THEME FOCUS Cause and Effect

Homeostasis is maintained by negative feedback in the endocrine system.

BIG Idea **The digestive system breaks down food to provide energy and nutrients for the body. The endocrine system produces hormones that regulate body functions.**

Reading Preview

Essential Questions

- What are the three main functions of the digestive system?
- What are the structures of the digestive system and what are their functions?
- What is the process of chemical digestion?

Review Vocabulary

nutrient: vital component of foods that provides energy and materials for growth and body functions

New Vocabulary

mechanical digestion
chemical digestion
amylase
esophagus
peristalsis
pepsin
small intestine
liver
villus
large intestine

Multilingual eGlossary

Video Lab

The Digestive System

Key Idea The digestive system breaks down food so nutrients can be absorbed by the body.

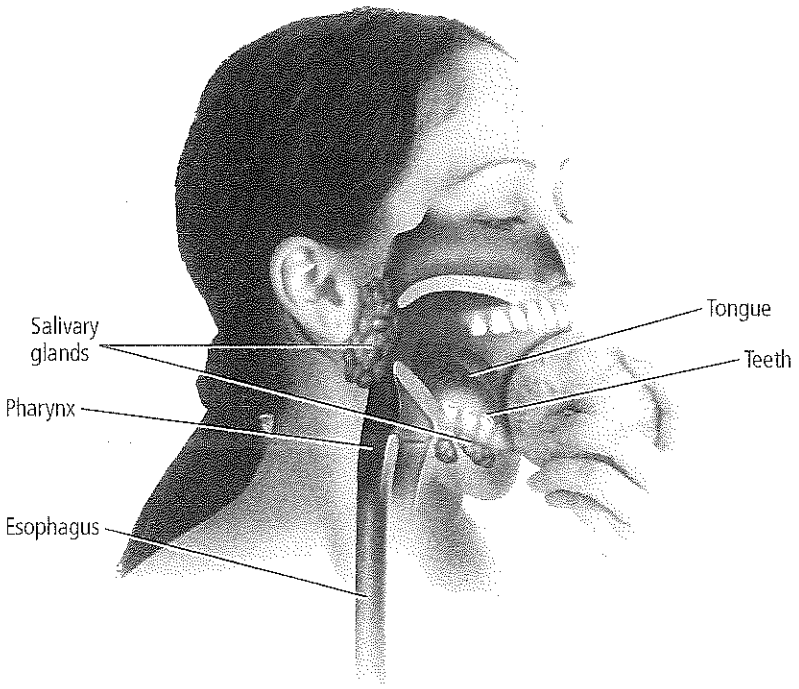
Real-World Reading Link During an average lifespan, as much as 45 tons of food can pass through a person's digestive system. The food will travel almost 9 m through the digestive tract. What happens as food passes through this long tube?

Functions of the Digestive System

There are three main functions of the digestive system. The digestive system ingests food, breaks it down so nutrients can be absorbed, and eliminates what cannot be digested. Refer to **Figure 1** and **Figure 2** as you learn about the structure and function of the digestive system.

Digestion Supose on Friday night, you and your friends meet to have pizza. You bite into a slice and begin to chew. How does your body digest that pizza?

Mechanical digestion involves chewing food to break it down into smaller pieces. It also includes the action of smooth muscles in the stomach and small intestine that churn the food. **Chemical digestion** involves the breakdown of large molecules in food into smaller substances by enzymes. The smaller substances can be absorbed into the body's cells. Enzymes are proteins that speed up biological reactions. When you chew the bites of pizza, **amylase,** an enzyme found in saliva, begins the process of chemical digestion by breaking down starches into sugars.



Tim Fuller

Figure 1 Mechanical digestion starts in the mouth. Secretions from the salivary glands keep food moist and begin the process of chemical digestion. Food moves through the pharynx into the esophagus.

Animation

Esophagus When the tongue pushes chewed food to the back of the mouth, the swallowing reflex is stimulated. The food is forced by the action of the tongue into the upper portion of the esophagus. The **esophagus** (ih SAH fuh gus) is a muscular tube that connects the pharynx, or throat, to the stomach, as illustrated in **Figure 2.** The wall of the esophagus is lined with smooth muscles that contract rhythmically to move the food through the digestive system in a process called **peristalsis** (per uh STAHL sus). Peristalsis continues throughout the digestive tract. Even if a person were upside down, food would still move toward the stomach.

When a person swallows, the small plate of cartilage called the epiglottis covers the trachea. If this opening is not closed, food can enter the trachea and cause a person to choke. The body responds to this by initiating the coughing reflex in an attempt to expel the food to keep the food from entering the lungs.

Stomach When food leaves the esophagus, it passes through a circular muscle called a sphincter, and into the stomach. The sphincter between the esophagus and stomach is the cardiac sphincter. The walls of the stomach are composed of three overlapping layers of smooth muscle that are involved with mechanical digestion. As the muscles contract, they further break down the food and mix it with the secretions of glands that line the inner wall of the stomach.

Connection to Chemistry Recall that pH is a measure of a solution's acidity. The environment inside the stomach is very acidic. Stomach glands, called gastric glands, secrete an acidic solution, which lowers the pH in the stomach to about 2. This is about the same level of acidity as lemon juice. If the sphincter in the upper portion of the stomach allows any leakage, some of this acid might move back into the esophagus, causing what is commonly known as heartburn.

The acidic environment in the stomach is favorable to the action of **pepsin,** an enzyme involved in the process of the chemical digestion of proteins. Cells in the lining of the stomach secrete mucus to help prevent damage from pepsin and the acidic environment. Although most absorption occurs in the small intestine, some substances, such as alcohol and aspirin, are absorbed by cells that line the stomach. While empty, the capacity of the stomach is about 50 mL. When full, it can expand to 2-4 L.

The muscular walls of the stomach contract and push food farther along the digestive tract. The consistency of the food resembles tomato soup as it passes through the pyloric sphincter at the lower end of the stomach into the small intestine. **Figure 3** illustrates peristalsis in the small intestine.

Reading Check **Compare** digestion in the mouth with digestion in the stomach.

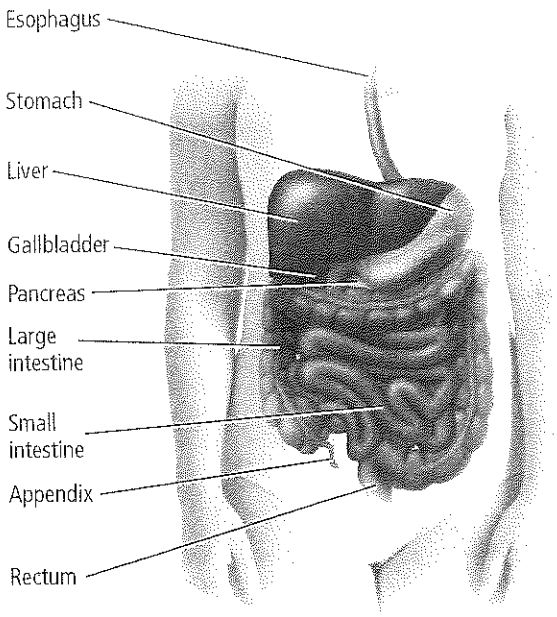
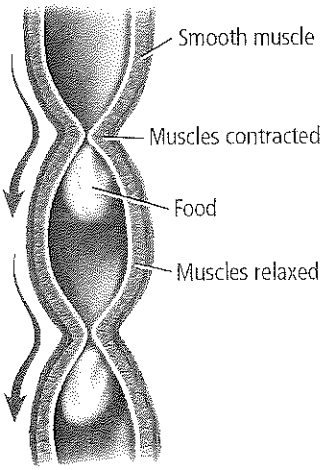


Figure 2 The esophagus extends from the pharynx to the stomach and is approximately 25 cm long.
Describe ***why humans are classified as coelomates.***

Figure 3 The smooth muscles in the walls of the digestive tract contract in the process of peristalsis.

Animation



Tim Fuller

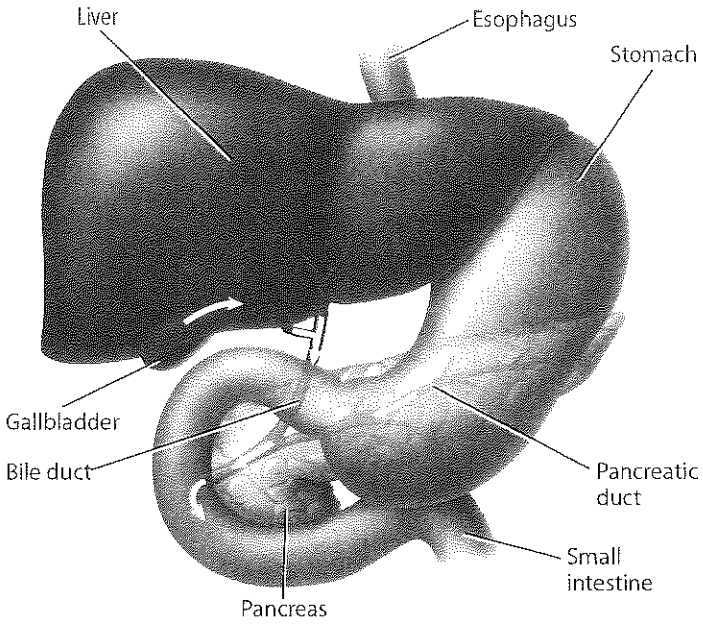


Figure 4 Chemical digestion in the small intestine depends on the activities of the liver, pancreas, and gallbladder.
Discuss *the importance of each of these organs in the process of chemical digestion.*

BrainPOP

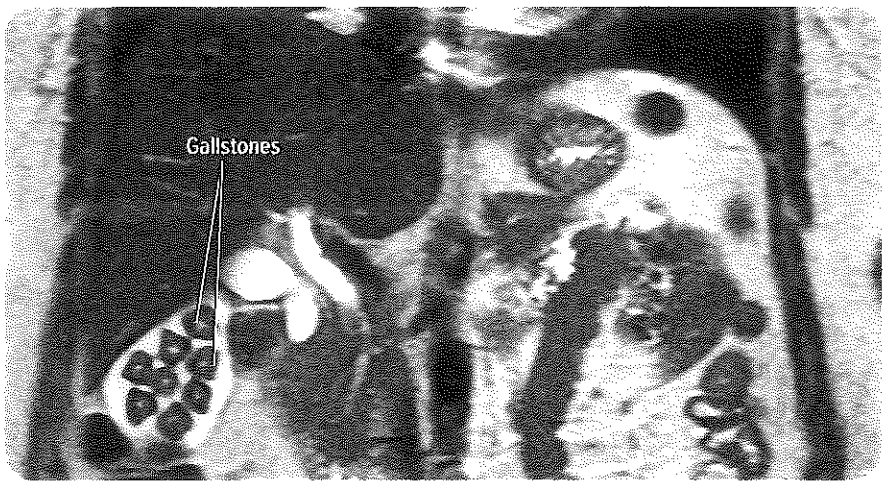
Study Tip

Sequence and Order Using your notes, work with a partner to review the sequence of the organs in the digestive system. Then, practice retelling the sequence without your notes. Ask questions of one another for deeper learning.

