3.2 Organs and Systems

Key Terms
medical imaging technology

Unlike the glass catfish shown in **Figure 3.8**, most animals, including humans, do not have transparent skin. How, then, can we learn how the body functions and what is happening when it does not work as it should?

In earlier times, when a patient was ill, doctors sometimes performed exploratory surgery. This was the only way to look inside the body to try to see what was wrong. Today physicians can use a variety of **medical imaging technologies** instead. **Figure 3.9**, for example, shows the human body as viewed using some of the medical imaging technologies you will read about in this section.

medical imaging technology techniques used to form an image of a body's internal cells, tissues, and organs

Figure 3.9 This image of the human body was put together using several types of medical imaging technologies, as well as dissection and artwork.

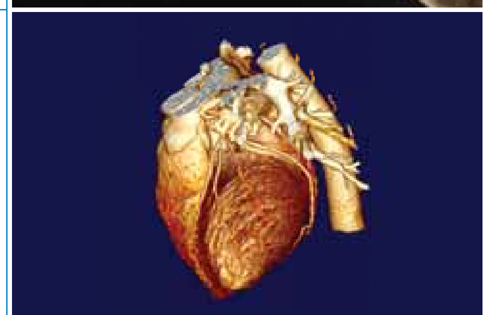
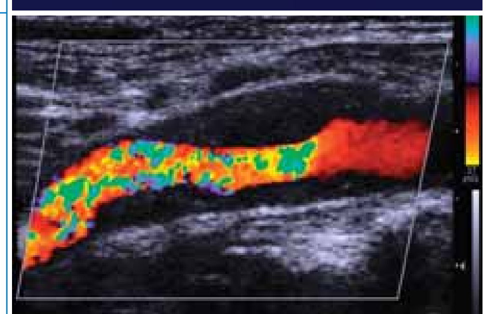
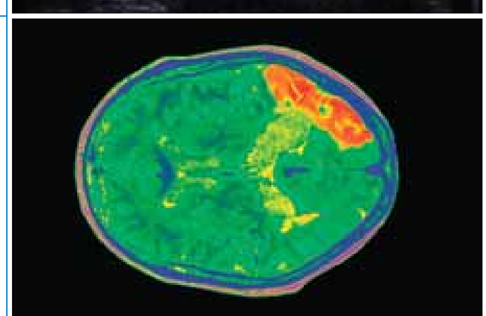
Figure 3.8 In these glass catfishes, many organs are in plain sight because they have transparent skin.

Which Technology Is Best?

Figure 3.10 CT scans are an expensive, but accurate method used to diagnose heart disease, cancer, and various other diseases.

Although physicians now have many ways to look inside the human body, their decision about which technology to use is not always straightforward. **Table 3.2** summarizes some of the main medical imaging technologies used today. A physician's decision about which technology to use often depends on a balance between wanting an accurate diagnosis for a reasonable cost, with as little negative impact (pain, anxiety, sickness) on the patient as possible. For example, an X ray is the most widely available technology, but details of organs like the brain are not visible. To diagnose a problem with brain functioning, specialists often start with instruments like a CT scanner, which you can see in **Figure 3.10**.

Table 3.2 Common Medical Imaging Technologies Used in Diagnosis

Type	Technology	Example
X ray	• produced by transmitting a wavelength of electromagnetic radiation through the body to expose photographic film on the other side Example (at right): X rays go through soft tissue, so they are best used for hard tissue, such as bone. Here you can see an X ray of a badly fractured leg.	
CT or CAT scan (computerized axial tomography)	• produced by taking X rays of very thin "slices" of a body part that can be reconstructed by a computer into a three-dimensional image Example (at right): This three-dimensional CT scan shows a healthy heart.	
Ultrasound (medical sonography)	• produced by directing high frequency sound waves at a part of the body, usually from a microphone attached to a computer • show real-time movement of body parts like the heart; useful for watching organ function Example (at right): This ultrasound image has been coloured to more clearly show blood flow through a neck artery. Blood flow is greatest when red and slowest when green.	
MRI scan (magnetic resonance imaging)	• produced using radio signals in a magnetic field to create images of body parts Example (at right): This MRI scan shows sites of bleeding in the brain, which has resulted in a stroke.	

Advances in Diagnosis

Endoscopy, in which a tiny camera and a light attached to a flexible tube are inserted into the body, provides options for diagnosis as well as treatment. **Figure 3.11** shows two ways a stomach (gastric) ulcer might be diagnosed. An ulcer is a hole in the protective mucous lining of the stomach or intestine. This hole allows *gastric juices* to start digesting body tissue, causing a burning sensation and pain. Such ulcers are sometimes diagnosed using a barium X ray. The patient drinks a "barium milkshake" that, when X-rayed, shows the lining of the stomach and any ulcerations or tumours. However, since this technique uses radiation, other techniques, such as endoscopy, are sometimes preferred.

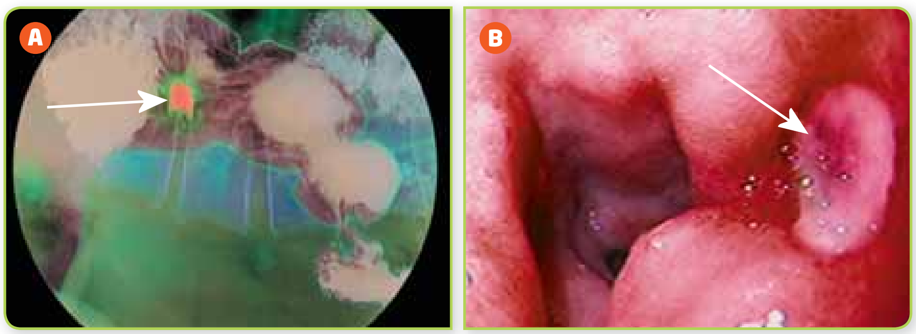


Figure 3.11 In **A**, you can see a barium X ray, which is a common means of diagnosing a stomach ulcer. In **B**, you can see an ulcer as seen through an endoscope. Endoscopy provides an alternative way to diagnose an ulcer without using radiation.

The Body's Organization: A Hierarchy

Advances in technology have also led to a better understanding of how bodies are organized and how various parts interact. For example, scientists know that organs, such as the heart, consist of several types of tissues working together to perform a task, such as pumping the blood throughout your body. As part of an organ system, the activities of different organs are co-ordinated to work together. In **Figure 3.12**, you can see that the body's cells are organized in a hierarchy, from cells to tissues, to organs, to systems.

