3.0

Healthy human function depends on a variety of interacting and reacting systems.

Key Concepts

In this section, you will learn about the following key concepts:

- cells
- organs
- tissues
- structure and function
- response to stimuli
- systems

Learning Outcomes

When you have completed this section, you will be able to:

- describe how various body systems work
- recognize the roles of organs and tissues in body systems
- describe how various cells help the body to function
- show how the body responds to changing conditions

Although each organ system must have the ability to **react** to changes both within and outside your body to maintain life, your body's organ systems actually depend strongly on one another. This means they work together, or **interact**, as a single unit to carry out all the functions that are vital to your survival.

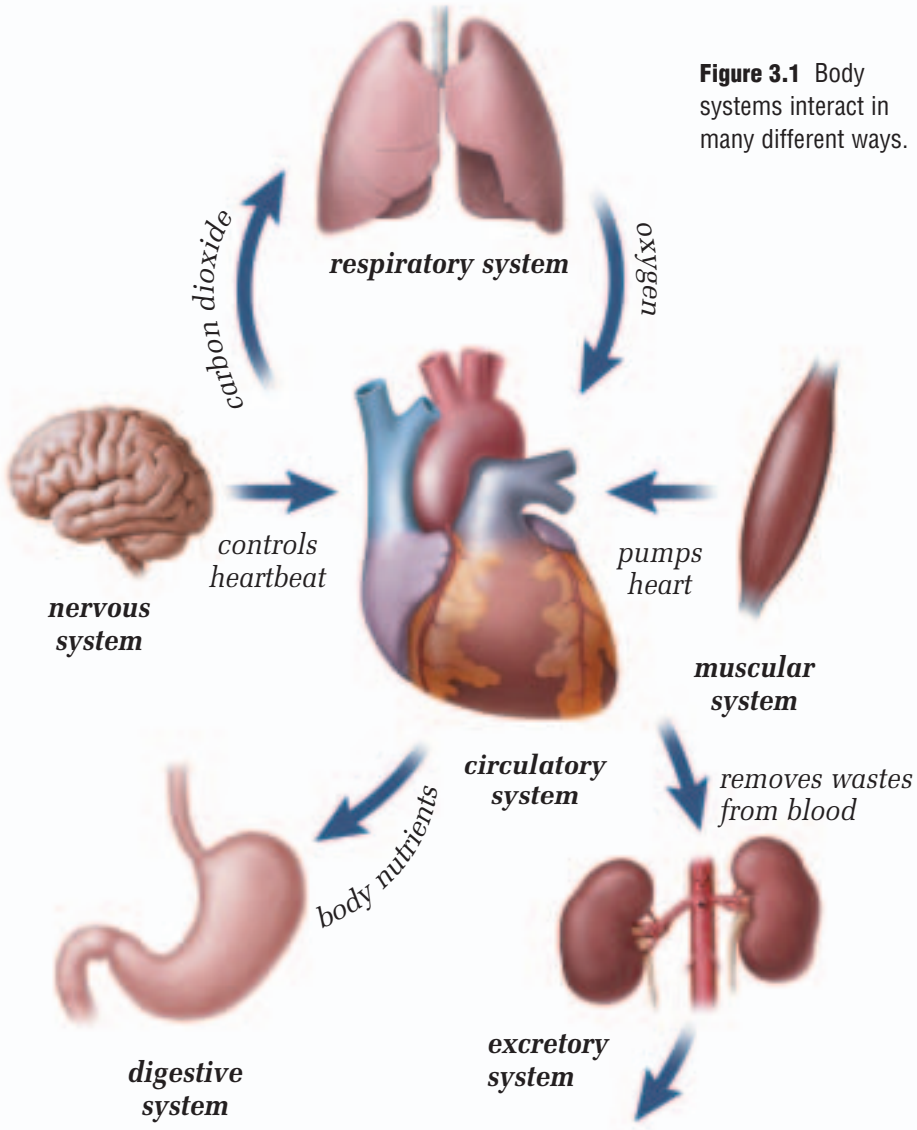


Figure 3.1 Body systems interact in many different ways.

For Web links relating to 3.0, visit **www.pearsoned.ca/scienceinaction**

3.1 Digestive System

Living organisms require energy to survive. Like other animals, you obtain energy from different sources such as carbohydrates (sugars and starches), lipids (fats and oils), and proteins. But before your cells can use any of these energy sources for fuel, they must be processed by your digestive system. Your digestive system is in charge of breaking down the food you eat into parts small enough to be used by your cells. Each of the different energy sources: carbohydrates, lipids, and proteins must be broken down into small usable particles as they travel through your digestive system.

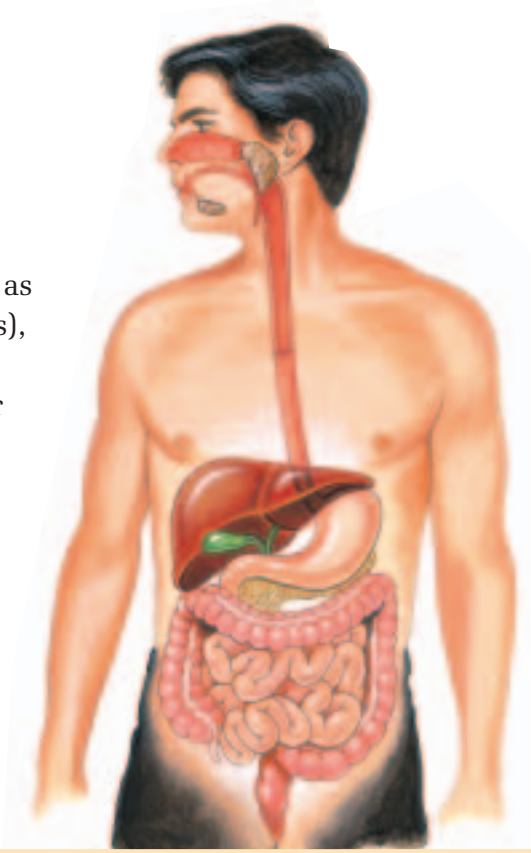


Figure 3.2 Organs of the digestive system

Give it a **TRY**

ACTIVITY

A Taste of Digestion

Your teacher will give you some unsalted soda crackers. Chew the soda crackers up thoroughly, and then hold them in your mouth for about 5 min without swallowing. (This can be a bit difficult to do, but do your best.) Swallow the crackers once you have finished the activity. At the end of 5 min, you will assess any changes in the taste of the crackers.

- How did the crackers taste as you first chewed them?
- Describe how the taste changed as you neared the 5-min mark of the test.
- Compare your taste experience with that of your classmates.
- What do you think caused any changes you experienced?

Types of Digestion

There are two types of digestion. **Mechanical digestion** involves the physical breakdown of food into very small pieces. **Chemical digestion** involves the breakdown of large particles into smaller particles by substances called **enzymes**. Mechanical and chemical digestion happen in several different places in our digestive systems.

Food's Path through the Digestive System

The digestive system is actually a long tube, with a few attachments along its length. It starts at your mouth and finishes at the rectum. To help you see how the digestive system works, imagine that you've just taken a big bite of your favourite snack. Of course, this snack is well balanced and nutritious, so it contains starch, lipids, protein, minerals, and vitamins.

The Mouth and Esophagus

Before the food you've eaten reaches the stomach, it comes into contact with many organs. Digestion begins at the entrance to the tube, the mouth, with the mechanical breakdown of your food. The teeth mechanically digest the food by grinding it and mixing it with saliva. Three pairs of salivary glands located in the tissues surrounding your mouth produce saliva. Saliva contains water to moisten the food, making the food easier to swallow. It also contains an enzyme known as salivary amylase. This enzyme chemically digests large starch molecules into smaller sugar molecules.

