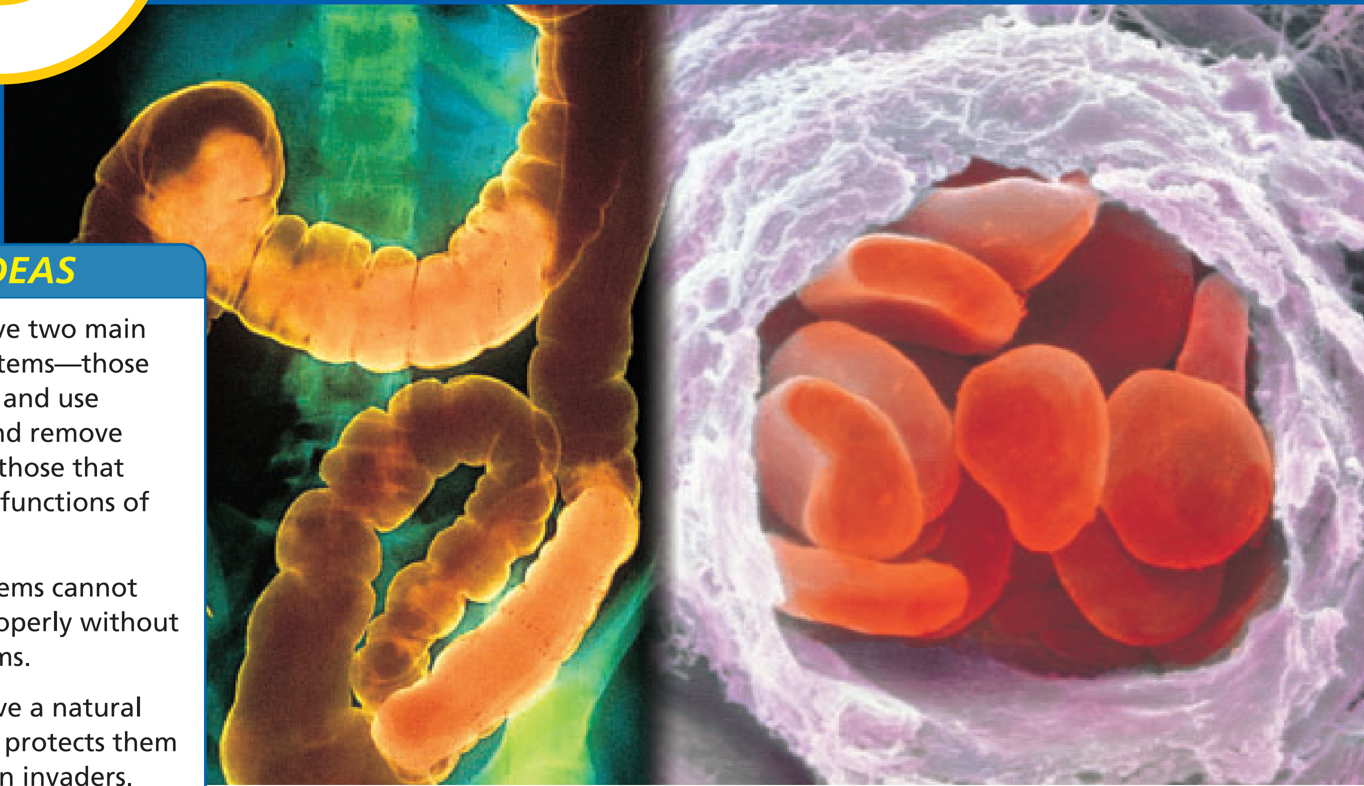
CHAPTER 3

Human Body Systems



KEY IDEAS

- Animals have two main types of systems—those that obtain and use nutrients and remove waste, and those that control the functions of the body.
- Animal systems cannot function properly without other systems.
- Humans have a natural system that protects them from foreign invaders.

A network of roads carries people and goods throughout a city. Similarly, a network of blood vessels, thousands of kilometres long, carries a living fluid throughout your body. The driving force is your heart, beating continuously day and night, over 40 million times a year. Why does your body need this system? Why is blood called a living fluid?

The heart is the engine of the body, but where does it get its fuel? All living things require a fuel, or source of energy. Humans get their energy from the food they eat. How does the body change the energy that is stored in food into the energy that is needed for physical activities and other life functions?

The human body can be compared with a complex machine. Like any machine, the body is made up of a number of systems. These systems work together to make the body function properly. Each system depends on every other system. If one system does not work properly, other systems will likely not work properly.

In this chapter, you will examine human body systems to understand the special functions that these systems carry out. By the end of this chapter, you will understand how human body systems are interdependent and work together to ensure that the body functions properly.

The Respiratory System 3.1

Oxygen enters a unicellular animal simply by diffusing across its cell membrane. The cell uses the oxygen and produces carbon dioxide, which diffuses out of the cell.

In larger and more complex animals, specialized cells work together to move fluids. For example, the respiratory system is responsible for absorbing oxygen from the air and removing carbon dioxide from the blood. Other systems are responsible for distributing the oxygen around the body and collecting the carbon dioxide.

The main organs of the human respiratory system are the trachea (commonly called the windpipe), the lungs, and the diaphragm (**Figure 1**). These organs are contained within the chest cavity. The chest cavity is surrounded and protected by the rib cage.

LEARNING TIP

Adjust your reading pace to reflect the importance of the material. Read more slowly until you have grasped the concepts.

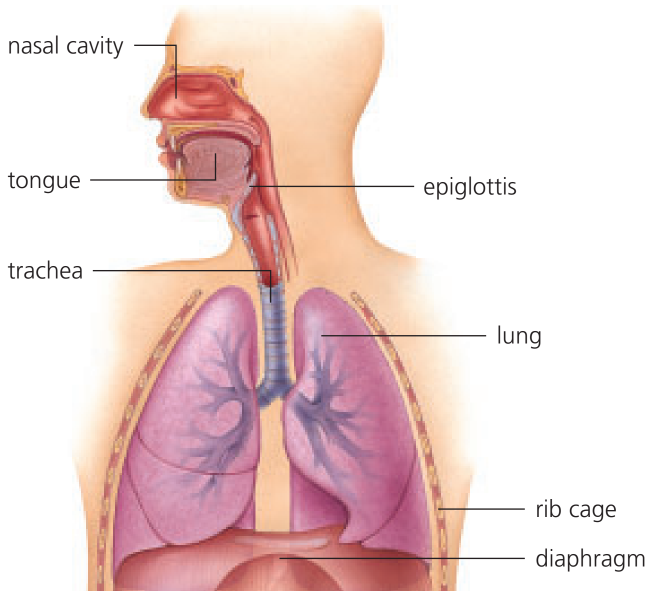


Figure 1
The human respiratory system

Breathing

The **diaphragm** is a large, thin sheet of muscle that spreads across the chest cavity below the lungs. The diaphragm is largely responsible for breathing. As well, the muscles between the ribs help with the movements of the chest that make you breathe. **Breathing** is the regular movement of air into and out of the lungs. When the diaphragm and the muscles between the ribs contract, you inhale. The chest cavity becomes larger, and air is forced into the lungs. When the diaphragm and the muscles between the ribs relax, you exhale. The chest cavity becomes smaller, and air is forced out of the lungs (**Figure 2**).

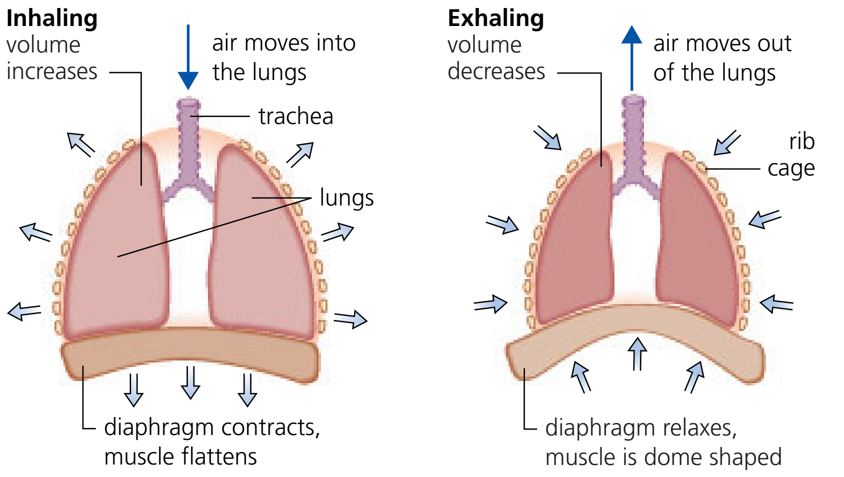


Figure 2
The contraction and relaxation of the diaphragm is largely responsible for breathing.

When you inhale, air moves through your mouth or nose and into the trachea. The **trachea** is a hard, ridged tube that leads to the lungs. You can feel the trachea in your throat—it feels something like a vacuum cleaner hose! The ridges are rings of cartilage that support the trachea and keep it open at all times. At the top of the trachea is a flap of tissue, called the **epiglottis**, that covers the opening of the trachea when you swallow. This prevents food or water from accidentally entering the lungs. Have you ever had food "go down the wrong way"? Sometimes, if you swallow quickly or laugh when you are swallowing, a little food or water gets into the trachea, and you automatically cough to remove it.

