DIGESTIVE AND EXCRETORY SYSTEMS

This is a scanning electron micrograph of a filtration membrane in the human kidney. (SEM 3060×)

NUTRIENTS

Carrots, fish, eggs, hamburgers, blackberries, cow's milk—the human body is able to convert each of these foods into nutrients that body cells need to function, grow, and replicate. In this section, you will learn what nutrients the human body needs and how it uses those nutrients to carry out life processes.

SECTION 1

OBJECTIVES

- **Relate** the role of each of the six classes of nutrients in maintaining a healthy body.
- **Describe** each of the parts of the USDA Food Guide Pyramid.
- **Identify** foods containing each of the organic nutrients.
- **Explain** the importance of vitamins, minerals, and water in maintaining the body's functions.
- **Identify** three disorders associated with improper nutrition.

VOCABULARY

nutrient
vitamin
mineral
dehydration

SIX CLASSES OF NUTRIENTS

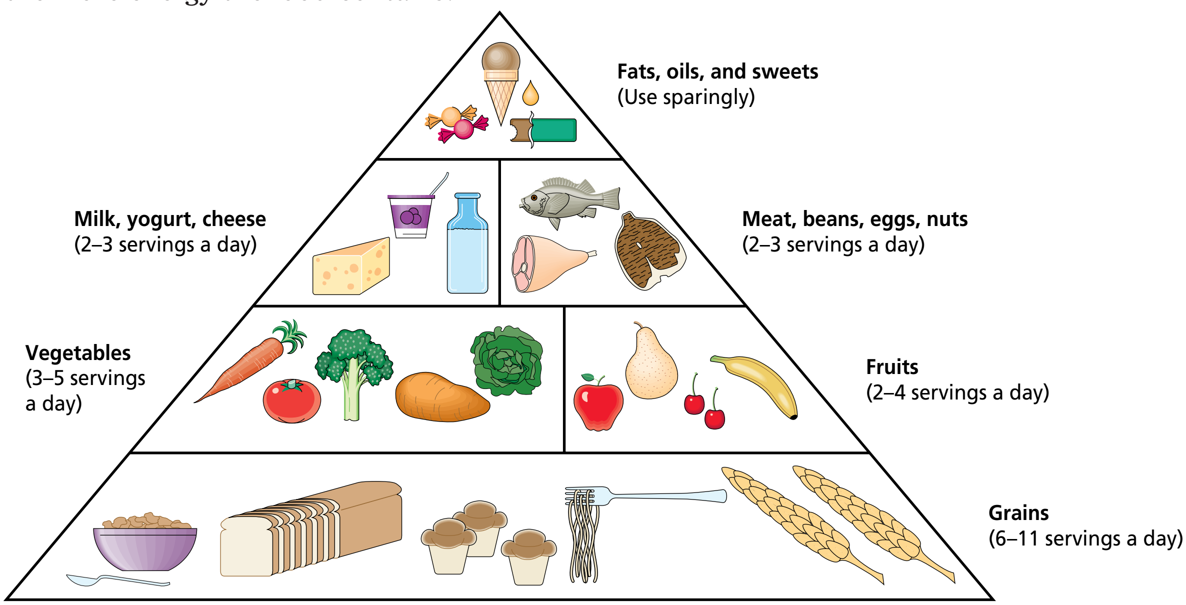
Organisms that do not carry out photosynthesis must obtain energy from nutrients in the food they consume. A **nutrient** is a substance required by the body for energy, growth, repair, and maintenance. All foods contain at least one of six basic nutrients: carbohydrates, proteins, lipids, vitamins, minerals, and water. Few foods contain all six nutrients. Most foods contain a concentration of just one or two.

Nutritionists classify foods into six groups—meat, milk, fruits, vegetables, breads and cereals, and fats, oils, and sweets—based on nutrient similarity. Each nutrient plays a different role in keeping an organism healthy. The USDA Food Guide Pyramid, shown in Figure 48-1, shows the number of servings from each food group needed for a balanced diet.

Some nutrients provide energy for powering cellular processes. The energy available in food is measured in kilocalories, or Calories, which is equal to 1,000 calories. A *calorie* is the amount of heat energy required to raise the temperature of 1 g of water 1°C (1.8°F). The greater the number of calories in a quantity of food, the more energy the food contains.

FIGURE 48-1

The USDA Food Guide Pyramid lists the daily number of servings needed from each food group to obtain a variety of nutrients and maintain a healthy diet.



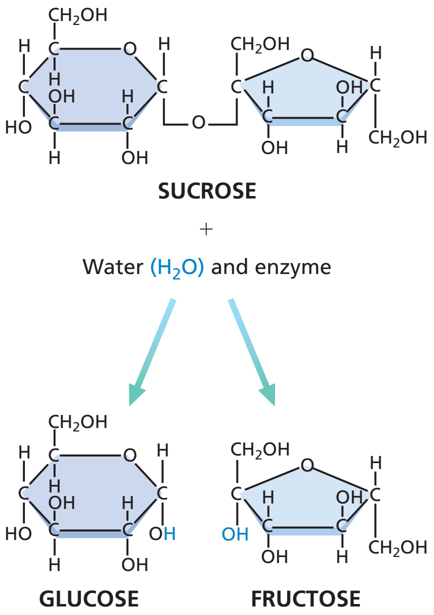


FIGURE 48-2

The hydrolysis of a disaccharide requires water and an enzyme. When sucrose is hydrolyzed, two monosaccharides are formed—glucose and fructose. These monosaccharides are then transported through cell membranes to be used by cells.

CARBOHYDRATES, PROTEINS, AND LIPIDS

The three nutrients needed by the body in the greatest amounts—carbohydrates, proteins, and lipids—are organic compounds. *Organic compounds* are compounds containing the elements carbon, hydrogen, and oxygen.

Carbohydrates

Carbohydrates are organic compounds composed of carbon, hydrogen, and oxygen. Carbohydrates are broken down in aerobic respiration to provide most of the body's energy. Although proteins and fats also supply energy, the body most easily uses the energy provided by carbohydrates. Carbohydrates contain sugars that are quickly converted into the usable energy ATP, but proteins and fats must go through many chemical processes before the body can use them to make ATP.