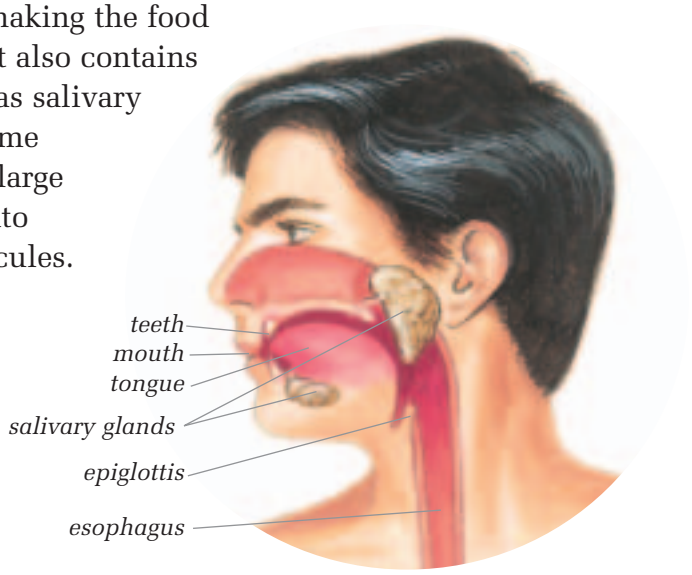


Figure 3.3 Saliva from salivary glands moistens food in the mouth.

*info*BIT

Accident Advances Science!

Much of what we know about the stomach can be attributed to Alexis St. Martin, a French-Canadian voyageur and his American doctor, William Beaumont. St. Martin was almost killed by an accidental gunshot wound to his left side. Because of the size of the wound, Beaumont was forced to leave a permanent opening through St. Martin's skin into his stomach. Beaumont used this access to the stomach to study digestion. Beaumont would dangle different food types on a string into St. Martin's stomach. Despite his unusual injury, St. Martin lived into his 80s.

Once you are ready to swallow your thoroughly chewed bite of food, your tongue pushes it to the back of your throat. As you swallow, a flap of skin called the epiglottis moves across your windpipe, and food is funnelled into the esophagus. The food moves down toward your stomach by a wave-like movement known as peristalsis. **Peristalsis** is caused by contractions of muscle tissue that lines the esophagus. Bands of muscle tissue line the remainder of the digestive system to push the food along toward the end. If you've ever taken a big bite of food and not chewed it properly, you might have felt pain or discomfort as the muscles contract around the food to push it toward your stomach.

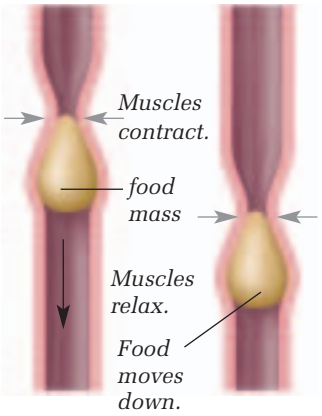


Figure 3.4 Peristalsis in the esophagus

The Stomach

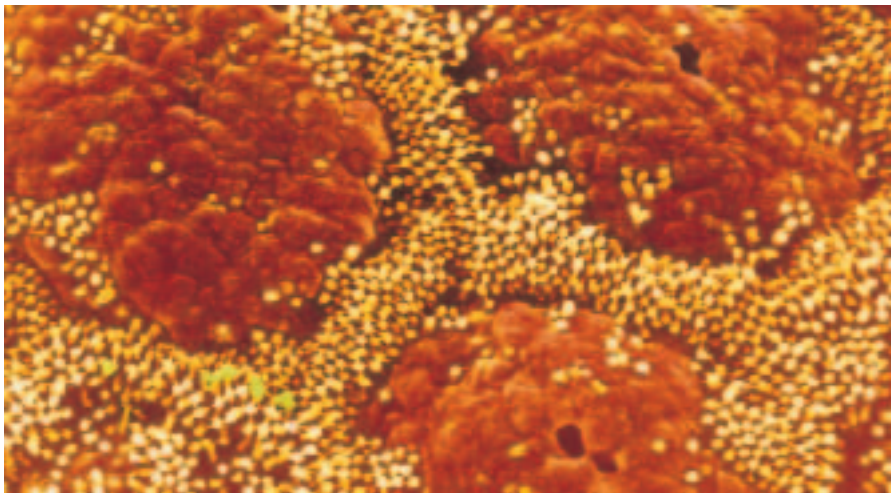


Figure 3.5 The yellow dots are droplets of mucus produced by the stomach wall.

The stomach responds to the stimulus of the arrival of food in a couple of ways. The muscular wall of the stomach churns the food back and forth, while mixing it with secretions from the wall of the stomach, known as gastric juice. **Gastric juice** is composed of mucus, hydrochloric acid, water, and digestive enzymes. The hydrochloric acid, along with the enzymes, chemically digests proteins into smaller particles. The mucus helps to prevent the gastric juice from digesting the stomach itself. The stomach slowly releases the food, which is now a liquid, into the small intestine.

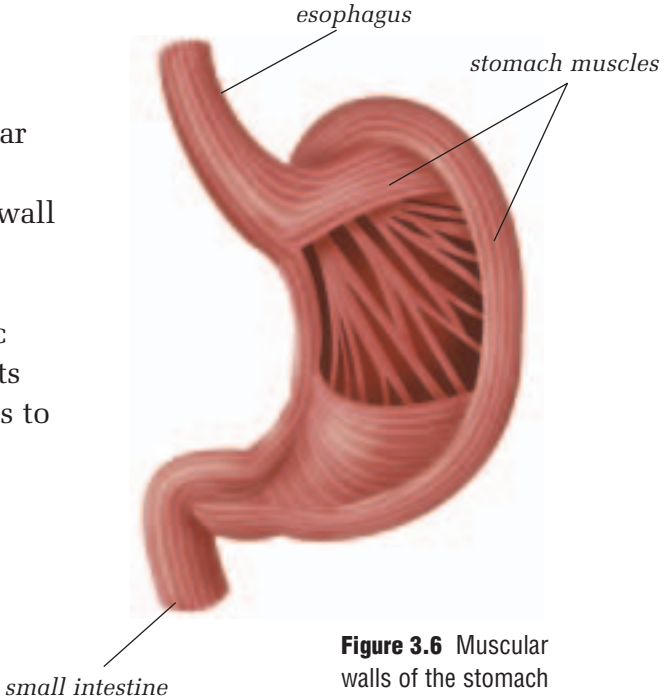


Figure 3.6 Muscular walls of the stomach

The Small Intestine, Pancreas, Liver, and Gall Bladder

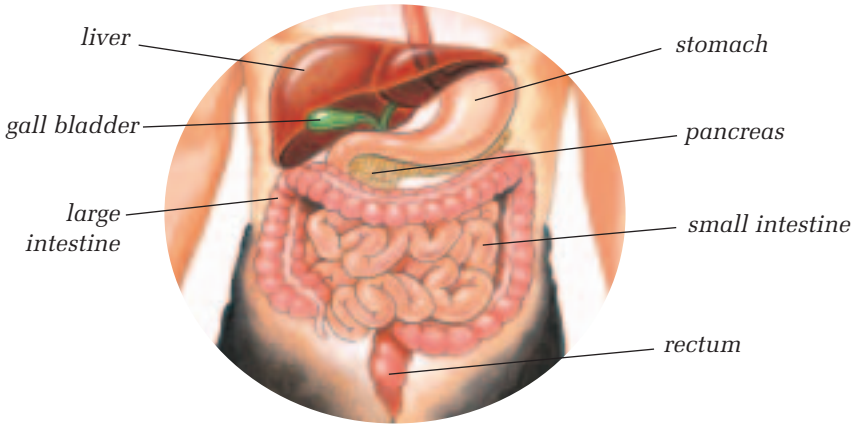


Figure 3.7 The lower part of the digestive system

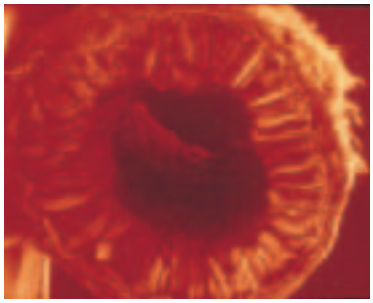


Figure 3.8 A cross-section of the small intestine showing villi on the inner surface

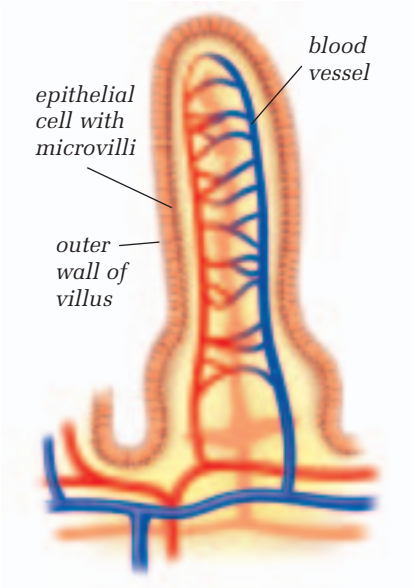


Figure 3.9 The inner structure of a villus

As food moves into the small intestine, chemical digestion continues. Here, the pancreas sends digestive enzymes into the small intestine. These enzymes, along with enzymes produced by the wall of the small intestine, complete the breakdown of starches and proteins into very small particles. The liver produces a substance called bile, which is stored in the gall bladder. The gall bladder sends bile into the small intestine where it breaks up large globules of lipids into much smaller droplets.