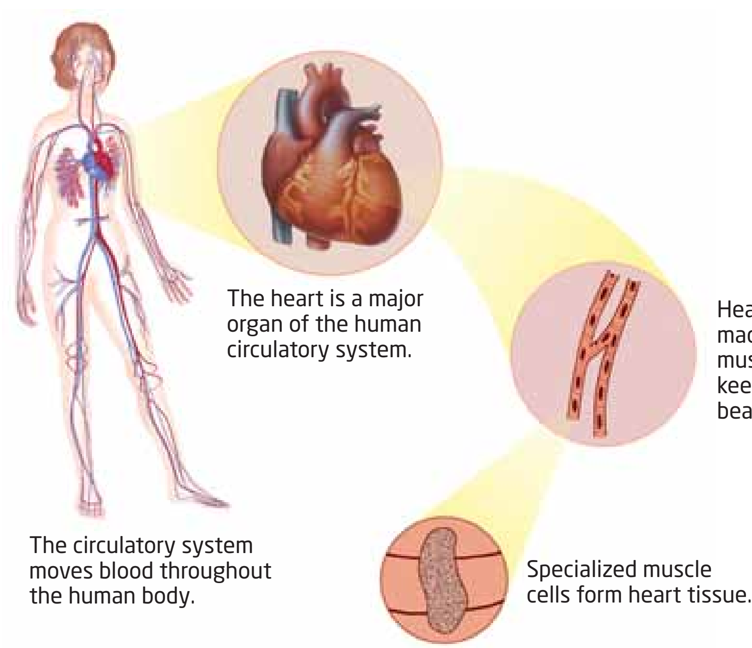
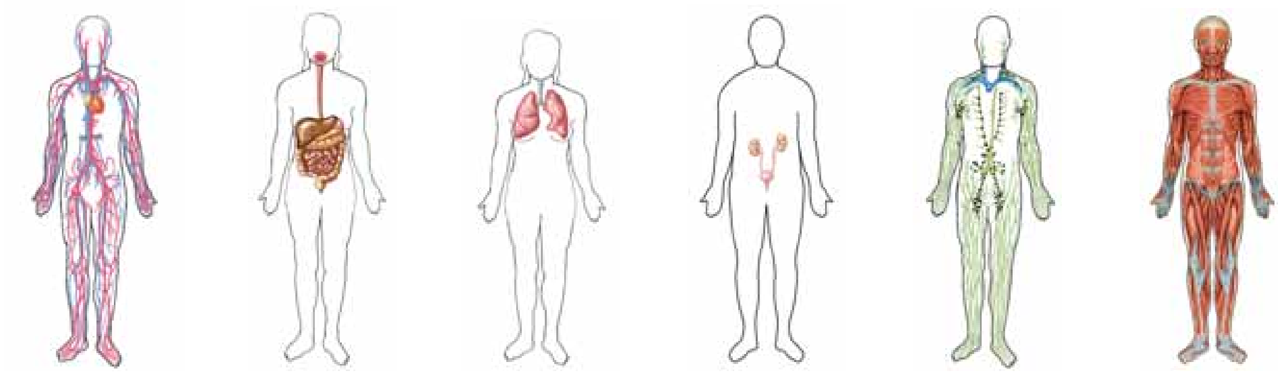


Figure 3.12 Each system in the human body has a specific function. It accomplishes this function through the co-ordination of its organs. Each organ is made of tissues, which in turn are made of groupings of specialized cells.

Human Organ Systems

As shown in **Figure 3.13**, the 11 organ systems of the human body keep you alive and healthy. In the rest of this section, you will focus on three of these systems—the digestive, respiratory, and circulatory systems—and how they interact in ways that are critical for survival.



Circulatory System

- transports blood, nutrients, gases, and wastes

Digestive System

- takes in food and breaks it down
- absorbs nutrients
- removes solid waste from the body

Respiratory System

- controls breathing
- exchanges gases in lungs

Excretory System

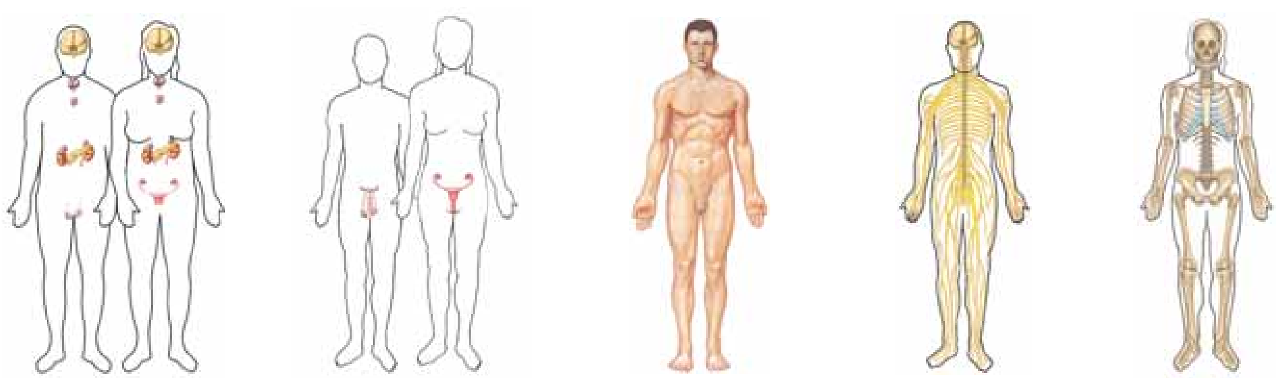
- removes liquid wastes from the body

Immune System

- defends the body against infections

Muscular System

- works with the bones to move parts of the body



Endocrine System

- manufactures and releases hormones that act, along with the nervous system, to keep various body systems in balance

Reproductive System

- includes reproductive organs for producing offspring

Integumentary System
[pronounced in-TEG-u-MEN-tar-ee]

- includes skin, hair, and nails
- creates a waterproof barrier around the body

Nervous System

- detects changes in the environment and signals these changes to the body, which then responds

Skeletal System

- supports, protects, and works with muscles to move parts of the body

Figure 3.13 The main functions of the human body to sustain life are accomplished by 11 organ systems working together.

Digestive system

As shown in **Figure 3.14**, organs forming the human digestive system mechanically and chemically break down food to produce nutrient molecules that the body's cells can absorb and use.