The fructose and glucose (also known as dextrose) in fruit and honey are simple sugars, or *monosaccharides.* These sugars can be absorbed directly into the bloodstream and made available to cells for use in cellular respiration. Sucrose (table sugar), maltose, and lactose (milk sugar) are *disaccharides.* Disaccharides are sugars that consist of two chemically linked monosaccharides. Before disaccharides can be used by the body for energy they must be split into two monosaccharides in a process called *hydrolysis.* Figure 48-2 shows how sucrose is hydrolyzed to produce glucose and fructose.

Polysaccharides are complex molecules that consist of many monosaccharides bonded together. The starch found in many grains and vegetables is a polysaccharide made up of long chains of glucose molecules. During digestion, the enzymes hydrolyze these long chains into individual glucose units.

Many foods we get from plants contain cellulose, a polysaccharide that forms the walls of plant cells. The body cannot break down cellulose into individual component sugars. Nevertheless it is an extremely important part of the human diet. Cellulose and other forms of fiber help move the food along by stimulating contractions of the smooth muscles that form the walls of the digestive organs.

Word Roots and Origins

hydrolysis

from the Greek *hydro,* meaning "water," and *lysis,* meaning "dissolve"

Proteins

The major structural and functional material of body cells are *proteins.* Proteins consist of long chains of amino acids. Proteins from food must be broken down into amino acids in order for the body to grow and to repair tissues. The human body uses 20 different amino acids to build the proteins it needs. The body can make many of these amino acids, but it cannot produce all of them in the quantities that it needs. Amino acids that must be obtained from food are called *essential amino acids*. Ten amino acids are essential to children and teenagers for growth. Only eight are essential to adults.

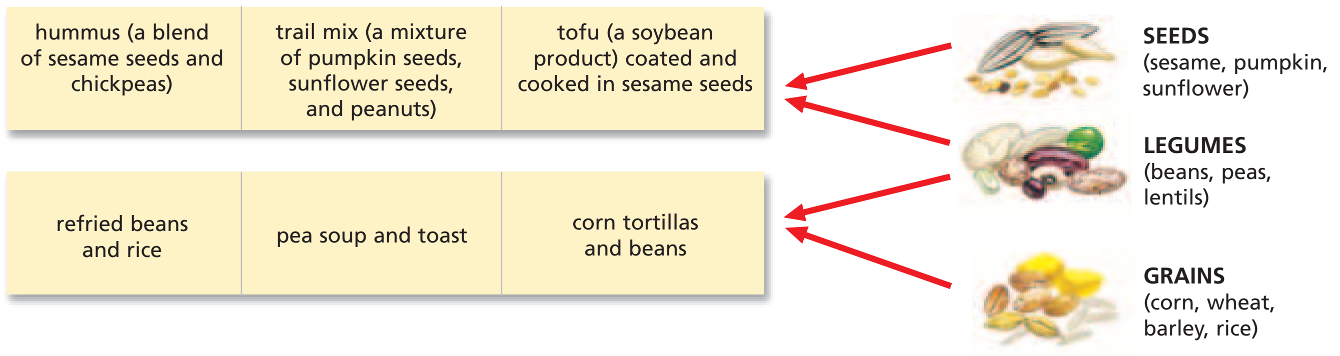


FIGURE 48-3

The combination of legumes, seeds, and grains furnishes all the essential amino acids.

Most of the foods we get from plants contain only small amounts of certain essential amino acids. Eating certain combinations of two or more plant products, such as those shown in Figure 48-3, can ensure an adequate supply of all the essential amino acids. Most animal products, such as eggs, milk, fish, poultry, and beef, contain larger amounts of all the essential amino acids.

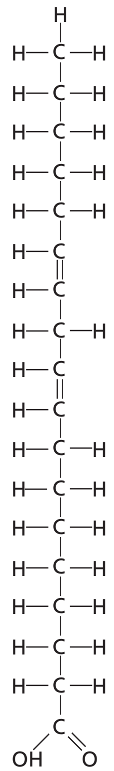
Lipids

Lipids are organic compound that are insoluble in water. They include fats, oils, and waxes. Lipids are used to make cell membranes and steroid hormones and to store energy.

The most common fats are *triglycerides* which are used for energy and to build cell membranes and other cell parts. The body stores excess fat from the diet. Excess carbohydrates and protein may also be converted to fat for storage. Stored fats are beneficial unless they are excessive. A light layer of body fat beneath the skin provides insulation in cold weather. Fat surrounding vulnerable organs, such as the kidneys and liver, acts as protective padding. Most important, fat reserves are a concentrated source of energy.

To use fats, the body must first break down each fat molecule into *glycerol* and *fatty acids.* The glycerol molecule is the same in all fats, but the fatty acids differ in both structure and composition. The body converts some fatty acids to other fatty acids, depending on which one the body needs at the time.

Scientists classify fats as saturated or unsaturated, based on structural differences in their fatty acids. A *saturated fatty acid* has all its carbon atoms connected by single bonds and thus contains as many hydrogen atoms as possible. An *unsaturated fatty acid* has at least one double bond between carbon atoms. If there are two or more double bonds, as shown in Figure 48-4, the fatty acid is called *polyunsaturated*. Although lipids are essential nutrients, too much fat in the diet is known to harm several body systems. A diet high in saturated fats is linked to heart disease and to high levels of blood-cholesterol. High cholesterol contributes to atherosclerosis, or build-up of fatty deposits within vessels. A diet high in fat also contributes to obesity, and can lead to late-onset diabetes. Diabetes is the leading cause of kidney failure, blindness, and amputation in adults.



Linoleic acid

FIGURE 48-4

The structure of linoleic acid, a fatty acid in margarine, is shown in this figure. Notice the two double bonds between carbon atoms.

VITAMINS, MINERALS, AND WATER

Vitamins, minerals, and water are nutrients that do not provide energy but are required for proper functioning of the body. **Vitamins** work as *coenzymes* to enhance enzyme activity. **Minerals** are necessary for making certain body structures, for normal nerve and muscle function, and for maintaining osmotic balance. Water transports gases, nutrients, and waste; is a reagent in some of the body's chemical reactions; and regulates body temperature. Table 48-1 summarizes the sources of vitamins and their functions.