Once the food has been broken up into small particles, the small intestine absorbs these particles. The inner surface of the small intestine forms into **villi**—small, finger-like projections. These increase the surface area of the intestine to aid in absorbing nutrients. Each villus (the singular term for villi) is covered with epithelial tissue. The food molecules get absorbed by this tissue. Blood vessels lie just below the epithelial tissue, and the nutrients are transferred to the bloodstream.

The small intestine is 6 m long; if your small intestine was stretched so that the villi unfolded, it would cover the whole floor of your classroom!

The cells of the epithelial tissue have modified cell membranes that form more finger-like projections called **microvilli**. Microvilli further increase the surface area of the small intestine to help absorb nutrients.

The Large Intestine

By the time the food reaches the large intestine, mechanical and chemical digestion are complete. In humans, the large intestine is about 1.5 m long. The large intestine absorbs water, along with some vitamins and minerals. Any parts of the food that have not been digested are formed into feces, which is collected in the rectum.

Check and Reflect

1. Make a chart like the one below and use information you have learned to fill it in.

Organ	Mechanical Digestion	Chemical Digestion

2. Imagine that you have just eaten a cheeseburger. Describe the path of the cheeseburger through your digestive system and the mechanical and chemical digestion that occurs to the food as it is broken down.
3. For each of the terms below, explain the relationship that exists.
   a) digestion, enzymes
   b) nutrients, villi
   c) enzymes, nutrients
   d) digestion, peristalsis
4. Explain how the small intestine, which fits into a fairly small space in the body, manages to have such a large area of food-absorbing surface.
5. Describe the role tissues and cells play in digestion.
6. You know that different organisms have slightly different structures to perform the same functions.
   a) Examine the digestive systems of the animals shown in Figure 3.10. In what ways are the structures of these systems similar and different?
   b) Describe how the functions of these structures may be similar and different.

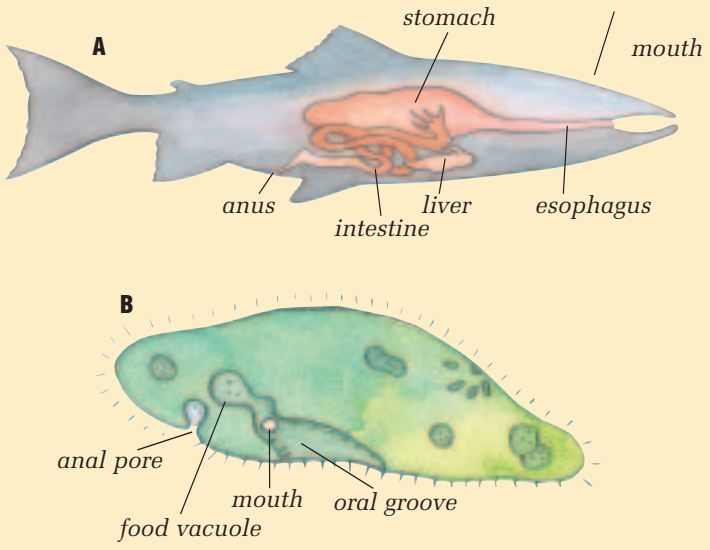
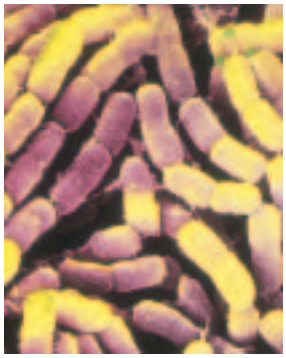


Figure 3.10

reSEARCH

Bacteria Breakdown

Many bacteria live in your large intestine, and they help break down certain foods and provide you with nutrients you would not get otherwise. Find out more about these bacteria, such as the nutrients they supply you with and the effect that taking antibiotics has on them.



3.2 Respiratory System

Your respiratory system is responsible for supplying your blood with oxygen and removing the carbon dioxide from your blood and returning it to the air outside your body.

Give it a **TRY** ACTIVITY

What's in Your Breath?

Your body needs oxygen in order to survive, and it must also rid itself of the waste carbon dioxide. Both of these are accomplished by breathing. While it is difficult to prove that the air we inhale contains oxygen, it is easy to prove that your exhaled breath contains carbon dioxide. Follow the procedure below to find out how.

- Add 10 mL of water and a few drops of bromothymol blue to each of 2 test tubes.
- Label the first test tube "A" and the second test tube "B."
- Use a straw to gently blow 5 big breaths into the liquid of test tube A, and note any changes you observe.

Bromothymol blue changes colour when it is mixed with carbon dioxide. Did a colour change occur in one of the test tubes? What does this colour change prove? Why was it important to include test tube B in this experiment? What compound is present in your exhaled breath?

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How's the Air Up There?

Mountain climbing is a dangerous sport, especially when you want to climb the tallest mountain in the world. However, the danger is not just due to avalanches, crevasses, and blinding snowstorms. Much of it is due to the lack of oxygen in the air at such high altitudes. Your respiratory system tries to compensate for the thin air by acclimatizing and deep breathing. But the brain's function and coordination are affected. According to Calgary educator, speaker, and mountain climber David Rodney (who reached the peak of Mt. Everest in May 1999), everyone is functioning at a lower thinking level because the air has only one-third of the oxygen that sea-level air has.

Breathing

Breathing is the process your respiratory system uses to move air in and out of your lungs. Breathing occurs because of your rib and **diaphragm** muscles. When you inhale, these muscles contract, pulling your ribs up, and your diaphragm down. This increases the size of your chest and lungs, pulling air into your lungs. When you exhale, these muscles relax: your ribs go down and your diaphragm goes up. This decreases the size of your chest and lungs, forcing air out.

math Link

You breathe about 20 times a minute. How many breaths would you take in a day? in a year?

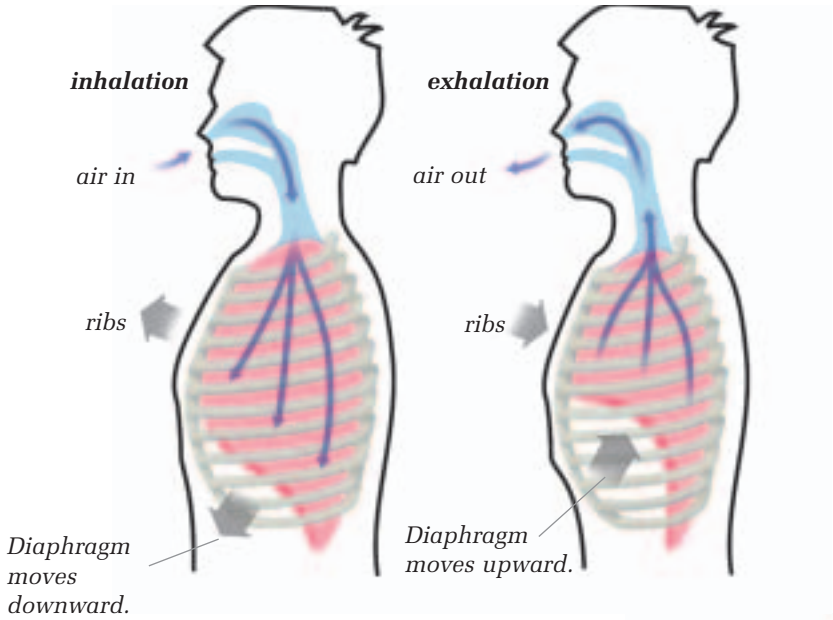


Figure 3.11 Movement of the ribs and diaphragm during breathing

Air enters your respiratory system through the structures shown in Figure 3.12.