You can control your breathing to some degree. You can consciously or intentionally make yourself breathe faster or deeper. You can even stop your breathing for short periods of time. Breathing, however, is an automatic body function. Therefore, you do not have to think about contracting and relaxing the muscles that help you breathe. You continue to breathe even when you are asleep, and you would continue to breathe even if you were unconscious.

Respiration

All animals take in oxygen and release carbon dioxide in the process of **respiration**. Large animals have many trillions of cells, so they cannot depend on diffusion alone to ensure that each cell gets the oxygen it requires. The respiratory system does, however, depend on diffusion. Oxygen from the air diffuses through cell membranes into the bloodstream. The bloodstream then distributes the oxygen to all the cells in the body.

The lungs have many tiny air sacs, where gases are exchanged between the air and the blood (**Figure 3**). These air sacs increase the amount of surface area that is available for the exchange of gases. When you breathe in, or inhale, air that contains oxygen is brought into the air sacs. The oxygen diffuses out of the air sacs into tiny blood vessels, which surround each air sac. The oxygen is then distributed throughout the body by the bloodstream and diffuses into the cells, where it is needed. Carbon dioxide, a waste material that is produced in the cells, diffuses into the bloodstream and is brought back to the lungs. The carbon dioxide diffuses into the air sacs and is pushed out of the body when you breathe out, or exhale.

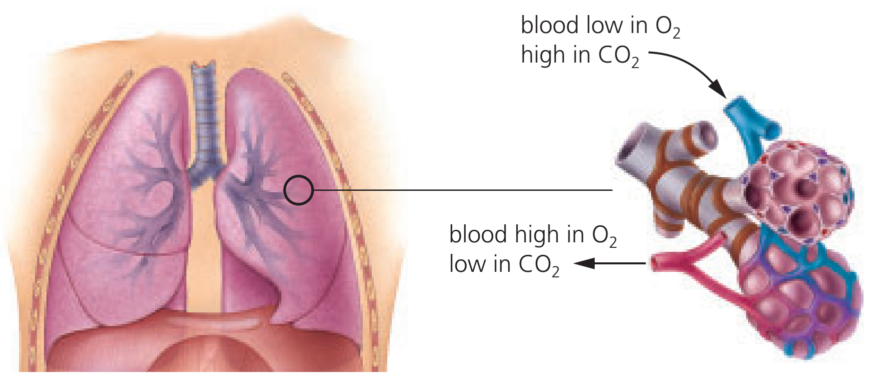


Figure 3
The inside of the lungs provides a very large surface area for oxygen to diffuse into the bloodstream and for carbon dioxide to diffuse out of the bloodstream.

3.1 CHECK YOUR UNDERSTANDING

1. Identify and explain the processes by which animals obtain the oxygen needed by their cells.
2. Even though you can control your breathing to some extent, why is breathing considered to be an automatic body function?
3. Explain the difference between breathing and respiration.
4. Where does diffusion take place in the respiratory system?

3.2 The Circulatory System

Life for a sponge is very simple. Seawater acts like a transport system, carrying nutrients and removing waste. Diffusion across the cell membranes moves the seawater into and out of the cells of the sponge.

As you have learned, a complex multicellular animal cannot rely on diffusion to deliver oxygen and nutrients to its cells. A circulatory system brings every cell into almost direct contact with oxygen and nutrients. In fact, no cell in the human body is farther than two cells away from a blood vessel that carries nutrients. The human circulatory system has about 96 000 km of blood vessels to sustain its 60 trillion cells.

Circulation

LEARNING TIP

Working with a partner, construct some key questions to guide your reading of the circulatory system. Locate the information needed to answer your questions by scanning the text for new vocabulary.

As its name suggests, the circulatory system circulates blood around the body. The blood carries oxygen-rich and nutrient-rich fluids to the body cells and picks up carbon dioxide and other waste to be eliminated from the body.

Open and Closed Circulatory Systems

In an open circulatory system, like that of the snail in **Figure 1**, blood carrying oxygen and nutrients is pumped into the body cavities, where it bathes the cells. When the heart relaxes, the blood is drawn back toward the heart through open-ended pores.

In a closed circulatory system, like that of the worm in **Figure 2**, blood is contained within blood vessels. The earthworm has five heart-like vessels that pump blood through two major blood vessels. Animals with more complex circulatory systems have larger blood

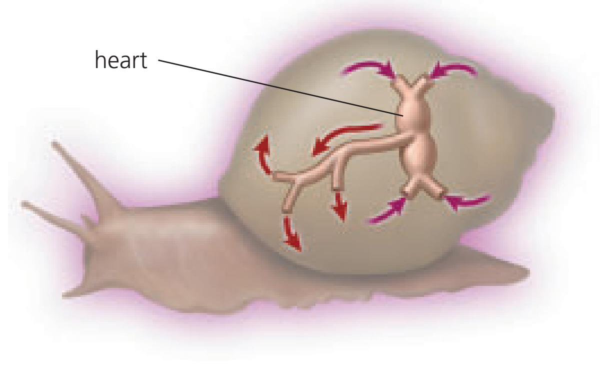


Figure 1
The snail has an open circulatory system.

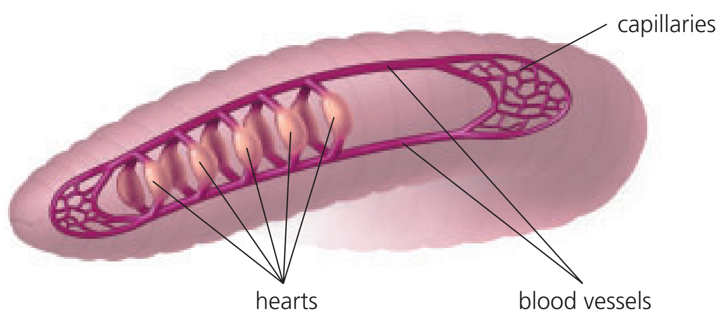


Figure 2
The worm has a closed circulatory system.

vessels that branch into smaller vessels, which supply blood to the various tissues. Blood vessels that carry blood away from the heart are called **arteries**. Blood vessels that return blood to the heart are called **veins**. Arteries branch into smaller and smaller blood vessels. The smallest blood vessels, called **capillaries**, are so small that red blood cells must travel through them in single file.

Twin Pumps

The heart is not a single pump in humans and other mammals, but two parallel pumps separated by a wall of muscle (**Figure 3**). There are four chambers: two atria (singular is *atrium*) and two ventricles. The **atria** are receiving chambers for the blood entering the heart. The stronger, more muscular **ventricles** pump the blood to distant tissues. The right atrium accepts blood that is low in oxygen from the body and sends it to the right ventricle. The right ventricle delivers this blood to the lungs, where it picks up oxygen. The left atrium accepts the freshly oxygenated blood from the lungs and pumps it to the left ventricle, which then pumps it to the body. The body cells remove oxygen and nutrients from the blood and add carbon dioxide and waste. The blood completes its journey by travelling back to the right side of the heart.

LEARNING TIP

Make connections to your prior knowledge. Ask yourself, "What do I already know about the human heart? What new information is here?"

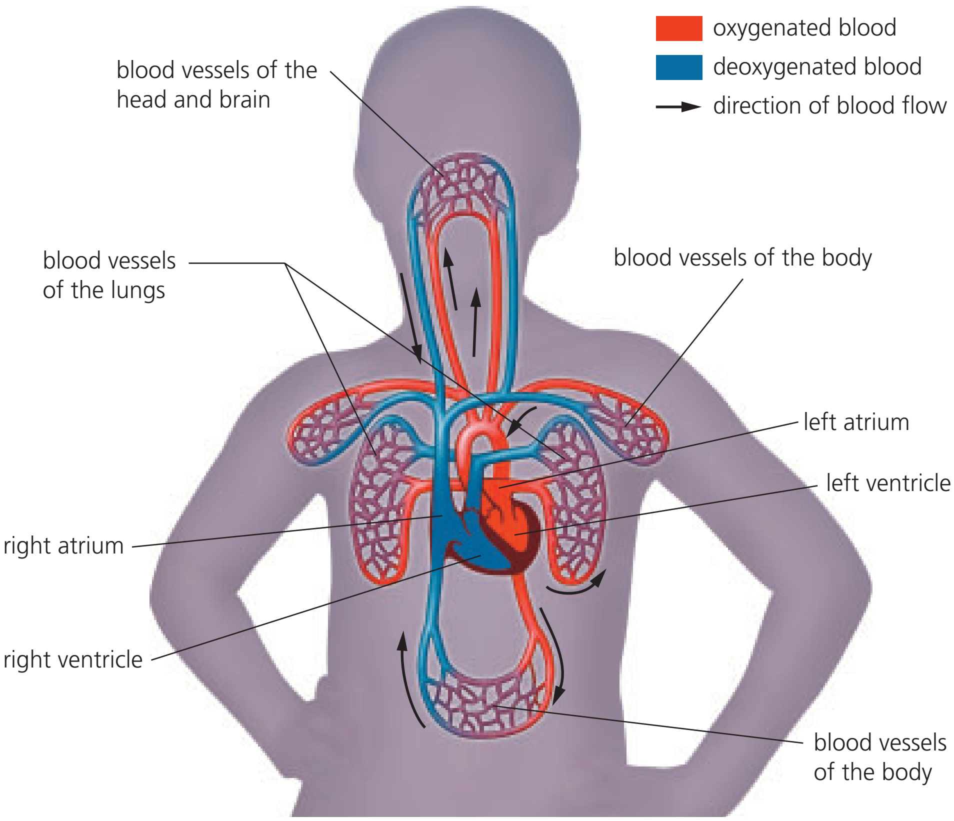


Figure 3
The human circulatory system is a closed system with a four-chambered, double pump.