TABLE 48-1 ***Food Sources of Vitamins***

Vitamins	Best sources	Essential for	Deficiency diseases and symptoms
Vitamin A (carotene; fat soluble)	fish-liver oils, liver and kidney, green and yellow vegetables, yellow fruit, tomatoes, butter, egg yolk	growth, health of the eyes, and functioning of the cells of the skin and mucous membranes	retarded growth, night blindness, susceptibility to infections, changes in skin, defective tooth formation
Vitamin B_1 (thiamin; water soluble)	meat, soybeans, milk, whole grains, legumes	growth; carbohydrate metabolism; functioning of the heart, nerves, muscles	beriberi—loss of appetite and weight, nerve disorders, and faulty digestion
Vitamin B_2 (riboflavin; water soluble)	meat, fowl, soybeans, milk, green vegetables, eggs, yeast	growth, health of the skin, eyes, and mouth, carbohydrate metabolism, red blood cell formation	retarded growth, dimness of vision, inflammation of the tongue, premature aging, intolerance to light
Vitamin B_3 (niacin; water soluble)	meat, fowl, fish, peanut butter, potatoes, whole grains, tomatoes, leafy vegetables	growth; carbohydrate metabolism; functioning of the stomach, intestines, and nervous system	pellagra—smoothness of the tongue, skin eruptions, digestive disturbances, and mental disorders
Vitamin B_6 (pyridoxine; water soluble)	whole grains, liver, fish 	protein metabolism, production of hemoglobin, health of the nervous system	dermatitis, nervous disorders
Vitamin B_{12} (cyanocobalamin; water soluble)	liver, fish, beef, pork, milk, cheese	red blood cell formation, health of the nervous system	a reduction in number of red blood cells, pernicious anemia
Vitamin C (ascorbic acid; water soluble)	fruit (especially citrus), tomatoes, leafy vegetables	growth, strength of the blood vessels, development of teeth, health of gums	scurvy—sore gums, hemorrhages around the bones, and tendency to bruise easily
Vitamin D (calciferol; fat soluble)	fish-liver oil, liver, fortified milk, eggs, irradiated foods	growth, calcium and phosphorus metabolism, bones and teeth	rickets—soft bones, poor development of teeth, and dental decay
Vitamin E (tocopherol; fat soluble)	wheat-germ oil, leafy vegetables, milk, butter	normal reproduction	anemia in newborns
Vitamin K (naphthoquinone; fat soluble)	green vegetables, soybean oil, tomatoes	normal clotting of the blood, liver functions	hemorrhages

Vitamins

Vitamins are small organic molecules that act as coenzymes. Coenzymes activate enzymes and help them function. Because vitamins generally cannot be synthesized by the body, a diet should include the proper daily amounts of all vitamins. Like enzymes, coenzymes can be reused many times. Thus, only small quantities of vitamins are needed in the diet.

Vitamins dissolve in either water or fat. The fat-soluble vitamins include vitamins A, D, E, and K. The water-soluble vitamins are vitamin C and the group of B vitamins. Because the body cannot store water-soluble vitamins, it excretes surplus amounts in urine. Fat-soluble vitamins are absorbed and stored like fats. Unpleasant physical symptoms and even death can result from storing too much or having too little of a particular vitamin.

The only vitamin that the body can synthesize in large quantities is vitamin D. This synthesis involves sunlight converting cholesterol to vitamin D precursors in the skin. People who do not spend a lot of time in the sun can get their vitamin D from food.

Minerals

Minerals are naturally occurring inorganic substances that are used to make certain body structures, to carry out normal nerve and muscle function, and to maintain osmotic balance. Some minerals, such as calcium, magnesium, and iron, are drawn from the soil and become part of plants. Animals that feed on plants extract the minerals and incorporate them into their bodies. Table 48-2 lists the primary sources and functions of a few of the minerals considered most essential to human beings. Iron, for example, is necessary for the formation of red blood cells, and potassium maintains the body's acid-base balance and aids in growth. Both are found in certain fruits and vegetables. Excess minerals are excreted through the skin in perspiration and through the kidneys in urine.

TABLE 48-2 ***Food Sources of Minerals***

Minerals	Source	Essential for
Calcium	milk, whole-grain cereals, vegetables, meats	deposition in bones and teeth; functioning of heart, muscles, and nerves
Iodine	seafoods, water, iodized salt	thyroid hormone production
Iron	leafy vegetables, liver, meats, raisins, prunes	formation of hemoglobin in red blood cells
Magnesium	vegetables	muscle and nerve action
Phosphorus	milk, whole-grain cereals, vegetables, meats	deposition in bones and teeth; formation of ATP and nucleic acids
Potassium	vegetables, citrus fruits, bananas, apricots	maintaining acid-base balance; growth; nerve action
Sodium	table salt, vegetables	blood and other body tissues; muscle and nerve action

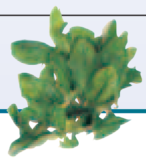


FIGURE 48-5

Athletes drink water to replace water lost through perspiration. Excess water loss can lead to a condition called dehydration.

Water

Water accounts for over half of your body weight. Most of the reactions that maintain life can take place only in water. Water makes up more than 90 percent of the fluid part of the blood, which carries essential nutrients to all parts of the body. It is also the medium in which waste products are carried away from body tissues.

Water also helps regulate body temperature. It absorbs and distributes heat released in cellular reactions. When the body needs to cool, perspiration—a water-based substance—evaporates from the skin, and heat is drawn away from the body. Usually, the water lost through your skin, lungs, and kidneys is easily replaced by drinking water or consuming moist foods. People, like the athletes in Figure 48-5, must drink water to avoid **dehydration**—excess water is lost and not replenished. Water moves from intercellular spaces to the blood by osmosis. Eventually, water will be drawn from the cells themselves. As a cell loses water, the cytoplasm becomes more concentrated until the cell can no longer function.

SECTION 1 REVIEW

1. Summarize the major role of each of the organic nutrients in the body's function.
2. Describe the type of information the USDA Food Guide pyramid provides.
3. Identify a food that is high in carbohydrates, another that is high in proteins, and a third that is high in lipids.
4. Identify the role that minerals play in maintaining a healthy body.
5. Explain the importance of water to the body.
6. Identify disorders caused by a diet high in saturated fats.