The Gas Exchange Process

Your cells need oxygen to release energy from nutrients such as glucose. They also need to rid themselves of the carbon dioxide waste gas produced at the same time. Two body systems work together so that cells can exchange these two gases.

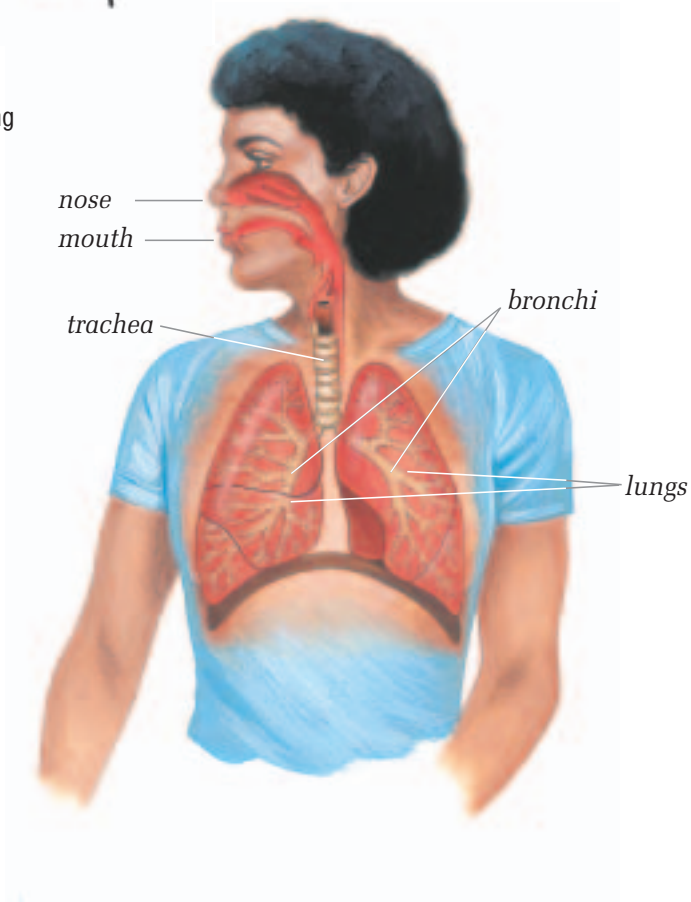


Figure 3.12 The pathway of air into the lungs

The respiratory system draws oxygen-rich air into the lungs through a series of tube-like passageways called **bronchi**. Bronchi are lined with tough connective tissue to keep the walls from collapsing. These bronchi narrow to **bronchioles** that end in about 600 000 000 tiny, air-filled sacs called **alveoli**. The alveoli, like the capillaries that surround them, are made of specialized epithelial tissue. This tissue is only one cell layer thick. This means that the distance between the air inside the alveoli and the blood inside the capillary is very short. If you think back to what you learned about diffusion, you probably have a good idea why this is so.

The air in the alveoli has a high concentration of oxygen and a low concentration of carbon dioxide. The blood in the capillaries surrounding the alveoli has a low concentration of oxygen and a high concentration of carbon dioxide. So oxygen naturally diffuses from the alveoli into the capillaries, and carbon dioxide naturally diffuses in the other direction.

It takes only one second for blood to travel through your lungs, picking up as much oxygen as it can hold and releasing its carbon dioxide waste.

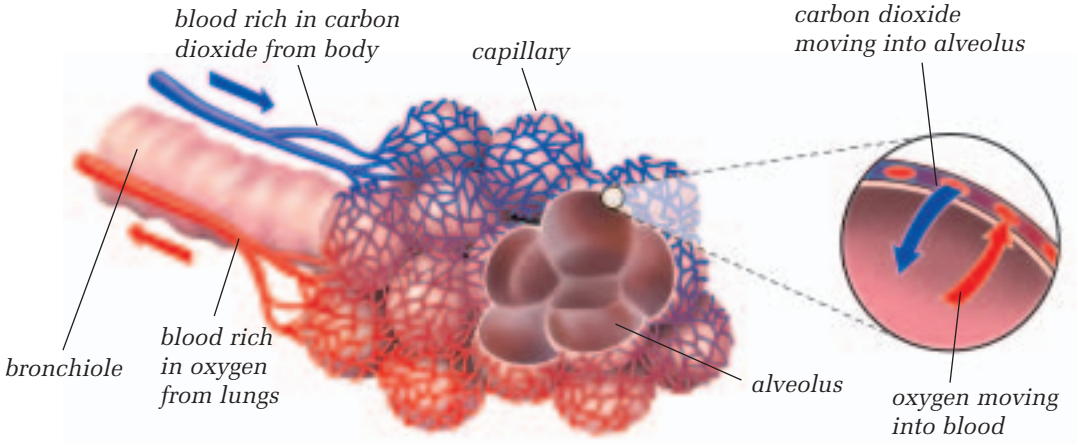


Figure 3.13 Alveoli are hollow sacs surrounded by capillaries. Gas exchange happens in the alveoli.

Check and Reflect

1. Draw a flowchart showing the process of respiration including the major organs and tissues involved and their functions.
2. List the structures that air particles pass through on their way to the alveoli.
3. Draw a diagram and label the structure of an alveolus.
4. What might be the effect of the following imaginary situations?
   a) The covering tissue of your capillaries is much thicker.
   b) Air-sac tissue is much thicker.
5. Why is it important to breathe deeply when exercising?

3.3 Circulatory System

One of the circulatory system's jobs is to deliver the nutrients absorbed by your digestive system to each cell in your body. The circulatory system, then, is your body's transportation network. Besides nutrients, your circulatory system must also transport oxygen to your cells and remove waste products.

Figure 3.14 How is your circulatory system similar to this highway interchange?

Figure 3.15
Arteries are in red; veins are in blue.

Give it a **TRY**

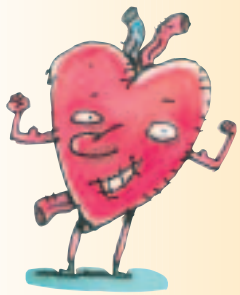
ACTIVITY

WHAT DO YOU KNOW?

What do you already know about the circulatory system? Write down the answers to these questions in your notebook.

- Where is the blood located? How does it move around your body?
- Why is some blood bright red and some blood dark red?

Discuss your ideas about the circulatory system with your classmates. As you work through this subsection, you will be able to compare your ideas against what you've learned.



The Heart

Your heart is an important part of your circulatory system. You probably know that the heart is a pump, but did you know it is actually two pumps? The right and left sides of your heart each act as a separate pump, and although they work together, each has its own job to do. The right side of the heart pumps blood to your lungs (where it receives fresh oxygen and gives off carbon dioxide). The left side of your heart receives this oxygen-rich blood from your lungs and pumps it to all the other parts of your body. The blood then returns to the right side of your heart to begin the cycle again. Each side of the heart is divided into two chambers. The top two chambers on each side are called **atria** (atrium is the singular form), and the bottom two chambers are called **ventricles**. Study the diagram below to learn more about the flow of blood through the heart.