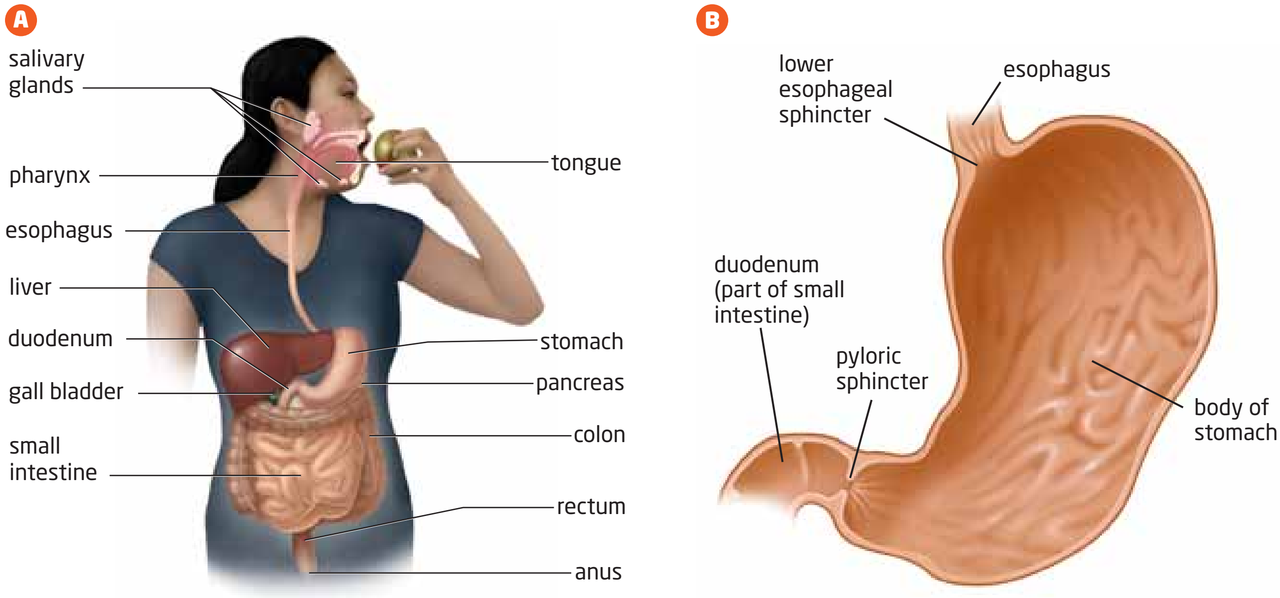


Figure 3.14 Diagram **A** shows the organs of the digestive system. On average, it takes 24 to 33 hours for each meal to complete its passage through the digestive tract. Diagram **B** shows the stomach, a major organ of the digestive system.

The Fate of a Meal

Digestion begins in the mouth, where the teeth begin the mechanical breakdown of food into smaller pieces. An enzyme in saliva, called amylase, starts the chemical breakdown. After the food is swallowed, it passes through the *pharynx* into a muscular tube called the *esophagus*. At this point, the food is in small chunks. The muscular walls of the esophagus contract and relax, pushing each chunk of food along until it gets to the stomach.

Gastric Juices Get to Work

In the stomach, the food chunks are surrounded by gastric juices that are secreted by the epithelial tissue that lines the stomach. These juices, which continue the chemical breakdown of the food, include hydrochloric acid and the enzyme pepsin. One of the reasons the gastric juices must be acidic is that pepsin, which breaks down protein, needs an acidic environment in which to function. The stomach lining also secretes *mucus*, which protects the stomach wall from breaking down in the presence of those protein-digesting juices.

Nerves in the stomach wall sense the presence of food and signal the stomach's muscle tissue to mix the contents, continuing the mechanical breakdown. Due to actions of the gastric juices and the churning of the stomach muscles, the partially digested food breaks down to a liquid.

Study Toolkit

Making Study Notes You can use the study notes model from page 84 for short sections of text as well as long. Practise the model using the section on gastric juices.

The Small Intestine

When the meal is fully mixed, a round muscle at the bottom of the stomach—called a *sphincter*—relaxes and some of the contents of the stomach are released into the *small intestine*. The first metre of the small intestine is called the *duodenum*, which is where most digestion takes place. This structure, shown in **Figure 3.15**, has small tubes called ducts that connect to the pancreas, liver, and gall bladder. These organs release more digestive enzymes into the duodenum, which completes the chemical breakdown of the food.

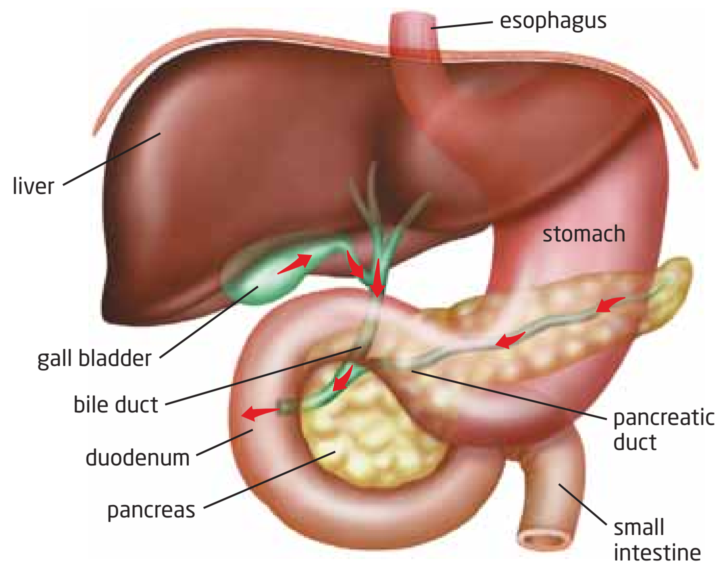


Figure 3.15 The liver produces bile, which is stored in the gall bladder. Bile breaks up globs of fat into small droplets. Pancreatic enzymes break the fat down into even smaller particles. Secretions from the pancreas are also critical for digesting proteins into amino acids, which body cells use to build new proteins.

When the digested food moves into the remaining length of the small intestine, it is ready to be absorbed into the body. The small intestine is covered with millions of interior folds, called villi and microvilli. These villi, shown in **Figure 3.16**, maximizes the surface area over which nutrients and water can be absorbed into the bloodstream.

Sense of scale

Villi and microvilli increase the surface area of the small intestine dramatically. A simple tube of the same length would have an inner surface area of only 0.5 m^2. Instead, the specialized structure of the inner wall of the small intestine has an area of approximately 250 m^2–the size of a volleyball court.

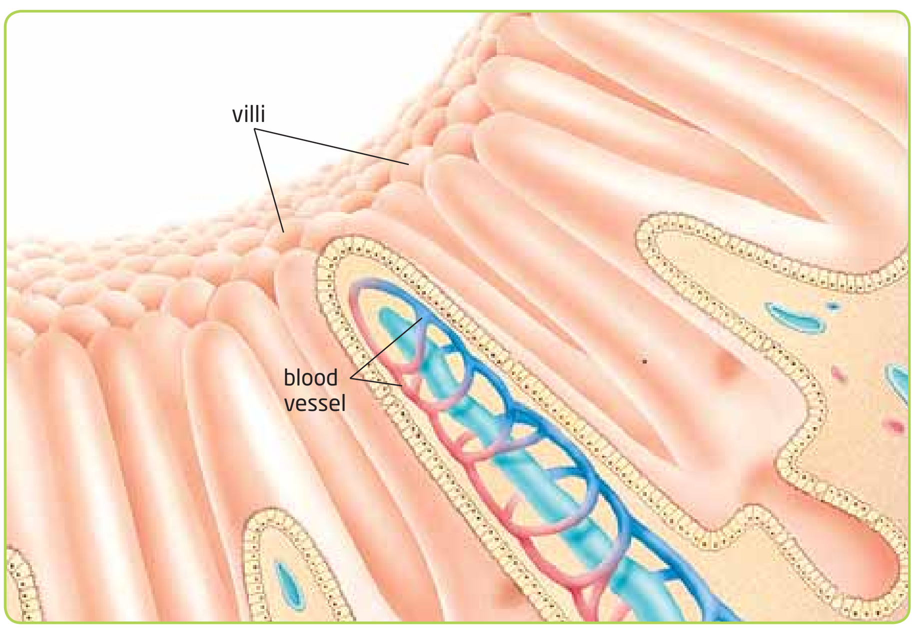


Figure 3.16 The small intestine is between 6 and 10 m long in an adult.