Small intestine The **small intestine** is approximately 7 m in length and is the longest part of the digestive tract. It is called *small* because its diameter is 2.5 cm compared to the 6.5 cm diameter of the large intestine. The smooth muscles in the wall of the small intestine continue the process of mechanical digestion and push the food farther through the digestive tract by peristalsis.

The completion of chemical digestion in the small intestine depends on three accessory organs–the pancreas, liver, and gallbladder, as illustrated in **Figure 4.** The pancreas serves two main functions. One is to produce enzymes that digest carbohydrates, proteins, and fats. The other is to produce hormones, which will be discussed later in this chapter. The pancreas secretes an alkaline fluid to raise the pH in the small intestine to slightly above 7, which creates a favorable environment for the action of intestinal enzymes.

The **liver** is the largest internal organ of the body and produces bile, which helps to break down fats. About 1 L of bile is produced every day, and excess bile is stored in the gallbladder to be released into the small intestine when needed. **Figure 5** shows gallstones, which are cholesterol crystals that can form in the gallbladder.



Simon Fraser/SPL/Photo Researchers

Figure 5 Gallstones can obstruct the flow of bile from the gallbladder. Note the gallstones on this MRI film of a gallbladder.

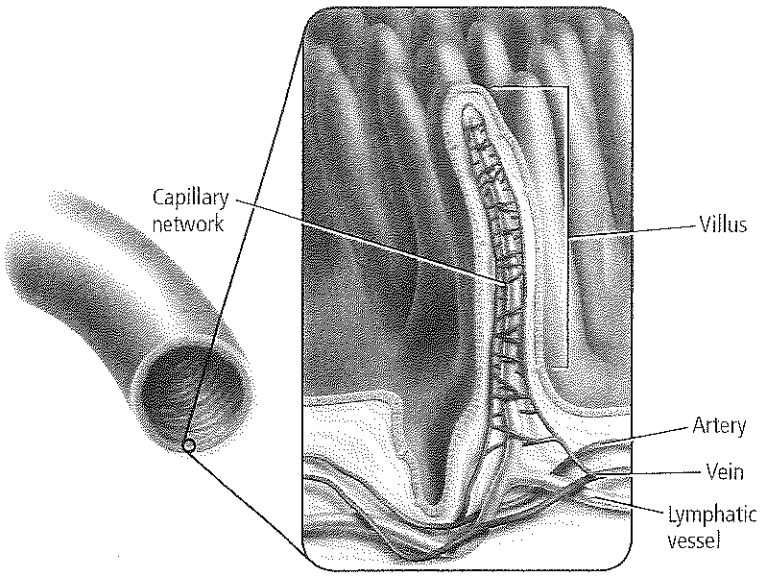


Figure 6 A villus is a fingerlike extension of the lining of the small intestine. Nutrients diffuse into capillaries in the villi and reach body cells by means of circulating blood.

Chemical digestion is completed and most of the nutrients from food are absorbed from the small intestine into the bloodstream through fingerlike structures called **villi** (VIH li) (singular, villus). Villi, illustrated in **Figure 6,** increase the surface area of the small intestine, giving the small intestine approximately the same surface area as a tennis court.

Refer again to **Figure 1** and **Figure 2** to follow the movement of digested food through the digestive system. Once digestion is complete, the remaining food, now in a semiliquid form called chyme (KIME), moves into the large intestine. Chyme is made up of materials that cannot be digested or absorbed by villi in the small intestine.

MiniLab

Investigate Digestion of Lipids

MiniLab

How do bile salts and pancreatic solution affect digestion? Lipids, or fats, are not water soluble. The body compensates by producing bile, a chemical that breaks apart fat and helps the molecules mix with the watery solution in the small intestine. In this lab, you will investigate the breakdown of lipids.

Procedure

1. Read and complete the lab safety form.
2. Study the lab procedure and construct a data chart.
3. Label **three test tubes.** Add 5 mL **vegetable oil** and 8-10 drops **phenolphthalein** to each. Shake well. If the color is not pink, add **NaOH solution** one drop at a time until the solution turns pink.
4. Add 125 mL **water** to a **250-mL beaker.** Warm to about 40°C.
5. Prepare the test tubes as follows, then seal each with a **stopper.**
   Test Tube A: 5 mL **distilled water,** pinch of **bile salt**
   Test Tube B: 5 mL **pancreatic solution,** pinch of bile salt
   Test Tube C: 5 mL pancreatic solution
6. Shake each tube to mix the contents and gently place in the beaker. Record your observations.
7. Dispose of test tube contents in the designated container.

Analysis

1. **Analyze** What did a color change inside a test tube indicate? What caused the change?
2. **Draw conclusions** based on your results. Describe the roles of bile and pancreatic solution in digestion.

Table 1 Time for Digestion — Interactive Table

Digestive Structure	Primary Function	Time Food in Structure
Mouth	Mechanical and chemical digestion	5–30 s
Esophagus	Transport (swallowing)	10 s
Stomach	Mechanical and chemical digestion	2–24 h
Small intestine	Mechanical and chemical digestion	3–4 h
Large intestine	Water absorption	18 h–2 days

Large intestine The **large intestine** is the end portion of the digestive tract. It is about 1.5 m long and includes the colon, the rectum, and a small saclike appendage called the appendix. Although the appendix has no known function, it can become inflamed and swollen, resulting in appendicitis. If inflamed, the appendix will likely have to be removed surgically.

Some kinds of beneficial bacteria are normal in the colon. These bacteria produce vitamin K and some B vitamins available to the body.

A primary function of the colon is to absorb water from the chyme. The indigestible material then becomes more solid and is called feces. Peristalsis continues to move feces toward the rectum, causing the walls of the rectum to stretch. This initiates a reflex that causes the final sphincter muscle to relax, and the feces are eliminated from the body through the anus. Refer to **Table 1** to review the primary function of each structure of the digestive system and how long food usually remains in each structure as it is being digested.

Section 1 Assessment

Section Summary

- The digestive system has three main functions.
- Digestion can be categorized as mechanical or chemical.
- Most nutrients are absorbed in the small intestine.
- Accessory organs provide enzymes and bile to aid digestion.
- Water is absorbed from chyme in the colon.

Understand Main Ideas

1. **Describe** the process that breaks down food so that nutrients can be absorbed by the body.
2. **Analyze** the difference between mechanical digestion and chemical digestion. Explain why chemical digestion is necessary for the body.
3. **Summarize** the three main functions of the digestive system.
4. **Analyze** what the consequence might be if the lining of the small intestine were completely smooth instead of having villi.

Think Critically

5. **Design** an experiment to gather data about the effect of pH on the digestion of different types of food.

MATH in Biology

6. A can of carbonated beverage typically holds about 354 mL of fluid. Compare this amount with the volume of an empty stomach. Give a ratio.
7. **Explain** why the pH in the digestive system changes. Give examples and explain the importance of these changes.

Online Quiz

Reading Preview

Essential Questions

- Depending on activity level, what caloric intake is needed to maintain proper body weight?
- How are proteins, carbohydrates, and fats used by the body?
- What are the roles of vitamins and minerals in maintaining homeostasis?
- How can you apply the information in MyPyramid and on food labels to establishing healthy eating habits?

Review Vocabulary

amino acid: the basic building block of proteins

New Vocabulary

nutrition
Calorie
vitamin
mineral

Multilingual eGlossary

Nutrition

MAIN Idea **Certain nutrients are essential for the proper function of the body.**

Real-World Reading Link There is a saying, "You are what you eat." What do you think that means? Much of the time, you have freedom to choose what you eat. However, your choices have consequences. What you eat can affect your health now and in the future.

Calories

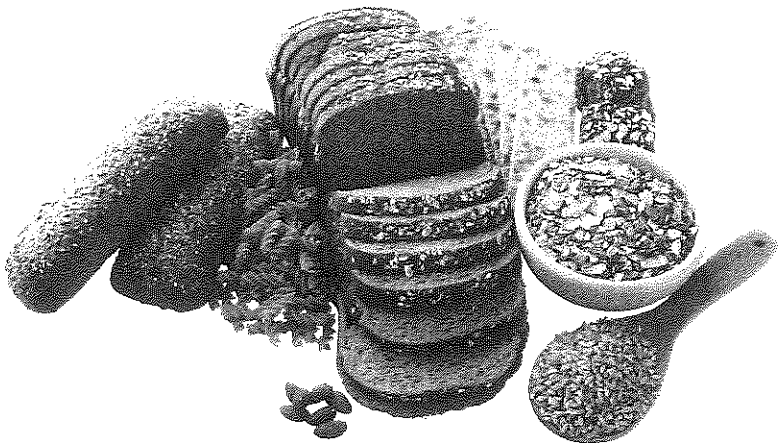
Nutrition is the process by which a person takes in and uses food. Foods supply the building blocks and energy to maintain body mass. The daily input of energy from food should equal the amount of energy a person uses daily. A **Calorie** (with an uppercase C) is the unit used to measure the energy content of foods. A Calorie is equal to 1 kilocalorie, or 1000 calories (with a lowercase c). A calorie is the amount of heat needed to raise the temperature of 1 mL of water by 1°C.

The energy content of a food can be measured by burning the food and converting the stored energy to heat. Not all foods have the same energy content. The same mass of different foods does not always equal the same number of Calories. For example, one gram of carbohydrate or protein contains four Calories. One gram of fat contains nine Calories. To lose weight, more Calories must be used than consumed. The opposite is true to gain weight. In 2005, the United States Department of Agriculture released new guidelines for nutrition and suggested that people should become more active and use more Calories. **Table 2** compares average Calorie usage with different activities. The exact number of calories burned will vary depending on weight and gender.

Table 2 Activities and Average Calorie Usage — Interactive Table

Activity	Calories Used Per Hour	Activity	Calories Used Per Hour
Baseball	282	Hiking and backpacking	564
Basketball	564	Hockey (field and ice)	546
Bicycling	240–410	Jogging	740–920
Cross-country skiing	700	Skating	300
Football	540	Soccer	540

Figure 7 Your body needs carbohydrate-rich foods like these every day.



VOCABULARY

Consume

Science usage: to eat or drink
We consume Calories when we eat food.

Common usage: to destroy
The fire consumed several buildings.