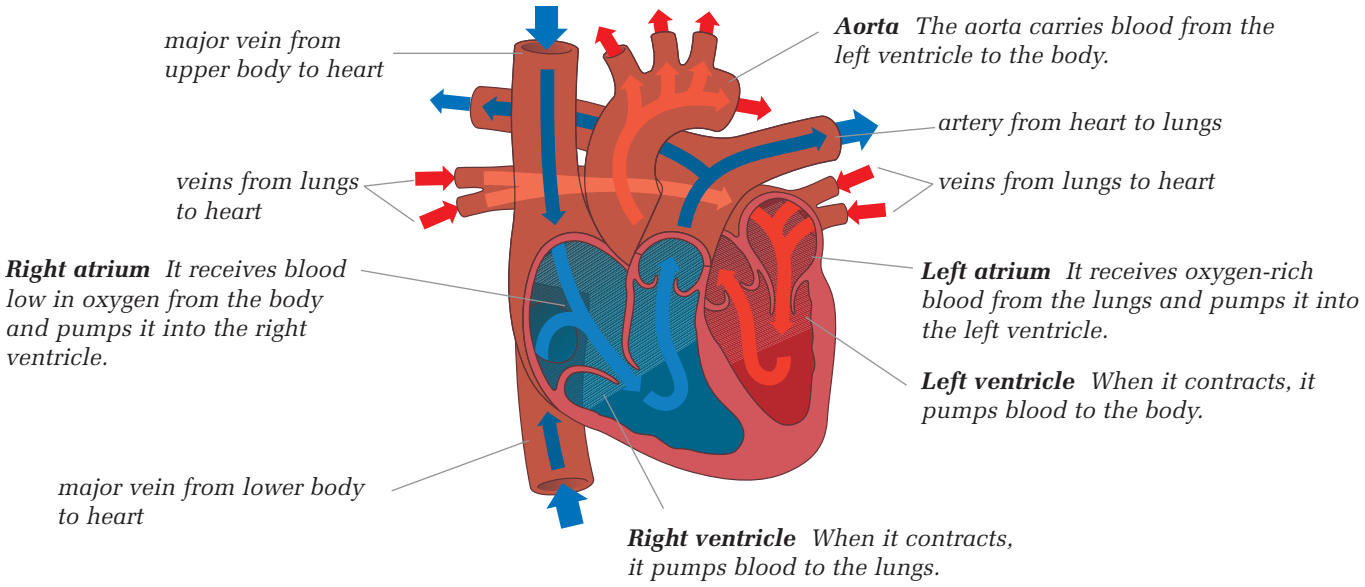


Figure 3.16 Blood flow through the heart. Blue arrows show the path of blood low in oxygen; red arrows show the path of blood high in oxygen.

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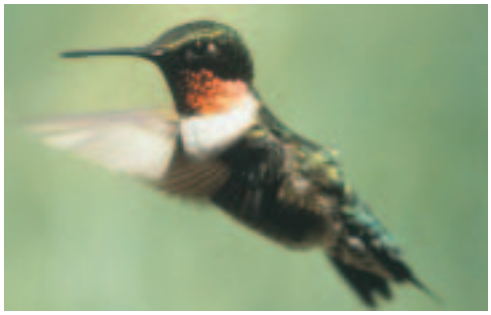
They've Got the Beat

The animal with the fastest heart rate is the hummingbird. Its heart beats about 1000 times a minute. A human's heart beats about 70 times a minute. An elephant's heart beats the slowest at about 25 beats per minute.



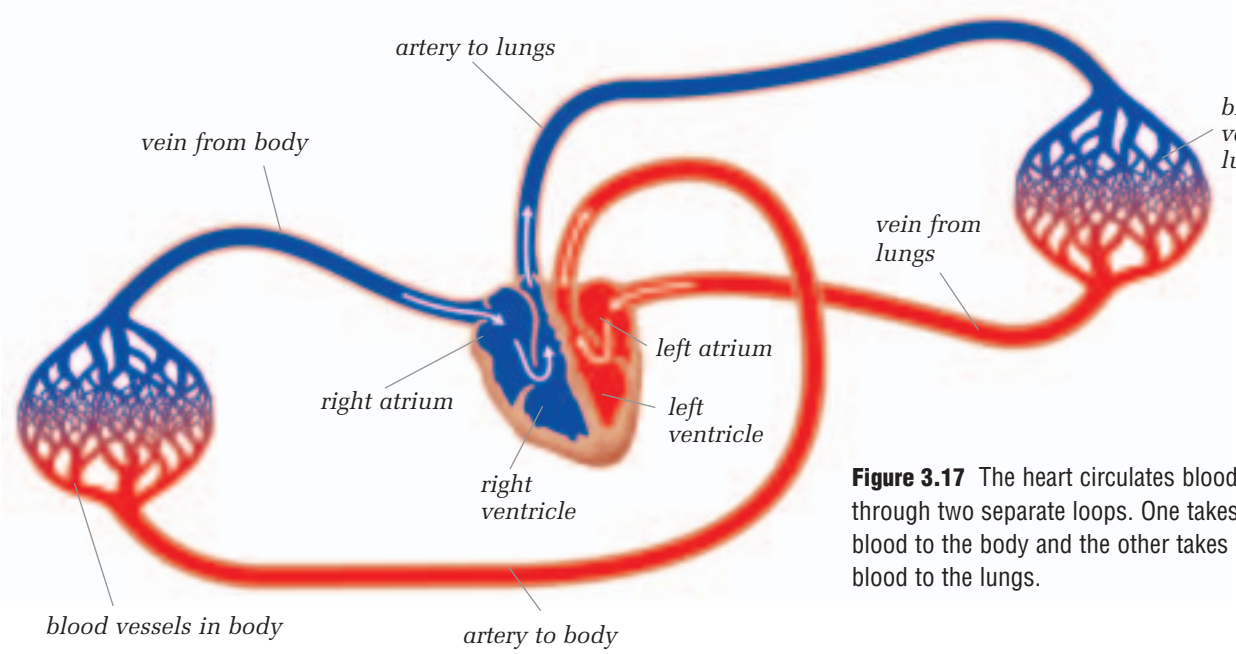


Figure 3.17 The heart circulates blood through two separate loops. One takes blood to the body and the other takes blood to the lungs.

Arteries, Veins, and Capillaries

Your heart is used to pump blood throughout your body. In fact, it has to pump blood through 100 000 km of blood vessels. The vessels that carry blood away from your heart to all the parts of your body are called **arteries**. Blood is returned from your body to the heart in **veins**. Blood vessels are made up of three of the four types of tissue: connective on the outside, muscle in the middle, and epithelial on the inside. Arteries, in particular, have a thick, muscular layer in the middle that expands and contracts to help push blood along. You feel this expansion of your arteries as a pulse. Veins are thinner and have valves that stop the blood from flowing backward.

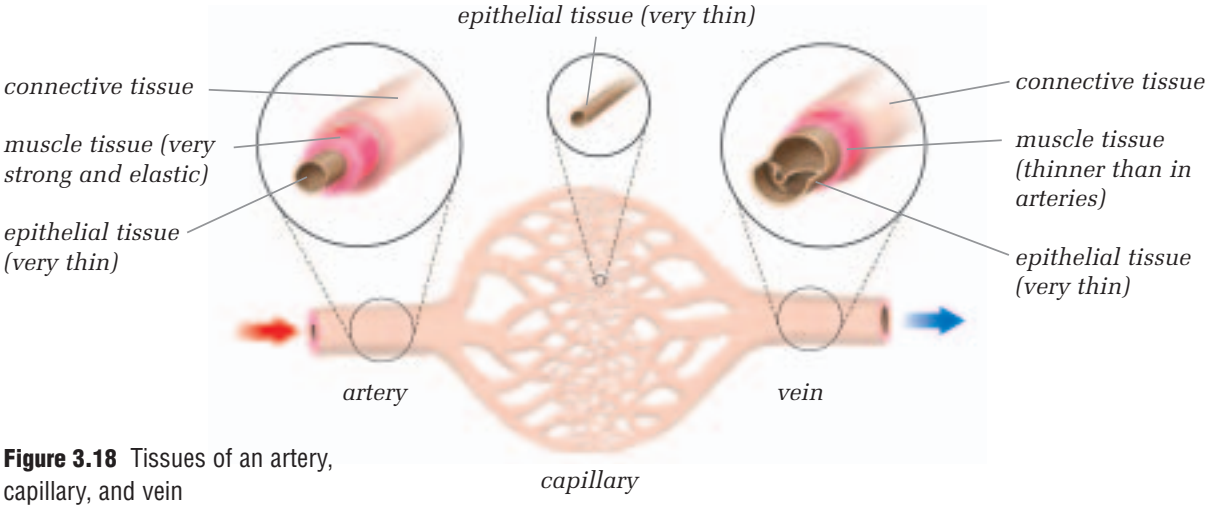


Figure 3.18 Tissues of an artery, capillary, and vein

Inquiry Activity

Changes in Heart Rate

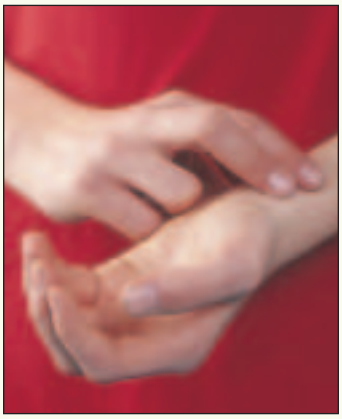


Figure 3.19 Two ways to measure your pulse

Materials & Equipment

For each pair of students:

- stopwatch, wristwatch, or clock with a second hand
- graph paper

Caution!
Do not complete this procedure if you cannot exercise for medical reasons.

