYU-Idaho from Liver by Netta07. Courtesy of Thinkstock #505486537.
22. Bile and micelle formation: Created at BYU-Idaho, 2016.
23. Lipid digestion: Created at BYU-Idaho, 2016.
24. Lipoprotein: Created at BYU-Idaho, 2016.
25. Classes of Lipoproteins: Created at BYU-Idaho, 2016.
26. The formation of plaque modified by BYU-Idaho from Atherosclerosis by Judith Glick Ehrenthal. Courtesy of Thinkstock #521550868.

27. What constitutes a drink by National Institutes of Health - http://www.niaaa.nih.gov/alcohol-health/overview-alcohol-consumption/what-standard-drink, Public Domain, https://commons.wikimedia.org/w/index.php?curid=46288449
28. Plaque development leading to a heart attack or stroke modified by BYU-Idaho from Atherosclerosis by Diamond_Images and Aterosclerose1 by JFalcetti. Courtesy of Thinkstock #153442838 and #539166207.
29. *Trans* fats and the food label: Created at BYU-Idaho, 2016.

Chapter 8

1. Jequier E, Constant F. Water as an essential nutrient: The physiological basis of hydration. *Eur J Clin Nutr.* 2010; 64: 115-123.
2. National Academy of Medicine on Dietary Reference Intakes for Electrolytes and Water. Dietary Reference Intakes for water, potassium, sodium, chloride and sulfate. Washington, DC. National Academies press, 2005.
3. Farrell DJ and Bower L. Fatal water intoxication. J *Clin Pathol.* 2003; 56(10): 803-804.
4. Center for Disease Control and Prevention. Salt Stats. Center for Disease Control and Prevention website. https://www.cdc.gov/salt/fact_sheets.htm. Updated November 2, 2016. Accessed February 8, 2017.
5. U.S. Department of Health and Human Services. Sodium in your diet: Use the nutrition facts label and reduce your intake. U.S. Food & Drug Administration website. https://www.fda.gov/food/resourcesforyou/consumers/ucm315393.htm. Published June 2, 2016.
6. Crawford A and Harris H. Balancing act: Na+ sodium K+ potassium. Nursing. 2011; 41: 44-50.
7. Academy of Nutrition and Dietetics. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. *J. Acad Nutr Diet.* 2016; 116(3): 501-528.
8. Understanding the Blood Pressure Readings. American Heart Association website. Accessed December, 2017. http://www.heart.org/HEARTORG/Conditions/HighBloodPressure/KnowYourNumbers/Understanding-Blood-Pressure-Readings_UCM_301764_Article.jsp#.WkV-Jd-nGUk
9. US Department of Health and Human Services. Risk factors for high blood pressure. Retrieved from National Heart Lung and Blood Institute website. https://www.nhlbi.nih.gov/health/health-topics/topics/hbp/atrisk. Published September 2015.
10. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans. 8th Edition. Office of Disease Prevention and Health Promotion website. Retrieved from: https://health.gov/dietaryguidelines/2015/guidelines/chapter-1/a-closer-look-inside-healthy-eating-patterns/#callout-dash. Published December 2015.
11. US Department of Health and Human Services. Health Benefits of the DASH eating plan. National Heart Lung and Blood Institute website. https://www.nhlbi.nih.gov/health/health-topics/topics/dash/benefits#DASHTrial. Published September 2015.
12. Gee LC and Ahluwalia A. Dietary Nitrate Lowers Blood Pressure: Epidemiological, Pre-clinical Experimental and Clinical Trial Evidence. *Curr Hypertens Rep.* 2016; 18: 17.
13. Harvard Medical School. Time for more Vitamin D. Harvard Health Publications website. http://www.health.harvard.edu/staying-healthy/time-for-more-vitamin-d. Published September 2008.
14. Cohen PA. American roulette — contaminated dietary supplements. N Engl J Med. 2009; 361: 1521-1525.
15. Maughan RJ. Contamination of dietary supplements and positive drug tests in sports. J Sports Sci. 2005; 23(9): 883-9.
16. US Department of Health and Human Services. Dietary supplements: What you Need to know. National Institute of Health website. https://ods.od.nih.gov/HealthInformation/DS_WhatYouNeedToKnow.aspx. Published June 17, 2011.

17. US Department of Health and Human Services. Dietary Supplements. US Food and Drug website. https://www.fda.gov/Food/DietarySupplements/default.htm. Published April 4, 2016.
18. US Department of Health and Human Services. Dietary and Herbal Supplements. National Center for Complementary and Integrative Health website. https://nccih.nih.gov/health/supplements. Published October 20, 2015.

Images – Ch8

1. Prickly pear cactus blooms on the grand canyon Rim by DGHayes. Courtesy of Thinkstock #588625688.
2. Painful joints by Sebastian Kaulitzki. Courtesy of Thinkstock #100988427.
3. Man balancing basketball on his finger by Creatas. Courtesy of Thinkstock #76723935.
4. Students walking to the college by simonkr. Courtesy of Thinkstock #507009199.
5. Family, including children (7-11) sitting at table in garden, toasting with orange juice and smiling by Maria Teijeiro. Courtesy of Thinkstock #74226923.
6. Dissected brain lateral view by alexluengo. Courtesy of Thinkstock #176932862.
7. Kidneys by 7activestudio. Courtesy of Thinkstock #491325253.
8. Football player sitting on bench by Thinkstock Images. Courtesy of Thinkstock #86481494.
9. Human kidney anatomy isolated on white background by Tigatelu. Courtesy of Thinkstock #509658516.
10. Thirsty workman drinking water by caraman. Courtesy of Thinkstock #601910146.
11. Lipid bilayer cell membrane with tyrosine Receptor by markusblanke. Courtesy of Thinkstock #481023913.
12. Osmosis and Reverse Osmosis by ttsz. Courtesy of Thinkstock #491059368.
13. Digital illustration of human nerve cell by Dorling Kindersley. Courtesy of Thinkstock #98193245.
14. Close up of fast food snacks and drink on table by dolgachov. Courtesy of Thinkstock #487077896.
15. Washed garden ripe grape tomatoes by DianaLynne. Courtesy of Thinkstock #507999222.
16. Tomato sauce on white by vovashevchuk. Courtesy of Thinkstock #611611518.
17. Roast pork by PeJo29. Courtesy of Thinkstock #177731987.
18. Chorizo slices by goir. Courtesy of Thinkstock #503545476.
19. Glass full of milk on white background by gzorgz. Courtesy of Thinkstock #140807128.
20. Slices of processed American cheese by The_Pixel. Courtesy of Thinkstock #178529147.
21. Baked Potato by JoeGough. Courtesy of Thinkstock #144967833.
22. French fries in the paper bag isolated on white by dla4. Courtesy of Thinkstock #505667696.
23. Potassium containing foods by photka. Courtesy of Thinkstock #511055492.
24. Woman drinking water by IvanMikhaylov. Courtesy of Thinkstock #614871332.
25. Doctor Measuring Blood Pressure of Male Patient by AndreyPopov. Courtesy of Thinkstock #513548574.
26. Multivitamins by ladyana89. Courtesy of Thinkstock #532686353.
27. Blank medicine bottle by Nastco. Courtesy of Thinkstock #487048555.
28. Herbal supplement pills by Elena Elisseeva. Courtesy of Thinkstock #100925606.

Figures – Ch8

1. Release of water during the formation of a peptide bond: Created at BYU-Idaho, 2016.
2. Regulation of fluid balance: Created at BYU-Idaho, 2016. Included the following images Courtesy of Thinkstock: Dissected brain lateral view by alexluengo; Thinkstock #176932862, Human kidney anatomy isolated on white background by Tigatelu; Thinkstock #509658516, and Thirsty workman drinking water by caraman; Thinkstock #601910146.
3. Urine hydration color chart: Created at BYU-Idaho, 2016.
4. The distribution of the cations, sodium and potassium in the body: Created at BYUI-Idaho, 2016. Adapted from Lipid Bilayer Cell Membrane

with Tyrosine Receptor by markusblanke. Courtesy of Thinkstock #481023913.

5. Movement of water across a semipermeable membrane. Created at BYUI-Idaho, 2016. Adapted from Osmosis and Reverse Osmosis by ttsz. Courtesy of Thinkstock #491059368
6. Electrolytes role in nerve conduction: Created at BYU-Idaho, 2016. Adapted from digital illustration of human nerve cell by Dorling Kindersley. Courtesy of Thinkstock #98193245
7. A vitamin and mineral supplement supplying 100% of less of the DV of selected nutrients: Created at BYUI-Idaho, 2016. Included the image, Blank medicine bottle by Nastco. Courtesy of Thinkstock #487048555.
8. A vitamin and mineral supplement supplying greater than 100% of the DV for some of the selected nutrients: Created at BYUI-Idaho, 2016. Included the image, Blank medicine bottle by Nastco. Courtesy of Thinkstock #487048555.

Chapter 9

1. The Holy Bible, KJV. Salt Lake City, UT: Intellectual Reserve, Inc; 1979.
2. Zimmerman, M.B. Iodine deficiency. Endocr Rev. 2009;30(4):376-408.
3. Hunt, J.R. Bioavailability of iron, zinc, and other trace minerals from vegetarian diets. Am J Clin Nutr. 2003; 78:633s-639s.
4. Golden, N.H., Abrams, S.A. Optimizing bone health in children and adolescence. Pediatrics. 2014; 134:1229-1243.
5. Dietary Reference Intakes Summary Table. The National Academies of Science, Engineering and Medicine Web Site. http://www.nationalacademies.org/hmd/~/media/Files/Activity%20Files/Nutrition/DRI-Tables/5Summary%20TableTables%2014.pdf?la=en. Accessed June 12, 2017.
6. Osteoporosis Overview. NIH Osteoporosis and Related Bone Disease National Resource Center Web site. https://www.niams.nih.gov/Health_Info/Bone/Osteoporosis/overview.asp. Published June 2015, Accessed June 6th, 2017.
7. Cashman, K.D. Calcium intake, calcium bioavailability and bone health. Br. J of Nutr. 2002;87:s169-s177
8. Institute of Medicine. 2011. *Dietary Reference Intakes for Calcium and Vitamin D*. Washington, DC: The National Academies Press.
9. Weaver, C.M. Plawecki, K.L. Dietary calcium: adequacy of a vegetarian diet. Am J Clin Nutr. 1994;59:1238S-1241S.
10. Rude, R.K., Helen G.E. Magnesium deficiency and osteoporosis: animal and human observations. J Nutr Biochem. 2004; 14:710-716
11. Castiglioni, S., Cazzaniga, Albisett, W., Maier, J.A. Magnesium and osteoporosis: current state of knowledge and future research directions. Nutrients. 2013; 5:3022-3033.
12. Gropper S, Smith J: Advanced Nutrition in Human Metabolism. 6th ed. Belmont, CA: Wadsworth, Cengage Learning; 2013: 482
13. Hurrell, R., Egli, I. Iron bioavailability and dietary reference values. Am J Clin Nutr. 2010; 91:1461S-1467S.
14. Camaschelle, C. Iron-deficiency anemia. NEJM. 2015; 372:1832-1843.
15. Short, M.W., Domagalaski, J.E. Iron deficiency anemia: evaluation and management. Am Fam Physician. 2013; 87:98-104
16. Iron Poisoning. WebMD Web Site. http://www.webmd.com/a-to-z-guides/iron-poisoning#1. Accessed June 6th, 2017
17. How is hemochromatosis treated. National Institute of Health's, National Heart Lung and Blood Institute's Web Site. https://www.nhlbi.nih.gov/health/health-topics/topics/hemo/treatment. Accessed June 5th, 2017.
18. Gropper S, Smith J: Advanced Nutrition in Human Metabolism. 6th ed. Belmont, CA: Wadsworth, Cengage Learning; 2013: 505
19. Institute of Medicine. 2001. *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: The National Academies Press.
20. Prasad, A.S. Zinc deficiency. BMJ. 2003; 326:409-410.
21. Zinc. National Institutes of Health Office of Dietary Supplements.

https://ods.od.nih.gov/factsheets/Zinc-HealthProfessional/. Accessed June 9th, 2017.

22. Hambridge, M. Zinc and health: current status and future directions. J Nutr. 2000;130:1344-1349
23. Farhana, A. and Ganie, S.A. Iodine, Iodine metabolism and iodine deficiency disorders revisited. Indian J Endocrinol Metab. 2010;14:13-17
24. Pearce, E.N., Pino, S. He, X., Bazrafshan, H.R., Less S.L and Braverman L.E. Sources of dietary iodine: bread, cows' milk, and infant formula in the Boston area. JCEM. 2004; 89:3421-3424
25. Micronutrient Deficiencies. World Health Organization. http://www.who.int/nutrition/topics/idd/en/. Accessed June 9th, 2017
26. Iodine. National Institutes of Health Office of Dietary Supplements. https://ods.od.nih.gov/factsheets/Iodine-HealthProfessional/#en1. Accessed June 9th, 2017
27. Gropper S, Smith J: Advanced Nutrition in Human Metabolism. 6th ed. Belmont, CA: Wadsworth, Cengage Learning; 2013: 547
28. Community Water Fluoridation. Centers for Disease Control and Prevention. https://www.cdc.gov/fluoridation/faqs/community-water-fluoridation.html. Accessed June 6th, 2017.
29. American Dental Association. *Science in the News* http://www.ada.org/en/science-research/science-in-the-news/federal-agencies-announce-scientific-assessments-and-an-update-to-the-recommended-
30. Gropper S, Smith J: Advanced Nutrition in Human Metabolism. 6th ed. Belmont, CA: Wadsworth, Cengage Learning; 2013:510-543.
31. Hemoglobin and functions of iron. USSF Medical Center website. https://www.ucsfhealth.org/education/hemoglobin_and_functions_of_iron/ Accessed November 3, 2017.
32. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism 7th Ed. 2016. Cengage Learning. Page 395.