A One-Way Flow

Valves, which operate as one-way doors, are found in both sides of the human heart. They keep blood flowing in one direction in the heart. The first set of valves is located between the atria and the ventricles. The second set is located between the ventricles and the arteries that carry blood away from the heart. There are also valves in the veins throughout the body. These valves prevent blood from flowing backward as the pressure decreases.

Blood is carried to the heart by the veins. As the heart relaxes, the atria fill with blood (**Figure 4(a)**). The atria contract and push the blood into the ventricles (**Figure 4(b)**). The ventricles then contract and push the blood against the valves that separate the atria from the ventricles. The closing of the valves produces the first heart sound, "lubb." The ventricles also push the blood into the arteries (**Figure 4(c)**). The ventricles now relax, and, because little blood remains, the pressure is low. As a result, blood is drawn back toward the ventricles from the arteries. This causes the valves to close, producing the second heart sound, "dubb" (**Figure 4(d)**).

DID YOU KNOW?

The Beat Goes On

If the average heart rate is 72 beats per minute and the average human life span is 76 years, the human heart beats about 3 billion times in a lifetime.

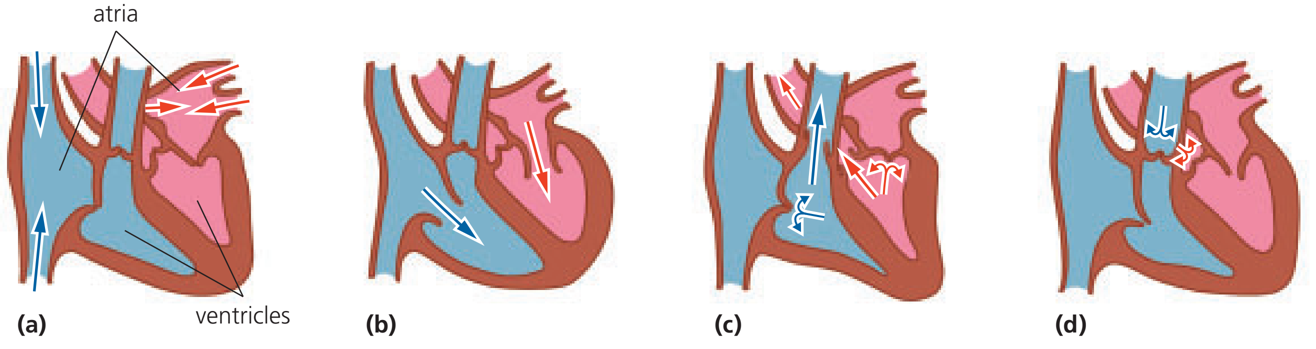


Figure 4
The valves of the heart keep the blood flowing in one direction. The closing of the valves produces the "lubb-dubb" sound that can be heard with a stethoscope.

3.2 CHECK YOUR UNDERSTANDING

1. Why do sponges not need a fluid transport system?
2. What is the difference between a closed circulatory system and an open circulatory system?
3. Draw a diagram that shows the movement of blood through the four chambers of the heart. In your own words, explain the movement of blood.
4. Explain the role of valves in the heart.

A Life Saved

Lives are saved every day by scientific knowledge and technology.

Delaney McIntyre (**Figure 1**) was born on October 13, 2002 in Nanaimo, British Columbia. Her parents were excited about their brand new baby girl who weighed 10 pounds! Unfortunately, Delaney was not healthy. Newborn babies are supposed to cry, breathe, and turn a lovely shade of pink when they are born. Delaney did not cry or breathe and she turned very blue. The hospital staff immediately called for a pediatrician (a doctor who specializes in caring for sick children).

Medical doctors are often like detectives. The tools that they use are based on science and technology. The pediatrician in Nanaimo used a special monitor to determine the amount of oxygen Delaney's blood cells were carrying. Her blood cells were not carrying enough oxygen for her brain cells to survive. Additional tests revealed that Delaney was born with a heart defect called transposition of the greater arteries.

Figure 1
Delaney McIntyre

In the heart, blood without oxygen travels through the pulmonary arteries to the lungs to pick up oxygen. Then the blood, with oxygen, returns to the heart and is pumped out to the entire body in a large artery called the aorta. In Delaney's heart, the aorta and pulmonary arteries were connected in the wrong spots. Because of this, Delaney's blood could not get to the lungs to pick up oxygen before being sent back out to the rest of her body.

Delaney was taken by helicopter to B.C. Children's Hospital in Vancouver (**Figure 2**). Some of the best medical experts in Canada work there to take care of sick children from all over British Columbia. The heart specialists gave Delaney medication to keep her sedated, so she would not move and require too much oxygen. The team also kept her on a ventilator, a special machine that breathes for the patient. After 11 days, Delaney had successful surgery to move the arteries to their proper positions. Thanks to the excellent care from the staff at the hospital and the use of scientifically developed diagnostic tools, medications, and equipment, Delaney has fully recovered and is growing up as a healthy, happy girl.

Figure 2
B.C. Children's Hospital provides specialized care for injured or sick children.

3.3 *The Excretory System*

The activities that take place in all the cells of the body produce different types of waste that must be eliminated. The carbon dioxide that is produced diffuses into the bloodstream and is eliminated by the respiratory system. The solid waste that remains after our food is digested is eliminated by the digestive system. Other types of waste are dissolved in water and eliminated by the excretory system (**Figure 1**).

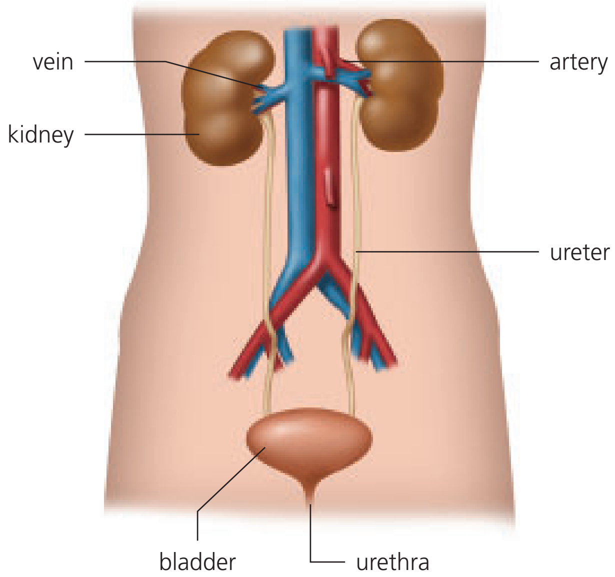


Figure 1
The human excretory system is designed to remove certain types of waste from the body.

Excretion

For unicellular organisms, getting rid of waste is just as important as bringing in nutrients. Without a way to get rid of waste, a cell would soon poison itself and die. Multicellular organisms, such as worms, insects, and humans, are faced with the same problem, but on a much larger scale. Not every cell is designed to remove waste, however. Specialized cells work together in the excretory system to remove waste from the body or to store waste until it can be removed. The process of removing waste is referred to as **excretion**.

When cells use the nutrients that are delivered by the circulatory system, they produce waste materials that diffuse back into the bloodstream. It is necessary to remove these waste materials as soon as possible. All the blood from around the body must therefore pass through the kidneys in a fairly short time. About 1 L of blood flows through the kidneys every minute. This is more than flows through any other organ in the body.

Proteins in your diet that are not needed for growth and repair are broken down in the liver. This provides some energy for the body, but it also produces a very toxic substance called ammonia. The liver changes the ammonia into a less toxic waste called urea. The urea is then dissolved in the bloodstream and carried to the kidneys.

Each kidney is made up of millions of tiny tubules, called **nephrons**. Each nephron is connected to the bloodstream by a small capsule of very tiny blood vessels (**Figure 2**). Blood pressure in these blood vessels is very high, so the waste is pushed across a thin membrane into a tubule. In each tubule, the waste is dissolved in a small amount of water, which is then collected in the ureter. The ureter carries the waste to the bladder, where it is stored as **urine**.

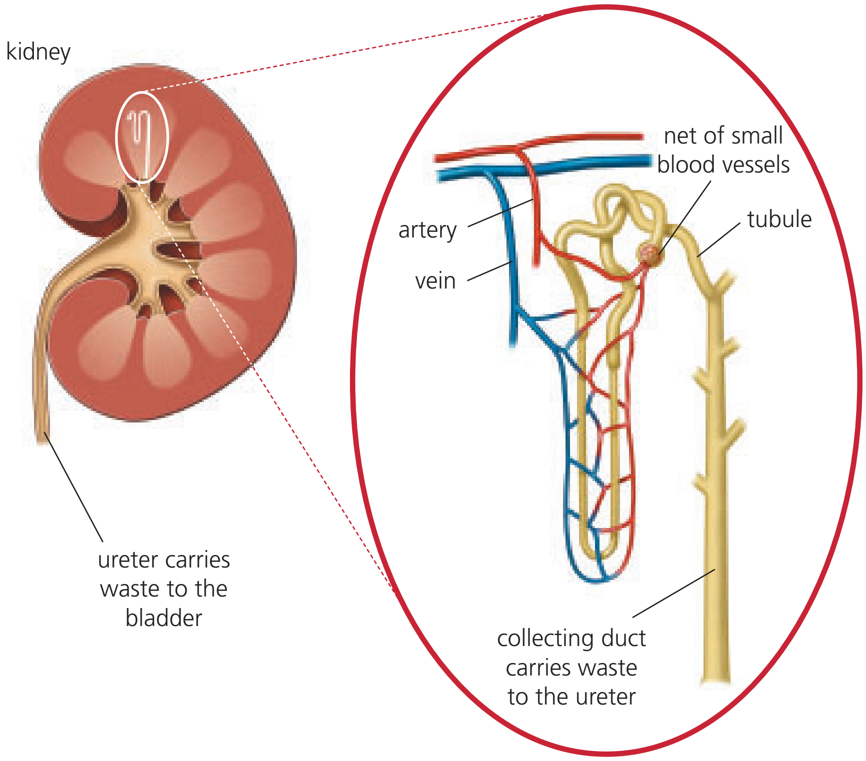


Figure 2
The human kidney contains millions of nephrons, which filter waste from the blood.