The Question

Does your heart rate return to normal immediately after exercising?

The Hypothesis

Form a hypothesis based on the question.

Procedure

1. Your teacher will show you two ways to measure your pulse, as shown in Figure 3.19.
2. Work with a partner. One of you will do the experiment, and the other will be the timer and recorder. After you finish the procedure, switch roles and use the other way to measure your pulse. Begin by taking your pulse for 1 min while you sit quietly in a chair. Record your heart rate in a table.
3. Exercise vigorously (run in place or do jumping jacks) for 5 min while your partner times you. After 5 min are up, take your pulse for 1 min. Record this in your table.
4. After 1 min, take your pulse again for 1 min.
5. Repeat step 4 another two times, or until your heart rate returns to the resting heart rate.

Recording Data

6. Record your partner's heart rate immediately after exercising and then at 1-min intervals.

Analyzing and Interpreting

7. Prepare a graph of your experimental data. Which would be the best kind of graph to use and why?

Forming Conclusions

8. What was your resting heart rate?
9. What was your maximum heart rate? When did this occur?
10. Why do you think your heart rate increases during exercise? Think in terms of stimulus and response.
11. How did your heart rate compare to your resting heart rate after 1 min? after 3 min?
12. Why do you think your heart rate stays high even after you've stopped exercising?
13. Which was the best way to measure your pulse and why?

Applying and Connecting

If you've ever watched a really scary movie, or have felt very nervous, you might have noticed that your heart is beating fast even though you haven't been exercising. Why do you think this is?

The processes that you learned about earlier, osmosis and diffusion, play important roles in the circulatory system. Diffusion is the process responsible for transporting oxygen from your blood into your cells and carbon dioxide from your cells into your blood. Diffusion is also used to transport some nutrients from your small intestine to your blood. The diffusion of nutrients and gases occurs in specialized blood vessels, located between arteries and veins, called **capillaries**. Capillaries have two adaptations for exchanging gases and nutrients: (1) they are made of specialized epithelial tissue that is only one cell layer thick, and (2) they are very narrow so that the blood cells must pass through in single file. Both of these adaptations help increase the rate of gas exchange between the blood and the cells.

Figure 3.20 A capillary sliced lengthwise. The red squiggles are red blood cells.

Give it a **TRY** ACTIVITY

The Sight of Blood

How many different types of blood cells can you identify in a prepared slide of human blood? Look at the slide, first on low power, then switch to high power. In your notebook, make a drawing of each type of blood cell you observed.

- How many different blood cells were you able to see?

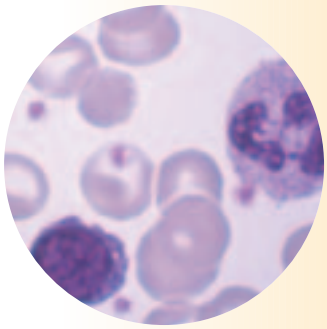


Figure 3.21 Human blood cells

The Blood

Your blood is the second largest example of connective tissue in your body. (Your bones are the largest example.) Your blood consists of red blood cells; white blood cells; tiny cells called platelets; and plasma—the liquid portion of blood. Plasma makes up 55% of your blood, while the other parts make up 45%.

Figure 3.22 This blood sample has been allowed to separate. The yellowish liquid is plasma.

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Dr. Charles Drew

In the 1940s, Dr. Charles Drew made many important discoveries about blood—such as how to store blood so it wouldn't spoil. Although he was an American, Drew attended medical school at McGill University in Montreal because, at the time, medical schools in the U.S. would not admit black students. Find out more about the discoveries and life of Dr. Drew.

Blood cells are highly specialized in order to perform their functions. The function of red blood cells is to carry oxygen. In order to carry the most oxygen possible, mature red blood cells have no nuclei—making more room for oxygen. Red blood cells are also very flexible, allowing them to bend and twist through the tight spaces of your capillaries. **White blood cells** are specialized to fight infection. Some of them are capable of eating bacteria at infection sites such as cuts. **Platelets** are cells that help to stop the bleeding at cuts. Plasma, the liquid portion of your blood, transports nutrients to your cells and carries wastes, such as carbon dioxide, away.

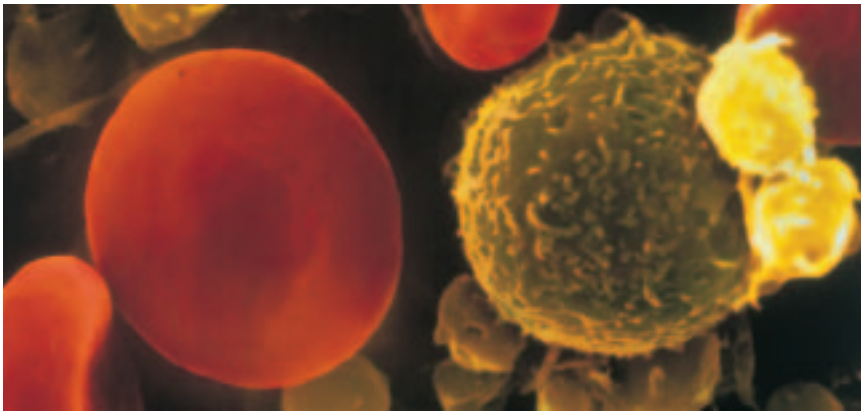

Figure 3.23 Red blood cell (left), white blood cell (right), and two platelets (far right)

mathLink

Using your resting heart rate (pulse), calculate how often your heart would beat in a day, in a year, in a lifetime (about 78 years if you're male or 85 years if you're female). Do you think this is an accurate estimate of heartbeats over a lifetime? Why or why not?

Check and Reflect

1. Name the organs and cells of your circulatory system and describe what they do.
2. Create a concept or mind map to show how the three systems you've studied so far are related.
3. Diffusion is a slow process. How does the structure of the capillaries help diffusion occur fast enough to keep you alive?
4. Describe why diffusion is an important process to your body.
5. Name and describe the four chambers in the human heart.

3.4 Excretory System

The body produces a number of different types of wastes. These wastes are poisonous, and, if not removed from the body, can cause you serious harm. The job of waste removal, **excretion**, is done by the excretory system. The interesting thing about the excretory system is that it involves organs from other systems. So different organ systems interact to get rid of wastes. What organs that you've learned about so far remove waste from the body?

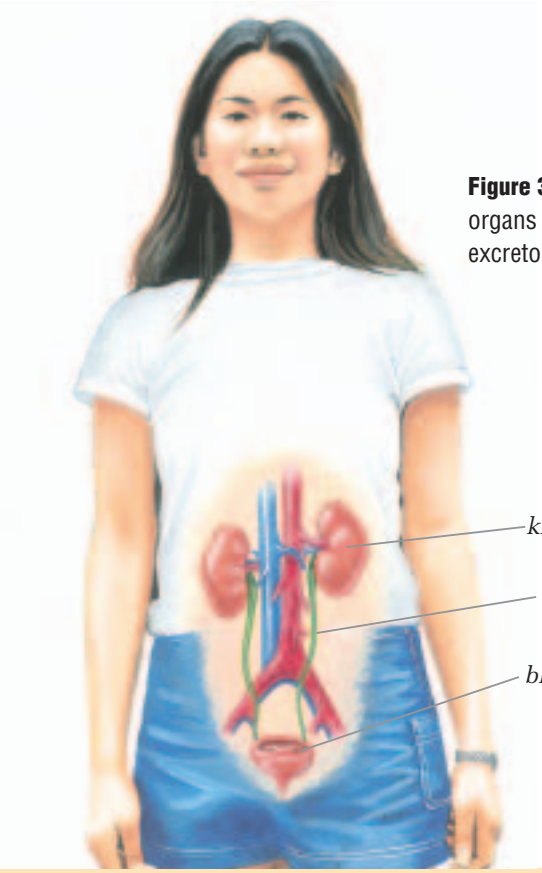

Figure 3.24 Some organs of the excretory system

Give it a **TRY** ACTIVITY

WHERE DOES IT GO?