Carbohydrates

Cereal, pasta, potatoes, strawberries, and rice all contain a high proportion of carbohydrates. Recall that sugars, such as glucose, fructose, and sucrose, are simple carbohydrates that are found in fruits, soda pop, and candy. Complex carbohydrates are macromolecules such as starches, which are long chains of sugars. Foods such as those shown in **Figure 7** have a high starch content, as do some vegetables.

Complex carbohydrates are broken down into simple sugars in the digestive tract. Simple sugars are absorbed through villi in the small intestine into blood capillaries and circulated throughout the body to provide energy for cells. Excess glucose is stored in the liver in the form of glycogen. Cellulose, sometimes called dietary fiber, is another complex carbohydrate found in plant foods. Although humans cannot digest fiber, it is important because fiber helps keep food moving through the digestive tract and helps with the elimination of wastes. Bran, whole-grain breads, and beans are good sources of fiber.

Reading Check **Compare** simple and complex carbohydrates.

Fats

In proper amounts, fats are an essential part of a healthful diet. Fats are the most concentrated energy source available to the body, and they are building blocks for the body. Fats also protect some internal organs and help maintain homeostasis by providing energy and by storing and transporting certain vitamins. However, not all fats are beneficial.

Connection to Recall that fats are classified according to their chemical structure as saturated or unsaturated. Meats, cheeses, and other dairy products are sources of saturated fats. A diet high in saturated fats might result in high blood levels of cholesterol, which can lead to heart problems. Plants are the main source of unsaturated fats. They are not associated with heart disease, although excessive consumption of any type of fat can lead to weight gain.

A general rule is that saturated fats are solid and unsaturated fats are liquid at room temperature. The olive oil in **Figure 8** contains less saturated fat than the butter, which is why the olive oil is liquid at room temperature. Fats are digested in the small intestine and broken down into fatty acids and glycerol. Fatty acids can be absorbed through the villi and circulated in the blood throughout the body.

Figure 8 The way in which naturally low-fat foods are cooked and served can increase saturated fat content. Olive oil may be a better cooking option than butter for this reason.

Tetra Images/Getty Images

Proteins

You have learned that proteins are basic structural components of all cells, and that amino acids are the building blocks of proteins. Enzymes, hormones, neurotransmitters, and membrane receptors are just a few important proteins in the body.

During the process of digestion, proteins in foods are broken down to their subunit amino acids. The amino acids are absorbed into the bloodstream and carried to various body cells. These body cells, through the process of protein synthesis, assemble the amino acids into proteins needed for body structures and functions.

Humans require 20 different amino acids for protein synthesis. The human body can produce 12 of the 20 amino acids needed for cellular function. Essential amino acids are the eight amino acids that must be included in a person's diet. Animal products, such as meats, fish, poultry, eggs, and dairy products, are sources of all eight essential amino acids. Vegetables, fruits, and grains contain amino acids, but no single plant food source contains all eight essential amino acids. However, certain combinations, such as the beans and rice shown in **Figure 9**, provide all of the essential amino acids.

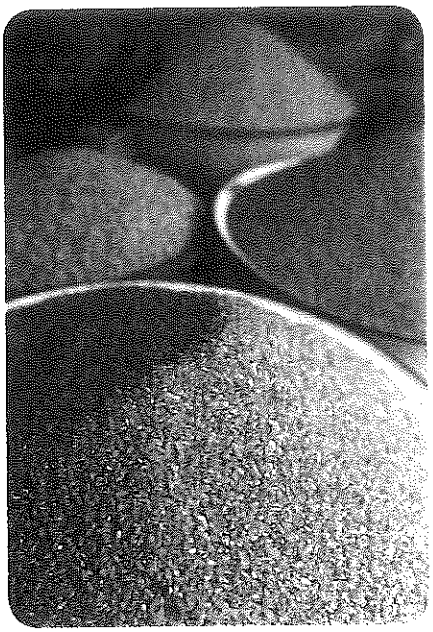


Figure 9 Beans and rice can be combined to provide all the essential amino acids.
Explain ***why it is important to eat foods that contain the essential amino acids.***

MyPlate

In 2011, the United States Department of Agriculture published a new nutrition guide, MyPlate, shown in **Figure 10**. MyPlate replaces the food pyramid, which had been a symbol of good nutrition since 1992. MyPlate emphasizes the ratios of food groups rather than exact serving sizes. It recommends that a person eat about 30 percent grains, 30 percent vegetables, 20 percent fruits, 20 percent protein, with a small side of dairy such as a yogurt cup or glass of skim milk.

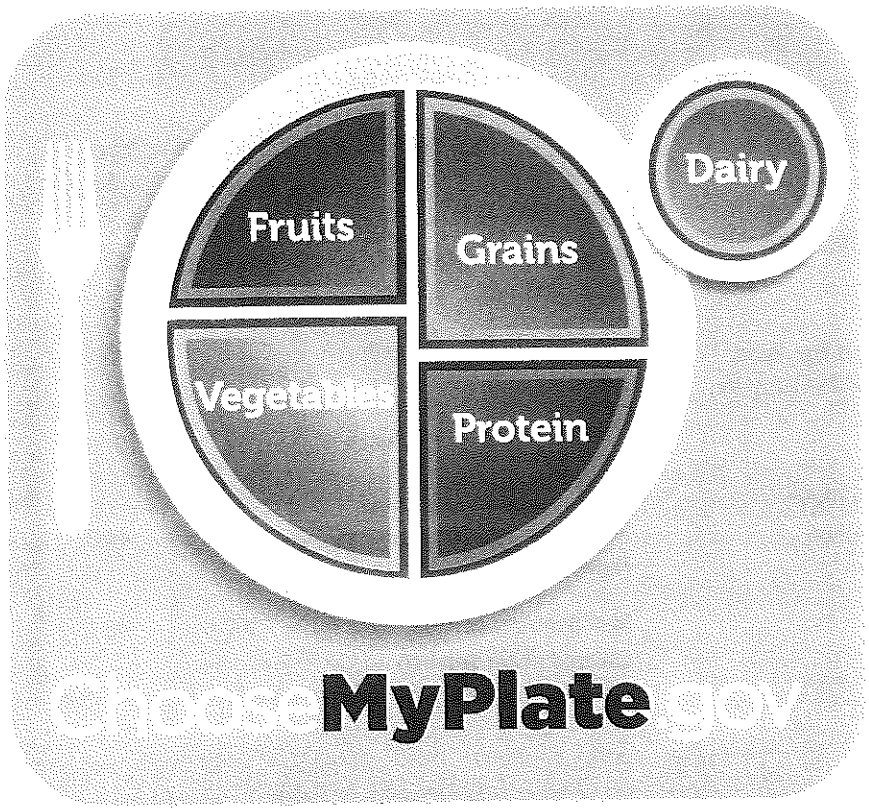


Figure 10 MyPlate can help you choose the foods and the amounts of those foods that are right for you.

Jodi Cobb/National Geographic Stock

Vitamins and Minerals

In addition to carbohydrates, fats, and proteins, your body needs vitamins and minerals to function properly. **Vitamins** are organic compounds that are needed in small amounts for metabolic activities. Many vitamins help enzymes function properly. Some vitamins are produced within the body. Vitamin D is made by cells in your skin. Some B vitamins and vitamin K are produced by bacteria living in the large intestine. However, sufficient quantities of most vitamins cannot be made by the body, but a well-balanced diet can provide the vitamins that are needed. Some vitamins that are fat-soluble can be stored in small quantities in the liver and fatty tissues of the body. Other vitamins are water-soluble and cannot be stored in the body. Foods providing an adequate level of these vitamins should be included in a person's diet on a regular basis.

Minerals are inorganic compounds used by the body as building materials, and they are involved with metabolic functions. For example, the mineral iron is needed to make hemoglobin. Recall that oxygen binds to hemoglobin in red blood cells and is delivered to body cells as blood circulates in the body. Calcium, another mineral, is an important component of bones.

Vitamins and minerals are essential parts of a healthy diet. **Table 3** on the next page lists some important vitamins and minerals, their benefits, and some food sources that can provide these necessary nutrients. Over-the-counter vitamins are also available. Taking more than the recommended daily allowance, however, can be dangerous and should not be done without consulting a doctor.

CAREERS IN BIOLOGY

Registered Dietician A registered dietician addresses a variety of health issues by showing patients how to make healthful decisions about their diets.

Virtual Lab

DATA ANALYSIS LAB 1

Based on Real Data*

Compares Data

How reliable are food labels? In a study conducted at the U.S. Department of Agriculture Human Nutrition Research Center, scientists measured the mass of 99 single-serving food products.

Data and Observations

The table compares the mass listed on the food package label with the actual mass of the food in five single-serving packages.

Food (1 serving)	Label Mass (g)	Actual Mass (g)
Cereal, bran flakes with raisins (1 box)	39	54.2
Cereal, toasted grains with supplement (1 box)	23	39.6
Cookie, chocolate sandwich (1 pkg)	57	67.0
Mini danish, apple (1 per serving)	35	44.8
Mini donut, chocolate covered (4 per serving)	100	116.5

Think Critically

1. **Calculate** the percent difference in mass between the label mass and the actual mass of the cookies.
2. **Compare** the trend in the percent differences.

*Data obtained from: Conway, J.M., D.G. Rhodes, and W.V. Rumpler. 2004. Commercial portion-controlled foods in research studies: how accurate are label weights? *Journal of the American Dietetic Association* 104: 1420–1424.

Table 3 Major Roles of Some Vitamins and Minerals

Interactive Table

Vitamin	Major Role in the Body	Possible Sources	Mineral	Major Role in the Body
A	• Vision • Health of skin and bones		Ca	• Strengthening of teeth and bone • Nerve conduction • Contraction of muscle
D	• Health of bones and teeth		P	• Strengthening of teeth and bone
E	• Strengthening of red blood cell membrane		Mg	• Synthesis of proteins
Riboflavin (B_2)	• Metabolism		Fe	• Synthesis of hemoglobin
Folic Acid	• Formation of red blood cells • Formation of DNA and RNA		Cu	• Synthesis of hemoglobin
Thiamine	• Metabolism of carbohydrates		Zn	• Healing of wounds
Niacin (B_3)	• Metabolism		Cl	• Balance of water
Pyridoxine (B_6)	• Metabolism of amino acids		I	• Synthesis of thyroid hormone
B_{12}	• Formation of red blood cells		Na	• Nerve conduction • Balance of pH
C	• Formation of collagen		K	• Nerve conduction • Contraction of muscle

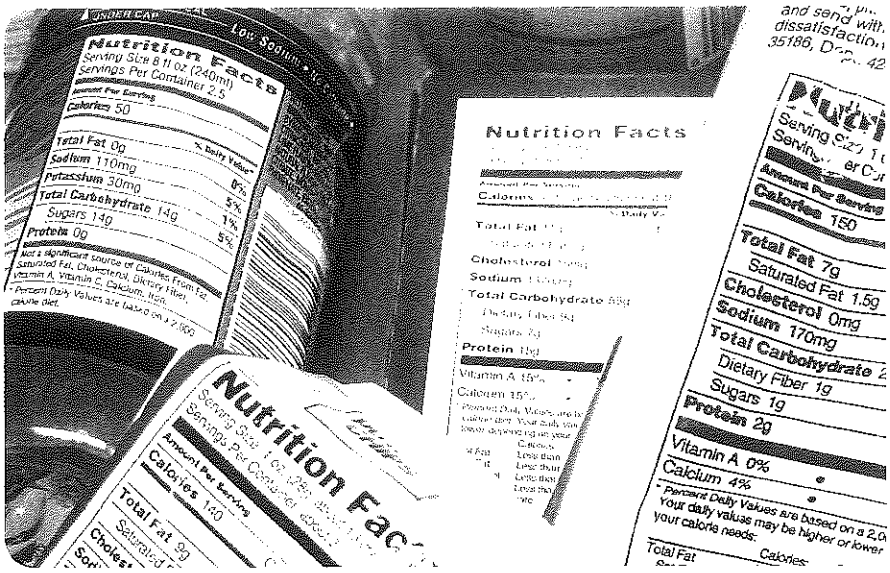


Figure 11 Notice how many servings are in each food container. The percent daily values are based on an individual serving, not the entire package.