CRITICAL THINKING

7. **Predicting Results** What might be the health consequences of a diet consisting of only water and rice?
8. **Justifying Conclusions** Why would large doses of vitamin B_2 be less harmful than large doses of vitamin A?
9. **Applying Information** Caffeine tends to increase the discharge of urine. Should an athlete drink a caffeinated beverage before a big game? Explain your answer.

DIGESTIVE SYSTEM

SECTION 2

Before your body can use the nutrients in the food you consume, the nutrients must be broken down physically and chemically. The nutrients must be absorbed, and the wastes must be eliminated.

OBJECTIVES

- **List** the major organs of the digestive system.
- **Distinguish** between mechanical digestion and chemical digestion.
- **Relate** the structure of each digestive organ to its function in mechanical digestion.
- **Identify** the source and function of each major digestive enzyme.
- **Summarize** the process of absorption in both the small and large intestine.

VOCABULARY

digestion
gastrointestinal tract
saliva
pharynx
epiglottis
peristalsis
gastric fluid
ulcer
cardiac sphincter
chyme
pyloric sphincter
gallbladder
villus
colon

THE GASTROINTESTINAL TRACT

The process of breaking down food into molecules the body can use is called **digestion.** Digestion occurs in the **gastrointestinal tract,** or digestive tract, a long, winding tube which begins at the mouth and winds through the body to the anus. The gastrointestinal tract, shown in Figure 48-6, is divided into several distinct organs. These organs carry out the digestive process. Along the gastrointestinal tract are other organs that are not part of the gastrointestinal tract, but that aid in digestion by delivering secretions into the tract through ducts.

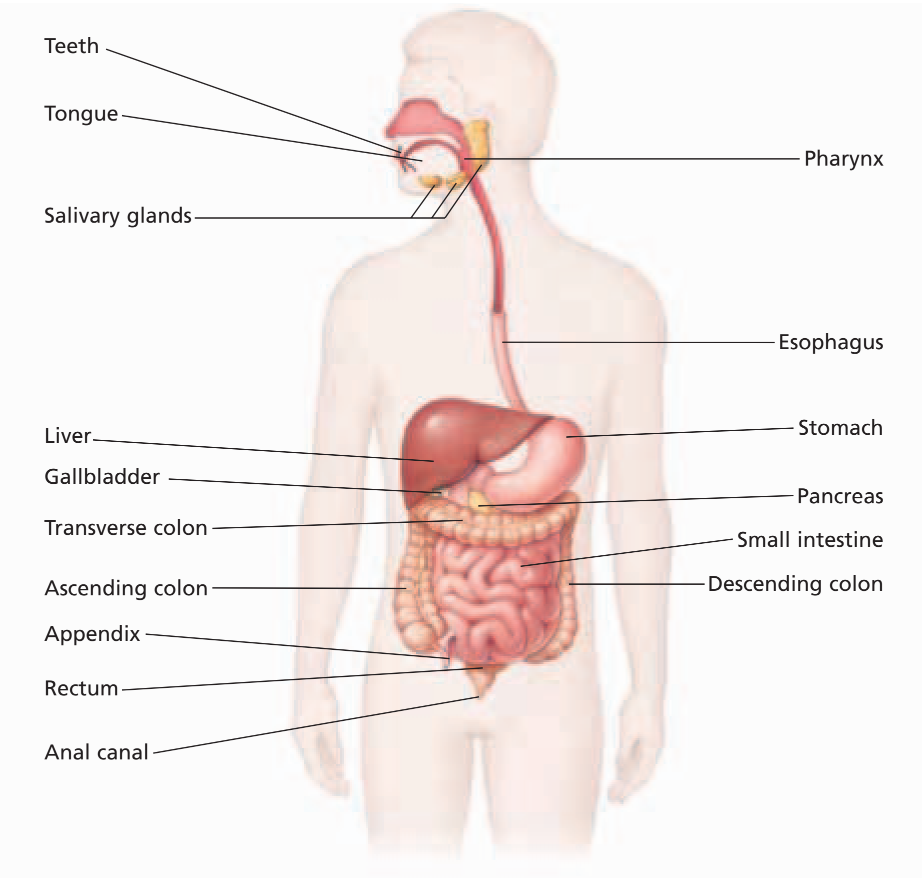
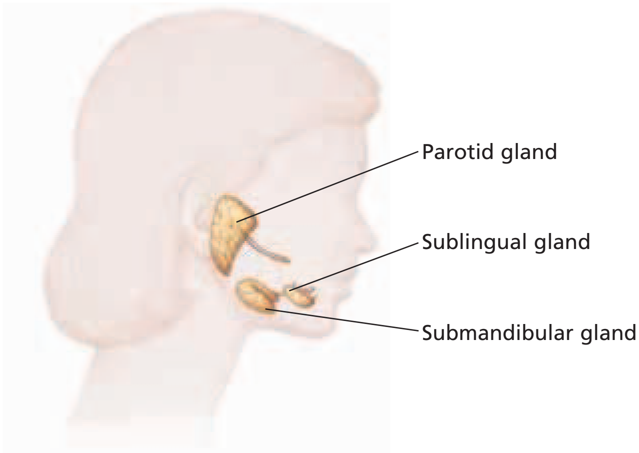


FIGURE 48-6

The digestive system is made up of the gastrointestinal tract, salivary glands, the liver, gallbladder, and pancreas. These organs break down food into nutrients that can be absorbed into the bloodstream.

FIGURE 48-7

Saliva is produced by three sets of glands located near the mouth. The set closest to the ear is the target of the virus that causes mumps.



THE MOUTH AND ESOPHAGUS

Digestion includes the mechanical and chemical breakdown of food into nutrients, the absorption of nutrients, and the elimination of waste. In the mechanical phase, the body physically breaks down chunks of food into small particles. Mechanical digestion increases the surface area on which digestive enzymes can act.