On any given day, you may take in about 2.5 L of water from what you eat and drink. What happens to this water? Below are the three main mechanisms for getting rid of water in your body. Match these mechanisms with the correct volume lost. When you are done, make a pie chart to illustrate your answer.

- sweat — a) 0.5 L
- urine and feces — b) 0.8 L
- breathed out air — c) 1.2 L

WASTE PRODUCTS

As you already know, our cells produce carbon dioxide as a waste product, and it is removed from the blood by the lungs during the gas exchange process. But our cells also produce other harmful waste products. When cells break down proteins, they produce a very toxic compound called ammonia. Chemical processes that happen in the cells also produce water and salts as waste products. We need water, but only a certain amount at a time. Each of these waste products has to be dealt with.

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In and Out

The average person takes in about 2550 mL of water a day, by drinking, eating, and processes occurring in your cells. However, you also lose about 2550 mL of water a day through urination, perspiration, breathing, and feces production. Overall, then, the amount of water in your body stays constant.

The Liver

The liver is an organ of the digestive system, but it also plays a role in excretion. It takes the highly toxic ammonia produced by the body's cells out of the bloodstream and converts it into a less harmful substance called **urea**. Even though it is less harmful, the urea still has to be disposed of. The liver releases urea into the bloodstream.

The Kidneys

The kidneys are about 10 cm long. They are the main organs of excretion; they act as filters to the blood, straining out the unwanted urea, water, and other salts, and they produce urine. Every drop of your blood is filtered about 300 times a day by the kidneys. Even though about 180 L of blood pass through the kidneys each day, you produce only about 1.5 L of urine. The amount of urine you produce also depends on how much water you drink. The kidneys keep the proper amount of water in your blood. If there is too much water, they excrete lots of water and so produce a lot of urine.

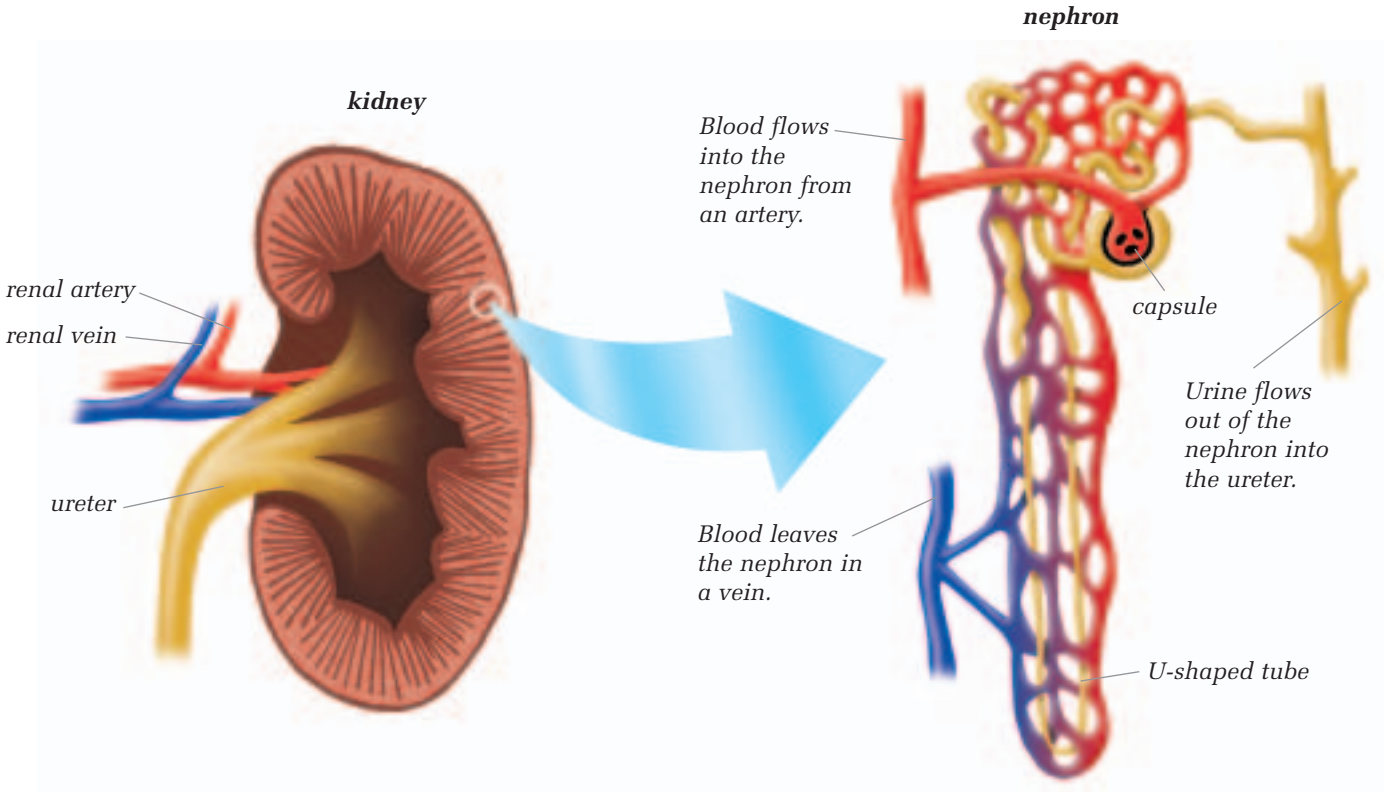

Figure 3.25 The structures of the excretory system

The Formation of Urine

The formation of urine is quite a complicated process. First, the blood enters the kidney by the renal artery. The artery branches into smaller and smaller vessels. These small capillaries enter filtering units called **nephrons**, as shown in Figure 3.25. The kidney has millions of nephrons. These microscopic units remove wastes from the blood and produce urine. The "clean" filtered blood returns to the body through the renal vein. The urine flows out a separate vessel and into the ureter.

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Transplants

Some organs of the excretory system can be transplanted. Find out which ones.

Ureters, Bladder, and Urethra

Ureters are long tubes that connect the kidneys to the bladder. The bladder is a sac covered in muscle tissue. As the urine enters the bladder, the bladder expands. The bladder can store about 1 L of urine. When it is full, the bladder muscles contract and push the urine out through the urethra.

The Skin

Have you ever tasted your sweat? If you have, you'll have noticed that it tastes salty. Your skin has thousands of tiny sweat glands just below the surface. In addition to producing sweat to keep you cool, these glands remove excess salt from your blood. This salt is added to your sweat, creating the salty taste. So when you sweat, you are excreting salt.

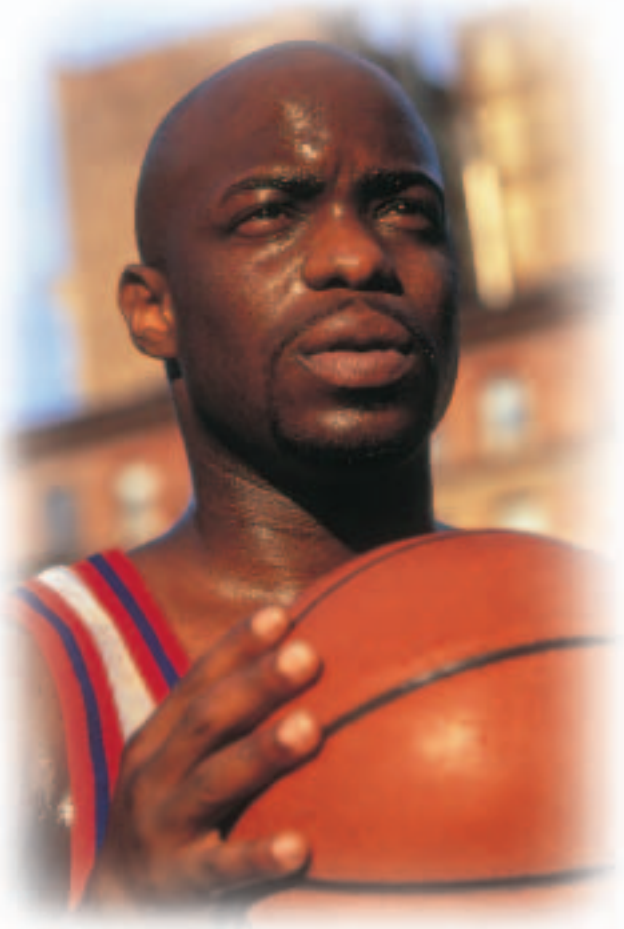

Figure 3.26 This athlete is excreting salt.