The Large Intestine

The final organ in the digestive system is the *large intestine*, which includes the *colon*, *rectum*, and *anus*. In humans, the large intestine has a larger diameter and a shorter length than the small intestine. The large intestine's main functions are to absorb water, vitamins, and various salts from the digested food and to eliminate undigested food through the anus as feces. Most of the material in the cell walls of plants, for example, cannot be broken down in the human digestive system and must be eliminated. The large intestine also contains bacteria, such as those shown in **Figure 3.17**. These bacteria finish the process of breaking down food and also produce essential nutrients, such as vitamin K.

Figure 3.17 One species of bacteria, *Escherichia coli* (*E. coli*), is common in the large intestine. Most strains of *E. coli* cause no harm, and some benefit humans by taking up space and nutrients that might otherwise be inviting to dangerous bacteria. However, some types of *E. coli* can cause death in people with weakened immune systems.

Learning Check

1. What is an organ system?
2. In what ways are human organ systems similar to machines?
3. Look back to **Figure 3.12**. In your own words, or with a diagram or graphic organizer, explain how cells, organs, tissues, and systems are related.
4. Look back at the 11 body systems shown in **Figure 3.13**. Which system is not critical for the maintenance of the body? What is its function?

The Excretory System

The digestive system is responsible for eliminating solid waste, but what about the body's liquid wastes? The excretory system, which you can see in **Figure 3.18**, takes care of these. Water and other materials absorbed through walls of the large intestine move into blood vessels. As blood passes through the kidneys, it is filtered and wastes are removed. As the blood is filtered, urine containing water and unneeded salts is formed. The urine is then stored in the bladder. When the bladder is full, the urine is flushed from the body.

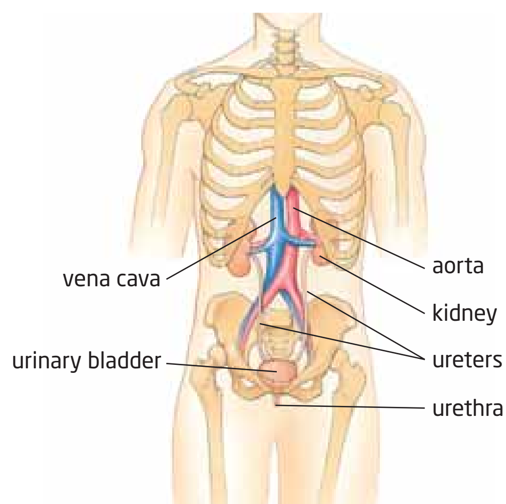


Figure 3.18 The excretory system eliminates liquid wastes from the body. To perform this task, the excretory system must interact with the digestive and circulatory systems.

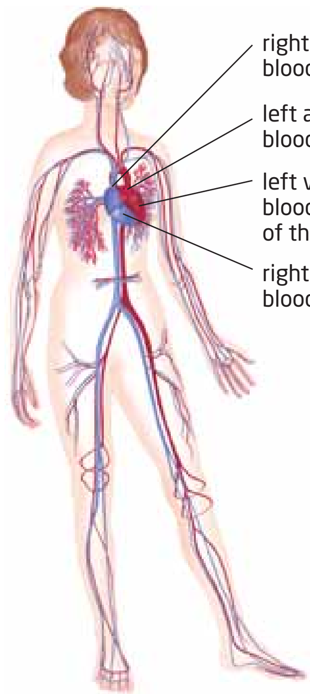


Figure 3.19 Arteries (shown in red) carry blood from the heart to all body parts. Veins (shown in blue) carry blood from body parts back to the heart. Along its pathways through the body, blood interacts with every other organ system.

Circulatory System

The circulatory system picks up and transports nutrients and oxygen to cells and carries wastes to the organs responsible for eliminating them from the body. **Figure 3.19** shows how the parts of the circulatory system branch throughout the body.

When the heart contracts, it produces pressure on the blood in the circulatory system. This pressure pushes blood through the body. Flexible flaps of tissue called *valves* are found throughout the circulatory system, including the heart and veins. They open when blood is pushed through them, and then close to prevent blood from flowing backward.

As **Figure 3.20** shows, the structure of the heart allows two separate paths through which the blood circulates. Blood that returns from the body is deoxygenated (has had its oxygen removed by body cells) and carries the body's carbon dioxide waste from cellular respiration. The first path the blood takes is therefore from the heart's right atrium to its right ventricle, which pumps the blood through the *pulmonary artery* to the lungs. There the blood eliminates carbon dioxide and picks up oxygen. This oxygenated blood then goes back to the heart, to its left atrium, and then to the left ventricle. From the left ventricle, it is pumped out through the *aorta*, a huge artery, to the rest of the body. Some of this blood goes to the heart itself, which, like all other organs, needs a constant supply of oxygenated blood in order to keep functioning.