Water Regulation

The excretory system has a second function in most animals—it helps to regulate body water. Just as the contractile vacuole of the paramecium and amoeba prevent these cells from swelling, the excretory system of the human body ensures that the water balance in

DID YOU KNOW?

When You Have To Go...

As urine collects, your bladder stretches slightly. Nerves in your bladder sense this stretching. They send a signal to your brain when approximately 200 mL of urine has collected. Your brain interprets this as the need to go to the washroom. If you ignore the signals and 600 mL of urine collects in your bladder, you will not make it to the washroom!

the body is maintained. People whose kidneys are not functioning properly experience swelling, especially in the feet. As well, they often have high blood pressure because their bodies cannot get rid of the excess water.

TRY THIS: A Filter Model

Skills Focus: observing, creating models, predicting

In this activity, you will create a model of a filtering excretory system.

1. Fill a funnel with aquarium charcoal, and put a small beaker beneath it (**Figure 3**). Fill a second beaker with about 25 mL of water, and add a few drops of food colouring.

Figure 3

2. Pour the coloured water through the funnel, and collect it in the small beaker. Compare the colour of the filtered water with the original.

(a) Predict what would happen if you filtered the water again.

3. Test your prediction.

3.3 CHECK YOUR UNDERSTANDING

1. List the main parts of the excretory system.
2. What organ, other than the kidneys, plays an important role in excretion? Explain the role of this organ.
3. Briefly describe the function of the nephron.
4. Where does diffusion take place in the excretory system?
5. Getting rid of waste requires a team approach in the body. What body systems are on the team? Describe how these systems work together to get rid of waste materials that are produced in the cells.

The Digestive System 3.4

Unlike plants, animals cannot make their own food. They get energy either from other organisms or from food products that come from other living things. They use specialized cells to break down food so that it can be used by their bodies.

Digestion is the process that your body uses to break large food molecules into smaller molecules. Your body uses the smaller molecules for "fuel" and as building blocks for growth and repair. Chemicals that help to speed up the process of digestion are called **enzymes**.

Digestion Along a Canal

More complex animals, such as earthworms, birds, and humans, digest food along a tube or canal that has a separate entrance opening (mouth) and exit opening (anus). Because food moves along the tube in only one direction, each area of the tube can have a specific function. For example, one area may have muscle cells to grind food into smaller particles. Another area may produce enzymes to break down large molecules. Other areas may be devoted to the storage or the absorption of digested molecules.

In the human digestive system (**Figure 1**, on the next page), digestion starts in the mouth. Chewing the food breaks it down into smaller pieces. The salivary glands secrete a liquid called saliva, which moistens the food. Saliva also contains an enzyme that begins to digest starch. When the food is chewed sufficiently, it is swallowed. It passes through the esophagus into the stomach. The stomach secretes very acidic gastric juices, which start to break down the protein in the food.

From the stomach, the food moves into the small intestine. Two other organs, the pancreas and the liver, contribute to the chemical digestion of the food as it enters the first section of the small intestine. The pancreas produces a fluid that neutralizes the acid arriving from the stomach. This fluid contains enzymes that further digest the proteins, carbohydrates, and fats in the food. The liver produces a chemical, called bile, that breaks down fats. Bile is stored in the gall bladder until it is needed. Food entering the small intestine is a signal to the gall bladder to contract and release bile.

DID YOU KNOW ?

Digestion—A Long Process

The average length of the small intestine in humans is between 6 m and 7 m, depending on the age and size of the individual. The large intestine is an additional 1.5 m.

As the food passes through the several metres of small intestine, digestion is completed and the nutrients are absorbed through the intestine walls. From the small intestine, the remaining materials pass into the large intestine, where water is reabsorbed and fibre and other waste materials that were not digested are stored. These waste materials are eliminated through the anus.

LEARNING TIP

Diagrams play an important role in reader comprehension. Look at **Figure 1**. Then look closely at each step of the human digestive system and follow its path. Try to visualize (make a mental picture of) the sequence of steps.

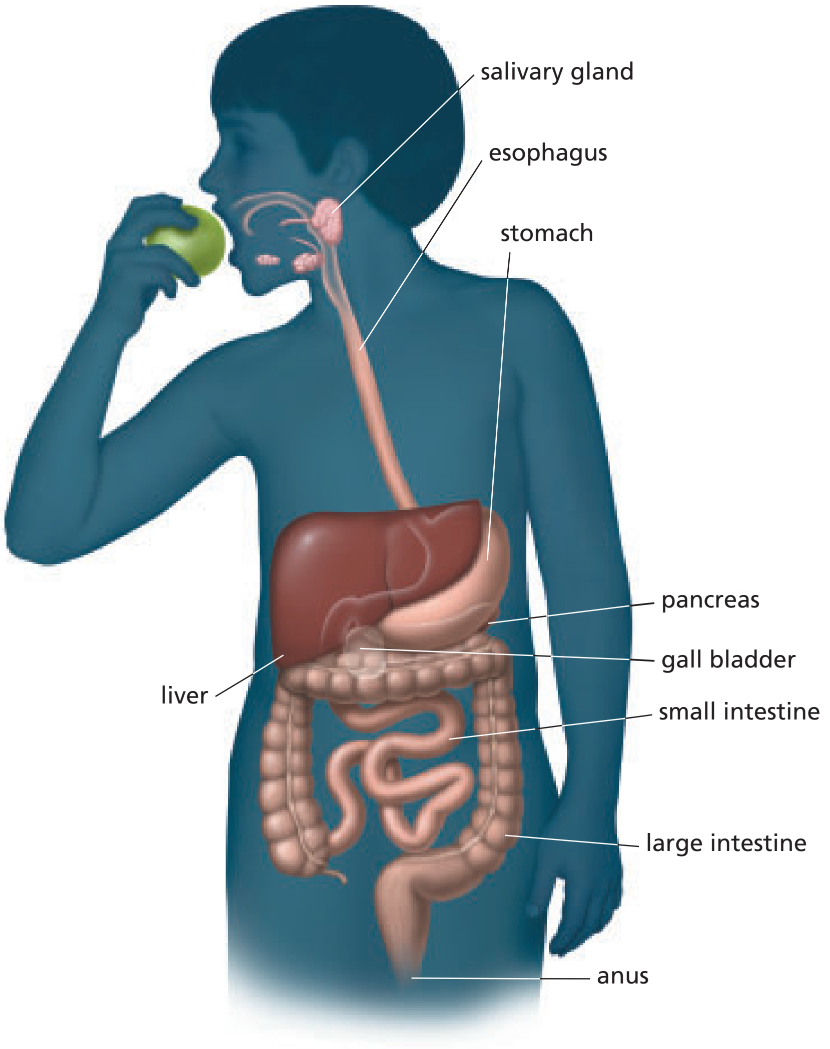


Figure 1
The human digestive system is more complex than that of other animals. Several different organs have specialized roles in the physical and chemical digestion of food and the absorption of nutrients.

PERFORMANCE TASK

What function is your model cell specialized to perform? Could you expect it to perform the functions of the digestive system? Could it live without the functions of the digestive system?

3.4 CHECK YOUR UNDERSTANDING

1. Explain digestion in your own words.
2. Using a table or diagram, summarize how human digestion occurs in the mouth, stomach, and small intestine.
3. Aspirin removes the protective mucous coating that lines the stomach. Explain why taking Aspirin tablets may cause digestive problems.

What Is Going On In There?

Patients with digestive system disorders can swallow a new space age pill that will help diagnose them.

Millions of people in Canada and the United States suffer from diseases of the digestive system. These diseases are estimated to cost the health-care system billions of dollars every year. To diagnose these diseases, there are several tests doctors can do, involving surgery, scopes (long tubes with cameras that are fed down the throat into the stomach), and various forms of X-rays. Unfortunately, all of the tests have some uncomfortable side effects for patients, and sometimes the information that is provided for doctors is insufficient or not accurate enough.

The SmartPill (**Figure 1**) is a small device about the size of a large vitamin pill that a patient can swallow during a regular office visit to a doctor. The device is made of a material that is safe for the patient and will not be affected by the very acidic gastric juices in the stomach. The SmartPill contains a miniature thermometer, pressure sensor, and pH sensor. The sensors pick up important information about the conditions inside the patient's digestive tract. A tiny microprocessor and radio transmitter inside constantly beam the sensor data out to a small receiver worn by the patient on a belt. After about 24 hours, the SmartPill passes out of the patient's system and is flushed down the toilet! The doctor scans the sensor data that was collected by the receiver on the patient's belt. A computer then analyzes the data.