Images – Ch9

1. Artist rendition of earth and galaxy at creation by Stephanie Frey. Courtesy of Shutterstock # 197769377
2. Adapted from periodic table of elements by Laschi. Courtesy of Shutterstock # 107494040
3. Skeleton model in class by serkan senturk. Courtesy of Shutterstock # 534949018
4. Calcitonin and parathormone. Regulation of calcium level in the blood by CT from the thyroid gland and by PTH from the parathyroid glands. Courtesy of Shutterstock # 314455082
5. Osteoporosis four stages in one rendering by Crevis. Courtesy of Shutterstock # 524364046
6. Foods rich in calcium such as sardines, bean, dried figs, almonds, cottage cheese, hazelnuts, parsley leaves, blue poppy seed, broccoli, Italian cabbage, cheese, milk by Evan Lorne. Courtesy of Shutterstock #366258461
7. Hand with pen drawing the chemical formula of ATP by Zerbor. Courtesy of Shutterstock #429243796.
8. Foods High in Magnesium on wooden table. Healthy eating by bitt24. Courtesy of Shutterstock #393853477.
9. Structure of human hemoglobin molecule. Vector diagram. Hemoglobin is the substance in red blood cells that carries oxygen by Designua. Courtesy of Thinkstock #487406161
10. Heme B is the part of both hemoglobin and myoglobin, and also peroxidase and cyclooxygenase families of enzymes. Vector medical illustration by lyricsaima. Courtesy of Shutterstock #355074899.
11. Collection iron rich foods as liver, buckwheat, eggs, parsley leaves, dried apricots, cocoa, lentil, bean, blue poppy seed, broccoli, dried mushrooms, peanuts and pistachios on wooden table by Evan Lome. Courtesy of Shutterstock #388305553.
12. Anemia, Screening by Image Point Fr. Courtesy of Shutterstock #167917790
13. Iron supplement pills by Myibean. Courtesy of Shutterstock #217349530
14. Foods with Zinc mineral on a wooden table. Top view by bitt24. Courtesy of Shutterstock #401701594.

15. Human thyroid gland by Nerthuz. Courtesy of Shutterstock #207763567
16. Glass of milk and sliced bread on white background by windu. Courtesy of Shutterstock #72032221
17. Background of healthy fresh cruciferous vegetables with broccoli, cabbage, cauliflower, Brussels sprouts, kale and kohlrabi, close up frame by stockcreations. Courtesy of Shutterstock #245873155
18. A large goiter by Dr. J.S.Bhandari, India (Own work) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons https://commons.wikimedia.org/wiki/File%3AGoiter.JPG
19. Full length, black and white photograph of a female 'cretin' who had a great enlargement of the thyroid. She was 24 years of age and had never been out of London. The goiter was of three years' duration. Medical Photographic Library Keywords: Godart, Thomas By http://wellcomeimages.org/indexplus/obf_images/46/c8/55473c7f38e27d210885dc7e68fe.jpgGallery: http://wellcomeimages.org/indexplus/image/L0062856.html, CC BY 4.0, https://commons.wikimedia.org/w/index.php?curid=36223445
20. Dental fluorosis (also termed mottled enamel) is hypomineralization of tooth enamel caused by ingestion of excessive fluoride during enamel formation. Metabolism dysfunction by Algirdas Gelazius. Courtesy of Shutterstock #521583421
21. Mechanism of iron absorption; iron metabolism by ellepigrafica. Courtesy of Shutterstock #276802253. (possibly not used)

Figures – Ch9

1. Adapted from periodic table of elements by Laschi. Courtesy of Shutterstock # 107494040
2. Major and trace minerals. Created at BYU-Idaho, 2017
3. Removal of Magnesium, Zinc and Copper during processing. Created at BYU-Idaho, 2016
4. Regulation of blood calcium levels adapted from Calcitonin and parathormone. Regulation of calcium level in the blood by CT from the thyroid gland and by PTH from the parathyroid glands. Courtesy of Shutterstock # 314455082
5. Bone mass over time By Anatomy & Physiology, Connexions Web site. http://cnx.org/content/col11496/1.6/, Jun 19, 2013. (OpenStax College) [CC BY 3.0 (http://creativecommons.org/licenses/by/3.0)], via Wikimedia Commons
6. Normal bone progressing to osteoporotic bone. Osteoporosis four stages in one rendering by Crevis. Courtesy of Shutterstock # 524364046
7. Structure of human hemoglobin molecule. Vector diagram. Hemoglobin is the substance in red blood cells that carries oxygen by Designua. Courtesy of Shutterstock #487406161
8. Heme B is the part of both hemoglobin and myoglobin, and also peroxidase and cyclooxygenase families of enzymes. Vector medical illustration by lyricsaima. Courtesy of Shutterstock #355074899.
9. Iron in the body compiled at BYU-Idaho. Compiled from Shutterstock images. Mechanism of iron absorption; iron metabolism by ellepigrafica, #276802253. Bone structure details by Yoko Design, #131448077. Human spleen by Designua, #281115437.

Chapter 10

1. Carpenter KJ. A short history of nutritional science: Part 2 (1885-1912). *J Nutr,* 2003; 133:975-984.
2. Carpenter KJ. A short history of nutritional science: Part 3 (1912-1944). *J Nutr.* 2003; 133:3023-3032.
3. Keresztesy JC. The water-soluble vitamins. *Annual Review of Biochemistry*. 1944 July; 13:367-410. doi:http://www.annualreviews.org/doi/pdf/10.1146/annurev.bi.13.070144.002055
4. Gregory JF. Accounting for differences in the bioactivity and bioavailability of vitamers. *Food Nutr Res*. 2012; 56:1-11.

5. Favell DJ. A comparison of the vitamin C content of fresh and frozen vegetables. *Food Chemistry*. 1998; 1:59-64.
6. Barrett DM. Maximizing the nutritional value of fruits and vegetables. *Food Technology*. 2007; 61(4):40-44.
7. Brown MJ, Ferruzzi MG, Nguyen ML, Cooper DA, Eldridge AL, Schwartz SJ, White WS. Carotenoid bioavailability is higher from salads ingested with full-fat than with fat-reduced salad dressings as measured with electrochemical detection. *Am J Clin Nutr.* 2004; 80:396-403.
8. Dawson-Hughes B, Harris SS, Lichtenstein AH, Dolnikowski G, Palermo NJ, Rasmussen H. Dietary fat increases vitamin D-3 absorption. *Journal of the Academy of Nutrition and Dietetics*. 2015; 115(2): 225-230. doi: http://dx.doi.org/10.1016/j.jand.2014.09.014
9. Jeanes YM, Hall WL, Ellard S, Lee E, Lodge JK. The absorption of vitamin E is influenced by the amount of fat in a meal and the food matrix. *British Journal of Nutrition*. 2004; 92:575-579. doi: 10.1079/BJN20041249
10. Gijsbers BL, Jie KS, Vermeer C. Effect of food composition on vitamin K absorption in human volunteers. *British Journal of Nutrition.* 1996; 76(2):223-9.
11. Jacob RS, Sotoudeh G. Vitamin C function and status in chronic disease. *Nutr Clin Care*. 2002; 5(2):66-74.
12. Manzetti S, Zhang J, van der Spoel D. Thiamin function, metabolism, uptake, and transport. *Biochemistry.* 2014; 53:821-835.
13. Institute of Medicine: Food and Nutrition Board. Dietary Reference Intakes: EAR, RDA, AI, Acceptable Macronutrient Distribution Ranges, and UL. http://www.nationalacademies.org/hmd/~/media/Files/Activity%20Files/Nutrition/DRI-Tables/5Summary%20TableTables%2014.pdf?la=en.
14. National Institute of Health: Medline Plus. Beriberi. https://medlineplus.gov/ency/article/000339.htm Accessed May 10, 2017
15. World Health Organization (WHO). (1999). Thiamine deficiency and its prevention and control in major emergencies. http://www.who.int/nutrition/publications/en/thiaminee_in_emergencies_eng.pdf; National Institutes of Health. Thiamin. https://ods.od.nih.gov/factsheets/Thiamin-HealthProfessional/. Accessed July 2, 2017.
16. Institute of Medicine: Food and Nutrition Board. Thiamin. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114331/
17. Institute of Medicine: Food and Nutrition Board. Riboflavin. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114322/
18. Institute of Medicine: Food and Nutrition Board. Niacin. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114304/
19. Mani P, Rohatgi A. Niacin therapy, HDL cholesterol, and cardiovascular disease: Is the HDL hypothesis defunct? *Curr Atheroscler Rep*. 2015; 17(8): 521. doi: 10.1007/s11883-015-0521-x
20. Linus Pauling Institute: Micronutrient Information Center. Niacin.

http://lpi.oregonstate.edu/mic/vitamins/niacin#reference10. Accessed July 24, 2017.

21. Said HM. Cell and molecular aspects of human intestinal biotin absorption. *Journal of Nutrition*. 2009; 139(1): 158-162.
22. Basu TK. Intestinal absorption in health and disease: Micronutrients. Best Practice and Research *Clinical Gastroenterology*. 2012; 17:957-979. doi: https://doi.org/10.1016/S1521-6918(03)00084-2
23. Institute of Medicine: Food and Nutrition Board. Biotin. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114297/
24. Institute of Medicine: Food and Nutrition Board. Pantothenic acid. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114311/
25. Institute of Medicine: Food and Nutrition Board. Vitamin B6. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114313/
26. National Institutes of Health: Office of Dietary Supplements. Vitamin B_6 Dietary supplement fact sheet. https://ods.od.nih.gov/factsheets/VitaminB6-HealthProfessional/. Accessed July 25, 2017.
27. Linus Pauling Institute: Micronutrient Information Center. Vitamin B_6. http://lpi.oregonstate.edu/mic/vitamins/vitamin-B6 Accessed July 25, 2017.
28. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism 7th Ed. 2016. Cengage Learning.
29. Nelson EM. Association of vitamin B6 deficiency with convulsions in infants. *Public Health Reports*. 1956; 71(5): 445-8.
30. NIH Office of Dietary Supplement. Folate: Dietary supplement fact sheet. https://ods.od.nih.gov/factsheets/Folate-HealthProfessional/ Accessed July 25, 2017.
31. Linus Pauling Institute: Micronutrient Information Center. Folate. http://lpi.oregonstate.edu/mic/vitamins/folate Accessed July 25, 2017
32. Center for Disease Control and Prevention. Facts about folic acid. https://www.cdc.gov/ncbddd/folicacid/about.html Accessed August 7, 2017.
33. National Birth Defects Prevention Network. NTD/folic acid. https://www.nbdpn.org/ntd_folic_acid_information.php. Accessed August 7, 2017.
34. Morbidity and Mortality Weekly Report. Updated estimates of neural tube defects prevented by mandatory folic acid fortification – United States, 1995-2011. 2015, January 16; 64(01):1-5. https://www.cdc.gov/mmwr/preview/mmwrhtml/mm6401a2.htm.
35. Institute of Medicine: Food and Nutrition Board. Folate. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114318/
36. Watanabe F. Vitamin B12 sources and bioavailability. *Exp Biol Med*. 2007; 232:1266-1274. doi:10.3181/0703-MR-67

37. Institute of Medicine: Food and Nutrition Board. Vitamin B_{12}. In: *Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes and its Panel on Folate, Other B Vitamins, and Choline. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline*. Washington (DC): National Academies Press; 1998. https://www.ncbi.nlm.nih.gov/books/NBK114302/
38. Gille D, Schmid A. Vitamin B12 in meat and dairy products. *Nutrition Reviews*. 2015; 73(2):106-115. doi:https://doi-org.byui.idm.oclc.org/10.1093/nutrit/nuu011
39. The James Lind Library. A treatise of the scurvy. http://www.jameslindlibrary.org/lind-j-1753/. Accessed August 7, 2017.
40. Linus Pauling Institute: Micronutrient Information Center. Vitamin C. Retrieved August 3, 2017 from http://lpi.oregonstate.edu/mic/vitamins/vitamin-C#function
41. Erdman JW, Macdonald IA, Zeisel, SH. *Present Knowledge in Nutrition 10th Ed.* John Wiley & Sons, Ltd. 2012.
42. National Institutes of Health: Office of Dietary Supplements. Vitamin C: Fact sheet for health professionals. https://ods.od.nih.gov/factsheets/VitaminC-HealthProfessional/#h5. Accessed August 3, 2017.
43. Institute of Medicine: Food and Nutrition Board. Vitamin C. In: *Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids.* Washington (DC): National Academies Press (US); 2000. https://www.ncbi.nlm.nih.gov/books/NBK225480/
44. National Institute of Health. *Scurvy*. https://rarediseases.info.nih.gov/diseases/10406/scurvy. Accessed August 7, 2017.
45. Maumenee, AE. The history of vitamin A and its ophthalmic implications. Arch Ophthalmol. 1993; 11(4):547-550. doi:10.1001/archopht.1993.01090040139048
46. Sommer, A. Vitamin A deficiency and clinical disease: An historical overview. J Nutr. 2008:138:1835-1839.
47. Ross, C. Vitamin A and retinoic acid in the T cell-related immunity. Am J Clin Nutr. 2012; 96(suppl):1166s-1172s.
48. Rao, A.V., Rao, LG. Carotenoids and human health. Pharmacol Res. 2007; 55:207-216.
49. National Institutes of Health: Office of Dietary Supplements. Vitamin A: Dietary supplement fact sheet. https://ods.od.nih.gov/factsheets/VitaminA-HealthProfessional/. Accessed June 29, 2017.
50. Institute of Medicine: Food and Nutrition Board. Vitamin A. In: *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: The National Academies Press; 2001. https://www.ncbi.nlm.nih.gov/books/NBK222318/
51. World Health Organization. Nutrition-Micronutrient deficiencies: Vitamin A deficiency. http://www.who.int/nutrition/topics/vad/en/. Accessed July 6th, 2017.
52. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism 7th Ed. 2016. Cengage Learning. Page 387.
53. Erdman JW, Macdonald IA, Zeisel, SH. *Present Knowledge in Nutrition 10th Ed.* John Wiley & Sons, Ltd. 2012.
54. Rodahl K, Moore T. The vitamin A content and toxicity of bear and seal liver. Biochem J 1943; 37:166-8.
55. Vieth R. Why vitamin D is not a hormone, and not a synonym for 1.25-dihydroxy-vitamin D, its analogs or deltanoids. J Steroid Biochem Mol Biol. 2004; 89-90(1-5):571-573.
56. Institute of Medicine Food and Nutrition Board. Overview of Vitamin D. In: *Dietary Reference Intakes for Calcium and Vitamin D*. Washington (DC): National Academies Press (US); 2011. https://www.ncbi.nlm.nih.gov/books/NBK56061/
57. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism 7th Ed. 2016. Cengage Learning. Page 395.