Nutrition Labels

Nutrition labels are provided on commercially packaged foods like those shown in **Figure 11.** These labels are based on a 2000-Calorie-per-day diet. Labels can be especially useful for monitoring fat and sodium intake, which are two nutrients that need to be consumed in moderation. The FDA requires that food labels list the following information.

- name of the food
- net weight or volume
- name and address of manufacturer, distributor, or packager
- ingredients
- nutrient content

Section 2 Assessment

Section Summary

- The energy content of food is measured in Calories.
- Carbohydrates, fats, and proteins are three major groups of nutrients.
- Carbohydrates are a major source of energy for the body.
- Fats and proteins provide energy and are important building blocks for the body.
- Vitamins and minerals are essential for proper metabolic functioning.
- The *MyPyramid Plan* and food labels are tools that you can use to eat healthfully.

Understand Main Ideas

1. **Explain** the roles of vitamins and minerals in the process of maintaining homeostasis.
2. **Describe** what proteins, carbohydrates, and fats are used for in the process of digestion.
3. **Recommend** what nutrients a vegetarian should add to his or her diet.
4. **Explain** why keeping a count of Calories consumed and Calories used is important in maintaining proper functioning of the body.

Think Critically

5. **Summarize** how many Calories you consume during one day by recording everything you eat or drink. Compare this to how many Calories you burn in an average day.

WRITING in Biology

6. Write a short article for your school newspaper describing what is needed for a well-balanced diet.

Online Quiz

Reading Preview

Essential Questions

- What are the functions of the glands that make up the endocrine system?
- What is the role of the endocrine system in maintaining homeostasis?
- What are the feedback mechanisms that regulate hormone levels in the body?

Review Vocabulary

homeostasis: the regulation of an organism's internal environment to maintain life

New Vocabulary

endocrine gland
hormone
pituitary gland
thyroxine
calcitonin
parathyroid hormone
insulin
glucagon
aldosterone
cortisol
antidiuretic hormone

Multilingual eGlossary

The Endocrine System

MAIN Idea **Systems of the human body are regulated by hormonal feedback mechanisms.**

Real-World Reading Link When driving a car, everyone usually maintains a similar speed. When cars go faster or slower than the accepted speed, the chance of an accident increases. Similarly, hormones must stay in the proper balance to maintain homeostasis in the body.

Action of Hormones

The endocrine system is composed of glands and functions as a communication system. **Endocrine glands** produce hormones, which are released into the bloodstream and distributed to body cells. A **hormone** is a substance that acts on certain target cells and tissues to produce a specific response. Hormones are classified as steroid hormones and nonsteroid or amino acid hormones, based on their structure and mechanism of action.

Steroid hormones Estrogen and testosterone are two examples of steroid hormones. Both of these hormones affect the human reproductive system. All steroid hormones work by causing the target cells to initiate protein synthesis, as illustrated in **Figure 12.**

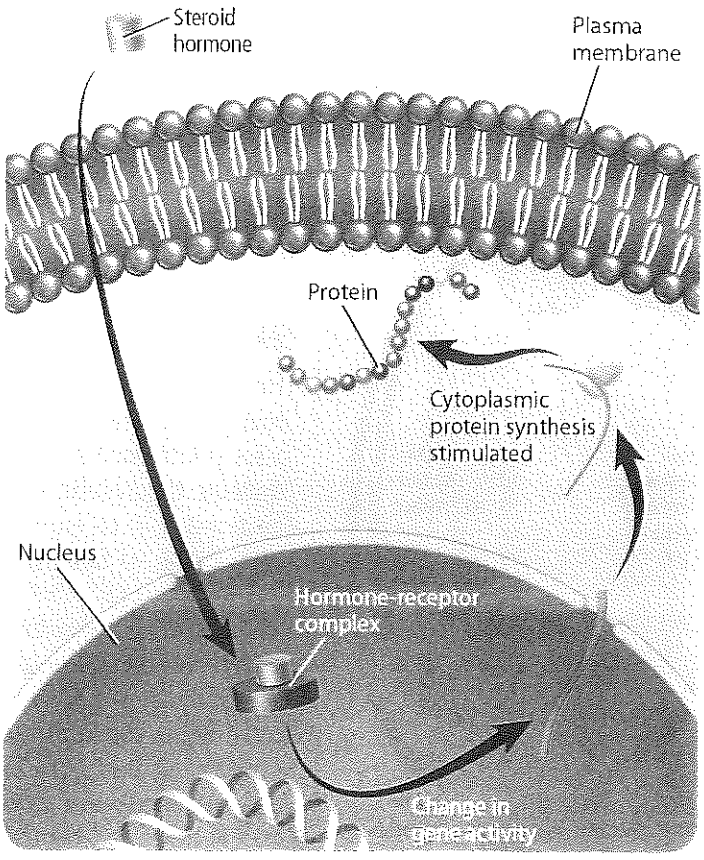


Figure 12 A steroid hormone passes through a cell membrane, binds to a receptor within the cell, and stimulates protein synthesis.

Animation

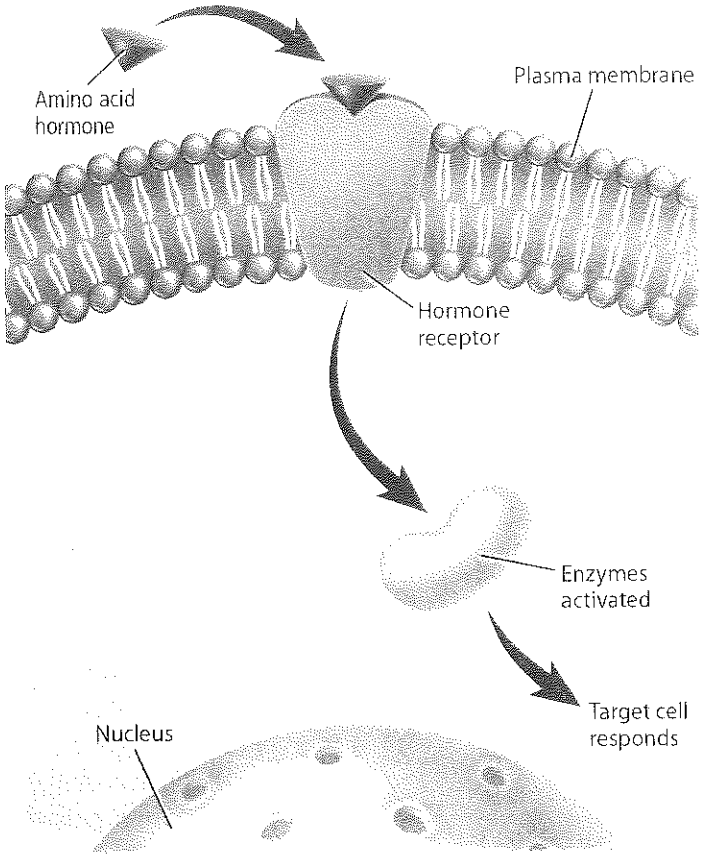


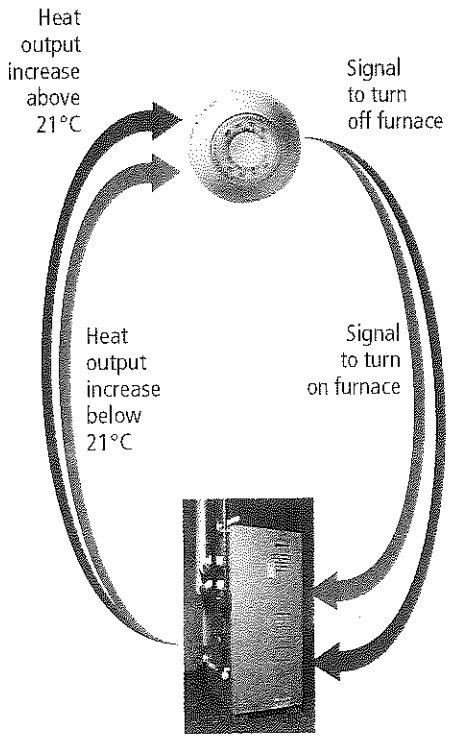
Figure 13 An amino acid hormone binds to a receptor on the plasma membrane before entering the cell.
Explain *the difference between amino acid hormones and steroid hormones.*

Animation

Steroid hormones are soluble in lipids and therefore can diffuse through the plasma membrane of a target cell. Once inside a target cell, they bind to a receptor in the cell. The hormone and the receptor that are bound together bind to DNA in the nucleus, which activates specific genes.

Amino acid hormones Insulin and growth hormones are two examples of nonsteroid, or amino acid, hormones. As the name implies, these hormones are composed of amino acids. Amino acid hormones must bind to receptors found on the plasma membrane of a target cell because they cannot diffuse through the plasma membrane. Once the hormone binds to the receptor, the receptor activates an enzyme found on the inside of the membrane. This usually initiates a biochemical pathway, eventually causing the cell to produce the desired response, as illustrated in **Figure 13.**

Figure 14 A furnace turns on or off based on the relationship of the detected room temperature and the set point.



Negative Feedback

Homeostasis in the body is maintained by internal feedback mechanisms called negative feedback. Negative feedback returns a system to a set point once it deviates sufficiently from that set point. As a consequence, the system varies within a particular range. You already might be familiar with an example of a negative feedback system in your own home, as illustrated in **Figure 14.**

For example, the temperature in a house might be maintained at 21°C. The thermostat in the house detects the temperature, and when the temperature drops below 21°C, the thermostat sends a signal to the heat source, which turns it on and produces more heat. Soon the temperature rises above 21°C, and the thermostat sends a signal to the heat source to shut off. The heat source will not turn on again until the room temperature drops below 21°C and is detected by the thermostat. Because this process can go on indefinitely, negative feedback often is described as a loop.