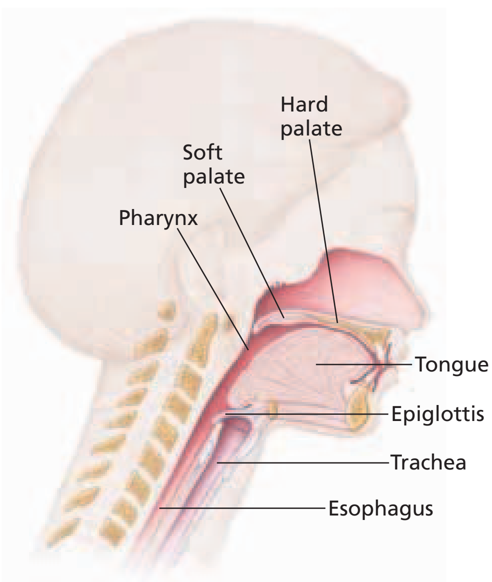
Mouth

When you take a bite of food, you begin the mechanical phase of digestion. *Incisors*—sharp front teeth—cut the food. Then, the broad, flat surfaces of *molars,* or back teeth, grind it up. The tongue helps keep the food between the chewing surfaces of the upper and lower teeth by manipulating it against the *hard palate,* the bony, membrane-covered roof of the mouth. This structure is different from the *soft palate,* an area located just behind the hard palate. The soft palate is made of folded membranes and separates the mouth cavity from the nasal cavity.

Chemical digestion involves a change in the chemical nature of the nutrients. Salivary glands produce **saliva** (suh-LIE-vuh), a mixture of water, mucus, and a digestive enzyme called *salivary amylase*. Besides the many tiny salivary glands located in the lining of the mouth, there are three pairs of larger salivary glands, as shown in Figure 48-7. The salivary amylase begins the chemical digestion of carbohydrates by breaking down some starch into the disaccharide maltose.

FIGURE 48-8

The pharynx is the only passage shared by the digestive and respiratory systems. Notice how the epiglottis can close off the trachea so that food can pass only down the esophagus.



Esophagus

After food has been thoroughly chewed, moistened, and rolled into a *bolus,* or ball, it is forced into the pharynx by swallowing action. The **pharynx,** an open area that begins at the back of the mouth, serves as a passageway for both air and food. As Figure 48-8 shows, a flap of tissue called the **epiglottis** (EP-uh-GLAHT-is) prevents food from entering the trachea, or windpipe, during swallowing. Instead, the bolus passes into the esophagus, a muscular tube approximately 25 cm long that connects the pharynx with the stomach.

The esophagus has two muscle layers: an inner circular layer that wraps around the esophagus and an outer longitudinal layer that runs the length of the tube. As you can see in Figure 48-9, alternating contractions of these muscle layers push the bolus through the esophagus and into the stomach. This series of rhythmic muscular contractions and relaxations is called **peristalsis.**

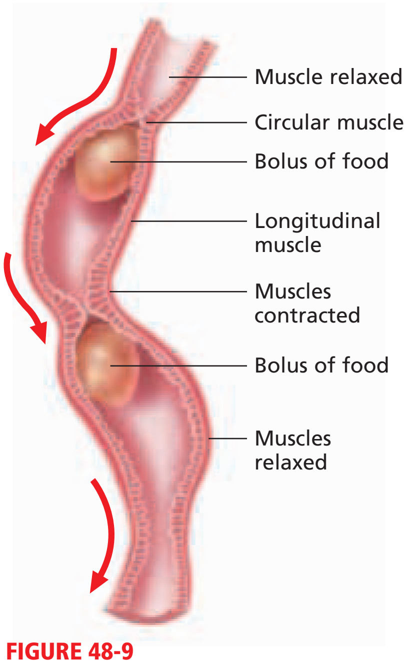


FIGURE 48-9

Peristalsis is so efficient at moving materials down the esophagus that you can drink while standing on your head. The smooth muscles move the water "up" the esophagus, against the force of gravity.

STOMACH

The stomach, an organ involved in both mechanical and chemical digestion, is located in the upper left side of the abdominal cavity, just below the diaphragm. It is an elastic bag that is J-shaped when full and that lies in folds when empty. You have probably heard your stomach "growl" when it has been empty for some time. These sounds are made by the contraction of smooth muscles that form the walls of the stomach.

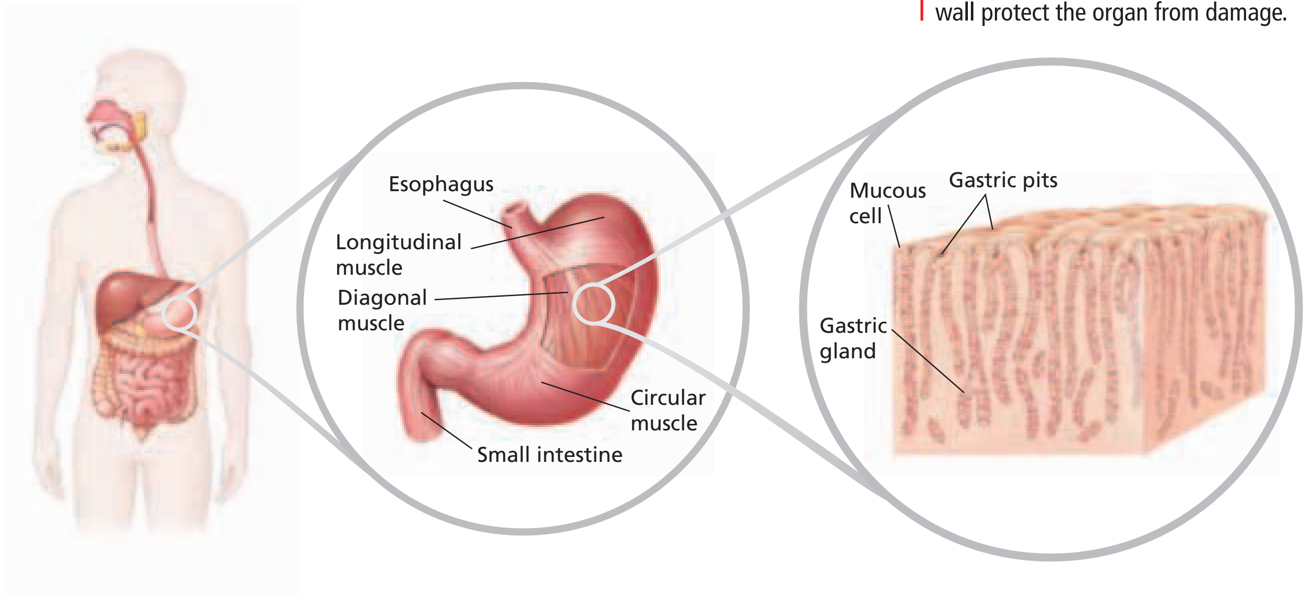
Mechanical Digestion

The walls of the stomach have several layers of smooth muscle. As you can see in Figure 48-10, there are three layers of muscle—a circular layer, a longitudinal layer, and a diagonal layer. When food is present, these muscles work together to churn the contents of the stomach. This churning helps the stomach carry out mechanical digestion.