58. Linus Pauling Institute: Micronutrient Information Center. Vitamin D. http://lpi.oregonstate.edu/mic/vitamins/vitamin-D Accessed August 24, 2017
59. National Institutes of Health: Office of Dietary Supplements. Vitamin D: Dietary supplement fact sheet. https://ods.od.nih.gov/factsheets/VitaminD-HealthProfessional. Accessed August 23, 2017.
60. Institute of Medicine: Food and Nutrition Board. Vitamin E. In: *Institute of Medicine (US) Panel on Dietary Antioxidants and Related Compounds. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids.* Washington (DC): National Academies Press (US); 2000. https://www.ncbi.nlm.nih.gov/books/NBK225461/
61. Linus Pauling Institute: Micronutrient Information Center. Vitamin E. http://lpi.oregonstate.edu/mic/vitamins/vitamin-E. Accessed September 9, 2017
62. National Institutes of Health: Office of Dietary Supplements. Vitamin E: Dietary supplement fact sheet. https://ods.od.nih.gov/factsheets/VitaminE-HealthProfessional/ Accessed September 9, 2017.
63. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism 7th Ed. 2016. Cengage Learning. Page 407.
64. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism 7th Ed. 2016. Cengage Learning. Page 408.
65. Linus Pauling Institute: Micronutrient Information Center. Vitamin K. http://lpi.oregonstate.edu/mic/vitamins/vitamin-K, Accessed September 15, 2017.
66. Shearer MJ, Xueyan F, Booth SL. Vitamin K nutrition, metabolism, and requirements: Current concepts and future research. *Advances in Nutrition*. 2012; 3:182-195. doi:103945/an.111.001800
67. Institute of Medicine: Food and Nutrition Board. Vitamin K. In: *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: The National Academies Press; 2001. https://www.ncbi.nlm.nih.gov/books/NBK222299/
68. National Institutes of Health: Office of Dietary Supplements. Vitamin K: Dietary supplement fact sheet. https://ods.od.nih.gov/factsheets/VitaminK-HealthProfessional/
69. Gropper SS, Smith JL. Advanced Nutrition and Human Metabolism, 7th Ed. Cengage Learning; 2016:309.
70. Cho E, Hunter DJ, Spiegelman D, et al. Intakes of vitamins A, C, and E and folate and multivitamins and lung cancer: A pooled analysis of 8 prospective studies. *Int J Cancer*. 2006; 118: 970-978.
71. Bai XY, Qu X, Jiang S, et al. Association between Dietary Vitamin C intake and risk of prostate cancer: A meta-analysis involving 103,658 subjects. *J of Cancer*. 2015; 6(9): 913-921.
72. Gaziano JM, Glynn RJ, Christen WG, et al., Vitamins E and C in the prevention of prostate and total cancer in men: The Physicians' Health Study II randomized controlled trial. *J Am Med Assoc.* 2009; 301: 52-62.

Images – Ch10

1. Beriberi from http://resource.nlm.nih.gov/101434597
2. Riboflavin picture By User:PatríciaR (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC BY-SA 4.0-3.0-2.5-2.0-1.0 (http://creativecommons.org/licenses/by-sa/4.0-3.0-2.5-2.0-1.0)], via Wikimedia Commons and https://commons.wikimedia.org/wiki/File:All-trans-Retinol.svg
3. Milk carton. Courtesy of Shutterstock #180407495
4. Angular cheilitis by Matthew Ferguson 57 (Own work) [CC BY-SA 3.0 https://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons
5. A young boy suffering from pellagra, the disease of the three D's: dermatitis, diarrhea, dementia. Photograph. Encyclopædia Britannica ImageQuest. Accessed Aug 26, 2017.

6. An illustration of an infant with spina Bifida. Center for Disease Control and Prevention. https://commons.wikimedia.org/wiki/File:Spina-bifida.jpg
7. *Spinal Bifida Myelomeningocele birth defect*. Photograph. *Encyclopædia Britannica ImageQuest*. Accessed Aug 3, 2017.
8. Folic acid food source. Courtesy of Shutterstock #672102592
9. Vitamin C in fruits and vegetables. Courtesy of Shutterstock #362885486
10. Grilled chicken liver in frying pan on wooden table. Courtesy of Shutterstock #317841452
11. Freshly washed shredded carrots in wooden bowl with baby spinach and salad oil in the background by Marie C Fields. Courtesy of Shutterstock #24813757
12. Keratomalacia from http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3936686/.
13. Portrait of Large white bear on ice. Courtesy of Shutterstock #130177340
14. *Hands of a person with the condition carotenaemia*. Photography. *Encyclopædia Britannica ImageQuest*. Accessed Sep 24, 2017.
15. *Cod-Liver Oil*. Photographer. *Encyclopædia Britannica ImageQuest*. Accessed Aug 23, 2017.
16. *Rickets*. Photography. *Encyclopædia Britannica ImageQuest*. Accessed Aug 26, 2017.
17. *Food rich in vitamin E. Courtesy of Shutterstock #380849872*

Figures – Ch10

1. Vitamin C degradation. Created at BYU-Idaho, 2017.
2. Beta-carotene and Vitamin A. Used images from https://commons.wikimedia.org/wiki/File:Beta-Carotin.svg
3. Antioxidants. Courtesy of Shutterstock #643327453
4. Coenzymes Created at BYU-Idaho, 2017.
5. Tryptophan and Niacin. Created at BYU-Idaho, 2017.
6. Coenzyme A and Pantothenic acid.
7. Megaloblastic/macrocytic anemia caused by insufficient folate and/or vitamin B12
8. Absorption of vitamin B_{12}. Created at BYU-Idaho, 2017.
9. Comparison of normal and megaloblastic red blood cells
Pernicious anemia megaloblasts. Photograph. *Encyclopædia Britannica ImageQuest*. Accessed Aug 3, 2017.
Red blood cells. Photography. *Encyclopædia Britannica ImageQuest*. Accessed Aug 3, 2017.
10. Vitamin C and Healthy Collagen Synthesis. Created by at BYU-Idaho, 2017.
11. A. Purpura rash with petechiae. Photography. *Encyclopædia Britannica ImageQuest*. Accessed Sep 27, 2017.
B. Symptoms of scurvy corkscrew hair *Corkscrew hairs on skin of scurvy patient*. Photography. *Encyclopædia Britannica ImageQuest*. Accessed Aug 3, 2017.
12. Human eye anatomy, detailed illustration by Tefi. Courtesy of Shutterstock #174265226.
13. Foods contain vitamin D. Skin absorbs solar UVB radiation and synthesis of vitamin D. Calcium homeostasis and metabolism. Courtesy of Shutterstock #361863287

Chapter 11

1. Centers for Disease Control and Prevention. The health effects of overweight and obesity. https://www.cdc.gov/healthyweight/effects/index.html. Accessed July 17, 2017.
2. The Holy Bible, KJV. Salt Lake City, UT: Intellectual Reserve, Inc; 1979.
3. Duyff RL. American Dietetic Association Complete Food & Nutrition Guide. 4th ed. New York, NY: Houghton Mifflin Harcourt; 2012.
4. Centers for Disease Control and Prevention. Defining adult overweight and obesity.

https://www.cdc.gov/obesity/adult/defining.html. Accessed July 17, 2017.
5. World Health Organization. Fact sheet on obesity. http://www.who.int/mediacentre/factsheets/fs311/en/. Accessed July 17, 2017.
6. Centers for Disease Control and Prevention. About adult BMI. https://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html. Accessed July 18, 2017.
7. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015-2020 Dietary Guidelines for Americans.
8. National Institutes of Health. Classification of overweight and obesity by BMI, waist circumference, and associated disease risks. https://www.nhlbi.nih.gov/health/educational/lose_wt/BMI/bmi_dis.htm. Accessed July 17, 2017.
9. Academy of Nutrition and Dietetics. Understanding Body Mass Index. http://www.eatright.org/resource/health/weight-loss/your-health-and-your-weight/understanding-body-mass-index. Accessed July 18, 2017.
10. Heo M, Faith MS, Pietrobelli A, Heymsfield SB. Percentage of body fat cutoffs by sex, age, and race-ethnicity in the US adult population from NHANES 1999-2004. Am J Clin Nutr. 2012; 95:594-602.
11. Wells JCK, Fewtrell MS. Measuring body composition. Arch Dis Child. 2006;91(7):612-617.
12. Dehghan M and Merchant AT. Is bioelectrical impedeance accurate for use in large epidemiological studies? Nutrition Journal. 2008;7:26.
13. Lee SY and Gallagher D. Assessment methods in humand body composition. Curr Opin Clin Nutr Metab Care. 2008;11:566-572.
14. Centers for Disease Control and Prevention. Assessing your weight. https://www.cdc.gov/healthyweight/assessing/index.html. Accessed July 19, 2017.
15. World Health Organization. Waist Circumference and Waist-Hip Ratio. http://apps.who.int/iris/bitstream/10665/44583/1/9789241501491_eng.pdf. Accessed July 26, 2017.
16. Centers for Disease Control and Prevention. Prevalence of overweight, obesity, and extreme obesity among adults: United States, trends 1960–1962 through 2007–2008. https://www.cdc.gov/nchs/data/hestat/obesity_adult_07_08/obesity_adult_07_08.pdf. Accessed July 28, 2017.
17. Centers for Disease Control and Prevention. Health, United States, 2016: With chartbook on long-term trends in health. https://www.cdc.gov/nchs/data/hus/hus16.pdf#053. Accessed July 28, 2017.
18. World Health Organization. Overweight and obesity. https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight Accessed September 1, 2020.
19. World Health Organization. Prevalence of obesity amount adults. https://www.who.int/data/gho/data/indicators/indicator-details/GHO/prevalence-of-obesity-among-adults-bmi-=-30-(crude-estimate)-(-) Accessed September 1, 2020.
20. National Institutes of Health. Balance Food and Activity. https://www.nhlbi.nih.gov/health/educational/wecan/healthy-weight-basics/balance.htm. Accessed July 31, 2017.
21. Academy of Nutrition and Dietetics. Position of the Academy of Nutrition and Dietetics: Interventions for the treatment of overweight and obesity in adults. J Acad Nutr Diet. 2016; 116:129-147.
22. Amin T, Mercer JG. Hunger and satiety mechanisms and their potential exploitation in the regulation of food intake. Curr Obes Rep. 2016; 5:106-112.
23. Villablanca P.A., et al. Nonexercise activity thermogenesis in obesity management. Mayo Clin Proc. 2015; 90:509-519.
24. Levine J.A. Non-exercise activity thermogenesis. Proc Nutr Soc. 2003; 62:667-679.
25. Herrera BM, Lindgren CM. The genetics of obesity. Curr Diab Rep. 2010;10(6):498-505.
26. Klok MD, Jakobsdottir S, Drent ML. The role of leptin and ghrelin in regulation of food intake

and body weight in humans: A review. Obes Rev. 2007;8(1):21-34.
27. Gruzdeva O, Borodkina D, Uchasova E, Dyleva Y, Barbarash O. Leptin resistance: underlying mechanisms and diagnosis. Diabetes Metab Syndr Obes. 2019; 12:191-198.
28. Centers for Disease Control. About child and teen BMI. https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html. Accessed June 2017 Accessed June 2017.