The SmartPill demonstrates how technology can be used to further scientific knowledge. Such technology provides safer and cheaper tools for doctors to use in helping millions of patients.

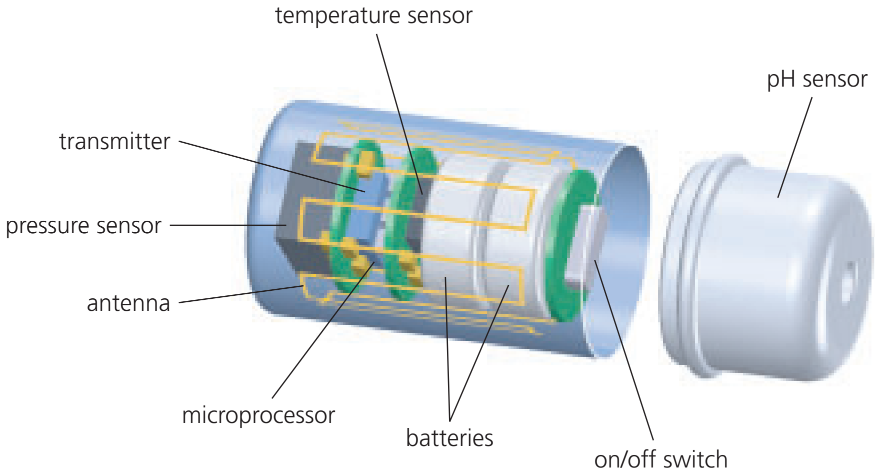


Figure 1
The SmartPill allows doctors to gain important information that they can use to help diagnose and treat diseases of the digestive system.

3.5 Organ Systems Working Together

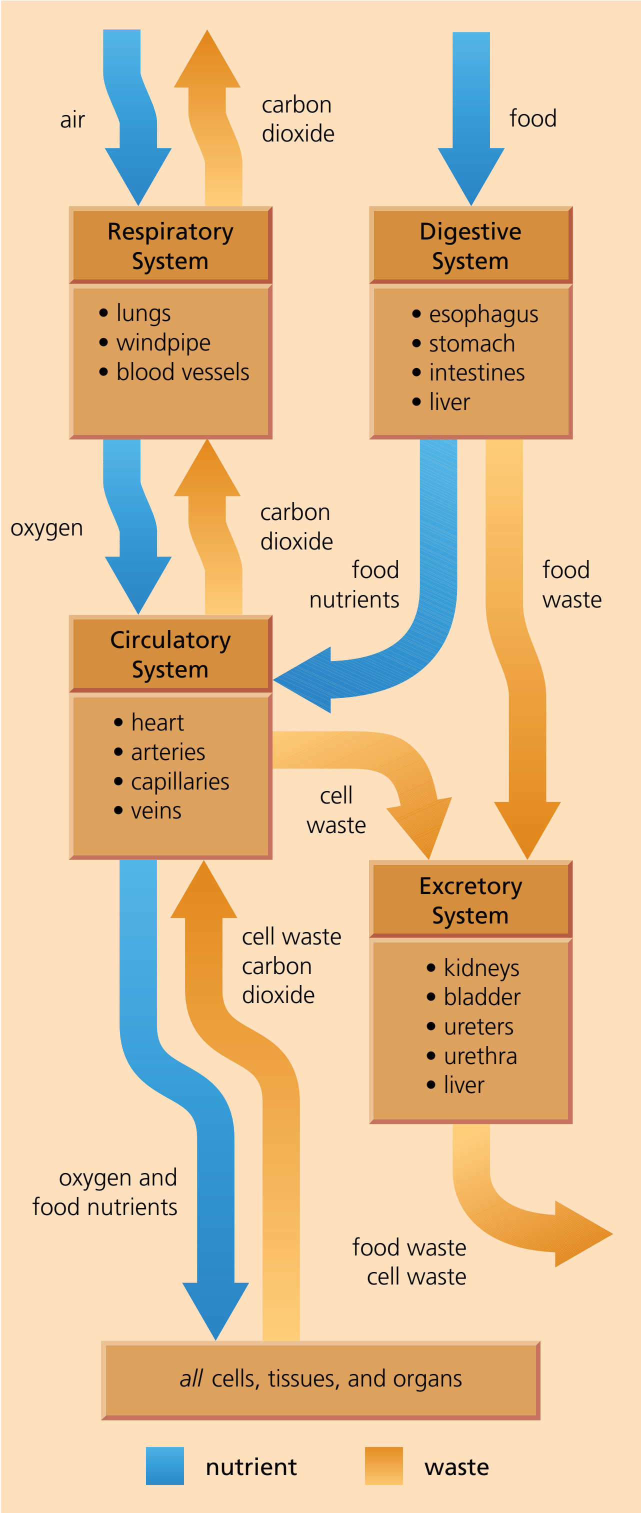


Figure 1
These four organ systems work together to supply nutrients and get rid of waste.

All your cells are organized into tissues, organs, and organ systems. To keep your body healthy, all your organ systems must work together. In your circulatory system, for example, blood carrying nutrients and oxygen is pumped to all the cells in your body. Without circulation, the cells of your skin and digestive system would not survive. In turn, the circulatory system relies on other systems: the respiratory system supplies oxygen; the digestive system, which includes the stomach and intestines, provides nutrients. Organ systems can be organized into two main groups. The first group of organ systems supplies nutrients and removes waste. The second group of organ systems regulates the body.

Supplying Nutrients and Removing Waste

There are four organ systems in this group: the respiratory, circulatory, digestive, and excretory systems (**Figure 1**). The respiratory system, consisting of the trachea, the lungs, and the blood vessels that are contained in the lungs, is responsible for absorbing oxygen from the air and getting rid of carbon dioxide. The oxygen is needed by all body cells to carry out the cellular processes and carbon dioxide is produced as a waste product. This exchange of gases takes place in the blood vessels in the lungs. It is these blood vessels that connect the respiratory system to the circulatory system. The respiratory system relies on the circulatory system to distribute the oxygen around the body and to return the waste carbon dioxide to the lungs to be exhaled.

The digestive system, made up of the mouth, esophagus, stomach, intestines, and liver, is responsible for breaking down the food we eat and making the nutrients available to all the cells of the body. This system, too, relies on the circulatory system to distribute the nutrients to the cells and to collect waste materials that are produced as the cells do their work.

The fourth system, the excretory system, plays a crucial role. The excretory system—kidneys, bladder, ureters, urethra—collects waste from the bloodstream and excretes it as urine. The kidneys act as filters through which the blood flows to be purified. While filtering waste, the kidneys also regulate the amount of water in the body. The excretory system ensures that our bodies are not poisoned by the waste that is produced in cells.

These four systems interact with and rely on each other to keep your body healthy.

Regulating the Body

Though many organ systems play a role in regulating the body, the two main systems are the endocrine system and the nervous system (**Figure 2**).

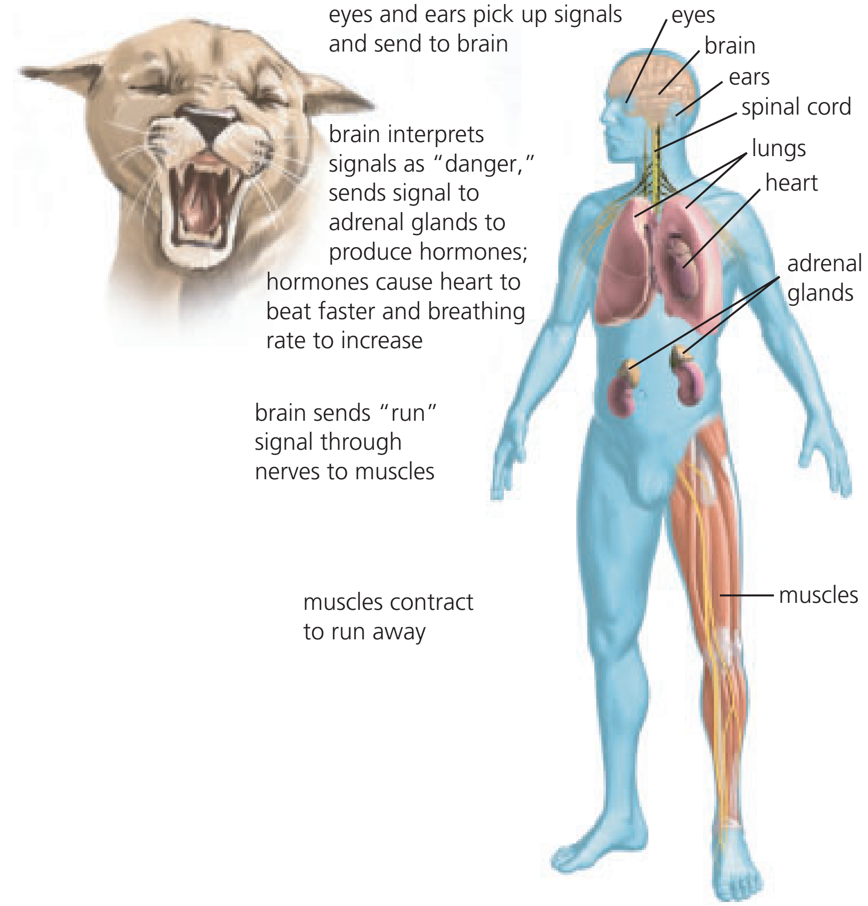


Figure 2
The endocrine system and the nervous system sometimes determine how other systems do their jobs.