The inner lining of the stomach is a thick, wrinkled mucous membrane composed of epithelial cells. This membrane is dotted with small openings called gastric pits. *Gastric pits,* which are shown in Figure 48-10, are the open ends of gastric glands that release secretions into the stomach. Some of the cells in gastric glands secrete mucus, some secrete digestive enzymes, and still others secrete hydrochloric acid. The mixture of these secretions forms the acidic digestive fluid.

FIGURE 48-10

Each of the muscle layers of the stomach is oriented in a different direction. The pH of the stomach is normally between 1.5 and 2.5, making it the most acidic environment in the body. Mucous cells lining the stomach wall protect the organ from damage.



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Chemical Digestion

Gastric fluid carries out chemical digestion in the stomach. An inactive stomach secretion called *pepsinogen* is converted into a digestive enzyme called *pepsin* at a low pH. Chemical digestion of proteins starts in the stomach when pepsin splits complex protein molecules into shorter chains of amino acids called *peptides*. Hydrochloric acid in the stomach not only ensures a low pH but also dissolves minerals and kills bacteria that enter the stomach along with food.

Mucus secreted in the stomach forms a coating that protects the lining from hydrochloric acid and from digestive enzymes. In some people, the mucous coating of the stomach tissue breaks down, allowing digestive enzymes to eat through part of the stomach lining. The result is called an **ulcer.** The breakdown of the mucous layer is often caused by bacteria that destroy the epithelial cells, which form the mucous layer.

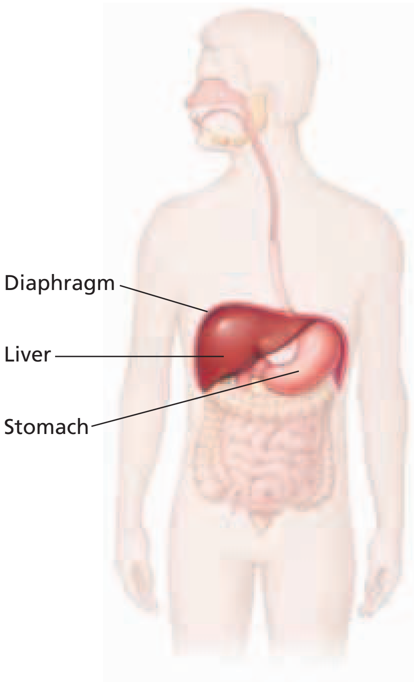
Formation of Chyme

The **cardiac sphincter** (SFINGK-tuhr) is a circular muscle located between the esophagus and the stomach. After the food enters the stomach, the cardiac sphincter closes to prevent the food from reentering the esophagus. Food usually remains in the stomach for three to four hours. During this time, muscle contractions in the stomach churn the contents, breaking up food particles and mixing them with gastric fluid. This process forms a mixture called **chyme** (KIEM).

Peristalsis forces chyme out of the stomach and into the small intestine. The **pyloric** (pie-LOHR-ik) **sphincter,** a circular muscle between the stomach and the small intestine, regulates the flow of chyme. Each time the pyloric sphincter opens, about 5 to 15 mL (about 0.2 to 0.5 oz) of chyme moves into the small intestine, where it mixes with secretions from the liver and pancreas.

FIGURE 48-11

The liver is the body's largest internal organ, weighing about 1.5 kg (3 lb). If a small portion is surgically removed because of disease or injury, the liver regenerates the missing section.

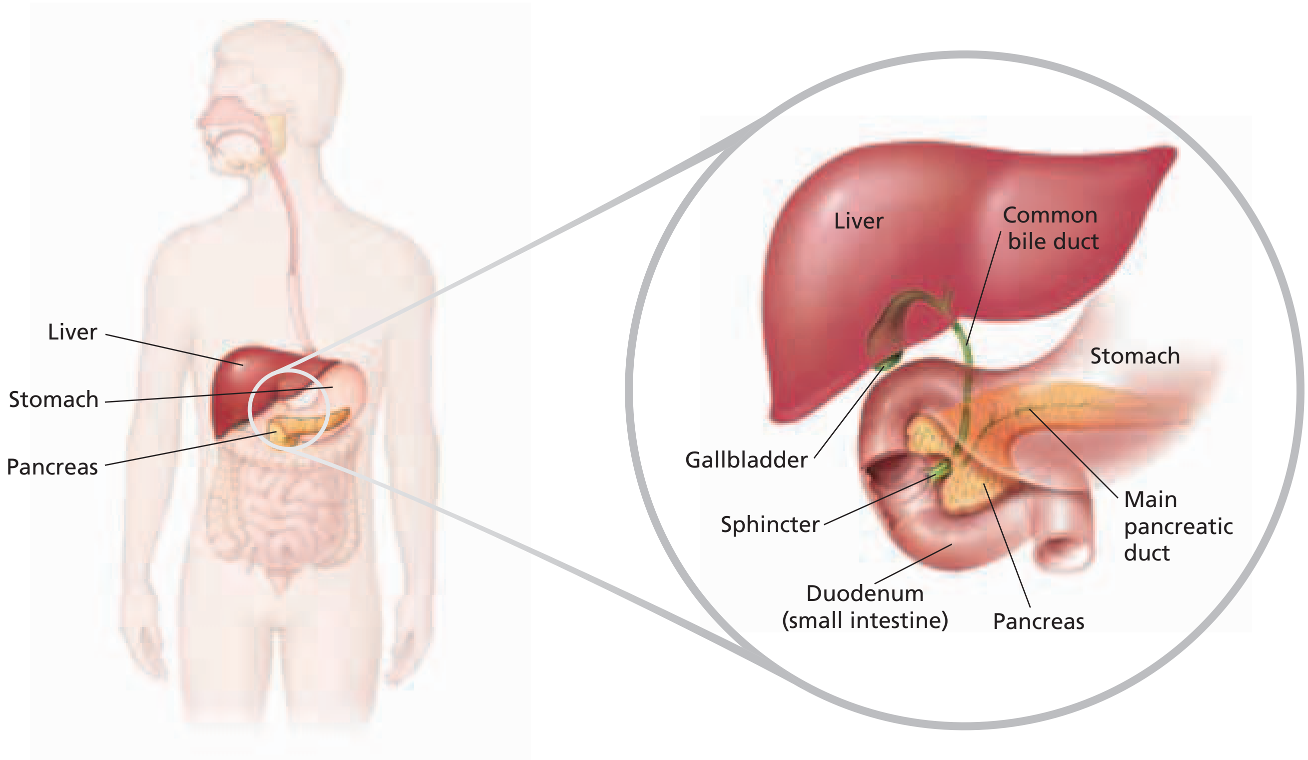


THE LIVER, GALLBLADDER, AND PANCREAS

Several of the organs involved in digestion do not come directly in contact with food. The liver, gallbladder, and pancreas work with the digestive system to perform several important functions.