Images – Ch11

1. Façade of Salt Lake Temple – Utah by milosk50. Courtesy of Shutterstock #293760422.
2. Muscular man working out in gym doing exercises with barbell at biceps, strong male by Nikolas_jkd. Courtesy of Shutterstock #439116364.
3. Skinfold test by Microgen. Courtesy of Shutterstock #658975417.
4. Bod Pod. Courtesy of Joint Base Langley-Eustis 100309-F-5594H-021. http://www.jble.af.mil/News/Photos/igphoto/2000385550/.
5. Female doctor examining woman in 40s at Bone Densitometer Machine by GagliardiImages. Courtesy of Shutterstock #236325787.
6. Close up of Athlete's Body Composition Analysis before Fitness Activity to See Key Components of Body by Giorgio Rossi. Courtesy of Shutterstock #315424622.
7. Apple and pear body shape – concept by ssimone. Courtesy of Shutterstock #300051305.
8. Medically accurate illustration of the hypothalamus by Sebastian Kaulitzki. Courtesy of Shutterstock #305272889.
9. The word Obesity in red letters hidden within a blue DNA strand to illustrate the hereditary nature of fat and the condition of being very heavy by iQoncept. Courtesy of Shutterstock #140899765.
10. Illustration of diagram of human stomach anatomy by corbac40. Courtesy of Shutterstock #197023640.
11. Control of food intake. Human hormones. Leptin, insulin, and ghrelin by Designua. Courtesy of Shutterstock #311817806.

Figures – Ch11

1. Health consequences of too much body fat: Created at BYU-Provo, 2017.
2. Body Mass Index-for-age percentiles: Boys, 2 to 20 years. Centers for Disease Control. About child and teen BMI. https://www.cdc.gov/healthyweight/assessing/bmi/childrens_bmi/about_childrens_bmi.html. Accessed June 2017.
3. Health risk- BMI and waist circumference: Created at BYU-Provo, 2017.
4. Prevalence of Overweight and Obesity in the U.S.: Created at BYU-Provo, 2017.
5. Worldwide obesity prevalence: Created at BYU-Provo, 2017.
6. Energy balance concept: Created at BYU-Idaho, 2017.
7. Energy expenditure: Created at BYU-Provo, 2017.
8. Energy expenditure-NEAT adapted from figure 6 created at BYU-Provo

---

Chapter 12

1. National Institutes of Health. Aim for a healthy weight- Facts about healthy weight. https://www.nhlbi.nih.gov/health-pro/resources/heart/aim-facts-html. Accessed August 11, 2017.
2. Academy of Nutrition and Dietetics. Position of the Academy of Nutrition and Dietetics: Interventions for the treatment of overweight and obesity in adults. J Acad Nutr Diet. 2016; 116:129-147.
3. Centers for Disease Control and Prevention. Losing weight. https://www.cdc.gov/healthyweight/losing_weight/index.html. Accessed August 11, 2017.
4. Duyff RL. American Dietetic Association Complete Food & Nutrition Guide. 4th ed. New York, NY: Houghton Mifflin Harcourt; 2012.
5. Kaufman C. 5 ways low-calorie diets can sabotage your health. http://www.eatright.org/resource/health/weight-loss/your-health-and-your-weight/5-ways-low-calorie-diets-can-sabotage-your-health. Accessed August 11, 2017.

6. Frechman R. What a healthy weight loss plan really looks like. http://www.eatright.org/resource/health/weight-loss/tips-for-weight-loss/what-a-healthy-weight-loss-plan-really-looks-like. Accessed August 11, 2017.
7. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK. American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. Med Sci Sports Exerc. 2009;41:1532.
8. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015-2020 Dietary Guidelines for Americans
9. Moule J. The A-B-C of behavior: Changing behavior through good design, one step at a time. http://johnnyholland.org/2011/01/the-a-b-c-of-behaviour/. Accessed August 14, 2017
10. Maxwell J. John Maxwell on leadership. http://www.johnmaxwell.com/blog/it-all-comes-down-to-what-you-do-daily. Accessed August 14, 2017.
11. U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015-2020 Dietary Guidelines for Americans.
12. National Institutes of Health. Prescription medications to treat overweight and obesity. https://www.niddk.nih.gov/health-information/weight-management/prescription-medications-treat-overweight-obesity. Accessed August 16, 2017.
13. Prescribers' Digital Reference. Phentermine hydrochloride. http://www.pdr.net/drug-summary/Phentermine-Hydrochloride-Capsules-phentermine-hydrochloride-23983. Accessed August 16, 2017.
14. Prescribers' Digital Reference. Orlistat. http://www.pdr.net/drug-summary/Xenical-orlistat-2101. Accessed August 16, 2017.
15. National Institutes of Health: National Center for Complementary and Integrative Health. Weight Control. https://nccih.nih.gov/health/weightcontrol. Accessed August 16, 2017.
16. National Institutes of Health: National Center for Complementary and Integrative Health. Energy Drinks. https://nccih.nih.gov/health/energy-drinks. Accessed August 16, 2017.
17. National Institutes of Health: National Center for Complementary and Integrative Health. Green Tea. https://nccih.nih.gov/health/greentea. Accessed August 16, 2017.
18. National Institutes of Health. Bariatric Surgery. https://www.niddk.nih.gov/health-information/weight-management/bariatric-surgery. Accessed August 16, 2017.
19. Institute of Medicine. "Weight Gain during Pregnancy: Reexamining the Guidelines." May 2009. http://www.iom.edu/~/media/Files/Report%20Files/2009/Weight-Gain-During-Pregnancy-Reexamining-the-Guidelines/Resource%20Page%20-%20Weight%20Gain%20During%20Pregnancy.pdf
20. Merck Manual. Accessed June 2017. http://www.merckmanuals.com/professional/pediatrics/perinatal-problems/small-for-gestational-age-sga-infant
21. Centers for Disease Control. Use and Interpretation of the WHO and CDC Growth Charts for Children from Birth to 20 Years in the United States. Accessed June 2017. https://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/growthchart.pdf
22. American Academy of Pediatrics. Bright Futures: Nutrition. Accessed June 2017. https://brightfutures.aap.org/Bright%20Futures%20Documents/BFNutrition3rdEditionSupervision.pdf
23. Fryar CD, Carroll MD, Ogden CL, Prevalence of overweight and obesity among children and adolescents: United States, 1963-1965 through 2011-2012. Atlanta, GA: National Center for Health Statistics, 2014.
24. U.S. Department of Agriculture and U.S. Department of Health and Human Services, Dietary Guidelines for Americans, 2015-2020. 2015, U.S. Government Printing Office: Washington, DC.
25. Vandenbroeck P, Goossens J, and Clemens M, Foresight, Foresight, tackling obesities: future choices–building the obesity system map. London: Government Office for Science, 2007.
26. Spiegelman BM, Flier JS, Obesity and the Regulation of Energy Balance. Cell, 2001. 104(4): p. 531-543.
27. Institute of Medicine, Accelerating progress in obesity prevention: solving the weight of the nation. 2012, Washington, DC: National Academies Press.
28. Centers for Disease Control and Prevention. Childhood obesity facts. Updated January 25, 2017.

Accessed June 2017. https://www.cdc.gov/healthyschools/obesity/facts.htm
29. Saltzman E, Karl JP. Nutrient deficiencies after gastric bypass surgery. *Annu Rev Nutr*. 2013; 233: 183-203.

Images – Ch12

1. Fitness and weight loss concept, dumbbells, white scale, towels, fruit, tape measure and digital tablet on a wooden table, top view by Stock-Asso. Courtesy of Shutterstock #282254006.
2. From obese man to sportsman by CLIPAREA I Custom media. Courtesy of Shutterstock #289820468.
3. Brunch choice crowd dining food options eating concept by Rawpixel.com. Courtesy of Shutterstock #384205462.
4. Photo of a wooden alphabet block spelling ABC by shutteratakan. Courtesy of Shutterstock #238125649.
5. Colorful vector brain illustration, brain hand drawn painting, mind concept drawing by Markovka. Courtesy of Shutterstock #614343662.
6. Male human body belonging to an adult man flat icon for apps and websites by Martial Red. Courtesy of Shutterstock #249408751.
7. Digital illustration of the stomach by Nicolas Primola. Courtesy of Shutterstock #500446795.
8. Pills isolated on white by NewSoul. Courtesy of Shutterstock #59980753.
9. Green tea leaf isolated on white background by artphotoclub. Courtesy of Shutterstock #379988305.
10. Roux-en-Y gastric bypass (RNY) weight loss surgery by Alila Medical Media. Courtesy of Shutterstock #93594667.

Figures – Ch12

1. The ABC of behavior: Created at BYU-Provo, 2017.
2. Roux-en-Y gastric bypass (RNY) weight loss surgery by Alila Medical Media. Courtesy of Shutterstock #93594667.
3. Distribution of recommended weight gain during pregnancy. Created at BYU-Idaho 2017.

Chapter 13

1. Mayo Clinic. "Healthy Sperm: Improving Your Fertility." © 1998–2012 Mayo Foundation for Medical Education and Research. Accessed February 21, 2012. http://www.mayoclinic.com/health/fertility/MC00023.
2. *The Latter-day Saint Woman: Basic Manual for Women, Part B*, (2000), 179–84
3. US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. http://www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes -discomforts.cfm.
4. Eliakim, R., O. Abulafia, and D. M. Sherer. "Hyperemesis Gravidarum: A Current Review." *Am J Perinatol* 17, no. 4 (2000): 207–18.
5. https://www.cdc.gov/pcd/issues/2014/13_0415.htm
6. Noctor, E., & Dunne, F. P. (2015). Type 2 diabetes after gestational diabetes: The influence of changing diagnostic criteria. *World Journal of Diabetes*, *6*(2), 234–244. http://doi.org/10.4239/wjd.v6.i2.234
7. Arshad A, Pasha W, Khattak T. A and Kiyani RB. Impact of Pregnancy Induced Hypertension on Birth Weight of Newborn at Term. Journal of Rawalpindi Medical College (JRMC);2011;15(2):113-115. Available at http://www.journalrmc.com/volumes/1394781698.pdf.
8. http://apps.who.int/iris/bitstream/10665/44703/1/9789241548335_eng.pdf
9. Centers for Disease Control. *Reproductive Health*. https://www.cdc.gov/reproductivehealth/maternalinfanthealth/pregnancy-weight-gain.htm
10. Dietary Reference Intakes Summary Table. The National Academies of Science, Engineering and Medicine Web Site. http://www.nationalacademies.org/hmd/~/media/Files/Activity%20Files/Nutrition/DRI-Tables/5Summary%20TableTables%2014.pdf?la=en. Accessed June 12, 2017.

11. Key Elements of Healthy Eating Patterns. Retrieved from U.S. Department of Health and Human Services and U.S. Department of Agriculture. 2015–2020 Dietary Guidelines for Americans. 8th Edition. May 2017. Available at http://health.gov/dietaryguidelines/2015/guidelines/
12. US Department of Health and Human Services, Office on Women's Health. "Pregnancy: Body Changes and Discomforts." Last updated September 27, 2010. http://www.womenshealth.gov/pregnancy/you-are-pregnant/body-changes - discomforts.cfm.
13. Kovacs CS. Calcium Metabolism during Pregnancy and Lactation. [Updated 2015 Mar 10]. In: De Groot LJ, Chrousos G, Dungan K, et al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2000-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK279173/
14. Allen, L.H. Biological mechanisms that might underlie iron's effect on fetal growth and preterm birth. J Nutr 2001; 131:5815-9S.
15. NIH: National Institute of Child Health and Human Development
16. Scholl, T.O., and Johnson, W.G. Folic acid: Influence on the outcome of pregnancy. *Am J Clin Nutr* 2000; 71 (Suppl.):1295S-1303S.
17. Genetic Alliance; District of Columbia Department of Health. Understanding Genetics: A District of Columbia Guide for Patients and Health Professionals. Washington (DC): Genetic Alliance; 2010 Feb 17. Appendix D, Teratogens/Prenatal Substance Abuse. Available from: https://www.ncbi.nlm.nih.gov/books/NBK132140/
18. Office of Disease Prevention and Health Promotion. 2018 *Physical Activity Guidelines for Americans 2nd edition*. Chapter 6: Additional consideration for some adults. https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf
19. National Institutes of Health, and Friends of the National Library of Medicine. "Should I Exercise During My Pregnancy?" *NIH Medline Plus 3*, no. 1 (Winter 2008): 26. http://www.nlm.nih.gov/medlineplus/magazine/issues/winter08/articles/winter08pg26.html
20. World Health Organization. *Breastfeeding.* Available at http://www.who.int/topics/breastfeeding/en/
21. King, J. "Contraception and Lactation: Physiology of Lactation." *Journal of Midwifery and Women's Health* 52, no. 6 (2007): 614–20. © 2007 Elsevier Science, Inc.
22. American Academy of Pediatrics. Executive Summary. Breastfeeding and the Use of Human Milk. Pediatrics: 129:3. 2012. Available at: http://www2.aap.org/breastfeeding/files/pdf/breastfeeding2012execsum.pdf
23. Infant and Young Child Feeding: Model Chapter for Textbooks for Medical Students and Allied Health Professionals. Geneva: World Health Organization; 2009. SESSION 2, The physiological basis of breastfeeding. Available from: https://www.ncbi.nlm.nih.gov/books/NBK148970/
24. National Cancer Institute. "Reproductive History and Breast Cancer Risk." Accessed June 25, 2017. http://www.cancer.gov/cancertopics/factsheet/Risk/reproductive-history
25. World Health Organization. "Infant and Young Child Feeding." June 2017. http://www.who.int/mediacentre/factsheets/fs342/en/index.html
26. *Galactosemia*. July 9, 2012. http://ghr.nlm.nih.gov/condition/galactosemia.
27. Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*, Institute of Medicine of the National Academies (Washington, D.C.: The National Academies Press, 2005), 169–70 https://www.nap.edu/read/10490/chapter/7#169
28. Food and Nutrition Board, Institute of Medicine. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*, Institute of Medicine of the National Academies (Washington, D.C.: The National Academies Press, 2005). https://www.nap.edu/read/10490/chapter/12#630
29. Juber, B. A., Jackson, K. H., Johnson, K. B., Harris, W. S., & Baack, M. L. (2016). Breast milk DHA levels may increase after informing women: a