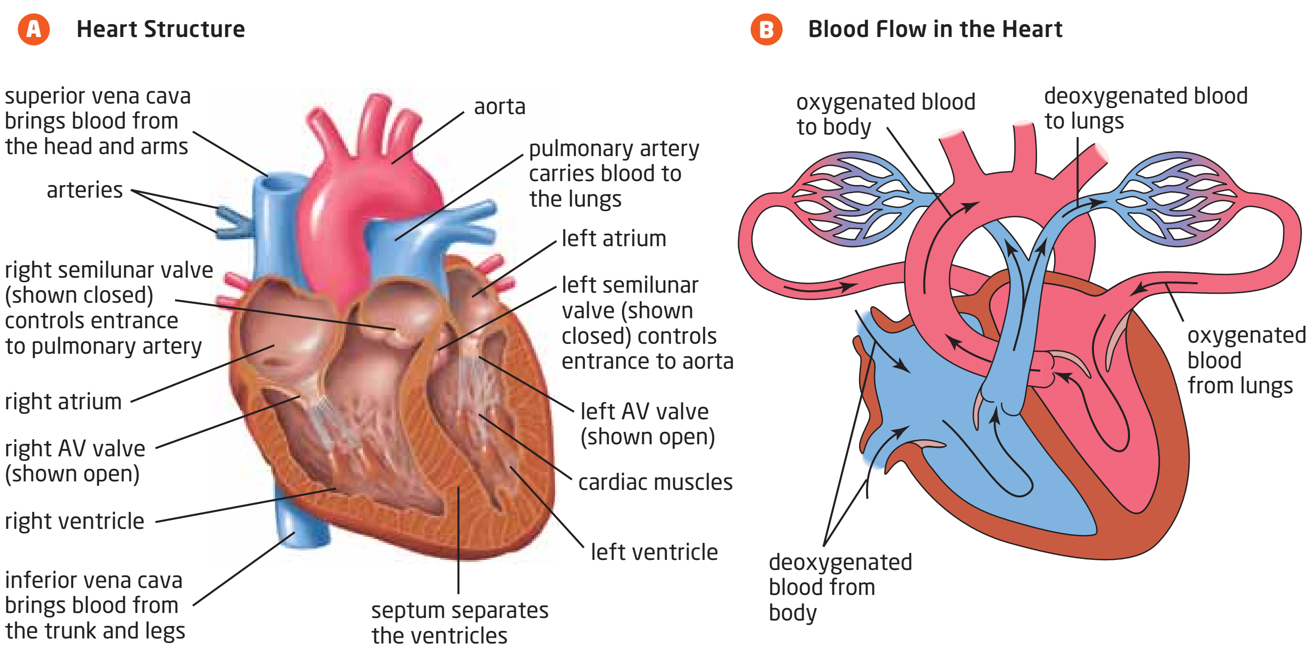


Figure 3.20 **A** The left ventricle is more muscular than the right, giving the heart a lopsided shape. **B** Note that the atria contract at the same time, and the ventricles contract at the same time. Thus, only two contractions are required to pump blood through all four chambers.

Same Task, Different Systems

All multicellular organisms have a way of getting oxygen to their cells. Some circulatory systems, like those of insects, are said to be *open*. They have one major vessel that empties oxygenated blood into parts of the body. In these places, cells are bathed in blood. Movements of body muscles take the blood back to be collected by the single vessel. In contrast, mammals and birds have a *closed* circulatory system—the blood stays in arteries and veins.

Fish have two-chambered hearts (one atrium and one ventricle), and amphibians have three-chambered hearts, as shown in **Figure 3.21**. The frog's heart has two atria, but only one ventricle. This means there is some mixing of oxygenated and deoxygenated blood, so some of the blood that is pumped back to the body has not passed through the lungs. However, the moist skin of frogs means that some oxygen diffuses directly through their skin, ensuring that their cells get enough oxygen.

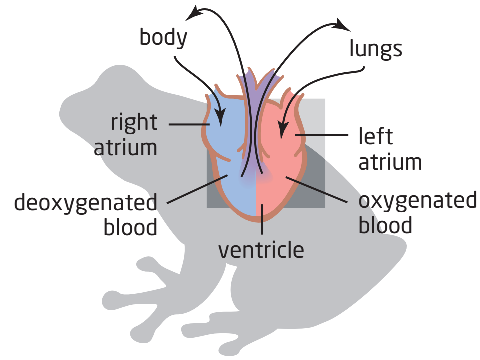


Figure 3.21 Amphibians like this frog have a three-chambered heart.

Activity 3-3

Changing Your Pulse Rate

Your pulse is produced by blood surging through your arteries each time your heart "beats." It is one indicator of how well your circulatory system is working. What factors affect the rate at which your heart pumps blood? Measure your pulse rate to find out.

Caution: Do not do this activity if you have any health problems that may put you at risk.

Materials

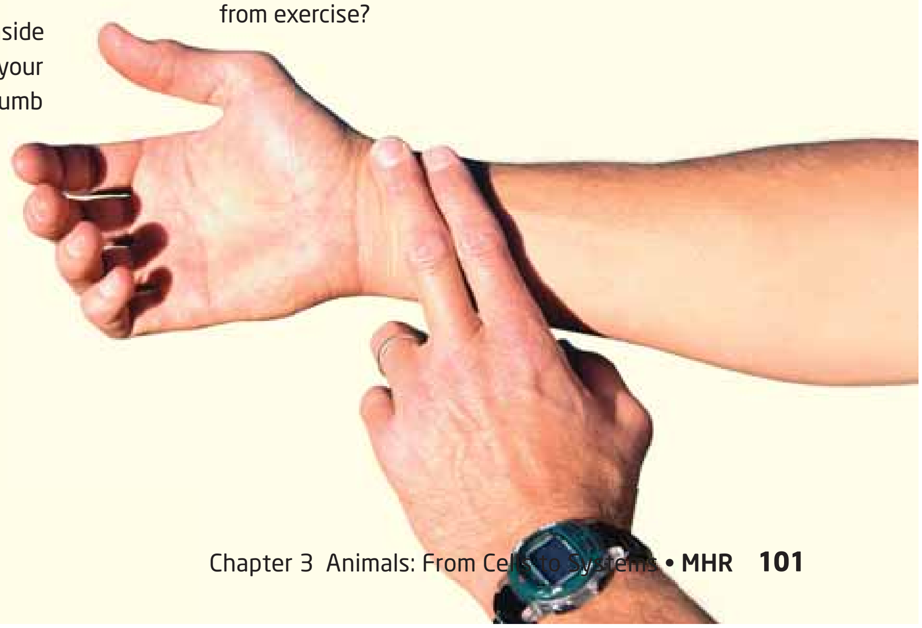
- watch or timer

Procedure

1. Locate one of your radial arteries, on the inside of your wrist in line with your thumb. Find your pulse using one or two fingers, not your thumb because your thumb has a pulse.
2. Using a watch or timer, count the number of pulses you feel in 15 s while you are sitting comfortably at rest. Multiply the number by 4 to obtain your pulse rate per minute. Record your results.
3. Stand up and run in place for 1 min. Immediately measure and record your pulse rate.
4. Rest for 2 min and measure and record your pulse rate again.

Questions

1. Using your results, explain the relationship between exercise and pulse rate. Suggest an explanation for this relationship.
2. Why is regular exercise good for your heart? What kind of heart tissue, in particular, would benefit from exercise?



Capillaries: Helping Systems Interact

Arteries and veins, shown in **Figure 3.22**, are connected by capillaries. Capillaries are extremely small, thin-walled blood vessels. They are only one epithelial cell thick! The areas where the branches of capillaries are close to one another are called capillary beds.

The capillaries bring blood into close contact with the tissues in organs throughout the body. For example, as you saw in **Figure 3.16**, capillaries bring blood into contact with the small intestine's villi and microvilli. There, blood picks up nutrients from digested food and delivers the nutrients to cells in the body. And as you will see on page 104, capillaries also bring the blood into close contact with tissue in the lungs, where it picks up oxygen. In every tissue of every organ in the human body, capillaries deliver blood that is rich in oxygen and nutrients. At the same time, blood in the capillaries picks up wastes from cells and transports them to the kidneys and lungs, where they are removed from the bloodstream.

Sense of scale

If the arteries, veins, and capillaries in your body were arranged end to end, they would stretch a distance of approximately 160 000 km.