Liver

The liver is a large organ located to the right of the stomach, as shown in Figure 48-11. The liver performs numerous functions in the body, including storing glucose as glycogen, making proteins, and breaking down toxic substances, such as alcohol. The liver also secretes bile, which is vital to the digestion of fats. Bile breaks fat globules into small droplets, forming a milky fluid in which fats are suspended. This process exposes a greater surface area of fats to the action of digestive enzymes and prevents small fat droplets from rejoining into large globules.



Gallbladder

The bile secreted by the liver passes through a Y-shaped duct, as shown in Figure 48-12. The bile travels down one branch of the Y-shaped duct and then up the other branch to the **gallbladder,** a saclike organ that stores and concentrates bile. When chyme is present in the small intestine, the gallbladder releases bile through the common bile duct into the small intestine.

FIGURE 48-12

Cholesterol deposits known as *gallstones* can form in the ducts leading from the liver and gallbladder to the small intestine. If the gallstones interfere with the flow of bile, they must be removed, along with the gallbladder in some cases.

Pancreas

As shown in Figure 48-12, the pancreas is an organ that lies behind the stomach, against the back wall of the abdominal cavity. The pancreas is a gland that serves several important functions. The pancreas acts as an endocrine gland, producing hormones that regulate blood sugar levels. As part of the digestive system, the pancreas serves two roles. It produces sodium bicarbonate, which neutralizes stomach acid. The pH of stomach acid is about 2. Pancreatic fluid raises the pH of the chyme from an acid to a base.

Neutralizing stomach acid is important in order to protect the interior of the small intestine and to ensure that the enzymes secreted by the pancreas can function. Many enzymes in the pancreatic fluid are activated by the higher pH. The pancreas produces enzymes that break down carbohydrates, proteins, lipids, and nucleic acids. These enzymes hydrolyze disaccharides into monosaccharides, fats into fatty acids and glycerol, and proteins into amino acids. Pancreatic fluid enters the small intestine through the pancreatic duct, which joins the common bile duct just before it enters the intestine.

SMALL INTESTINE

If the small intestine were stretched to its full length, it would be nearly 7 m (about 21 ft) long. The *duodenum,* the first section of this coiled tube, makes up only the first 25 cm (about 10 in.) of that length. The *jejunum* (jee-JOO-nuhm), the middle section, is about 2.5 m (about 8 ft) long. The *ileum,* which makes up the remaining portion of the small intestine, is approximately 4 m (about 13 ft) in length. As shown in Figure 48-13, the entire length of the small intestine lies coiled in the abdominal cavity.

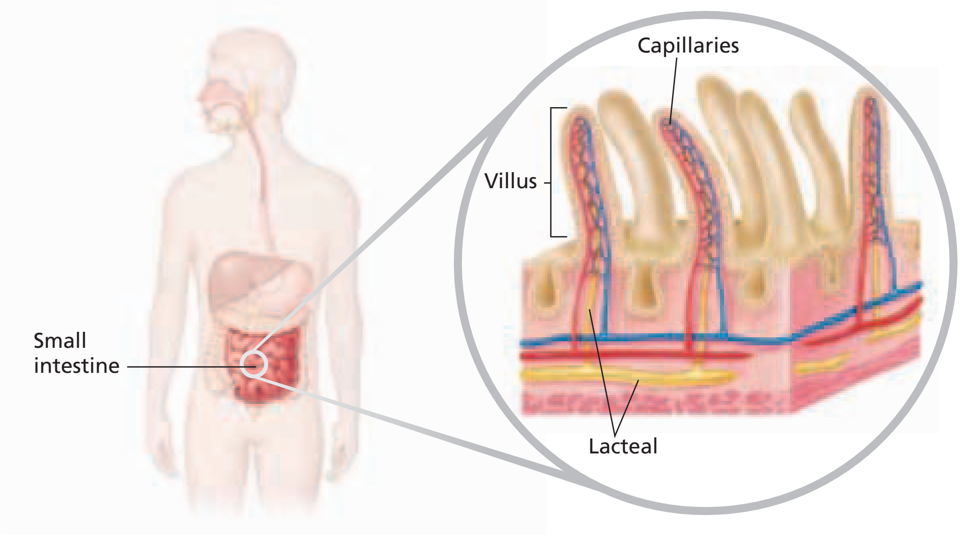
Secretions from the liver and pancreas enter the duodenum, where they continue the chemical digestion of chyme. When the secretions from the liver and pancreas, along with the chyme, enter the duodenum, they trigger intestinal mucous glands to release large quantities of mucus. The mucus protects the intestinal wall from protein-digesting enzymes and the acidic chyme. Glands in the lining of the small intestine release enzymes that complete digestion by breaking down peptides into amino acids, disaccharides into monosaccharides, and fats into glycerol and fatty acids.

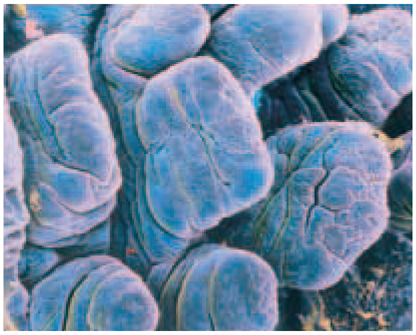
Absorption

During *absorption,* the end products of digestion—amino acids, monosaccharides, glycerol, and fatty acids—are transferred into the circulatory system through blood and lymph vessels in the lining of the small intestine. The structure of this lining provides a huge surface area for absorption to take place. The highly folded lining of the small intestine is covered with millions of fingerlike projections called **villi** (singular, *villus*), which are shown in Figure 48-13. The cells covering the villi, in turn, have extensions on their cell membranes called *microvilli*. The folds, villi, and microvilli give the small intestine a surface area of about 250 m^2 (about 2,685 ft^2), or roughly the area of a tennis court. Nutrients are absorbed through this surface by means of diffusion and active transport.