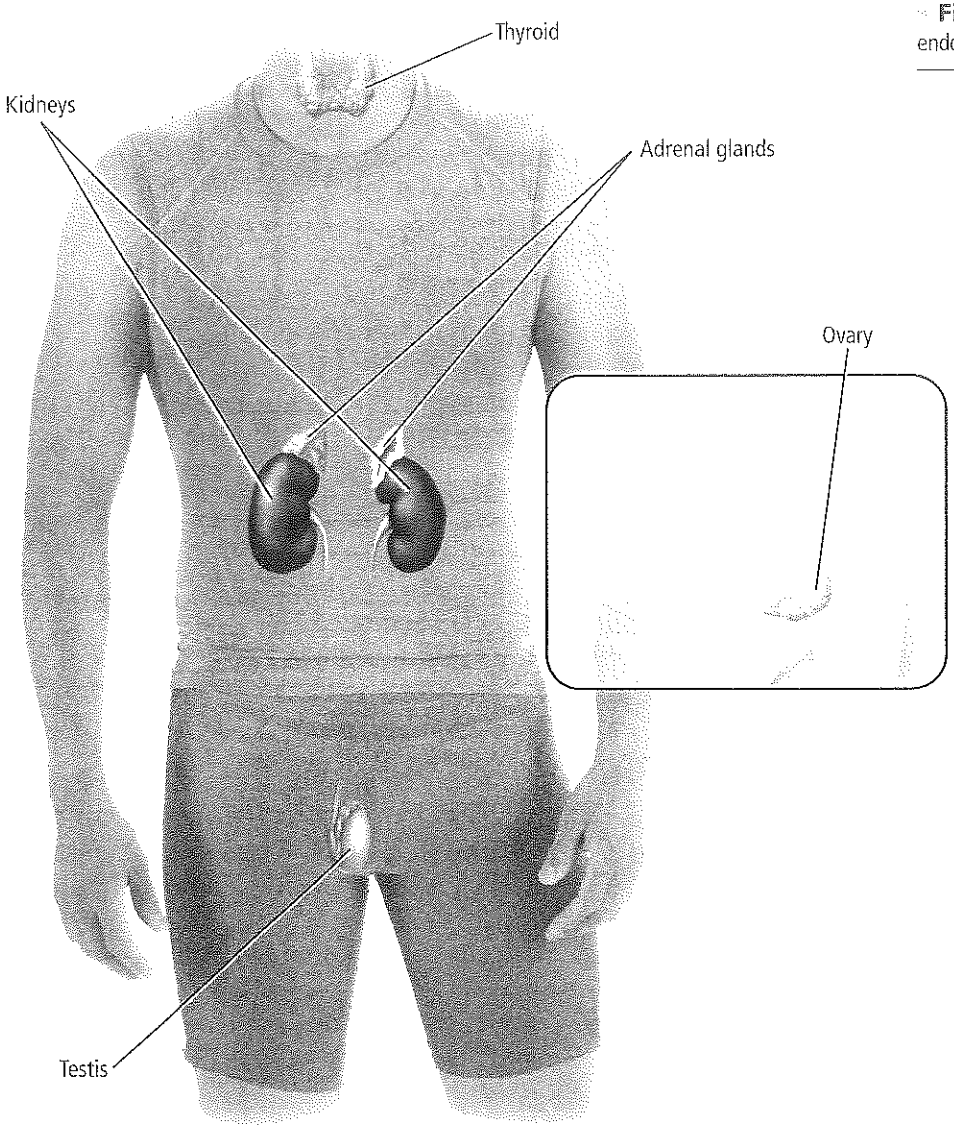


Figure 15 The principal glands of the endocrine system are located throughout the body.

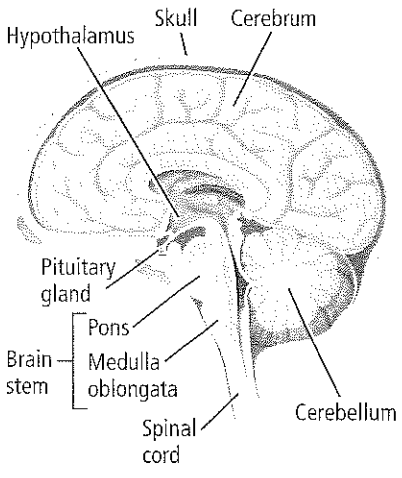
Endocrine Glands and Their Hormones

The endocrine system, shown in **Figure 15,** includes all the glands that secrete hormones—pituitary, thyroid, parathyroid, and adrenal glands, the pancreas, ovaries, testes, pineal gland, and the thymus gland.

Pituitary gland The pituitary gland is situated at the base of the brain, as illustrated in **Figure 16.** This gland is sometimes called the "master gland" because it regulates so many body functions. Despite its small size, it is the most important endocrine gland. The **pituitary gland** secretes hormones that not only regulate many body functions but also regulates other endocrine glands, such as the thyroid gland, the adrenal glands, the testes, and the ovaries.

A few pituitary hormones act on tissues rather than on specific organs. Human growth hormone (hGH) regulates the body's physical growth by stimulating cell division in muscle and bone tissue. This hormone is especially active during childhood and adolescence.

Figure 16 The pituitary gland is located at the base of the brain. This gland has a diameter of approximately 1 cm and weighs 0.5–1 g.



Tim Fuller

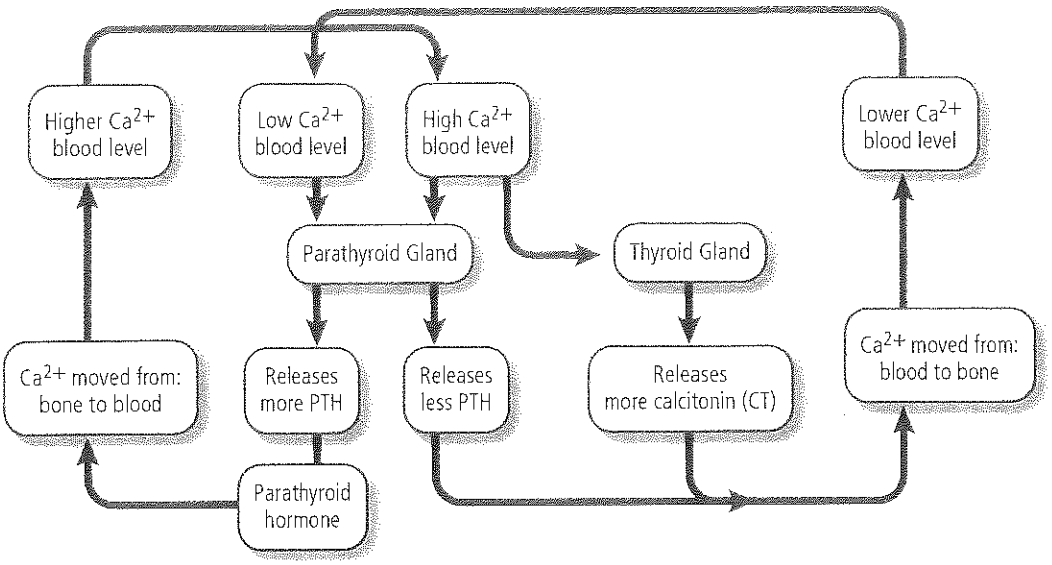
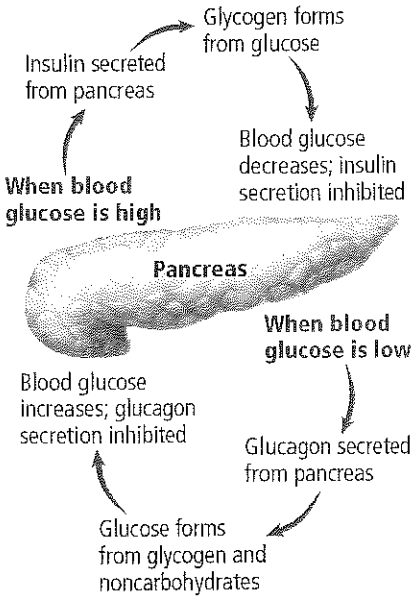


Figure 17 Parathyroid hormone (PTH) and calcitonin (CT) regulate the level of calcium in the blood.
Explain *how PTH and CT illustrate negative feedback.*

Personal Tutor

Figure 18 Glucagon and insulin work together to maintain the level of sugar in the blood.



Thyroid and parathyroid glands Identify the thyroid and parathyroid glands in **Figure 17.** One hormone produced by the thyroid gland is thyroxine. Like hGH, **thyroxine** does not act on specific organs; rather, it causes cells of the body to have a higher rate of metabolism. The thyroid gland also produces calcitonin. **Calcitonin** (kal suh TOH nun) is a hormone that is partly responsible for the regulation of calcium, an important mineral for bone formation, blood clotting, nerve function, and muscle contraction. Calcitonin lowers blood calcium levels by signaling bones to increase calcium absorption and also signaling the kidneys to excrete more calcium.

When blood calcium levels are too low, the parathyroid glands increase production of parathyroid hormone. **Parathyroid hormone** increases blood calcium levels by stimulating the bones to release calcium. The action of this hormone also causes the kidneys to reabsorb more calcium and the intestines to absorb more calcium from food. The thyroid and parathyroid glands have opposite effects on blood calcium levels. However, as they work together, they maintain homeostasis.

Reading Check **Explain** how negative feedback is important in maintaining homeostasis.

Pancreas As discussed in Section 1, the pancreas has a crucial role in the production of enzymes that digest carbohydrates, proteins, and fats. The pancreas also secretes the hormones insulin and glucagon, which work together to maintain homeostasis, as illustrated in **Figure 18.** When blood glucose levels are high, the pancreas releases insulin. **Insulin** signals body cells, especially liver and muscle cells, to accelerate the conversion of glucose to glycogen, which is stored in the liver. When blood glucose levels are low, glucagon is released from the pancreas. **Glucagon** (GLEW kuh gahn) binds to liver cells, signaling them to convert glycogen to glucose and release the glucose into the blood.

Diabetes is a disease that results from the body not producing enough insulin or not properly using insulin. Type 1 diabetes, which usually appears in people by the age of 20, occurs when the body cannot produce insulin. Type 2 diabetes occurs in 70-80 percent of people diagnosed with diabetes, and usually occurs after the age of 40. It results from the cells of the body becoming insensitive to insulin. Complications from diabetes include coronary heart disease, retinal and nerve damage, and acidosis, or low blood pH. In both types of diabetes, the blood glucose levels must be monitored and maintained to prevent complications from the disease.