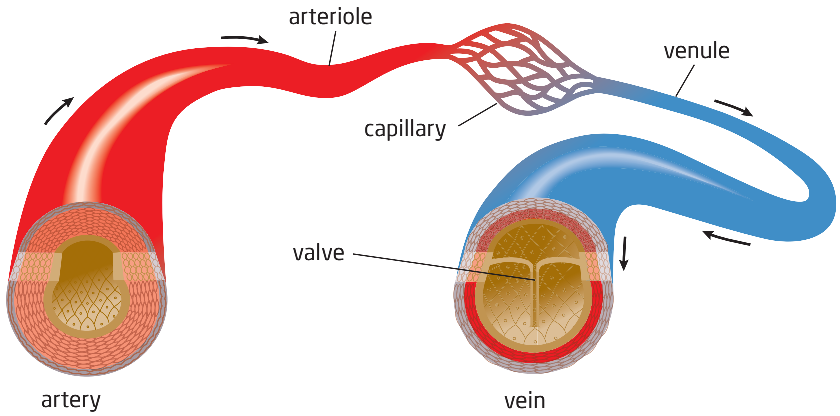


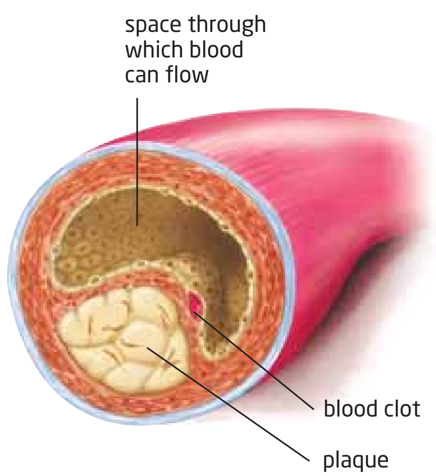
Figure 3.22 Veins are lined with valves that prevent the backflow of blood as it travels back to the heart. Veins have thinner walls than arteries, which have thicker, more muscular walls that expand when the heart contracts.

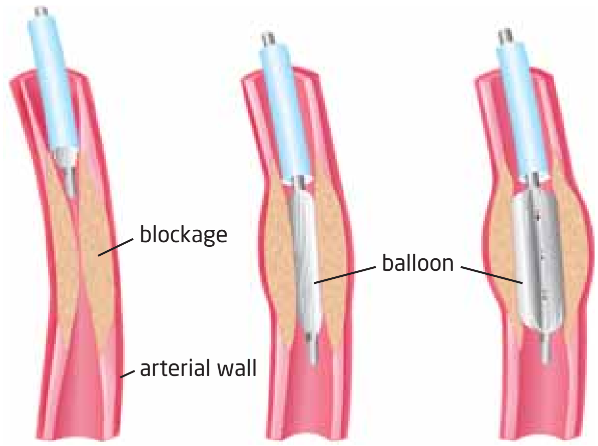
Heart Disease and Stroke

The delivery of blood is essential for the proper functioning of all of the other systems in the human body. Therefore, it is important that the heart works well. Unfortunately, there are an estimated 70 000 heart attacks each year in Canada, about 25 percent of which result in death.

The two most common causes of heart disease are hypertension (high blood pressure) and arteriosclerosis. Arteriosclerosis is a thickening of the walls of the arteries, which narrows the passageway for blood, as shown in **Figure 3.23**. Hypertension and arteriosclerosis can cause the formation of *blood clots*. If a blood clot breaks free, it may flow to a coronary artery and block a vessel, causing a *heart attack*. If the blood clot reaches the brain, it may block a vessel there, causing a *stroke*. When a stroke occurs, part of the brain is damaged due to oxygen deprivation. A type of surgery called angioplasty, shown in **Figure 3.24**, uses a balloon or laser to try to open clogged arteries.

Figure 3.23 An accumulation of cholesterol or other fatty substances—called plaque—can restrict blood flow through arteries.





Suggested Investigation
Real World Investigation 3-A, Heart Disease: Making the Public Aware, on page 116

Figure 3.24 During an angioplasty, a surgeon inserts a plastic tube into an artery in an arm or leg and threads it all the way to the heart. When the tube reaches the blockage in the coronary artery, the surgeon inflates a balloon at the end of the tube to break up a clot or open up a vessel clogged with plaque. This procedure allows blood to pass through.

The Respiratory System

The organs of the respiratory system, shown in **Figure 3.25**, are responsible for the body's gas exchange, bringing oxygen into the body and getting rid of carbon dioxide. The respiratory system is connected to the circulatory system. One system could not do its work without the proper functioning of the other.

When you breathe, muscle contractions cause your rib cage to move up and out and your diaphragm to move down. This causes air to be pulled into your body through your nose or mouth. The air passes by epithelial cells that have microscopic, hair-like projections called *cilia*. These cells also secrete mucus. The mucus and cilia help keep foreign particles, such as dust and bacteria, out of your body.

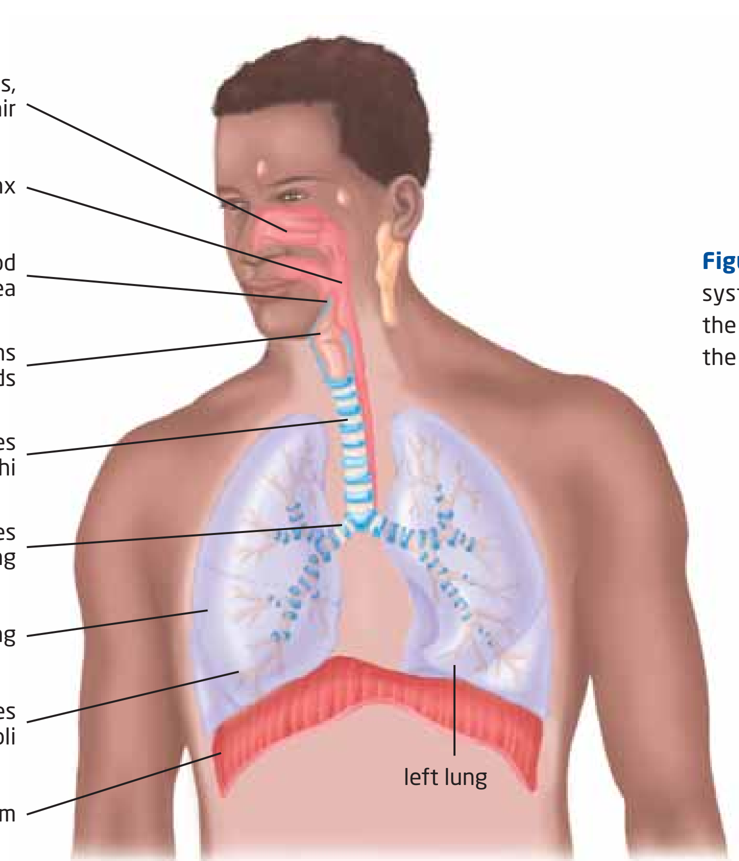


Figure 3.25 The respiratory system consists of the lungs and the airways that connect them to the outside world.