community-based cohort study from South Dakota USA. *International Breastfeeding Journal*, *12*, 7. http://doi.org/10.1186/s13006-016-0099-0
30. Institute of Medicine, Food and Nutrition Board. Dietary Reference Intakes: Water, Potassium, Sodium, Chloride and Sulfate. Washington, DC: National Academies Press, 2004.
31. Baker, Robert D. Greer, Frank R. The Committee on Nutrition. American Academy of Pediatrics. Pediatrics: 126:5. 2004. Accessed at: http://pediatrics.aappublications.org/content/126/5/1040
32. American Academy of Pediatrics. Where we stand: fluoride recommendations. Accessed June 2017: https://www.healthychildren.org/English/ages-stages/baby/feeding-nutrition/Pages/Fluoride-Supplements.aspx
33. Clark, Melinda B. Slayton. Rebecca L. American Academy of Pediatrics. Fluoride use in caries prevention in the primary care setting. Pediatrics; 134:3. 2014. Accessed June 2017: https://www.aap.org/en-us/about-the-aap/aap-press-room/Pages/AAP-Recommends-Fluoride-to-Prevent-Dental-Caries.aspx
34. American Academy of Pediatrics. Starting solid foods. Accessed June 2017 https://www.healthychildren.org/English/ages-stages/baby/feeding-nutrition/Pages/Switching-To-Solid-Foods.aspx
35. American Family Physician. *Infant botulism*. Accessed June 2017: http://www.aafp.org/afp/2002/0401/p1388.html
36. United States Department of Agriculture Food Safety and Inspection Service. Clostridium botulinum. Accessed June 2017: https://www.fsis.usda.gov/wps/wcm/connect/a70a5447-9490-4855-af0d-e617ea6b5e46/Clostridium_botulinum.pdf?MOD=AJPERES
37. Centers for Disease Control. Use and Interpretation of the WHO and CDC Growth Charts for Children from Birth to 20 Years in the United States. Accessed June 2017. https://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/growthchart.pdf
38. American Academy of Pediatrics. Bright Futures: Nutrition. Accessed June 2017. https://brightfutures.aap.org/Bright%20Futures%20Documents/BFNutrition3rdEditionSupervision.pdf
39. United States Department of Agriculture. Choose My Plate. Meal and Snack Patterns. Accessed June 2017. https://www.choosemyplate.gov/preschoolers-meal-and-snack-patterns
40. National Institutes of Health. NIH Osteoporosis and related bone diseases national resource center. *Kids and the Bones: A guide for parents.* Accessed June, 2017. https://www.niams.nih.gov/health_info/bone/Bone_Health/Juvenile/default.asp
41. Kazal Jr., L. A., MD. "Prevention of Iron Deficiency in Infants and Toddlers." *American Academy of Family Physicians* 66, no. 7 (October 1, 2002): 1217—25. http://www.aafp.org/afp/2002/1001/p1217.html.
42. Riley LK, Rupert J, Boucher O. Nutrition in Toddlers. *American Family Physician.* 2018 98(4): 227-233.
43. Heyman, Melvin B. Abrams, Steven A. Section on gastroenterology, hepatology, and nutrition, committee on nutrition. Fruit Juice in Infants, Children, and Adolescents: Current Recommendations. Pediatrics Jun 2017, 139 (6) e20170967. Accessed July 2017. http://pediatrics.aappublications.org/content/139/6/e20170967.
44. US National Library of Medicine. National Institutes of Health. Medline Plus: Food jags. Accessed June 2017. https://medlineplus.gov/ency/article/002425.htm
45. US Department of Health and Human Services. "Consumption of Added Sugar among US Children and Adolescents." *NCHS Data Brief*, No. 87 (March 2012).
46. Forestell CA, Mennella JA. Early determinants of fruit and vegetable acceptance. *Pediatrics*. 2007; 120: 1247-1254.
47. Sullivan SA, Birch LL. Infant dietary experience and acceptance of solid foods. *Pediatrics.* 1994; 93: 271-277.
48. Satter, Ellyn. Ellyn Satter's Division of Responsibility in Eating. 2016. Accessed June 2017. http://www.ellynsatterinstitute.org/dor/divisionofresponsibilityinfeeding.php

49. The Church of Jesus Christ of Latter-day Saints. The Family: A Proclamation to the World. 1995. Accessed June 2017. https://www.lds.org/topics/family-proclamation?lang=eng&old=true
50. The Church of Jesus Christ of Latter-day Saints. *Agency and Accountability*. Accessed June 2017. https://www.lds.org/topics/agency?lang=eng
51. Special recognition to *An Introduction to Nutrition*, a Creative Commons textbook. http://2012books.lardbucket.org/books/an-introduction-to-nutrition/
52. Fetal alcohol spectrum disorders (FASDs). Centers for Disease Control and Prevention Website. https://www.cdc.gov/ncbddd/fasd/alcohol-use.html. Updated July 21, 2016. Accessed November 22, 2017.

Images – Ch13

1. Close up photo of pregnant woman by Jaengpeng. Courtesy of Shutterstock #364954439
2. Pregnant woman with a strong toxicosis sitting in bathroom by Vaula Vitaly. Courtesy of Shutterstock #49830286
3. Doctor measures the pressure of a pregnant woman by adriaticfoto. Courtesy of Shutterstock #384195979
4. Isolated on white ripe banana by swinner. Courtesy of Shutterstock #47042092
5. Delicious, nutritious and healthy fresh plain yogurt on vintage Italian carrara marble setting by tacar. Courtesy of Shutterstock #283368935
6. Strawberry preserves being spread on while wheat toast by Stephanie Frey. Courtesy of Shutterstock #35581300
7. Smiling pretty pregnant woman eating yogurt by Dragon Images. Courtesy of Shutterstock #600370328
8. Selection food sources of omega 3 and unsaturated fats. Superfood high vitamin e for healthy food. Almond, pecan, hazelnuts, walnuts, olive oil, flax, chia, avocado and salmon on bamboo cutting board by Kerdkanno. Courtesy of Shutterstock #550832053
9. Pretty pregnant woman exercising with dumbbells at home by michaeljung. Courtesy of Shutterstock #154139006
10. Teenage Girl With Nurse Holding Newborn Baby in Hospital by Monkey Business Images. Courtesy of Shutterstock #361337075
11. Mom feeds the baby soup By Pavel Ilyukhin. Courtesy of Shutterstock #492311254
12. Baby mashed with spoon in glass jar on white background by 279photo Studio. Courtesy of Shutterstock #549529189
13. Washing fruits and vegetables close-up by Africa Studio. Courtesy of Shutterstock #219001450
14. Kids with aprons preparing a healthy vegetables meal in the kitchen by Ilike. Courtesy of Shutterstock #96136955Little girl and boy preparing breakfast in white kitchen By FamVeld. Courtesy of Shutterstock #275099381
15. Little girl and boy preparing breakfast in white kitchen By FamVeld. Courtesy of Shutterstock #275099381
16. Collection iron rich foods as liver, buckwheat, eggs, parsley leaves, dried apricots, cocoa, lentil, bean, blue poppy seed, broccoli, dried mushrooms, peanuts and pistachios on wooden table by Evan Lorne. Courtesy of Shutterstock #388311052

Figures – Ch13

1. Visual representation of additional Calories recommended during pregnancy. Created using the following images: Isolated on white ripe banana by swinner. Courtesy of Shutterstock #47042092, Delicious, nutritious and healthy fresh plain yogurt on vintage Italian carrara marble setting by tacar. Courtesy of Shutterstock #283368935, Strawberry preserves being spread on while wheat toast by Stephanie Frey. Courtesy of Shutterstock #35581300, Created at BYU-Idaho, 2017.
2. Comparison of adult and infant macronutrient distribution. Created at BYU-Idaho, 2017.
3. Meal and snack pattern visual. United States Department of Agriculture. Choose My Plate. Meal and Snack Patterns. Accessed June 2017. https://www.choosemyplate.gov/preschoolers-meal-and-snack-patterns
4. Juice recommendations for children. Adapted from Kazal Jr., L. A., MD. "Prevention of Iron Deficiency in Infants and Toddlers." *American Academy of Family Physicians* 66, no. 7 (October 1, 2002): 1217—25.

Appendix

Reproduction of the Canadian Dietary Reference Intakes available at https://www.canada.ca/en/health-canada/services/food-nutrition/healthy-eating/dietary-reference-intakes/tables.html

Dietary Reference Intakes
Definitions

Estimated Average Requirement (EAR)

- The EAR is the median daily intake value that is estimated to meet the requirement of half the healthy individuals in a life-stage and gender group. At this level of intake, the other half of the individuals in the specified group would not have their needs met.
- The EAR is based on a specific criterion of adequacy, derived from a careful review of the literature. Reduction of disease risk is considered along with many other health parameters in the selection of that criterion.
- The EAR is used to calculate the RDA. It is also used to assess the adequacy of nutrient intakes, and can be used to plan the intake of groups.

Recommended Dietary Allowance (RDA)

- The RDA is the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98 percent) healthy individuals in a particular life-stage and gender group.
- The RDA is the goal for usual intake by an individual.

Adequate Intake (AI)

- If sufficient scientific evidence is not available to establish an EAR on which to base an RDA, an AI is derived instead.
- The AI is the recommended average daily nutrient intake level based on observed or experimentally determined approximations or estimates of nutrient intake by a group (or groups) of apparently healthy people who are assumed to be maintaining an adequate nutritional state.
- The AI is expected to meet or exceed the needs of most individuals in a specific life-stage and gender group.
- When an RDA is not available for a nutrient, the AI can be used as the goal for usual intake by an individual. The AI is not equivalent to an RDA.

Tolerable Upper Intake Level (UL)

- The UL is the highest average daily nutrient intake level likely to pose no risk of adverse health effects to almost all individuals in a given life-stage and gender group.
- The UL is not a recommended level of intake
- As intake increases above the UL, the potential risk of adverse effects increases.

Estimated Energy Requirement (EER)

- An EER is defined as the average dietary energy intake that is predicted to maintain energy balance in healthy, normal weight individuals of a defined age, gender, weight, height, and level of physical activity consistent with good health. In children and pregnant and lactating women, the EER includes the needs associated with growth or secretion of milk at rates consistent with good health.
- Relative body weight (i.e. loss, stable, gain) is the preferred indicator of energy adequacy.

Acceptable Macronutrient Distribution Range (AMDR)

- The AMDR is a range of intake for a particular energy source (protein, fat, or carbohydrate), expressed as a percentage of total energy (kcal), that is associated with reduced risk of chronic disease while providing adequate intakes of essential nutrients.

Dietary Reference Intakes
Abbreviations and Reference Heights and Weights

Abbreviations

See definitions and conversion factors for further details.

AI	Adequate Intake
AMDR	Acceptable Macronutrient Distribution Range
DFE	Dietary Folate Equivalent
EAR	Estimated Average Requirement
EER	Estimated Energy Requirement
g	gram
IU	International Unit
kcal	kilocalorie
kg	kilogram
m	metre
mg	milligram
N/A	Not Applicable
ND	Not Determinable
NE	Niacin Equivalent
PA	Physical Activity Coefficient
PAL	Physical Activity Level
RAE	Retinol Activity Equivalent
RDA	Recommended Dietary Allowance
RE	Retinol Equivalent
UL	Tolerable Upper Intake Level
µg	microgram
y	year

Reference Heights and Weights

	Reference Height (m)	Reference Weight (kg)	Reference Height (inches)	Reference Weight (pounds)
Infants				
2-6 mo	0.62	6	24	13
7-12 mo	0.71	9	28	20
Children				
1-3 y	0.86	12	34	27
4-8 y	1.15	20	45	44
Males				
9-13 y	1.44	36	57	79
14-18 y	1.74	61	68	134
19-30 y	1.77	70	70	154
Females				
9-13 y	1.44	37	57	81
14-18 y	1.63	54	64	119
19-30 y	1.63	57	64	126

Calculated from median height and median body mass index for ages 4 through 19 years from CDC/NCHS growth charts (http://www.cdc.gov/nchs/about/major/nhanes/growthcharts/clinical_charts.htm).

Since there is no evidence that weight should change with ageing if activity is maintained, the reference weights for adults 19-30 years of age apply to all adult age groups.