The endocrine system produces **hormones** (chemical messengers) that travel to other organs and tell the organs how to adjust to what is going on outside and inside the body. The nervous system detects what is going on outside and inside the body and sends electrical messages throughout the body.

In some situations, the nervous system and endocrine system work together. For example, if a cougar jumps into your path, your eyes (and perhaps your ears and nose) detect the cougar and send an electrical message to your brain through the nervous system. Once you recognize that the cougar is dangerous and you decide to run away, your brain sends electrical signals through your nerves to the appropriate muscles. The signals cause your muscles to contract, and you begin to run.

Meanwhile, other nerves carry messages from your brain to your endocrine glands. Your endocrine glands respond by pumping chemical messengers into your blood. For example, there is a small gland near the top of your kidneys that releases a chemical messenger called adrenaline into your blood. When the adrenaline reaches the cells of your heart and your respiratory system, your heart starts beating faster and your lungs take in more oxygen. As a result, your muscle cells suddenly have more oxygen and nutrients available to them, and you can run faster.

3.5 CHECK YOUR UNDERSTANDING

1. Name two organ systems not mentioned in **Figure 1** on page 78.
2. Choose any two human body systems. Explain how the two systems are interdependent, that is, how each system helps the other system do its job.
3. Which system, the nervous system or the endocrine system, is best suited to detect danger? Explain why.
4. What is the difference between a response by the nervous system and a response by the endocrine system? Explain.
5. If you stepped on a tack, how would your nervous system respond? What other organ systems would be signalled? Explain.
6. Categorize the following as either *organs that supply nutrients and remove waste* or *organs that regulate the body*.

   heart intestines artery liver kidney

   eyes brain stomach lungs
7. How do nerves and muscles work together?
8. Speculate about what would happen to skin cells if the circulatory system failed to work.
9. Explain why organ systems that regulate or control other body systems are important.

Protecting the Body

3.6

The human body is a fascinating "system of systems." All of these systems must work together to keep the body operating properly. Most of the time they work well and the body functions as it should. There are, however, environmental conditions and other organisms that can negatively affect how the body functions. Micro-organisms, such as bacteria, that cause diseases are referred to as **pathogens.** If pathogens are able to enter the body, they either interfere directly with cells or tissues, or produce toxins (poisonous chemicals) that can affect the normal functioning of the body. Fortunately, the body has developed a number of ways to defend itself from invasion by foreign organisms and their toxins.

DID YOU KNOW?

The Largest Organ

The skin is the largest organ of the body with a surface area of about 2 m^2. It ranges in thickness from about 0.5 mm (on the eyelids) to about 4 mm (on the palms of the hands). The top layer of skin cells is constantly being replaced by new cells, so you have an entirely new skin about every month.

The First Line of Defence

The body's first line of defence consists of physical barriers. It works by keeping foreign invaders outside the body. The largest organ of the body, the skin, is a physical barrier that cannot normally be penetrated by bacteria or viruses, unless it is broken (**Figure 1**). Micro-organisms cannot normally grow on the skin, partly because we wash the skin frequently and partly because the skin produces natural acidic oils and sweat that prevent micro-organisms from growing.

Figure 1
The skin is generally a very effective barrier to any foreign invaders.

Where the skin leads to the inside of the body, such as in the mouth, nose, eyes, and ears, the body has other physical barriers that prevent invaders from entering. The nostrils have hairs that filter out particles of dust, dirt, and any micro-organisms that are in the air. The ear canals have a waxy material that traps any foreign particles and micro-organisms that enter. The eye produces tears, which have a

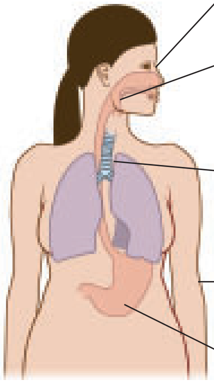


Figure 2
The human body has several features that prevent bacteria from entering the internal environment.

special chemical that kills bacteria. The lining of the mouth, nose, and trachea is covered with mucus, a sticky substance that acts like flypaper. Micro-organisms stick to the mucus, and cilia on the cells of the lining sweep the mucus and accumulated debris toward the mouth and throat, where they can be removed by coughing or swallowing. If a micro-organism gets past the hairs and mucus and ends up in the stomach, it probably will not survive the very acidic gastric juices that are secreted to help break down food (**Figure 2**).

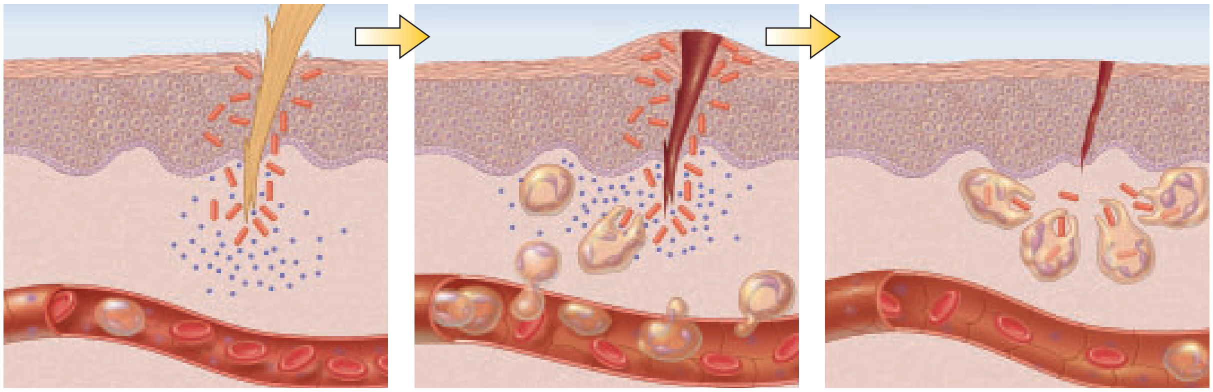
Though all of these barriers are effective in keeping foreign invaders out of the body, they are not foolproof. Invaders do occasionally get inside the body. A second line of defence must then be called into action.

The Second Line of Defence

The circulatory system acts as the second line of defence by circulating white blood cells. When invading organisms enter the body through a break in the skin, special white blood cells move from the bloodstream to the injured area. These white blood cells detect, capture, and destroy invading organisms the way that an amoeba captures food.

First, the invaders release a chemical signal that alerts the second line of defence (**Figure 3(a)**). The chemical signal causes increased blood flow to the injured area and attracts special white blood cells (**Figure 3(b)**). The white blood cells engulf and digest the invaders (**Figure 3(c)**). The body can then heal the tissues in the injured area.

The remaining fragments of dead white blood cells and digested invaders are called pus. The presence of pus is a sure sign that the second line of defence is working.



(a) **(b)** **(c)**

Figure 3
Injury or invasion by foreign organisms causes a response by the second line of defence.

Breaking Through the Defences

Although the two lines of defence are generally successful in protecting the body, they are not always able to stop the invasion. For example, there are other ways that foreign organisms can enter the body, without encountering the first two lines of defence. Microscopic pathogens can enter the body in food or water. The tragedy in Walkerton, Ontario, in 2000 was caused by drinking water that was contaminated with deadly bacteria called *E. coli* O157:H7 (**Figure 4**). *E. coli* produce a toxin that can cause chills, fever, and other potentially fatal symptoms.

Disease-causing organisms can also be transmitted when insects and ticks suck blood from the body. For example, mosquitoes can become infected with the West Nile virus when they draw blood from infected birds. The virus can then be passed on to humans when the mosquitoes feed on blood from humans (**Figure 5**). The bacteria that cause Lyme disease are transmitted mainly by deer ticks and black-legged ticks, which are present throughout British Columbia.

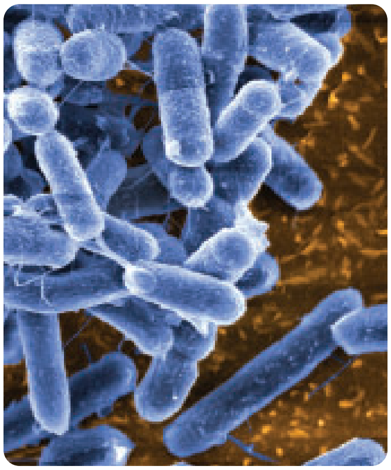


Figure 4
E. coli O157:H7 (magnified 6500X) look harmless enough but produce a deadly toxin.

Figure 5
Pathogens can be passed from one organism to another by insects such as mosquitoes.

The Immune System

When a pathogen does get past the first two lines of defence, the body's immune system is called into action. All foreign organisms contain or produce a chemical called an **antigen** (from *anti*body *gen*erator). The antigen signals the body to produce antibodies. Each antigen causes the production of a specific antibody that attaches only to this antigen (**Figure 6**).