Through Smaller and Smaller Tubes

Once through the nasal passages and pharynx, the air moves into the *trachea*. A muscular flap, the epiglottis, opens so air can pass. When food is in the passage, the epiglottis closes so no food gets in the trachea. The air passes into branching tubes called the *bronchi* (singular bronchus). Each bronchus then continues to branch into smaller tubes called *bronchioles*. Muscle tissue in the walls of bronchioles allows the diameters of the tubes to contract or relax to control the amount of air entering the lung.

After entering the bronchioles, the air passes into increasingly smaller tubes until it ends up in tiny sacs called *alveoli*, shown in **Figure 3.26**. In the alveoli, the air is only one thousandth of a millimetre away from the bloodstream. This thin layer of epithelial tissue keeps most inhaled bacteria and viruses out of the bloodstream, but still allows gases to cross (oxygen out of the lungs and carbon dioxide back in).

Your red blood cells contain a protein called hemoglobin, which attaches to oxygen molecules. As shown in **Figure 3.26**, when deoxygenated red blood cells pass by the alveoli, the hemoglobin they contain causes them to pick up oxygen. The oxygenated blood then travels throughout the body, delivering its oxygen to cells that need it for cellular respiration.

When your chest muscles and diaphram relax, you exhale and the carbon dioxide in the alveoli is carried out of your body. Your body constantly monitors the amount of carbon dioxide being carried in the blood. When the level of carbon dioxide is too high, your breathing rate increases so this waste product can be eliminated more quickly.

Sense of place

People normally have around 13 kilopascals (kPa) of oxygen in their bloodstream. A person with 6 kPa is generally close to death. However, in 2009, a team of researchers at the top of Mount Everest (8850 m) were shocked to measure their oxygen levels at between 2.5 and 4 kPa.

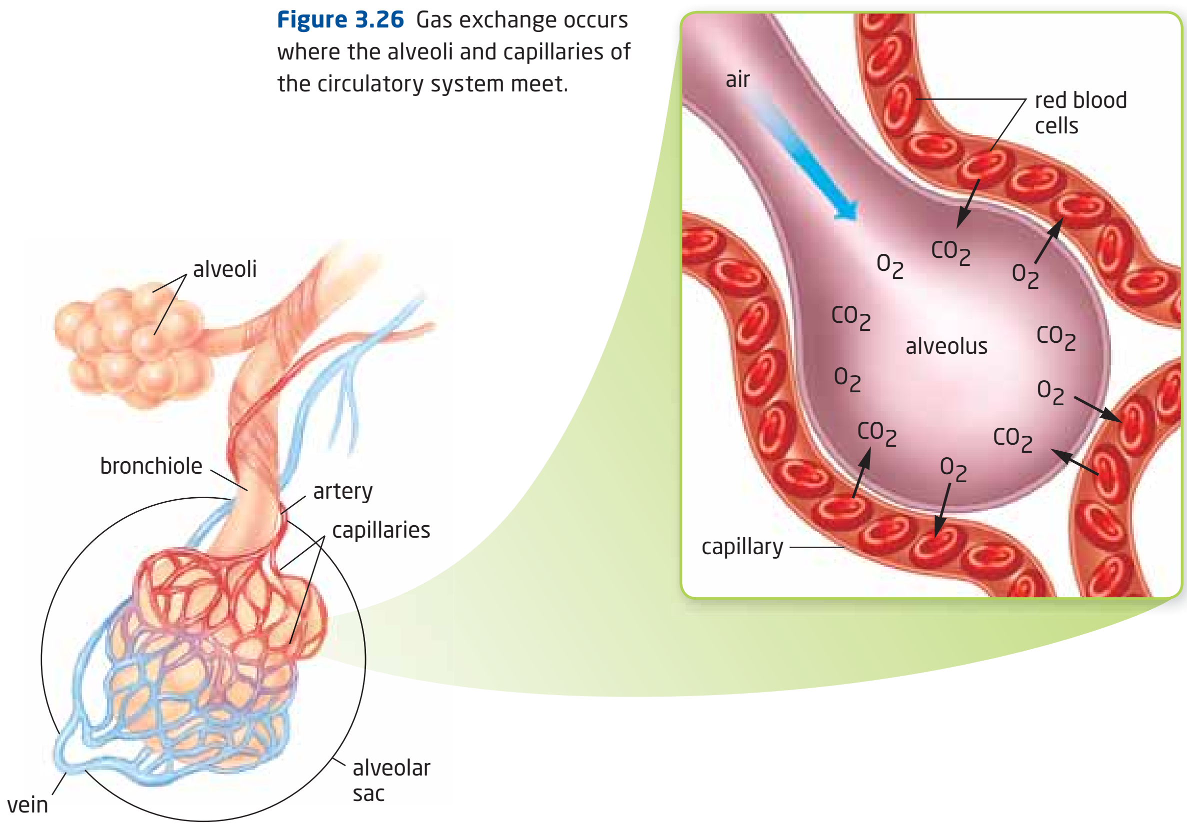


Figure 3.26 Gas exchange occurs where the alveoli and capillaries of the circulatory system meet.

Diseases Related to Smoking

You probably know that smoking is not good for your health, but do you know why? One problem is that smoking damages the cilia, preventing them from sweeping foreign particles out on cells of the respiratory system. Another is that cigarette smoke is filled with more than 4000 chemicals, including over 40 that are known carcinogens. In addition, cigarette smoke has over 1000 times the level of carbon monoxide that is known to be harmful to human health. Cigarette smoke also contains tar, which accumulates in the lungs. Tar is responsible for many respiratory problems. People who smoke a pack of cigarettes a day absorb about 250 mL of tar into their lungs each year. **Figure 3.27** shows how lung tissue can be damaged by smoking.

Study Toolkit

Asking Questions Read the section "Diseases Related to Smoking" and write at least four who, what, when, where why, and how questions. Reread the text to find answers, or do your own research.

Figure 3.27 The cross section of the lung on the left looks mostly healthy, although some blackened tissue can be seen. This tissue may have been damaged by environmental conditions. The cross section on the right shows a lung destroyed by cancer. You can see a large white tumour and many black tar deposits due to cigarette smoking.

Other Gas Exchange Systems

Birds, many amphibians, reptiles, and other mammals have lungs just as humans do. Other animals, like the fish shown in **Figure 3.28**, have different ways to accomplish the same gas exchange function.