Dietary Reference Intakes
Unit Conversion Factors

Vitamin A	1 RAE = 1 μg retinol = 3.33 IU retinol For preformed vitamin A, 1 RE = 1 RAE.
Carotenoids	1 RAE = 12 μg beta-carotene 1 RAE = 24 μg alpha-carotene 1 RAE = 24 μg beta-cryptoxanthin To calculate RAE from RE of provitamin A carotenoids in foods, divide RE by 2.
Vitamin D	1 μg = 40 IU
Vitamin E	1 mg alpha-tocopherol = 1.25 mg alpha-tocopherol equivalents (αTE) 1 mg alpha-tocopherol = 1.49 IU *d*-alpha-tocopherol (natural, *RRR* form) 1 mg alpha-tocopherol = 2.22 IU *dl*-alpha-tocopherol (synthetic, *all racemic* form)
Folate	1 DFE = 1 μg food folate 1 DFE = 0.6 μg folic acid from fortified food or from a supplement consumed with food 1 DFE = 0.5 μg folic acid from a supplement taken on an empty stomach
Niacin	1 NE = 1 mg niacin 1 NE = 60 mg tryptophan
Sodium	1 g sodium = 2.53 g salt
Height	1 inch = 0.0254 m
Weight	1 pound = 0.454 kg
Metric Units	1000 μg = 1 mg 1000 mg = 1 g 1000 g = 1 kg
Energy yield of macronutrients	Carbohydrate = 4 kcal /g Protein = 4 kcal /g Fat = 9 kcal /g Alcohol = 7 kcal /g

Dietary Reference Intakes
Equations to estimate energy requirement

Infants and young children Estimated Energy Requirement (kcal/day) = Total Energy Expenditure + Energy Deposition	
0-3 months	EER = (89 × weight [kg] –100) + 175
4-6 months	EER = (89 × weight [kg] –100) + 56
7-12 months	EER = (89 × weight [kg] –100) + 22
13-35 months	EER = (89 × weight [kg] –100) + 20
Children and Adolescents 3-18 years Estimated Energy Requirement (kcal/day) = Total Energy Expenditure + Energy Deposition	
Boys 3-8 years	EER = 88.5 – (61.9 × age [y]) + PA× { (26.7 × weight [kg]) + (903 × height [m]) } + 20
9-18 years	EER = 88.5 – (61.9 × age [y]) + PA× { (26.7 × weight [kg]) + (903 × height [m]) } + 25
Girls 3-8 years	EER = 135.3 – (30.8 × age [y]) + PA× { (10.0 × weight [kg]) + (934 × height [m]) } + 20
9-18 years	EER = 135.3 – (30.8 × age [y]) + PA× { (10.0 × weight [kg]) + (934 × height [m]) } + 25
Adults 19 years and older Estimated Energy Requirement (kcal/day) = Total Energy Expenditure	
Men	EER = 662 – (9.53 × age [y]) + PA× { (15.91 × weight [kg]) + (539.6 × height [m]) }
Women	EER = 354 – (6.91 × age [y]) + PA× { (9.36 × weight [kg]) + (726 × height [m]) }
Pregnancy Estimated Energy Requirement (kcal/day) = Non-pregnant EER + Pregnancy Energy Deposition	
1st trimester	EER = Non-pregnant EER + 0
2nd trimester	EER = Non-pregnant EER + 340
3rd trimester	EER = Non-pregnant EER + 452
Lactation Estimated Energy Requirement (kcal/day) = Non-pregnant EER + Milk Energy Output – Weight Loss	
0-6 months postpartum	EER = Non-pregnant EER + 500 – 170
7-12 months postpartum	EER = Non-pregnant EER + 400 – 0

These equations provide an estimate of energy requirement. Relative body weight (i.e. loss, stable, gain) is the preferred indicator of energy adequacy.

Physical Activity Coefficients (PA values) for use in EER equations

	Sedentary (PAL 1.0-1.39)	**Low Active** (PAL 1.4-1.59)	**Active** (PAL 1.6-1.89)	**Very Active** (PAL 1.9-2.5)
	Typical daily living activities (e.g., household tasks, walking to the bus)	Typical daily living activities PLUS 30 - 60 minutes of daily moderate activity (ex. walking at 5-7 km/h)	Typical daily living activities PLUS At least 60 minutes of daily moderate activity	Typical daily living activities PLUS At least 60 minutes of daily moderate activity PLUS An additional 60 minutes of vigorous activity or 120 minutes of moderate activity
Boys 3 - 18 y	1.00	1.13	1.26	1.42
Girls 3 - 18 y	1.00	1.16	1.31	1.56
Men 19 y +	1.00	1.11	1.25	1.48
Women 19 y +	1.00	1.12	1.27	1.45

Dietary Reference Intakes
Reference Values for Vitamins

	Vitamin A [1, 2]						Vitamin D **						Vitamin E [5]			Vitamin K	
Unit	µg/day (RAE)			IU/day (RAE)			µg/day [4]			IU/day [4]			mg/day			µg/day	
	EAR	RDA/AI	UL [3]	EAR	RDA/AI	UL [3]	EAR	RDA/AI	UL	EAR	RDA/AI	UL	EAR	RDA/AI	UL [6]	AI	UL [7]
Infants																	
0-6 mo	*ND*	400*	600	*ND*	1333*	2000	*ND*	10*	25	*ND*	400*	1000	*ND*	4*	ND	2.0*	ND
7-12 mo	*ND*	500*	600	*ND*	1667*	2000	*ND*	10*	38	*ND*	400*	1500	*ND*	5*	ND	2.5*	ND
Children																	
1-3 y	*210*	**300**	600	*700*	**1000**	2000	*10*	**15**	63	*400*	**600**	2500	*5*	**6**	200	30*	ND
4-8 y	*275*	**400**	900	*917*	**1333**	3000	*10*	**15**	75	*400*	**600**	3000	*6*	**7**	300	55*	ND
Males																	
9-13 y	*445*	**600**	1700	*1483*	**2000**	5667	*10*	**15**	100	*400*	**600**	4000	*9*	**11**	600	60*	ND
14-18 y	*630*	**900**	2800	*2100*	**3000**	9333	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	800	75*	ND
19-30 y	*625*	**900**	3000	*2083*	**3000**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	120*	ND
31-50 y	*625*	**900**	3000	*2083*	**3000**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	120*	ND
51-70 y	*625*	**900**	3000	*2083*	**3000**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	120*	ND
>70 y	*625*	**900**	3000	*2083*	**3000**	10000	*10*	**20**	100	*400*	**800**	4000	*12*	**15**	1000	120*	ND
Females																	
9-13 y	*420*	**600**	1700	*1400*	**2000**	5667	*10*	**15**	100	*400*	**600**	4000	*9*	**11**	600	60*	ND
14-18 y	*485*	**700**	2800	*1617*	**2333**	9333	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	800	75*	ND
19-30 y	*500*	**700**	3000	*1667*	**2333**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	90*	ND
31-50 y	*500*	**700**	3000	*1667*	**2333**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	90*	ND
51-70 y	*500*	**700**	3000	*1667*	**2333**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	90*	ND
>70 y	*500*	**700**	3000	*1667*	**2333**	10000	*10*	**20**	100	*400*	**800**	4000	*12*	**15**	1000	90*	ND
Pregnancy																	
≤ 18 y	*530*	**750**	2800	*1767*	**2500**	9333	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	800	75*	ND
19-30 y	*550*	**770**	3000	*1833*	**2567**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	90*	ND
31-50 y	*550*	**770**	3000	*1833*	**2567**	10000	*10*	**15**	100	*400*	**600**	4000	*12*	**15**	1000	90*	ND
Lactation																	
≤ 18 y	*885*	**1200**	2800	*2950*	**4000**	9333	*10*	**15**	100	*400*	**600**	4000	*16*	**19**	800	75*	ND
19-30 y	*900*	**1300**	3000	*3000*	**4333**	10000	*10*	**15**	100	*400*	**600**	4000	*16*	**19**	1000	90*	ND
31-50 y	*900*	**1300**	3000	*3000*	**4333**	10000	*10*	**15**	100	*400*	**600**	4000	*16*	**19**	1000	90*	ND

This table presents *Estimated Average Requirements (EARs) in italics*, **Recommended Dietary Allowances (RDAs) in bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). Tolerable Upper Intake Levels (ULs) are in shaded columns.

** New 2010 values have replaced previous 1997 values.
[1] As Retinol Activity Equivalents (RAE). See conversion factors for more details.
[2] No DRIs are established for beta-carotene or other carotenoids. However, existing recommendations for consumption of carotenoid-rich fruits and vegetables are supported.
[3] UL as preformed vitamin A only. Beta-carotene supplements are advised only to serve as a provitamin A source for individuals at risk of vitamin A deficiency.
[4] These reference values assume minimal sun exposure.
[5] EAR and RDA/AI as alpha-tocopherol (*2R*-stereoisomeric forms) only. See conversion factors for more details.
[6] The UL for vitamin E applies only to synthetic vitamin E (all isomeric forms) obtained from supplements, fortified foods, or a combination of the two.
[7] Due to lack of suitable data, a UL could not be established for vitamin K. This does not mean that there is no potential for adverse effects resulting from high intakes.

NOTE: These are reference values for normal, apparently healthy individuals eating a typical mixed North American diet. An individual may have physiological, health, or lifestyle characteristics that may require tailoring of specific nutrient values.

Dietary Reference Intakes
Reference Values for Vitamins

	Vitamin C [8]			Thiamin			Riboflavin			Niacin [10]			Vitamin B6		
Unit	mg/day			mg/day			mg/day			mg/day (NE)			mg/day		
	EAR	RDA/AI	UL	EAR	RDA/AI	UL [9]	EAR	RDA/AI	UL [9]	EAR	RDA/AI	UL [11]	EAR	RDA/AI	UL
Infants															
0-6 mo	*ND*	40*	ND	*ND*	0.2*	ND	*ND*	0.3*	ND	*ND*	2* [a]	ND	*ND*	0.1*	ND
7-12 mo	*ND*	50*	ND	*ND*	0.3*	ND	*ND*	0.4*	ND	*ND*	4*	ND	*ND*	0.3*	ND
Children															
1-3 y	*13*	**15**	400	*0.4*	**0.5**	ND	*0.4*	**0.5**	ND	*5*	**6**	10	*0.4*	**0.5**	30
4-8 y	*22*	**25**	650	*0.5*	**0.6**	ND	*0.5*	**0.6**	ND	*6*	**8**	15	*0.5*	**0.6**	40
Males															
9-13 y	*39*	**45**	1200	*0.7*	**0.9**	ND	*0.8*	**0.9**	ND	*9*	**12**	20	*0.8*	**1.0**	60
14-18 y	*63*	**75**	1800	*1.0*	**1.2**	ND	*1.1*	**1.3**	ND	*12*	**16**	30	*1.1*	**1.3**	80
19-30 y	*75*	**90**	2000	*1.0*	**1.2**	ND	*1.1*	**1.3**	ND	*12*	**16**	35	*1.1*	**1.3**	100
31-50 y	*75*	**90**	2000	*1.0*	**1.2**	ND	*1.1*	**1.3**	ND	*12*	**16**	35	*1.1*	**1.3**	100
51-70 y	*75*	**90**	2000	*1.0*	**1.2**	ND	*1.1*	**1.3**	ND	*12*	**16**	35	*1.4*	**1.7**	100
>70 y	*75*	**90**	2000	*1.0*	**1.2**	ND	*1.1*	**1.3**	ND	*12*	**16**	35	*1.4*	**1.7**	100
Females															
9-13 y	*39*	**45**	1200	*0.7*	**0.9**	ND	*0.8*	**0.9**	ND	*9*	**12**	20	*0.8*	**1.0**	60
14-18 y	*56*	**65**	1800	*0.9*	**1.0**	ND	*0.9*	**1.0**	ND	*11*	**14**	30	*1.0*	**1.2**	80
19-30 y	*60*	**75**	2000	*0.9*	**1.1**	ND	*0.9*	**1.1**	ND	*11*	**14**	35	*1.1*	**1.3**	100
31-50 y	*60*	**75**	2000	*0.9*	**1.1**	ND	*0.9*	**1.1**	ND	*11*	**14**	35	*1.1*	**1.3**	100
51-70 y	*60*	**75**	2000	*0.9*	**1.1**	ND	*0.9*	**1.1**	ND	*11*	**14**	35	*1.3*	**1.5**	100
>70 y	*60*	**75**	2000	*0.9*	**1.1**	ND	*0.9*	**1.1**	ND	*11*	**14**	35	*1.3*	**1.5**	100
Pregnancy															
≤ 18 y	*66*	**80**	1800	*1.2*	**1.4**	ND	*1.2*	**1.4**	ND	*14*	**18**	30	*1.6*	**1.9**	80
19-30 y	*70*	**85**	2000	*1.2*	**1.4**	ND	*1.2*	**1.4**	ND	*14*	**18**	35	*1.6*	**1.9**	100
31-50 y	*70*	**85**	2000	*1.2*	**1.4**	ND	*1.2*	**1.4**	ND	*14*	**18**	35	*1.6*	**1.9**	100
Lactation															
≤ 18 y	*96*	**115**	1800	*1.2*	**1.4**	ND	*1.3*	**1.6**	ND	*13*	**17**	30	*1.7*	**2.0**	80
19-30 y	*100*	**120**	2000	*1.2*	**1.4**	ND	*1.3*	**1.6**	ND	*13*	**17**	35	*1.7*	**2.0**	100
31-50 y	*100*	**120**	2000	*1.2*	**1.4**	ND	*1.3*	**1.6**	ND	*13*	**17**	35	*1.7*	**2.0**	100

This table presents *Estimated Average Requirements (EARs) in italics*, **Recommended Dietary Allowances (RDAs) in bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). Tolerable Upper Intake Levels (ULs) are in shaded columns.

[8] Because smoking increases oxidative stress and metabolic turnover of vitamin C, the requirement for smokers is increased by 35 mg/day.
[9] Due to lack of suitable data, ULs could not be established for thiamin and riboflavin. This does not mean that there is no potential for adverse effects resulting from high intakes.
[10] As Niacin Equivalents (NE). See conversion factors for more details.
[11] The UL for niacin applies only to synthetic forms obtained from supplements, fortified foods, or a combination of the two.
[a] As preformed niacin, not NE, for this age group.