Adrenal glands Refer again to **Figure 15.** The adrenal glands are located just above the kidneys. The outer part of the adrenals is called the cortex, which manufactures the steroid hormone aldosterone and a group of hormones called glucocorticoids. **Aldosterone** (al DAWS tuh rohn) primarily affects the kidneys and is important for reabsorbing sodium. **Cortisol,** another glucocorticoid, raises blood glucose levels and also reduces inflammation.

The body has different mechanisms for responding to stress, such as those concerning the role of the nervous system and the "fight or flight response." The endocrine system also is involved with these types of responses. An "adrenaline rush" occurs when there seems to be a sudden burst of energy during a stressful situation. The inner portions of the adrenal glands secrete epinephrine (eh puh NEH frun), also called adrenaline, and norepinephrine. Together, these hormones increase heart rate, blood pressure, breathing rate, and blood sugar levels, all of which are important in increasing the activity of body cells.

CAREERS IN BIOLOGY

Endocrinologist An endocrinologist studies glands that secrete hormones and the diseases involving those glands.

FOLDABLES

Incorporate information from this section into your Foldable.

MiniLab 2

MiniLab

Model the Endocrine System

How do hormones help the body maintain homeostasis? Activities such as taking a test or running a race place demands on your body. Your body's responses to these demands cause changes in your body. Your endocrine and nervous systems work together to ensure a stable internal environment.

Procedure

1. Read and complete the lab safety form.
2. Identify a sport or activity. Brainstorm what body actions occur as you prepare for, take part in, and recover from the activity.
3. Imagine that you are writing a computer program that your body will follow to complete the activity. Sequence the steps that you brainstormed in Step 2.
4. Review your program. Insert steps where the endocrine system might secrete hormones to maintain homeostasis. Use your knowledge and available resources to identify the specific hormones involved. Include body responses to these hormones as separate steps.
5. Compare your program with those developed by other students.

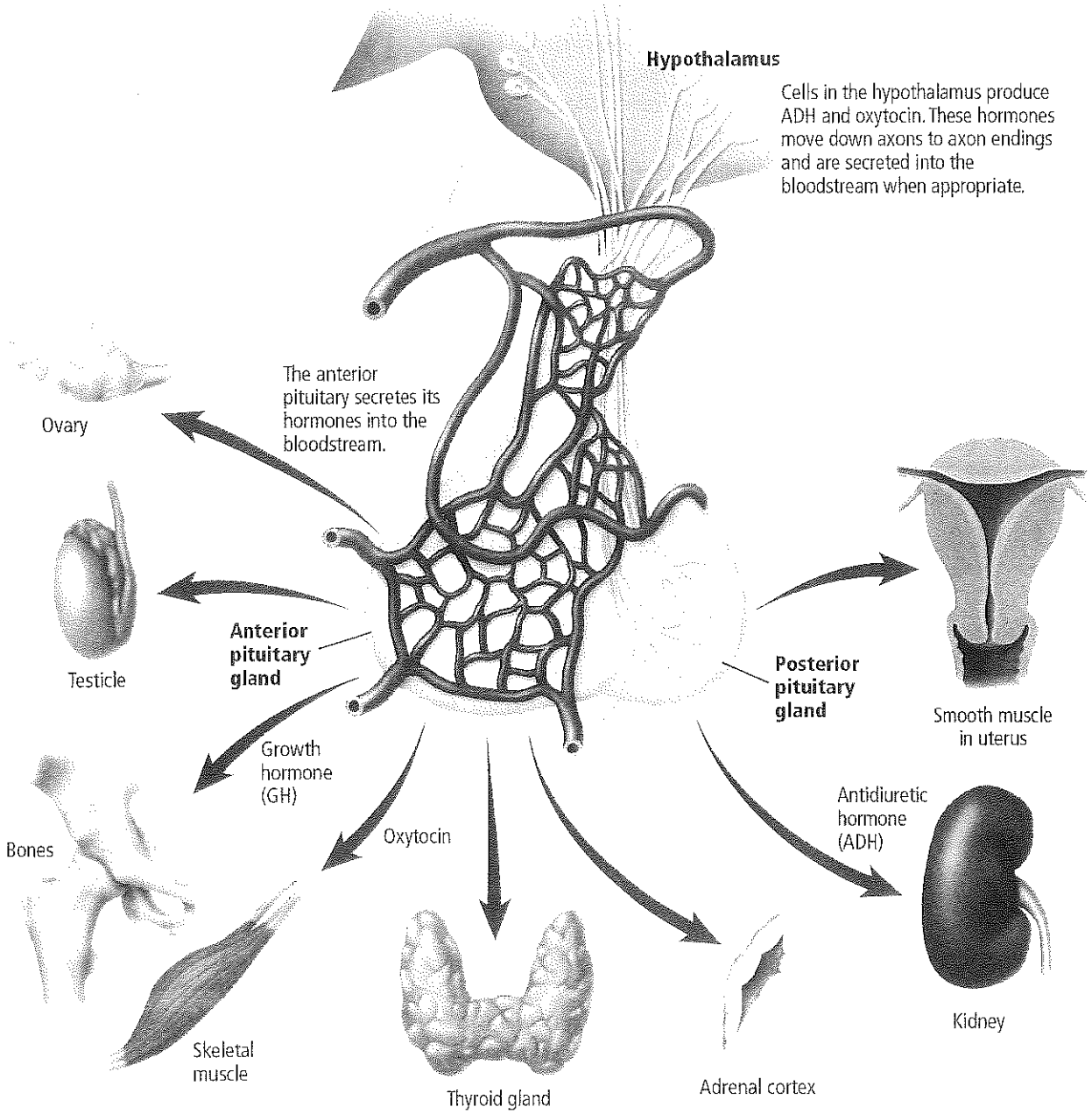
Analysis

1. **Think Critically** Did some of the same hormones appear in most of the other programs that you studied in Step 5? Why or why not?
2. **Draw conclusions** by describing the major body systems represented in your program. What does this show about the range of body functions controlled by the endocrine system?

Visualizing the Endocrine System

Figure 19

The hypothalamus maintains homeostasis by serving as a link between the nervous system and the endocrine system. The pituitary releases growth hormone, ADH, and oxytocin as needed by the body. The pituitary gland also manufactures and secretes hormones that regulate the testes, the ovaries, and the thyroid and adrenal glands.



Link to the Nervous System

The nervous and endocrine systems are similar in that they both are involved in regulating the activities of the body and maintaining homeostasis. Refer to **Figure 19** to study the role of the hypothalamus in homeostasis. Recall that this part of the brain is involved with many aspects of homeostasis. The hypothalamus produces two hormones, oxytocin (ahk sih TOH sun) and antidiuretic hormone (ADH). These hormones are transported through axons and stored in axon endings located in the pituitary gland.

The **antidiuretic** (AN ti DY yuh REH tic) **hormone** (ADH) functions in homeostasis by regulating water balance. ADH affects portions of the kidneys called the collecting tubules. Think back to the last time you were working outside on a hot summer day. You produced a lot of sweat to help keep you cool, and you might have become dehydrated. When this happens, cells in your hypothalamus detect that you are dehydrated--that the level of water in the blood is low--and respond by releasing ADH from axons in the pituitary gland that have been storing the hormone.

As illustrated in **Figure 20,** ADH travels in the blood to the kidneys, where it binds to receptors on certain kidney cells. This causes the kidneys to reabsorb more water and decrease the amount of water in the urine, increasing the water level in the blood. If there is too much water in a person's blood, the hypothalamus decreases the release of ADH, and the urine tends to be more dilute. ADH production is stimulated by nausea and vomiting, both of which cause dehydration. Blood loss of 15 or 20 percent by hemorrhage results in the release of ADH.

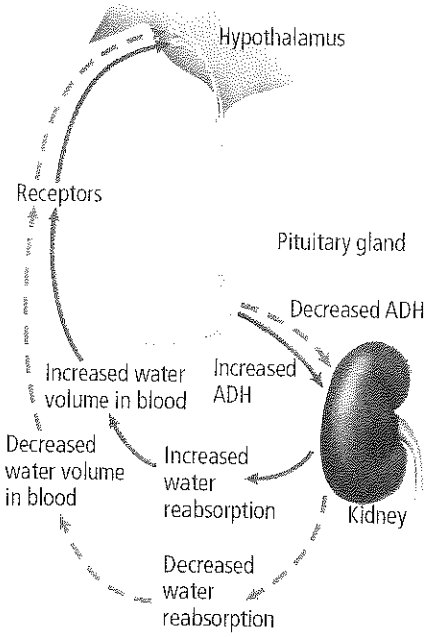


Figure 20 Antidiuretic hormone (ADH) helps to control the concentration of water in the blood.

Section 3 Assessment

Section Summary

- Endocrine glands produce substances called hormones.
- Hormones travel throughout the body in the bloodstream.
- Hormones are classified as steroid hormones or amino acid hormones.
- Hormone levels are influenced by feedback systems.
- The endocrine system helps to maintain homeostasis with signals from internal mechanisms called negative feedback.

Understand Main Ideas

1. **Assess** the reasons why hormone feedback systems are referred to as "negative feedback."
2. **Predict** when you would expect to find high levels of insulin in a person's blood and when you would expect to find high levels of glucagon in a person's blood.
3. **Explain** how the endocrine and nervous systems work together to maintain homeostasis.
4. **Identify** and describe the functions of pituitary, thyroid, parathyroid, pancreas, and adrenal glands.

Think Critically

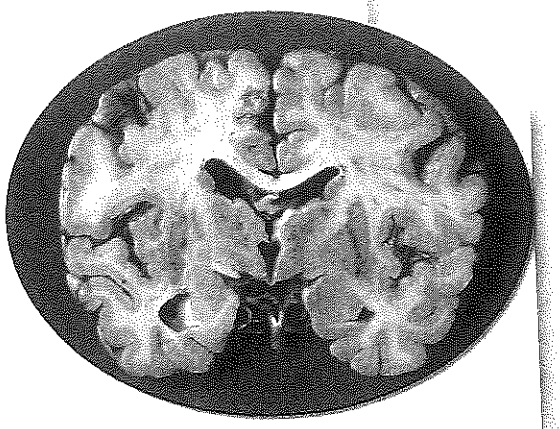
5. **Research** Iodine is essential for thyroid gland function. Fetal and childhood iodine deficiency is a major cause of mental retardation in the world, yet the deficiency is preventable. Predict how iodine deficiency might lead to mental retardation or other health issues. Research what has been and what is being done to alleviate this concern. Include information about sources of iodine in your response.
6. **Analyze** how a malfunction in a negative feedback mechanism can lead to the death of an organism.