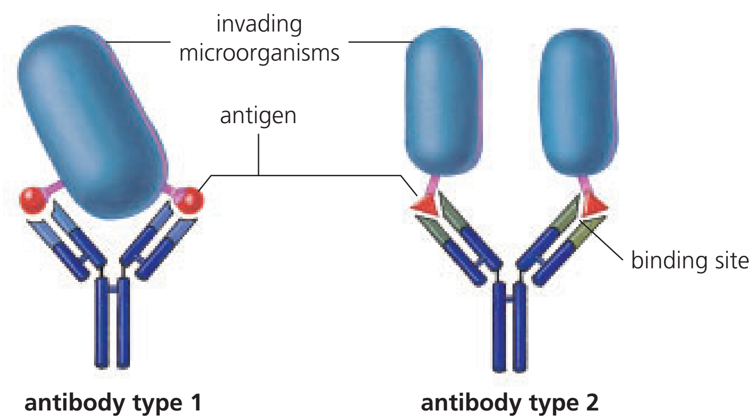
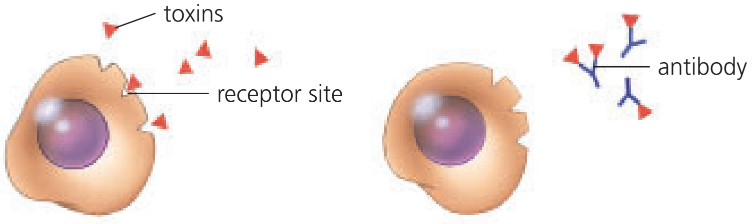


Figure 6
The body recognizes antigens on harmful micro-organisms and produces unique antibodies to attack them.

Antibodies also attack toxins and prevent them from attaching to a cell and interfering with its function (**Figure 7**). Scientists have estimated that the average human body may contain more than 10 million different antibodies, ready to respond to almost any invasion.



(a) Toxins attach to receptor sites.

(b) Antibodies prevent toxins from becoming attached to receptor sites.

Figure 7
Antibodies attacking toxins

Not everyone who becomes infected with a pathogen develops serious symptoms. A properly functioning immune system can disable the pathogen with antibodies.

The use of antibodies to fight a pathogen is called an **immune response**. In many cases, the first exposure to a pathogen causes the body to produce its own antibodies, which protect the body against any future attacks by the same pathogen. In other cases, temporary or permanent immunity is achieved by vaccination (**Figure 8**). In a vaccination, blood plasma that has been exposed to the pathogen is injected into the blood stream of an individual. This causes the immune system to produce antibodies as protection against future attacks.

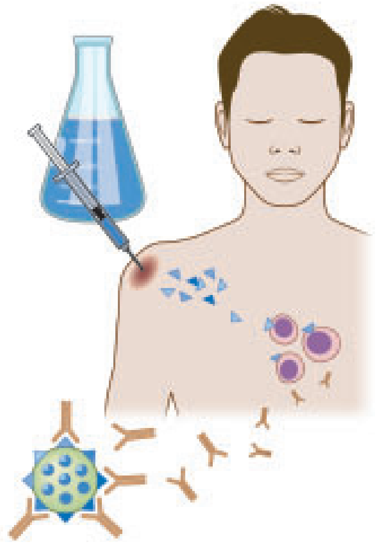


Figure 8
Vaccination stimulates the immune system to produce the appropriate antibodies.

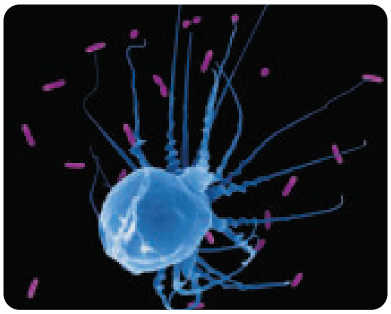


Figure 9

PERFORMANCE TASK

Do you expect your model cell to perform the functions needed to protect the body? How is your model cell affected by the body's defence system?

3.6 CHECK YOUR UNDERSTANDING

1. Explain why pathogens are a threat to the body.
2. Name and briefly describe the three lines of defence that the body uses to fight infection.
3. The electron micrograph in **Figure 9** shows a white blood cell (blue) and *E. coli* bacteria (pink). Describe what is happening. Which line of defence is in action here?
4. Compare the features shared by an amoeba and a specialized cell in the human defence system.
5. How do antibodies protect the body from attack?
6. Explain two ways that we can become immune to diseases.

Inquiry Investigation 3.7

INQUIRY SKILLS

- ○ Questioning
- ● Hypothesizing
- ○ Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Evaluating
- ● Communicating

Factors that Affect Reaction Time

The nervous system is an elaborate communication network. In the brain alone, there are more than 100 billion **neurons** or nerve cells. Like all cells, neurons contain a nucleus and cytoplasm. Unlike most cells, however, they have a direct connection to other cells because of the thin projections of their cytoplasm. These connections make the cells a network. **Figure 1** shows two kinds of neurons. **Sensory neurons** carry messages from sensory cells to the brain. These specialized cells are found all over the body, particularly in the sense organs—the eyes, ears, tongue, nose, and skin. For example, you have sensory neurons in your skin to detect changes in temperature or pressure. **Motor neurons** carry signals from the brain to muscles, causing movement.

Every move you make relies on the network of neurons. For example, catching a falling ruler seems fairly simple, but millions of cells inside your body must work together to make the catch happen.

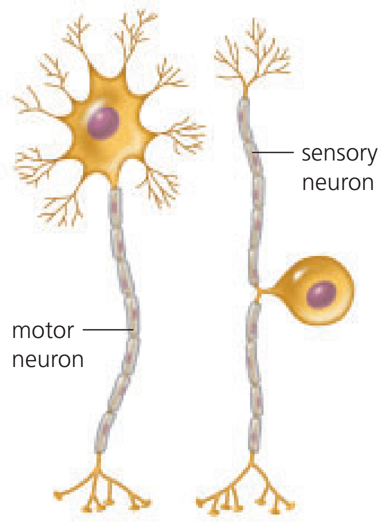


Figure 1
Neurons are specialized cells that carry signals among different cells, tissues, and organs.

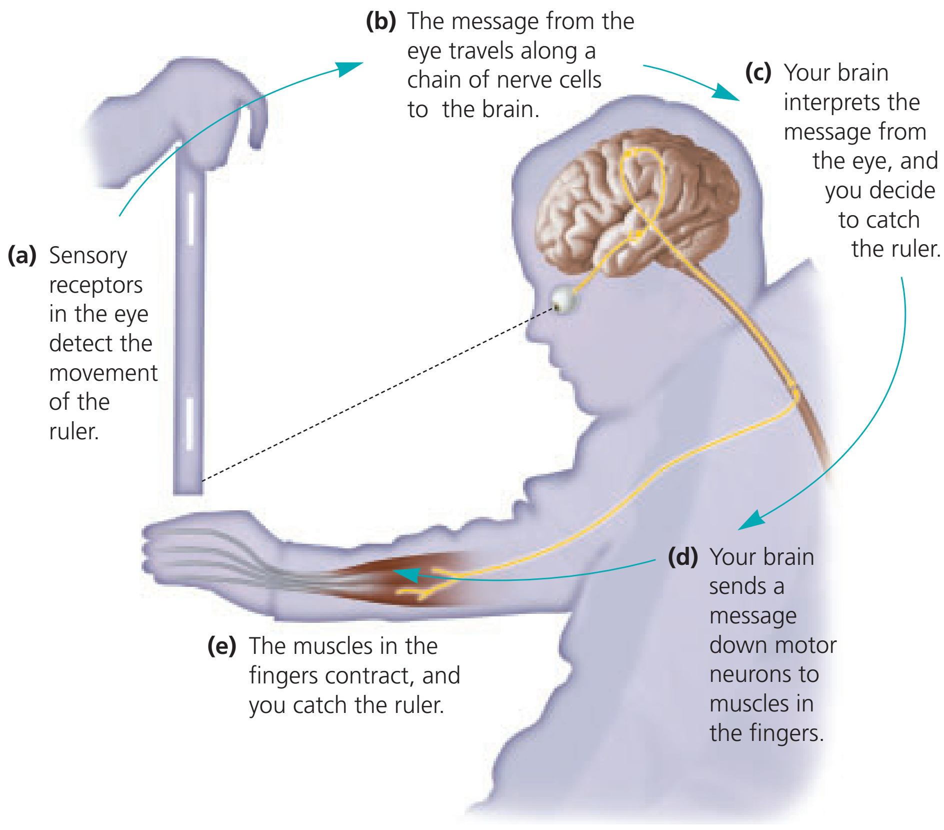


Figure 2
Between sighting the dropping ruler and catching it, there is a long chain of nerve cells and their messages.

LEARNING TIP

Do not rush when you are looking at diagrams. The longer you look, the more you will notice. Learning slowly sometimes results in learning more.

Figure 2 shows the series of events that must take place as nerve signals travel from your eye to your brain and back to your hand to make the catch. Your **reaction time** is the time required for you to react to a signal. During this time, the signal goes from the sensory neurons to the brain and then to the motor neurons and muscles.

Question

How do certain factors affect reaction times?

LEARNING TIP

For help with writing a hypothesis, see "Hypothesizing" in the Skills Handbook section **Conducting an Investigation**. For help with creating a data table, see "Recording Data and Observations" in the Skills Handbook section **Designing Your Own Investigation**.

Hypothesis

(a) Write a hypothesis for the effect of each of three factors on reaction time—hand dominance, temperature, and fatigue.

Experimental Design

In this Investigation, you will measure the distance a ruler drops before it is caught. You will use the distance as a measure of your subject's reaction time.

(b) Read the Procedure, and make a data table to record the data you will collect.

Materials

- ruler (at least 30 cm long)
- cold water
- large plastic container

Procedure

1. Ask your subject to place the forearm of his or her dominant hand flat on the desk. The subject's entire hand should extend over the edge of the desk. The index finger and thumb of the subject should be about 2 cm apart.

Step 1

2. Place a 30 cm ruler between the thumb and forefinger of the subject. The end of the ruler should be even with the top of the thumb and forefinger. Release the ruler. Measure the distance that the ruler falls before being caught between the subject's thumb and forefinger. Record the distance.