NOTE: These are reference values for normal, apparently healthy individuals eating a typical mixed North American diet. An individual may have physiological, health, or lifestyle characteristics that may require tailoring of specific nutrient values.

Dietary Reference Intakes
Reference Values for Vitamins

	Folate [12]			Vitamin B12			Pantothenic Acid		Biotin		Choline [15]	
Unit	**µg/day (DFE)**			**µg/day**			**mg/day**		**µg/day**		**mg/day**	
	EAR	RDA/AI	UL [13]	EAR	RDA/AI	UL [14]	AI	UL [14]	AI	UL [14]	AI	UL
Infants												
0-6 mo	*ND*	65*	ND	*ND*	0.4*	ND	1.7*	ND	5*	ND	125*	ND
7-12 mo	*ND*	80*	ND	*ND*	0.5*	ND	1.8*	ND	6*	ND	150*	ND
Children												
1-3 y	*120*	**150**	300	*0.7*	**0.9**	ND	2*	ND	8*	ND	200*	1000
4-8 y	*160*	**200**	400	*1.0*	**1.2**	ND	3*	ND	12*	ND	250*	1000
Males												
9-13 y	*250*	**300**	600	*1.5*	**1.8**	ND	4*	ND	20*	ND	375*	2000
14-18 y	*330*	**400**	800	*2.0*	**2.4**	ND	5*	ND	25*	ND	550*	3000
19-30 y	*320*	**400**	1000	*2.0*	**2.4**	ND	5*	ND	30*	ND	550*	3500
31-50 y	*320*	**400**	1000	*2.0*	**2.4**	ND	5*	ND	30*	ND	550*	3500
51-70 y	*320*	**400**	1000	*2.0*	**2.4** [d]	ND	5*	ND	30*	ND	550*	3500
>70 y	*320*	**400**	1000	*2.0*	**2.4** [d]	ND	5*	ND	30*	ND	550*	3500
Females												
9-13 y	*250*	**300**	600	*1.5*	**1.8**	ND	4*	ND	20*	ND	375*	2000
14-18 y	*330*	**400** [b]	800	*2.0*	**2.4**	ND	5*	ND	25*	ND	400*	3000
19-30 y	*320*	**400** [b]	1000	*2.0*	**2.4**	ND	5*	ND	30*	ND	425*	3500
31-50 y	*320*	**400** [b]	1000	*2.0*	**2.4**	ND	5*	ND	30*	ND	425*	3500
51-70 y	*320*	**400**	1000	*2.0*	**2.4** [d]	ND	5*	ND	30*	ND	425*	3500
>70 y	*320*	**400**	1000	*2.0*	**2.4** [d]	ND	5*	ND	30*	ND	425*	3500
Pregnancy												
≤18 y	*520*	**600** [c]	800	*2.2*	**2.6**	ND	6*	ND	30*	ND	450*	3000
19-30 y	*520*	**600** [c]	1000	*2.2*	**2.6**	ND	6*	ND	30*	ND	450*	3500
31-50 y	*520*	**600** [c]	1000	*2.2*	**2.6**	ND	6*	ND	30*	ND	450*	3500
Lactation												
≤18 y	*450*	**500**	800	*2.4*	**2.8**	ND	7*	ND	35*	ND	550*	3000
19-30 y	*450*	**500**	1000	*2.4*	**2.8**	ND	7*	ND	35*	ND	550*	3500
31-50 y	*450*	**500**	1000	*2.4*	**2.8**	ND	7*	ND	35*	ND	550*	3500

This table presents *Estimated Average Requirements (EARs) in italics*, **Recommended Dietary Allowances (RDAs) in bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). Tolerable Upper Intake Levels (ULs) are in shaded columns.

[12] As Dietary Folate Equivalents (DFE). See conversion factors for more details.
[13] The UL for folate applies only to synthetic forms obtained from supplements, fortified foods, or a combination of the two.
[14] Due to lack of suitable data, ULs could not be established for vitamin B12, pantothenic acid or biotin. This does not mean that there is no potential for adverse effects resulting from high intakes.
[15] Although AIs have been set for choline, there are few data to assess whether a dietary supply of choline is needed at all stages of the life cycle, and it may be that the choline requirement can be met by endogenous synthesis at some of these stages.
[b] In view of evidence linking the use of supplements containing folic acid before conception and during early pregnancy with reduced risk of neural tube defects in the fetus, it is recommended that all women capable of becoming pregnant take a supplement containing 400µg of folic acid every day, in addition to the amount of folate found in a healthy diet.
[c] It is assumed that women will continue consuming 400 µg folic acid from supplements until their pregnancy is confirmed and they enter prenatal care. The critical time for formation of the neural tube is shortly after conception.
[d] Because 10 to 30 percent of older people may malabsorb food-bound vitamin B12, it is advisable for those older than 50 years to meet the RDA mainly by consuming foods fortified with vitamin B12 or a supplement containing vitamin B12.

NOTE: These are reference values for normal, apparently healthy individuals eating a typical mixed North American diet. An individual may have physiological, health, or lifestyle characteristics that may require tailoring of specific nutrient values.

Dietary Reference Intakes
Reference Values for Elements

	Arsenic [16]		Boron		Calcium **			Chromium		Copper			Fluoride		Iodine		
Unit	N/A		mg/day		mg/day			µg/day		µg/day			mg/day		µg/day		
	AI	UL [17]	AI	UL	EAR	RDA/AI	UL	AI	UL [17]	EAR	RDA/AI	UL	AI	UL	EAR	RDA/AI	UL
Infants																	
0-6 mo	ND	ND	ND	ND	*ND*	200*	1000	0.2*	ND	*ND*	200*	ND	0.01*	0.7	*ND*	110*	ND
7-12 mo	ND	ND	ND	ND	*ND*	260*	1500	5.5*	ND	*ND*	220*	ND	0.5*	0.9	*ND*	130*	ND
Children																	
1-3 y	ND	ND	ND	3	*500*	**700**	2500	11*	ND	*260*	**340**	1000	0.7*	1.3	*65*	**90**	200
4-8 y	ND	ND	ND	6	*800*	**1000**	2500	15*	ND	*340*	**440**	3000	1*	2.2	*65*	**90**	300
Males																	
9-13 y	ND	ND	ND	11	*1100*	**1300**	3000	25*	ND	*540*	**700**	5000	2*	10	*73*	**120**	600
14-18 y	ND	ND	ND	17	*1100*	**1300**	3000	35*	ND	*685*	**890**	8000	3*	10	*95*	**150**	900
19-30 y	ND	ND	ND	20	*800*	**1000**	2500	35*	ND	*700*	**900**	10000	4*	10	*95*	**150**	1100
31-50 y	ND	ND	ND	20	*800*	**1000**	2500	35*	ND	*700*	**900**	10000	4*	10	*95*	**150**	1100
51-70 y	ND	ND	ND	20	*800*	**1000**	2000	30*	ND	*700*	**900**	10000	4*	10	*95*	**150**	1100
>70 y	ND	ND	ND	20	*1000*	**1200**	2000	30*	ND	*700*	**900**	10000	4*	10	*95*	**150**	1100
Females																	
9-13 y	ND	ND	ND	11	*1100*	**1300**	3000	21*	ND	*540*	**700**	5000	2*	10	*73*	**120**	600
14-18 y	ND	ND	ND	17	*1100*	**1300**	3000	24*	ND	*685*	**890**	8000	3*	10	*95*	**150**	900
19-30 y	ND	ND	ND	20	*800*	**1000**	2500	25*	ND	*700*	**900**	10000	3*	10	*95*	**150**	1100
31-50 y	ND	ND	ND	20	*800*	**1000**	2500	25*	ND	*700*	**900**	10000	3*	10	*95*	**150**	1100
51-70 y	ND	ND	ND	20	*1000*	**1200**	2000	20*	ND	*700*	**900**	10000	3*	10	*95*	**150**	1100
>70 y	ND	ND	ND	20	*1000*	**1200**	2000	20*	ND	*700*	**900**	10000	3*	10	*95*	**150**	1100
Pregnancy																	
≤ 18 y	ND	ND	ND	17	*1100*	**1300**	3000	29*	ND	*785*	**1000**	8000	3*	10	*160*	**220**	900
19-30 y	ND	ND	ND	20	*800*	**1000**	2500	30*	ND	*800*	**1000**	10000	3*	10	*160*	**220**	1100
31-50 y	ND	ND	ND	20	*800*	**1000**	2500	30*	ND	*800*	**1000**	10000	3*	10	*160*	**220**	1100
Lactation																	
≤ 18 y	ND	ND	ND	17	*1100*	**1300**	3000	44*	ND	*985*	**1300**	8000	3*	10	*209*	**290**	900
19-30 y	ND	ND	ND	20	*800*	**1000**	2500	45*	ND	*1000*	**1300**	10000	3*	10	*209*	**290**	1100
31-50 y	ND	ND	ND	20	*800*	**1000**	2500	45*	ND	*1000*	**1300**	10000	3*	10	*209*	**290**	1100

This table presents *Estimated Average Requirements (EARs) in italics*, **Recommended Dietary Allowances (RDAs) in bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). Tolerable Upper Intake Levels (ULs) are in shaded columns.

** New 2010 values have replaced previous 1997 values.
[16] Although a UL was not determined for arsenic, there is no justification for adding arsenic to food or supplements.
[17] Due to lack of suitable data, ULs could not be established for arsenic and chromium. This does not mean that there is no potential for adverse effects resulting from high intakes.

NOTE: These are reference values for normal, apparently healthy individuals eating a typical mixed North American diet. An individual may have physiological, health, or lifestyle characteristics that may require tailoring of specific nutrient values.

Dietary Reference Intakes
Reference Values for Elements

	Iron[18]			**Magnesium**			**Manganese**		**Molybdenum**			**Nickel**		**Phosphorus**		
Unit	**mg/day**			**mg/day**			**mg/day**		**µg/day**			**mg/day**		**mg/day**		
	EAR	RDA/AI	UL	EAR	RDA/AI	UL[19]	AI	UL	EAR	RDA/AI	UL	AI	UL	EAR	RDA/AI	UL
Infants																
0-6 mo	*ND*	0.27*	40	*ND*	30*	ND	0.003*	ND	*ND*	2*	ND	ND	ND	*ND*	100*	ND
7-12 mo	*6.9*	**11**	40	*ND*	75*	ND	0.6*	ND	*ND*	3*	ND	ND	ND	*ND*	275*	ND
Children																
1-3 y	*3.0*	**7**	40	*65*	**80**	65	1.2*	2	*13*	**17**	300	ND	0.2	*380*	**460**	3000
4-8 y	*4.1*	**10**	40	*110*	**130**	110	1.5*	3	*17*	**22**	600	ND	0.3	*405*	**500**	3000
Males																
9-13 y	*5.9*	**8**	40	*200*	**240**	350	1.9*	6	*26*	**34**	1100	ND	0.6	*1055*	**1250**	4000
14-18 y	*7.7*	**11**	45	*340*	**410**	350	2.2*	9	*33*	**43**	1700	ND	1.0	*1055*	**1250**	4000
19-30 y	*6*	**8**	45	*330*	**400**	350	2.3*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	4000
31-50 y	*6*	**8**	45	*350*	**420**	350	2.3*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	4000
51-70 y	*6*	**8**	45	*350*	**420**	350	2.3*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	4000
>70 y	*6*	**8**	45	*350*	**420**	350	2.3*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	3000
Females																
9-13 y	*5.7*[e]	**8**[e]	40	*200*	**240**	350	1.6*	6	*26*	**34**	1100	ND	0.6	*1055*	**1250**	4000
14-18 y	*7.9*[e]	**15**[e]	45	*300*	**360**	350	1.6*	9	*33*	**43**	1700	ND	1.0	*1055*	**1250**	4000
19-30 y	*8.1*[e]	**18**[e]	45	*255*	**310**	350	1.8*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	4000
31-50 y	*8.1*[e]	**18**[e]	45	*265*	**320**	350	1.8*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	4000
51-70 y	*5*[e]	**8**[e]	45	*265*	**320**	350	1.8*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	4000
>70 y	*5*[e]	**8**[e]	45	*265*	**320**	350	1.8*	11	*34*	**45**	2000	ND	1.0	*580*	**700**	3000
Pregnancy																
≤18 y	*23*	**27**	45	*335*	**400**	350	2.0*	9	*40*	**50**	1700	ND	1.0	*1055*	**1250**	3500
19-30 y	*22*	**27**	45	*290*	**350**	350	2.0*	11	*40*	**50**	2000	ND	1.0	*580*	**700**	3500
31-50 y	*22*	**27**	45	*300*	**360**	350	2.0*	11	*40*	**50**	2000	ND	1.0	*580*	**700**	3500
Lactation																
≤18 y	*7*	**10**	45	*300*	**360**	350	2.6*	9	*35*	**50**	1700	ND	1.0	*1055*	**1250**	4000
19-30 y	*6.5*	**9**	45	*255*	**310**	350	2.6*	11	*36*	**50**	2000	ND	1.0	*580*	**700**	4000
31-50 y	*6.5*	**9**	45	*265*	**320**	350	2.6*	11	*36*	**50**	2000	ND	1.0	*580*	**700**	4000

This table presents *Estimated Average Requirements (EARs) in italics*, **Recommended Dietary Allowances (RDAs) in bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). Tolerable Upper Intake Levels (ULs) are in shaded columns.