Online Quiz

In the Field

Careers: Forensic Pathologist and Forensic Toxicologist

Tools and Techniques of Forensic Pathology



A brain slice might be used to determine a cause of death.

Can a dead person talk? In a way, yes. The condition of a dead body can speak volumes about the circumstances surrounding the death. Forensic pathologists gather data from a body, then analyze it to determine when and how a person died. The tools, techniques, and scientific methods that forensic pathologists use help investigators plot the last hours of a person's life, as well as the events that led to death.

Clues from an autopsy The purpose of an autopsy is to make a permanent legal record of a body's characteristics. A forensic pathologist is trained to examine victims of sudden, unexpected, or violent deaths. During an autopsy, the pathologist examines and weighs the lungs, brain, heart, liver, and stomach. He or she uses a scalpel to slice thin sections of the organs, such as the brain slice shown at the right. The slices are chemically preserved to prevent further decay.

Digestion and time of death During the autopsy, the pathologist examines the victim's stomach contents. Why is this important? At the moment of death, digestion stops. The pathologist can use the condition of the stomach to estimate a time line. If the stomach is entirely empty, the victim probably died at least three hours after he or she last ate. If the small intestine also is empty, death likely occurred at least ten hours after the last meal.

Is it possible to identify the type of food in the stomach? In some cases, yes. A scanning electron microscope can be used to identify food particles. A stomach sample that matches the last known meal also can help investigators establish a time period.

Stomach contents can reveal poisoning Toxic substances such as household products, poisons, and drugs can be involved in a death. A forensic toxicologist, a specialist who can identify foreign chemicals that can lead to death, might be called.

While one piece of evidence rarely serves as conclusive proof, forensic pathologists are trained to note specific details. These details can add up and sometimes help tell the story of the final hours of a person's life.

WRITING in Biology

Classifieds Your city has an opening for a forensic pathologist. Write an advertisement for the job. Be sure to include specific techniques and procedures with which applicants should be familiar, as well as general skills and characteristics applicants should have.

WebQuest

BIOLAB

Design Your Own

HOW DOES THE RATE OF STARCH DIGESTION COMPARE AMONG CRACKERS?

Background: **Starch digestion begins in the mouth. The enzyme amylase, present in saliva, catalyzes the breakdown of starch into sugar molecules, the smallest of which is glucose, an important energy source. Foods, including crackers, vary in starch content. In this lab, you will compare how quickly starch is digested in several types of crackers to determine the relative amount in each.**

Question: *How does the amount of time required for starch digestion by amylase compare among various types of crackers?*

Possible Materials

variety of crackers
mortar and pestle
test tubes and test tube rack
filter paper
funnels
balance
beaker
Bunsen burner or hot plate
graduated cylinder
iodine solution
droppers
watch glasses
amylase solution
glass markers or wax pencil

Safety Precautions

WARNING: ***Iodine can irritate and will stain skin.***

Plan and Perform the Experiment

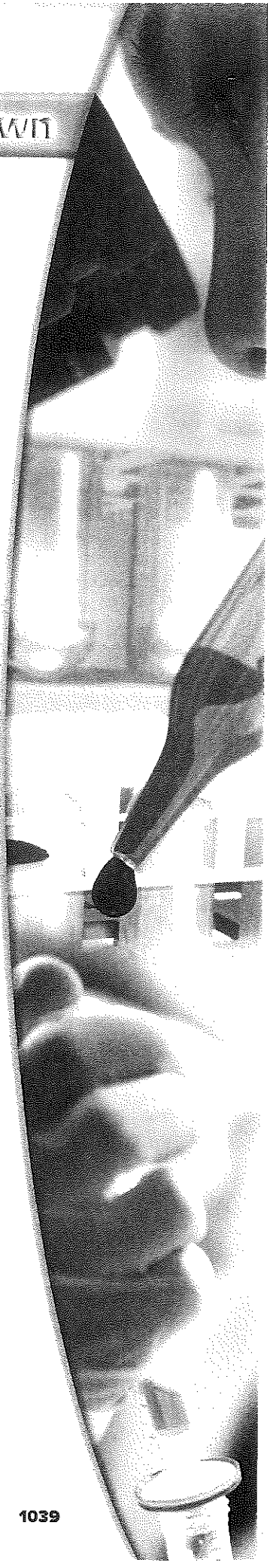
1. Read and complete the lab safety form.
2. Examine three types of crackers. Design an experiment to compare the amount of time required to digest the starch in each. You will use the enzyme amylase to stimulate the digestion of starch. Iodine, a chemical indicator that turns blue-black when starch is present, will indicate when starch digestion is complete.
3. Construct a data chart to record your observations.
4. Consider these points with your group and modify the plan as necessary.
   - What factors will be held constant?
   - Have you established a control sample?
   - How will you know when starch digestion is complete in each sample?
   - How will you keep constant the amount of each type of cracker tested?
   - Will the chart accommodate your data?
5. Make sure your teacher approves your plan before you proceed.
6. Carry out your experiment.
7. **Cleanup and Disposal** Dispose of test tube contents as directed. Clean and return glassware and equipment. Wash your hands thoroughly after handling chemicals and glassware.

Analyze and Conclude

1. **Analyze** how the amylase affected the starch in the crackers.
2. **Observe and Infer** In which cracker was starch digested most quickly? What does this indicate about the amount of starch in this cracker compared to the others?
3. **Think Critically** What variations among human mouths might affect the action of amylase on starch? Explain.
4. **Error Analysis** Did any steps in your procedure introduce uncontrolled variables into the experiment? Explain how the procedure could be redesigned to make these factors constant.

APPLY YOUR SKILL

Design an experiment to determine how varying a condition such as temperature or pH would affect the digestion of starch by amylase in one of the crackers.



Chapter 35 Study Guide

THEME FOCUS Cause and Effect Homeostasis is maintained by negative feedback in glands such as the thyroid, parathyroid, pancreas, and adrenal glands.

BIG Idea The digestive system breaks down food to provide energy and nutrients for the body. The endocrine system produces hormones that regulate body functions.

Section 1 The Digestive System

mechanical digestion (p. 1020)
chemical digestion (p. 1020)
amylase (p. 1020)
esophagus (p. 1021)
peristalsis (p. 1021)
pepsin (p. 1021)
small intestine (p. 1022)
liver (p. 1022)
villus (p. 1023)
large intestine (p. 1024)

Key Idea The digestive system breaks down food so nutrients can be absorbed by the body.

- The digestive system has three main functions.
- Digestion can be categorized as mechanical or chemical.
- Most nutrients are absorbed in the small intestine.
- Accessory organs provide enzymes and bile to aid digestion.
- Water is absorbed from chyme in the colon.

Section 2 Nutrition

nutrition (p. 1025)
Calorie (p. 1025)
vitamin (p. 1028)
mineral (p. 1028)

Key Idea Certain nutrients are essential for the proper function of the body.

- The energy content of food is measured in Calories.
- Carbohydrates, fats, and proteins are three major groups of nutrients.
- Carbohydrates are a major source of energy for the body.
- Fats and proteins provide energy and are important building blocks for the body.
- Vitamins and minerals are essential for proper metabolic functioning.
- The *MyPyramid Plan* and food labels are tools you can use to eat healthfully.

Section 3 The Endocrine System

endocrine gland (p. 1031)
hormone (p. 1031)
pituitary gland (p. 1033)
thyroxine (p. 1034)
calcitonin (p. 1034)
parathyroid hormone (p. 1034)
insulin (p. 1034)
glucagon (p. 1034)
aldosterone (p. 1035)
cortisol (p. 1035)
antidiuretic hormone (p. 1037)

Key Idea Systems of the human body are regulated by hormonal feedback mechanisms.

- Endocrine glands produce substances called hormones.
- Hormones travel throughout the body in the bloodstream.
- Hormones are classified as steroid hormones or amino acid hormones.
- Hormone levels are influenced by feedback systems.
- The endocrine system helps to maintain homeostasis with signals from internal mechanisms called negative feedback.

Vocabulary eGames

Chapter 35 Assessment

Section 1

Vocabulary Review

For each set of terms, choose the one term that does not belong and explain why it does not belong.

1. esophagus, pancreas, large intestine

2. pepsin, glycogen, glucose

3. bile, amylase, peristalsis

Understand Main Ideas

4. Which action takes place in the stomach?
   - A. Large fat molecules are digested into smaller molecules.
   - B. Proteins are broken down.
   - C. Amylase breaks down starches into smaller sugar molecules.
   - D. Insulin is secreted for use in the small intestine.

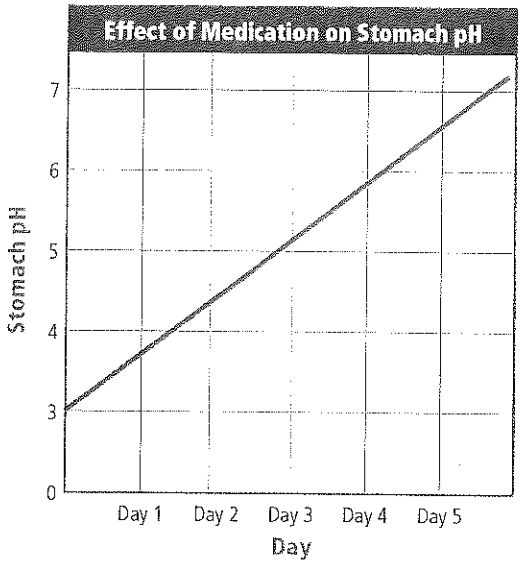
5. Which row in the chart contains the words that best complete this statement? The (1) produces (2), which is secreted into the (3).

Row	1	2	3
A	liver	bile	small intestine
B	gallbladder	pepsin	stomach
C	pancreas	acid	large intestine
D	villi	amylase	mouth

   - A. Row A
   - B. Row B
   - C. Row C
   - D. Row D

6. A person complaining of digestion problems is not digesting fats well. Which is a reasonable explanation for this condition?
   - A. The pyloric sphincter is blocked.
   - B. The bile duct is blocked.
   - C. The person is secreting excess bile.
   - D. The stomach is secreting too much acid.

Use the graph to answer question 7.



7. A person has been taking a medication for 5 days. Which of the following is likely to be a consequence of this medication?
   - A. Pepsin would not be able to break down proteins.
   - B. Amylase would not be able to break down starch.
   - C. Bile would not be able to be produced.
   - D. Enzymes secreted by the pancreas would not function well.

Constructed Response

8. **Short Answer** Explain why the term *heartburn* is an inaccurate description of this condition.

9. LINK Refer to **Table 1** to summarize the digestive processes that occur in the following structures: mouth, large intestine, stomach, small intestine, and esophagus.

10. **Open Ended** Why can a person live without a gall bladder? Assess the effects, if any, that this would have on the person's ability to digest food.