3. Repeat steps 1 and 2 twice more.

Step 2

4. Record your subject's dominant hand.

5. Repeat steps 1 and 2 three times for the subject's non-dominant hand and record your findings.

Procedure (continued)

6. Have your subject clench his or her dominant hand into a fist and then unclench it, vigorously and repeatedly for 2 min.

Step 6

7. Repeat steps 1 to 3 with your subject's dominant hand. Record your findings.

8. Ask the subject to immerse his or her dominant hand in cold water for 1 min.

9. Repeat steps 1 to 3 with your subject's dominant hand. Record your findings.

Step 8

Do not keep your hand in cold water longer than 1 min.

Analysis

(c) Why should you do more than one trial for each hand?

(d) How does hand dominance affect reaction time? What evidence supports your answer?

(e) How does fatigue affect reaction time? In what part of the Investigation did you collect evidence to support your answer?

(f) How does temperature affect reaction time? In what part of the Investigation did you collect evidence to support your answer?

(g) If reaction time changes as temperature falls, do impulses move slower or faster along nerves at low temperatures? What other factors affect reaction time?

Evaluation

(h) Did the results of this Investigation support your hypothesis? Explain.

(i) Describe some possible sources of error in this Investigation.

(j) How could you improve the procedure for this Investigation?

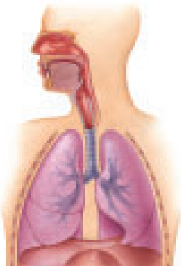
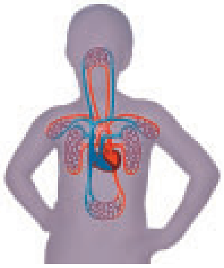
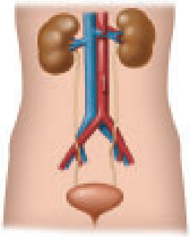
CHAPTER 3

Review Human Body Systems

Key Ideas

Animals have two main types of systems—those that obtain and use nutrients and remove waste, and those that control the functions of the body.

- The respiratory system absorbs oxygen and gets rid of carbon dioxide.
- The circulatory system distributes blood containing oxygen and nutrients.
- Kidneys get rid of waste and regulate the amount of water in the body.
- Different parts of the digestive system and other organs play special roles in the digestion of food.
- The nervous system transmits messages throughout the body: sensory neurons send messages to the brain, motor neurons carry messages from the brain to muscles.
- The nervous system and endocrine system regulate what goes on inside the body.

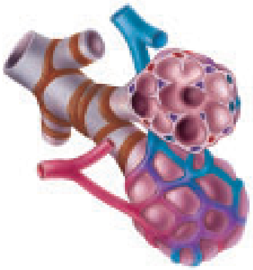

Animal systems cannot function properly without other systems.

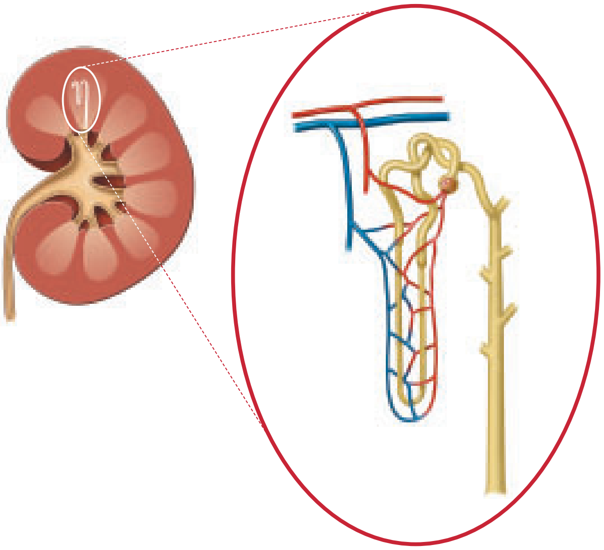
- The respiratory system brings in oxygen and the circulatory system distributes it around the body.
- Cells produce waste that diffuse into the blood stream to be filtered out by the kidneys and eliminated from the body.

Vocabulary

diaphragm, p. 65
breathing, p. 65
trachea, p. 66
epiglottis, p. 66
respiration, p. 66
arteries, p. 69
veins, p. 69
capillaries, p. 69
atria, p. 69
ventricles, p. 69
excretion, p. 72
nephrons, p. 73
urine, p. 73
digestion, p. 75
enzymes, p. 75
hormones, p. 80
pathogens, p. 81
antigen, p. 83
immune response, p. 84
neurons, p. 85
sensory neurons, p. 85
motor neurons, p. 85
reaction time, p. 86

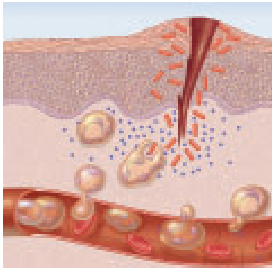
- The digestive system breaks down food and the circulatory system distributes the nutrients around the body.

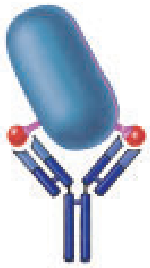




Humans have a natural system that protects them from foreign invaders.

- Physical barriers such as skin, mucus, ear wax, and tears keep invaders out of the human body.
- Special white blood cells engulf and destroy invaders.
- The immune system produces antibodies that destroy invaders.





Review Key Ideas and Vocabulary

1. What is the name of the tube that allows air to enter the lungs?
   (a) bronchus
   (b) esophagus
   (c) trachea
   (d) epiglottis
   (e) nasal cavity
2. Which sequence represents the blood flow in the circulatory system?
   (a) right atrium → right ventricle → lungs → left atrium → left ventricle → body
   (b) right atrium → left atrium → lungs → right ventricle → left ventricle → body
   (c) right ventricle → right atrium → lungs → left ventricle → left atrium → body
   (d) right atrium → right ventricle → left atrium → lungs → left ventricle → body
   (e) right atrium → left ventricle → lungs → left atrium → right ventricle → body
3. Which structure is part of the excretory system?
   (a) epiglottis
   (b) esophagus
   (c) neuron
   (d) nephron
   (e) atrium
4. What is the name of the chemical substance that is produced by the liver to break down fat in the small intestine?
   (a) gall bladder
   (b) saliva
   (c) enzymes
   (d) gastric juices
   (e) bile
5. Which body system(s) is (are) responsible for providing cells with oxygen?
   (a) circulatory system
   (b) respiratory system
   (c) digestive system
   (d) circulatory and respiratory systems
   (e) circulatory system or respiratory system
6. **Figure 1**, on page 76, shows the outline of a person about to eat an apple. List the structures that the apple passes through, in order, from the first bite until the waste is eliminated.
7. What is the advantage of having digestion take place along a canal rather than in one location?
8. Give an example of an organ that plays a role in more than one system. Explain its role in each system.
9. Explain the connection between an antigen and an antibody.
10. If the body's first two lines of defence are effective, how is a pathogen able to gain access to the body's internal environment?
11. Suppose that you are a hockey goalie. Describe the sequence of events in your nervous system that enable you to make a save.

Use What You've Learned

12. "Fluid movement is the most important function of the human body systems." Explain what this statement means. In your explanation, answer the following questions:
    - What fluids are involved?
    - What body systems are involved?
    - How are the fluids moved?
    - Why are these fluids so important to the body?
13. Explain why multicellular animals need
    (a) a respiratory system
    (b) an excretory system
    (c) a circulatory system

14. What would happen in the circulatory system and in the whole body if the heart valves failed? Why would this be a dangerous situation?
15. You are at a restaurant where drink refills are free, so you drink four glasses of pop. Assuming that you are healthy, why does your body not swell? How does your body take care of the excess water?
16. "Organ systems interact and are interdependent." Explain what this statement means.
17. Pus around a cut or sore may look dangerous, but it is actually a good sign. Explain why.
18. Explain how the health of an animal would be affected if disease damaged an organ that
    (a) delivered nutrients
    (b) removed waste
    (c) informed the animal about environmental change
    (d) controlled other organ systems

Think Critically

19. How could an animal use specialized cells to improve its fluid transport system?
20. Compare an open circulatory system with a closed circulatory system. Which do you think is more efficient? Give your reasons.
21. Obesity among young people is considered to be a serious problem in Canada. Research this problem using the Internet and other resources, and answer the following questions.
    (a) What is the definition of obesity?
    (b) What proportion of young people in Canada are considered to be obese?
    (c) What are the main causes of obesity in Canada?
    (d) What can be done to reduce the rate of obesity among young people?

www.science.nelson.com GO

22. Explain why you think the body needs to have three lines of defence against invasion?
23. Use the Internet and other resources to research Lyme disease or the West Nile virus. Prepare a report that addresses the following topics:
    - the cause of the disease
    - how the disease is transmitted
    - symptoms of the disease
    - treatments for the disease
    - safety precautions

www.science.nelson.com GO

24. As the captain of your school's football team, you are responsible for selecting players to be on the team. One of the criteria for evaluating potential players is reaction time. Explain why reaction time is an important factor for athletes. Then describe a procedure that you could use to test a player's reaction time.

Reflect on Your Learning

25. In this chapter, you have learned about the interactions of body systems. How might this influence your decisions about how you look after your body?
26. Smoking is a factor in about 87 % of all lung cancer cases. How do you feel about lifestyle choices, such as smoking, that have a negative impact on health?

Visit the Quiz Centre at

www.science.nelson.com GO