[18] The requirement for iron is 1.8 times higher for vegetarians due to the lower bioavailability of iron from a vegetarian diet.
[19] The UL for magnesium represents intake from a pharmacological agent only and does not include intake from food and water.
[e] For the EAR and RDA, it is assumed that girls younger than 14 years do not menstruate and that girls 14 years and older do menstruate. It is assumed that women 51 years and older are post-menopausal.

NOTE: These are reference values for normal, apparently healthy individuals eating a typical mixed North American diet. An individual may have physiological, health, or lifestyle characteristics that may require tailoring of specific nutrient values.

Dietary Reference Intakes
Reference Values for Elements

	Selenium			Silicon [20]		Vanadium [22]		Zinc [23]			Potassium [24]		Sodium [25]		Chloride [26]		Sulfate [27]	
Unit	μg/day			N/A		mg/day		mg/day			mg/day		mg/day		mg/day		N/A	
	EAR	RDA/AI	UL	AI	UL [21]	AI	UL	EAR	RDA/AI	UL	AI	UL [21]	AI	UL	AI	UL	AI	UL [21]
Infants																		
0-6 mo	*ND*	15*	45	ND	ND	ND	ND	*ND*	2*	4	400*	ND	120*	ND	180*	ND	ND	ND
7-12 mo	*ND*	20*	60	ND	ND	ND	ND	*2.5*	**3**	5	700*	ND	370*	ND	570*	ND	ND	ND
Children																		
1-3 y	*17*	**20**	90	ND	ND	ND	ND	*2.5*	**3**	7	3000*	ND	1000*	1500	1500*	2300	ND	ND
4-8 y	*23*	**30**	150	ND	ND	ND	ND	*4.0*	**5**	12	3800*	ND	1200*	1900	1900*	2900	ND	ND
Males																		
9-13 y	*35*	**40**	280	ND	ND	ND	ND	*7.0*	**8**	23	4500*	ND	1500*	2200	2300*	3400	ND	ND
14-18 y	*45*	**55**	400	ND	ND	ND	ND	*8.5*	**11**	34	4700*	ND	1500*	2300	2300*	3600	ND	ND
19-30 y	*45*	**55**	400	ND	ND	ND	1.8	*9.4*	**11**	40	4700*	ND	1500*	2300	2300*	3600	ND	ND
31-50 y	*45*	**55**	400	ND	ND	ND	1.8	*9.4*	**11**	40	4700*	ND	1500*	2300	2300*	3600	ND	ND
51-70 y	*45*	**55**	400	ND	ND	ND	1.8	*9.4*	**11**	40	4700*	ND	1300*	2300	2000*	3600	ND	ND
>70 y	*45*	**55**	400	ND	ND	ND	1.8	*9.4*	**11**	40	4700*	ND	1200*	2300	1800*	3600	ND	ND
Females																		
9-13 y	*35*	**40**	280	ND	ND	ND	ND	*7.0*	**8**	23	4500*	ND	1500*	2200	2300*	3400	ND	ND
14-18 y	*45*	**55**	400	ND	ND	ND	ND	*7.3*	**9**	34	4700*	ND	1500*	2300	2300*	3600	ND	ND
19-30 y	*45*	**55**	400	ND	ND	ND	1.8	*6.8*	**8**	40	4700*	ND	1500*	2300	2300*	3600	ND	ND
31-50 y	*45*	**55**	400	ND	ND	ND	1.8	*6.8*	**8**	40	4700*	ND	1500*	2300	2300*	3600	ND	ND
51-70 y	*45*	**55**	400	ND	ND	ND	1.8	*6.8*	**8**	40	4700*	ND	1300*	2300	2000*	3600	ND	ND
>70 y	*45*	**55**	400	ND	ND	ND	1.8	*6.8*	**8**	40	4700*	ND	1200*	2300	1800*	3600	ND	ND
Pregnancy																		
≤18 y	*49*	**60**	400	ND	ND	ND	ND	*10.5*	**12**	34	4700*	ND	1500*	2300	2300*	3600	ND	ND
19-30 y	*49*	**60**	400	ND	ND	ND	ND	*9.5*	**11**	40	4700*	ND	1500*	2300	2300*	3600	ND	ND
31-50 y	*49*	**60**	400	ND	ND	ND	ND	*9.5*	**11**	40	4700*	ND	1500*	2300	2300*	3600	ND	ND
Lactation																		
≤18 y	*59*	**70**	400	ND	ND	ND	ND	*10.9*	**13**	34	5100*	ND	1500*	2300	2300*	3600	ND	ND
19-30 y	*59*	**70**	400	ND	ND	ND	ND	*10.4*	**12**	40	5100*	ND	1500*	2300	2300*	3600	ND	ND
31-50 y	*59*	**70**	400	ND	ND	ND	ND	*10.4*	**12**	40	5100*	ND	1500*	2300	2300*	3600	ND	ND

This table presents *Estimated Average Requirements (EARs) in italics*, **Recommended Dietary Allowances (RDAs) in bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). Tolerable Upper Intake Levels (ULs) are in shaded columns.

[20] Although silicon has not been shown to cause adverse effects in humans, there is no justification for adding silicon to supplements.
[21] Due to lack of suitable data, ULs could not be established for silicon, potassium, and sulfate. This does not mean that there is no potential for adverse effects resulting from high intakes.
[22] Although vanadium in food has not been shown to cause adverse effects in humans, there is no justification for adding vanadium to food and vanadium supplements should be used with caution. The UL is based on adverse effects in laboratory animals and this data could be used to set a UL for adults but not children and adolescents.
[23] The requirement for zinc may be as much as 50 percent greater for vegetarians, particularly for strict vegetarians whose major food staples are grains and legumes, due to the lower bioavailability of zinc from a vegetarian diet.
[24] The beneficial effects of potassium appear to be mainly from the forms of potassium found naturally in foods such as fruits and vegetables. Supplemental potassium should only be provided under medical supervision because of the well-documented potential for toxicity.
[25] Grams of sodium × 2.53 = grams of salt.
[26] Sodium and chloride are normally found in foods together as sodium chloride (table salt). For this reason, the AI and UL for chloride are set at a level equivalent on a molar basis to those for sodium, since almost all dietary chloride comes with sodium added during processing or consumption of foods.
[27] An AI for sulfate was not established because sulfate requirements are met when dietary intakes contain recommended levels of sulfur amino acids (protein).

NOTE: These are reference values for normal, apparently healthy individuals eating a typical mixed North American diet. An individual may have physiological, health, or lifestyle characteristics that may require tailoring of specific nutrient values.

Dietary Reference Intakes
Reference Values for Macronutrients

	Carbohydrate (Digestible)			Total Protein [29]				Total Fat		Linoleic Acid (n-6)		α-linolenic Acid (n-3)		Total Fibre [31]		Total Water [33]	
Unit	g/day			g/kg/day		g/day [30]		g/day		g/day		g/day		g/day		Litres/day	
	EAR	RDA/AI	UL [28]	EAR	RDA/AI	RDA/AI	UL [28]	AI	UL [28]	AI	UL [28]	AI	UL [28]	AI [32]	UL [28]	AI	UL [28]
Infants																	
0-6 mo	*ND*	60*	ND	*ND*	1.52*	9.1*	ND	31*	ND	4.4*	ND	0.5*	ND	ND	ND	0.7*	ND
7-12 mo	*ND*	95*	ND	*1.0*	**1.2**	**11.0**	ND	30*	ND	4.6*	ND	0.5*	ND	ND	ND	0.8*	ND
Children																	
1-3 y	*100*	**130**	ND	*0.87*	**1.05**	**13**	ND	ND	ND	7*	ND	0.7*	ND	19*	ND	1.3*	ND
4-8 y	*100*	**130**	ND	*0.76*	**0.95**	**19**	ND	ND	ND	10*	ND	0.9*	ND	25*	ND	1.7*	ND
Males																	
9-13 y	*100*	**130**	ND	*0.76*	**0.95**	**34**	ND	ND	ND	12*	ND	1.2*	ND	31*	ND	2.4*	ND
14-18 y	*100*	**130**	ND	*0.73*	**0.85**	**52**	ND	ND	ND	16*	ND	1.6*	ND	38*	ND	3.3*	ND
19-30 y	*100*	**130**	ND	*0.66*	**0.80**	**56**	ND	ND	ND	17*	ND	1.6*	ND	38*	ND	3.7*	ND
31-50 y	*100*	**130**	ND	*0.66*	**0.80**	**56**	ND	ND	ND	17*	ND	1.6*	ND	38*	ND	3.7*	ND
51-70 y	*100*	**130**	ND	*0.66*	**0.80**	**56**	ND	ND	ND	14*	ND	1.6*	ND	30*	ND	3.7*	ND
>70 y	*100*	**130**	ND	*0.66*	**0.80**	**56**	ND	ND	ND	14*	ND	1.6*	ND	30*	ND	3.7*	ND
Females																	
9-13 y	*100*	**130**	ND	*0.76*	**0.95**	**34**	ND	ND	ND	10*	ND	1.0*	ND	26*	ND	2.1*	ND
14-18 y	*100*	**130**	ND	*0.71*	**0.85**	**46**	ND	ND	ND	11*	ND	1.1*	ND	26*	ND	2.3*	ND
19-30 y	*100*	**130**	ND	*0.66*	**0.80**	**46**	ND	ND	ND	12*	ND	1.1*	ND	25*	ND	2.7*	ND
31-50 y	*100*	**130**	ND	*0.66*	**0.80**	**46**	ND	ND	ND	12*	ND	1.1*	ND	25*	ND	2.7*	ND
51-70 y	*100*	**130**	ND	*0.66*	**0.80**	**46**	ND	ND	ND	11*	ND	1.1*	ND	21*	ND	2.7*	ND
>70 y	*100*	**130**	ND	*0.66*	**0.80**	**46**	ND	ND	ND	11*	ND	1.1*	ND	21*	ND	2.7*	ND
Pregnancy																	
≤ 18 y	*135*	**175**	ND	*0.88* [f]	**1.1** [f]	**71** [f]	ND	ND	ND	13*	ND	1.4*	ND	28*	ND	3.0*	ND
19-30 y	*135*	**175**	ND	*0.88* [f]	**1.1** [f]	**71** [f]	ND	ND	ND	13*	ND	1.4*	ND	28*	ND	3.0*	ND
31-50 y	*135*	**175**	ND	*0.88* [f]	**1.1** [f]	**71** [f]	ND	ND	ND	13*	ND	1.4*	ND	28*	ND	3.0*	ND
Lactation																	
≤ 18 y	*160*	**210**	ND	*1.05*	**1.3**	**71**	ND	ND	ND	13*	ND	1.3*	ND	29*	ND	3.8*	ND
19-30 y	*160*	**210**	ND	*1.05*	**1.3**	**71**	ND	ND	ND	13*	ND	1.3*	ND	29*	ND	3.8*	ND
31-50 y	*160*	**210**	ND	*1.05*	**1.3**	**71**	ND	ND	ND	13*	ND	1.3*	ND	29*	ND	3.8*	ND

This table presents *Estimated Average Requirements (EARs) in italics*, **Recommended Dietary Allowances (RDAs) in bold type** and Adequate Intakes (AIs) in ordinary type followed by an asterisk (*). Tolerable Upper Intake Levels (ULs) are in shaded columns.

[28] Although a UL was not set for any of the macronutrients, the absence of definitive data does not signify that people can tolerate chronic intakes of these substances at high levels.
[29] Available evidence does not support recommending a separate protein requirement for vegetarians who consume complimentary mixtures of plant proteins, as these can provide the same quality of protein as that from animal proteins.
[30] Recommendations for total protein are determined as the amount needed per kg body weight multiplied by the reference weight.
[31] Total fibre is defined as the sum of dietary fibre and functional fibre. See definitions for further details.
[32] The AI for total fibre is based on 14 g/1000 kcal multiplied by the median usual daily energy intake from the Continuing Survey of Food Intakes by Individuals (CSFII 1994-1996, 1998).
[33] Total water includes drinking water, water in beverages, and water that is part of food.
[f] The EAR and RDA for pregnancy are only for the second half of pregnancy. For the first half of pregnancy, protein requirements are the same as those of the nonpregnant woman.

NOTE: These are reference values for normal, apparently healthy individuals eating a typical mixed North American diet. An individual may have physiological, health, or lifestyle characteristics that may require tailoring of specific nutrient values.

Dietary Reference Intakes
Reference Values for Macronutrients

Acceptable Macronutrient Distribution Ranges (AMDR)

Males & Females [34]	Total Carbohydrate Percent of Energy	Total Protein Percent of Energy	Total Fat Percent of Energy	n-6 polyunsaturated fatty acids (linoleic acid) Percent of Energy	n-3 polyunsaturated fatty acids (α-linolenic acid) Percent of Energy [35]
1-3 years	45 – 65 %	5 – 20 %	30 – 40 %	5 – 10 %	0.6 – 1.2 %
4-18 years	45 – 65 %	10 – 30 %	25 – 35 %	5 – 10 %	0.6 – 1.2 %
19 years and over	45 – 65 %	10 – 35 %	20 – 35 %	5 – 10 %	0.6 – 1.2 %

[34] Includes pregnant and lactating women.
[35] Up to 10% of the AMDR can be consumed as eicosapentaenoic acid (EPA) and/or docosahexaenoic acid (DHA).