Think Critically

11. **Explain** why a drug manufacturer might add vitamin K to some antibiotics in tablet or pill form.

12. **Hypothesize** why the human body has an appendix if the appendage has no known useful function.

Chapter 35 Assessment

Section 2

Vocabulary Review

Describe each of the following vocabulary terms.

13. nutrition

14. vitamin

15. Calorie

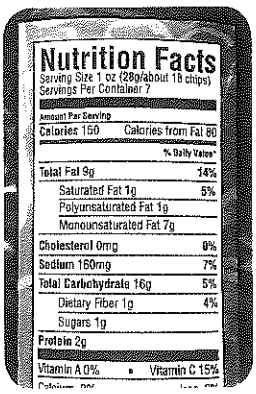
Understand Main Ideas

16. Which are characteristics of saturated fats?
    - A. liquid at room temperature and found in vegetable oils
    - B. mostly absorbed in the large intestine
    - C. derived from animal sources and are solid at room temperature
    - D. tend to lower blood cholesterol

17. Which carbohydrate is not digestible and provides fiber in your diet?
    - A. sucrose
    - B. starch
    - C. glycogen
    - D. cellulose

18. Which combinations in the stomach break down high-protein foods?
    - A. a low pH and pepsin
    - B. a high pH and bile
    - C. a high pH and pepsin
    - D. a low pH and bile

Use the image below to answer question 19.



19. If you ate the entire bag of chips, what percent of the recommended daily value of saturated fat would you consume?
    - A. 14 percent
    - B. 28 percent
    - C. 5 percent
    - D. 35 percent

Constructed Response

20. CAREERS IN BIOLOGY According to dieticians, low-carbohydrate diets are usually high in fat and protein. Evaluate what health risks might be associated with a long-term intake of foods high in fats and proteins.

21. THINK (Diet) Describe what factors, besides not having enough food, might cause a person to be malnourished.

Think Critically

22. **Explain** why a diet high in fiber might reduce the chance of colon cancer.

23. **Infer** the reasons why obesity rates in the United States have continued to rise steadily for at least the past 30 years.

Section 3

Vocabulary Review

Explain the difference between the terms in each pair. Then explain how the terms are related.

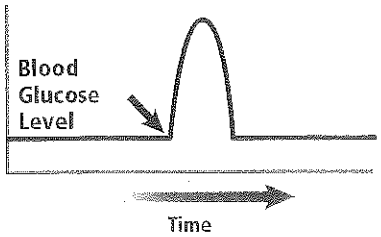
24. insulin, glucagon

25. estrogen, growth hormone

26. cortisol, epinephrine

Understand Main Ideas

Use the graph below to answer question 27.



27. The graph shows blood glucose levels over a period of time. Which hormone might have caused a sudden surge as indicated by the arrow?
    - A. antidiuretic hormone
    - B. growth hormone
    - C. glucagon
    - D. insulin

Jonathan Nourok/PhotoEdit

Online Test Practice

28. Which hormones are released from nerve cells rather than from endocrine glands?
   A. antidiuretic hormone and oxytocin
   B. growth hormone and thyroxine
   C. insulin and glucagon
   D. norepinephrine and epinephrine

29. Which pairs of hormones have opposite effects?
   A. calcitonin and parathyroid hormone
   B. epinephrine and norepinephrine
   C. growth hormone and thyroxine
   D. aldosterone and cortisol

Use the photos below to answer question 30.

A.

B.

30. Which person is likely to have high levels of epinephrine?
   A. person A
   B. person B
   C. both persons
   D. neither person

Constructed Response

31. **THEME FOCUS Cause and Effect** What would be the direct effect of overproduction of calcitonin? Analyze how this might disrupt homeostasis in systems other than the endocrine system.

32. **Short Answer** Assess how the long-term use of cortisol would impact a person's ability to fight infection.

Think Critically

33. **BIG Idea** Create an analogy using a balance describing the relationship between calcitonin and parathyroid hormone.

34. **Hypothesize** Why is insulin usually injected instead of taken orally?

Summative Assessment

35. **BIG Idea** Breakfast is considered the most important meal of the day. Based on the food pyramid, plan a balanced breakfast and explain why the nutrients are important. Then describe the processes that will take place in your digestive and endocrine systems after you have eaten. Why is breakfast so important?

36. **WRITING in Biology** This chapter began with a situation where you were eating a pizza. Write a short story describing the events that occur as the food moves through your digestive tract. *Hint: Be sure to include all major groups of nutrients.*

Document-Based Questions

Source: *Dietary Guidelines for America 2005*

Estimated Calorie Requirements in Gender and Age Groups

Gender	Age	Moderately Active	Active
Female	9–13	1600–2000	1800–2200
	14–18	2000	2400
	19–30	2000–2200	2400
	31–50	2000	2200
	51+	1800	2000–2200
Male	9–13	1800–2200	2000–2600
	14–18	2400–2800	2800–3200
	19–30	2600–2800	3000
	31–50	2400–2600	2800–3000
	51+	2400	2400–2800

37. According to the chart, which gender needs more Calories?

38. Describe the general trend regarding the number of Calories needed to maintain energy balance in relation to age.

39. Why do individuals in the 19-30-year-old group need the most Calories?

Online Test Practice

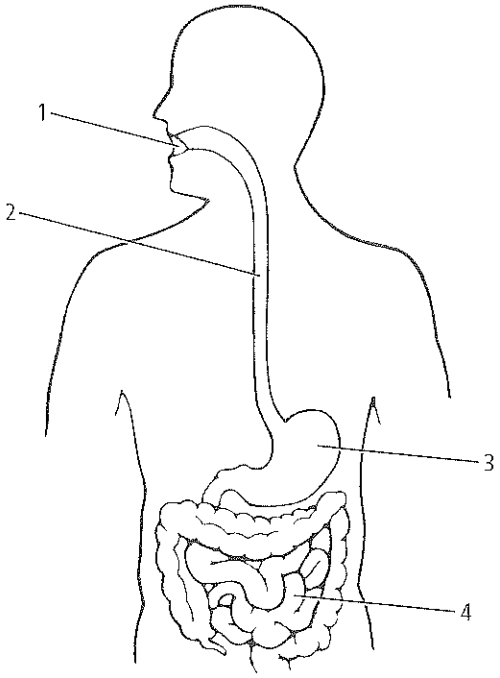
Standardized Test Practice

Cumulative

Multiple Choice

1. What is the function of melanin in the epidermis?
   A. to protect tissue from ultraviolet radiation
   B. to provide support for blood vessels
   C. to stimulate the growth of hair in the follicles
   D. to waterproof and protect the skin surface

Use the diagram below to answer questions 2 and 3.

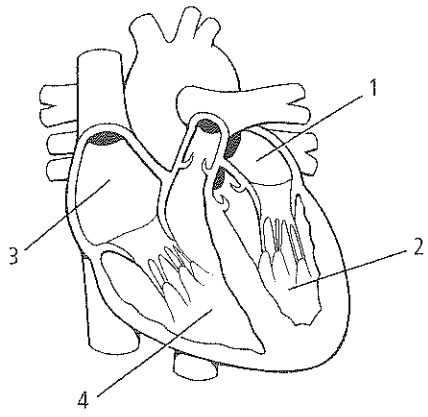


2. In which part of the digestive system do chemical and mechanical digestion first occur?
   A. 1
   B. 2
   C. 3
   D. 4

3. Which process happens first in a nerve cell when a stimulus reaches its threshold?
   A. Potassium channels in the cell membrane open.
   B. Neurotransmitters are released into the synapse.
   C. Sodium ions move into the nerve cell.
   D. The cell becomes negatively charged.

4. Where would fat stored in bones be found?
   A. compact bone
   B. osteocytes
   C. red marrow
   D. yellow marrow

Use the diagram below to answer question 5.

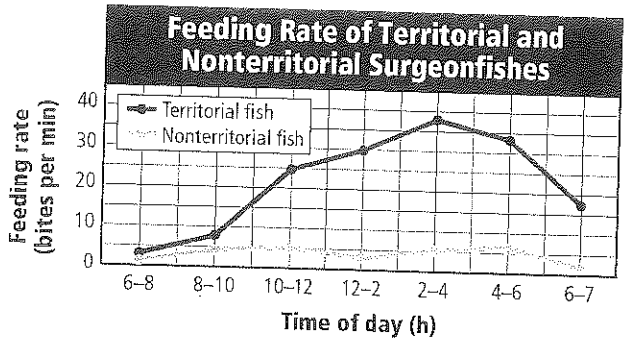


5. Which is the path that blood follows as it flows through the heart immediately after returning from the head and body?
   A. 1 → 2
   B. 2 → 1
   C. 3 → 4
   D. 4 → 3

6. Which describes how filtering occurs in the excretory system?
   A. Blood enters nephrons of the kidneys, and excess water and wastes are filtered from the blood.
   B. Urine leaves the kidneys through ureters.
   C. Water and nutrients are absorbed back into the blood.
   D. Water is added to excess nitrogenous wastes from the digestive system to form urine.

Short Answer

Use the graph below to answer questions 7 and 8.



7. Compare and contrast the feeding behavior of the fishes shown in the graph.

8. Predict how the graph might appear if the territorial fish showed territorial behavior only during one season of the year.

9. Assess why a diet with no protein would be unhealthy.

10. What are two benefits to the young of mammals in receiving milk from their mothers?

11. Explain how the different body structures in roundworms and annelids enable them to move.

12. A person who exercises in extreme heat can lose salts that contain potassium and sodium through his or her sweat. What can you infer about the effect of overexertion on the nervous system?

13. Differentiate the three main vessels through which blood flows as it goes from the heart through the body and returns to the heart.

Extended Response

14. Evaluate how a swim bladder helps a fish maintain its depth.

15. Evaluate how high blood pressure and kidney damage could be related.

16. Name three components of sympathetic stimulation, and assess how they could be helpful to a human's survival.

Essay Question

Humans need vitamin C in their diets because it strengthens the function of the immune system and prevents a disease called scurvy. Vitamin C is water-soluble, so it is not stored in the body. Vitamin C is often suggested for someone who is just getting sick or is already sick. Some people recommend taking very high doses of vitamin C, sometimes even thousands of times higher than the recommended dose. Medical researchers disagree about the effectiveness of taking large doses of vitamin C. Some think that it does nothing, while others think that it is helpful. However, almost all medical researchers agree that taking large doses of vitamin C for short periods of time is probably not harmful.

Using the information in the paragraph above, answer the following question in essay format.

17. Formulate a hypothesis about whether taking large doses of vitamin C for a cold is helpful. Explain one way this hypothesis could be tested.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Review Section . . .	32.1	35.1	33.1	32.2	34.1	34.3	31.1	31.1	35.2	30.1	25.3	33.1	34.1	28.2	34.3	33.2	35.2