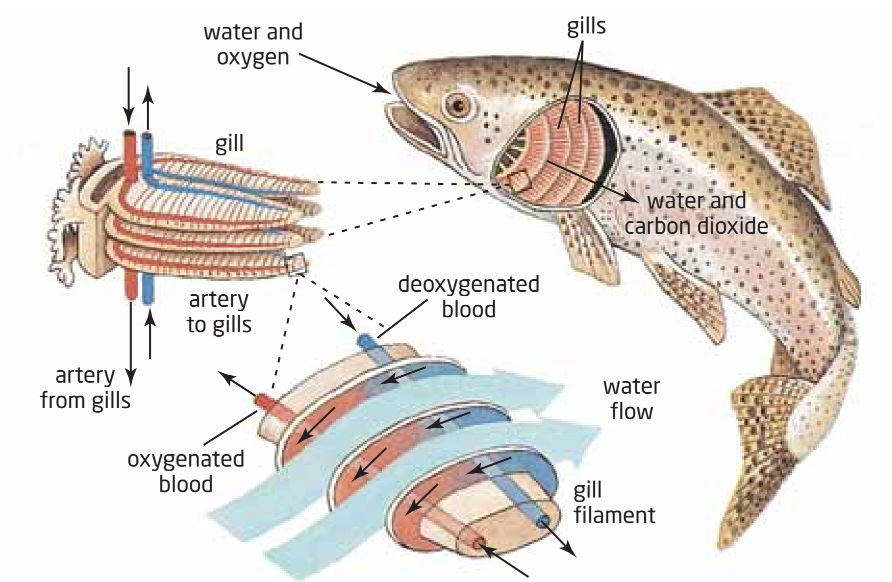


Figure 3.28 A fish draws water through its mouth and over its gills. As water passes over the gills, oxygen diffuses into the adjacent blood vessels. At the same time, carbon dioxide diffuses out.

Learning Check

5. Draw and label a diagram showing the four chambers of the heart.
6. Examine **Figure 3.20** and the description of the parts of the heart and their functions. Why do you think the left side of the heart has stronger muscles than the right?
7. Describe the path air must take to reach the alveoli, where gas exchange takes place
8. Anemia is a fairly common condition in children, teens, and adult women. It usually results from having too few red blood cells. People with anemia often do not seem to have much energy. Use what you know about the circulatory system to explain why.

Anatomical Arrangements

Go to **scienceontario** to find out more

Much of the efficiency of our organs and organ systems, and their ability to interact, is due to how they are positioned anatomically. As you have seen, the close contact between thin-walled capillaries and the villi of the small intestine and the alveoli of the lungs permits the movement of nutrients, oxygen, and wastes. This type of interaction happens in other systems and body parts as well, as you can see in **Figure 3.29**.

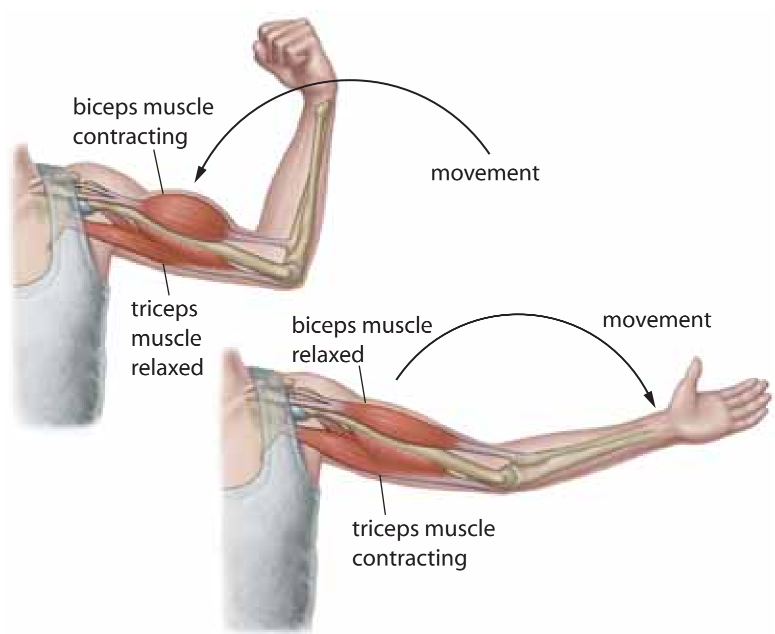


Figure 3.29 You can move because pairs of skeletal muscles work together with your body's bones. As shown here, when your bicep muscle contracts, it pulls the bone in your forearm up. When your bicep relaxes, the tricep muscle contracts and the forearm drops.

Suggested Investigation

Inquiry Investigation 3-B, Frog Dissection, on page 117

For centuries, scientists have used dissection to study how organs are arranged to carry out their functions. Students in introductory science courses often dissect frogs, earthworms, or fetal pigs. Today, when specimens are not readily available or if it is considered more appropriate for the course, students sometimes carry out virtual dissections rather than actual dissections.

Section 3.2 Review

Section Summary

- The human body has 11 organ systems that interact with one another in order to perform the tasks necessary for survival and reproduction.
- The stomach is a major organ in the body's digestive system, which is responsible for taking in nutrients and breaking them down into a form that can be used by other cells in the body.
- The heart is a major organ in the body's circulatory system, which is responsible for moving gases, nutrients, and wastes in the body.
- The lungs are major organs in the body's respiratory system, which is responsible for gas exchange.

Review Questions

K/U **1.** What features of the small intestine's structure help it accomplish its task?

T/I **2.** In patients with cystic fibrosis, the duct joining the pancreas to the small intestine is often blocked. What effect might this have on digestion?

A **3.** What do people mean when they talk about "food that went down the wrong way"?

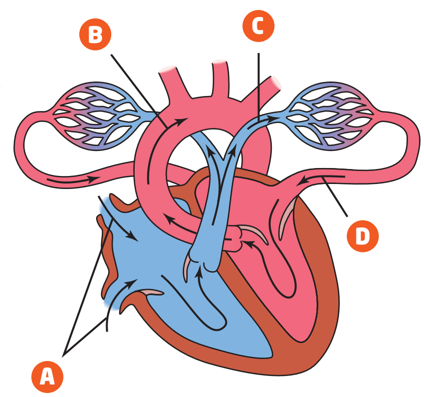
K/U **4.** Match the correct label to each letter on the diagram to the right.

a. deoxygenated blood to lungs

b. oxygenated blood to body

c. oxygenated blood from lungs

d. deoxygenated blood from body



T/I **5.** At altitudes of 5500 m above sea level, the body has more difficulty functioning because there is less oxygen available to breathe. The highest city in the world is Wenzhuan, in the Himalayas, at an elevation of 5099 m above sea level. How does your knowledge of the circulatory and respiratory systems help you make a connection between these two facts?

K/U **6.** Describe what happens in the alveoli.

T/I **7.** Hyperventilation refers to breathing in and out deeply and rapidly. One effect of hyperventilation is to get rid of a large percentage of the carbon dioxide in your blood. A side effect is that your brain does not get enough oxygen, which may cause you to lose consciousness. Why might this occur?

C **8.** Use cutouts or draw a diagram of the lungs, heart, and major blood vessels coming to and from them to show the relationships among these major organs. Using your cutouts or diagram, explain to a partner how blood gets to and from the lungs and what happens to the blood while it is in the lungs.