FIGURE 48-13

Although the small intestine is nearly 7 m long, only the first 25 cm are involved in digesting food. The rest is involved in the absorption of nutrients. Villi, as shown in the SEM (137×) and the diagram, expand the surface area of the small intestine to allow greater absorption of nutrients.




SEM of intestinal villi

Inside each of the villi are capillaries and tiny lymph vessels called *lacteals* (LAK-tee-uhlz). The lacteals can be seen in Figure 48-13. Glycerol and fatty acids enter the lacteals, which carry them through the lymph vessels and eventually to the bloodstream through lymphatic vessels near the heart. Amino acids and monosaccharides enter the capillaries and are carried to the liver. The liver neutralizes many toxic substances in the blood and removes excess glucose, converting it to glycogen for storage. The filtered blood then carries the nutrients to all parts of the body.

LARGE INTESTINE

After absorption in the small intestine is complete, peristalsis moves the remaining material on to the large intestine. The large intestine, or **colon,** is the final organ of digestion. Study Figure 48-14 to identify the four major parts of the colon: *ascending colon, transverse colon, descending colon,* and *sigmoid colon.* The sigmoid colon leads into the very short, final portions of the large intestine called the *rectum* and the *anal canal.*

Most of the absorption of nutrients and water is completed in the small intestine. About 9 L (9.5 qt) of water enter the small intestine daily, but only 0.5 L (0.53 qt) of water is present in the material that enters the large intestine. In the large intestine, only nutrients produced by bacteria that live in the colon, as well as most of the remainder of the water, are absorbed. Slow contractions move material in the colon toward the rectum. Distension of the colon initiates contractions that move the material out of the body. As this matter moves through the colon, the absorption of water solidifies the mass. The solidified material is called *feces.*

As the fecal matter solidifies, cells lining the large intestine secrete mucus to lubricate the intestinal wall. This lubrication makes the passing of the feces less abrasive. Mucus also binds together the fecal matter, which is then eliminated through the anus.

FIGURE 48-14

This X ray shows the large intestine, or colon. The ascending colon is on the left. The transverse colon crosses the abdominal cavity. The descending colon can be seen on the right. The sigmoid colon is the small section that leads to the anal canal.

SECTION 2 REVIEW

1. Sequence the organs that are involved in each step of digestion.
2. Explain the difference between mechanical digestion and chemical digestion.
3. Describe the processes involved in mechanical digestion.
4. Identify the source and function of each class of digestive enzymes.
5. Explain how the small intestine and large intestine are related to the function of absorption.

CRITICAL THINKING

6. **Applying Information** Which of the six basic nutrients might a person need to restrict after an operation to remove the gallbladder? Why?
7. **Predicting Results** Explain how the gastrointestinal tract would be affected if the pancreas were severely damaged.
8. **Forming Reasoned Opinions** Considering the stomach's role in the digestive system, is it possible for a person to digest food without a stomach? Explain your answer.

Science in Action

Can Saris Prevent Cholera?

Health authorities in Bangladesh urge villagers to boil surface water before drinking it, but a severe shortage of wood makes this process impossible for most people. Millions of people therefore must still use surface water and are at risk of cholera. However, scientist Rita Colwell came up with a method to filter out disease-causing organisms with an item available even in the poorest homes.

Dr. Rita Colwell

HYPOTHESIS: Simple Filtration Methods Will Reduce the Incidence of Cholera

Cholera is a severe disease that causes thousands of deaths each year. Symptoms of cholera include abdominal cramps, nausea, vomiting, dehydration, and shock. If untreated, death may occur after severe fluid and electrolyte loss. The responsible agent is a comma-shaped bacterium called *Vibrio cholerae.* In certain developing regions around the world where people must obtain untreated drinking water from streams and lakes, *V. cholerae* infection can occur.

Dr. Colwell, one of the world's leading cholera researchers, observed that *V. cholerae* lives in association with microscopic copepods, which are a type of zooplankton. Dr. Colwell also showed that cholera outbreaks occurred seasonally in association with temperature changes and blooms of the copepod organisms.

Dr. Colwell and her colleagues knew that villagers often strained flavored beverages through a piece of fine cloth cut from an old, discarded sari, a woman's long flowing garment. Colwell came up with a hypothesis: Straining drinking water through an old piece of sari cloth could remove copepods and the associated cholera bacteria and prevent cases of cholera.

METHODS: Compare Filtration Methods

Colwell's team chose 142 villages in Bangladesh where people use untreated river or pond water for drinking and have high rates of cholera. They assigned over 45,000 participants to three groups. The control group would continue to use unfiltered, untreated water. One experimental group would collect water in jars by tying four layers of sari cloth over the opening. The other experimental group would collect water in containers covered by filter fabric designed to remove copepod-sized organisms. Field workers collected medical data on cholera cases during the study period.

RESULTS: Cholera Cases Are Reduced

The team compared the incidence of cholera for the control group with that of the two experimental groups. They found that the control group had the usual number of cholera cases (about 3 per 1,000 people per year). However, using either nylon filtration cloth or sari cloth cut the number of cases in half. Interestingly, old cloth worked better than new cloth because older fibers soften, the pore size is reduced, and more copepods and attached bacteria are trapped in the pores.

CONCLUSION: Saris Can Reduce the Incidence of Cholera

Rita Colwell and her team concluded that saris are a simple, practical solution to a serious global problem. They are currently looking at ways to expand this filtration idea to other parts of the world. Women don't wear saris everywhere, but old cloth is available in virtually every home.

REVIEW

1. Identify the relationship between copepods, *V. cholerae,* and drinking water.
2. Explain the reason that the age of the saris made a difference in filtration.
3. **Critical Thinking** If the *V. cholerae* bacteria were not associated with copepods, would this filtration have been successful? Explain your reasoning.

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