Inquiry Activity

Testing Artificial Urine

Urine contains waste products, but sometimes other compounds can appear in the urine. When they do, they can indicate diseases. Normally, urine does not contain protein or glucose. Protein in the urine is a sign of kidney failure, and glucose in the urine is a sign of diabetes.

Materials & Equipment

- 6 test tubes
- test-tube rack
- masking tape
- pen
- water
- glucose solution
- protein solution
- 3 simulated urine samples
- tweezers
- glucose test strips
- paper towel
- 6 eyedroppers
- Biuret solution

Figure 3.27 Step 4

Caution!
Biuret solution is toxic and corrosive. Handle with care and **wear safety goggles** for this activity.

The Question

Can we find out whether three fictitious patients have diabetes or kidney disease by testing their urine?

The Hypothesis

Based on the question, form a hypothesis.

Procedure

1. Place 6 test tubes in a test-tube rack. Place masking tape on each one and label as follows: water, glucose, protein, patient 1, patient 2, and patient 3.
2. Fill each test tube about two-thirds full with the solution indicated on its label.

Collecting Data

3. Create a data table to record your results.
4. To test for glucose, use tweezers to place a glucose test strip on a paper towel in front of each test tube. Then, use an eyedropper to add a drop of the solution from each test tube to the glucose strip in front of it, as shown in Figure 3.27. Note: Clean the eyedropper with water between tests. Record the colour of the test strip.
5. To test for the presence of protein, add 10 drops of Biuret solution to each test tube. Gently swirl each test tube. Carefully observe each test tube and record the colour in the data table.

Analyzing and Interpreting

6. What colour did the glucose test strip turn when the glucose solution was added to it?
7. What colour did the protein solution turn when Biuret solution was added to it?

Forming Conclusions

8. Did any of the patient samples show any signs of diabetes? Did any of the patient samples show any signs of kidney failure? Explain your answers.
9. What was the purpose of the glucose and protein test tubes?

Applying and Connecting

Several years ago, science students would test their own urine in such activities. Why do you think it is considered no longer safe to do so?

Urine Can Reveal Diseases

Doctors can determine if you have certain diseases by testing your urine. Certain diseases can affect how the kidneys function, and these changes in function will show up in the urine. Patients whose kidneys are failing often have protein in their urine because their kidneys have lost the ability to filter blood properly. People who have diabetes will often have glucose in their urine. Their cells cannot absorb glucose, and glucose builds up in the bloodstream. Because the blood has so much glucose, the nephrons filter it out and add it to the urine.

Dialysis

Sometimes, as a result of damage or disease, kidneys don't work properly. Luckily, people whose kidneys don't function well can still lead normal lives thanks to a machine that acts as a kidney. It's called a kidney **dialysis** machine, and it removes all the wastes from the blood that a kidney normally would.

When a person undergoes dialysis, his or her blood flows into special tubing inside the machine. The tubing is made of a selectively permeable material, allowing only certain substances to diffuse through it. This tubing is surrounded by fluid. Wastes from the blood diffuse out of the blood into the fluid, and certain substances from the fluid diffuse into the blood. The blood then flows back into the person. It takes four to six hours to fully clean the blood.

Figure 3.28 People undergo dialysis roughly three times a week.

Check and Reflect

1. Add the process of excretion to the concept map you started previously.
2. What is the function of the excretory system?
3. What is urea and how is it formed?
4. If your water intake on a certain day were higher than usual, how would your body respond to this?
5. A freshwater fish produces a lot of urine, and a camel produces very little urine. Explain why this is so.

3.5 Nervous System

Figure 3.29 This goalie is reacting to the stimulus of the flying puck. How might you react to this stimulus if you were sitting in the stands and the puck was flying toward you?

The crowd is going wild! A player sends the puck flying toward the net. The goalie makes a split-second decision and catches the puck with one swift movement. The goalie is reacting to a stimulus. As you learned earlier, a stimulus is a change in your environment. Stimuli (the plural form of stimulus) can occur in many forms, such as changes in pressure, heat, cold, light, sound, or body chemistry. Stimuli may be external (outside your body), such as when you walk from the cold outdoors into a warm room, or they can be internal, such as the arrival of food in your stomach. It is the job of the nervous system to monitor and respond to these stimuli.

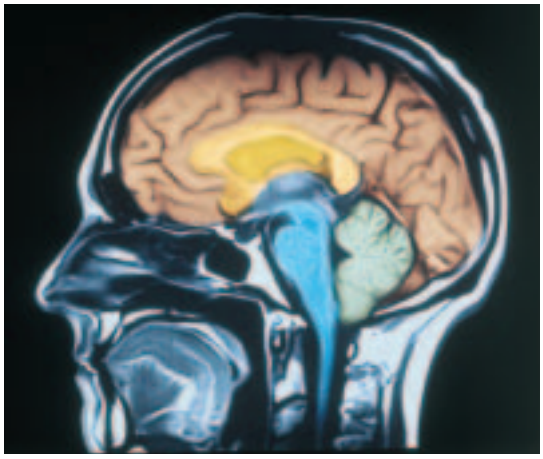

Figure 3.30 MRI scan showing the structures of the human brain

Neurons

Unlike the other body systems, the nervous system is mostly made up of one type of tissue called **nervous tissue**. Nervous tissue is made entirely of specialized cells called **neurons**. Your brain, spinal chord, and nerves are all made of them. A neuron's job is to send and receive messages.

A neuron receives messages from small branches of the cell called **dendrites**. The incoming messages are passed from the dendrites through the cell body to the **axon**. The axon is a long extension of the cell that ends in small branches. It carries impulses away from the cell body to its branches. These branches transmit the message to the dendrites of neighbouring nerve cells.

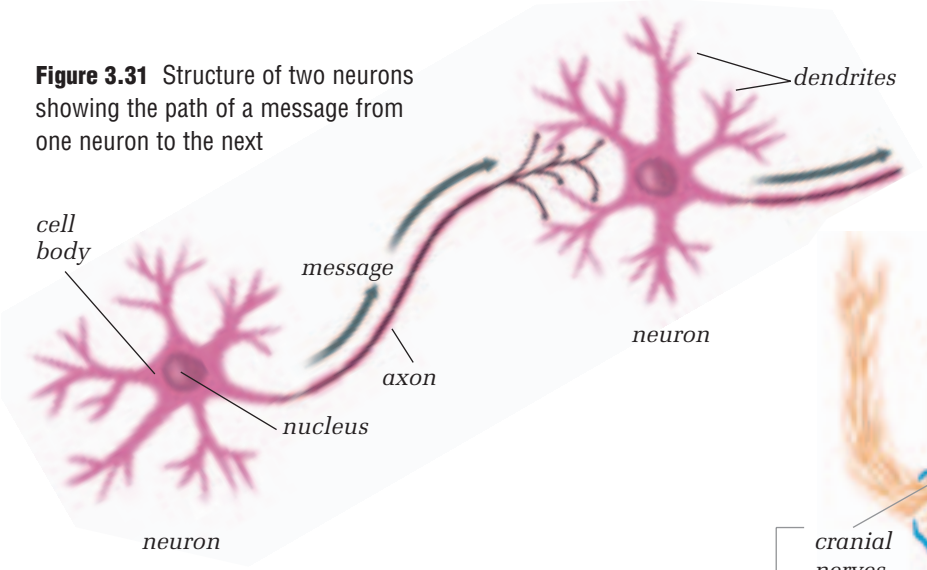

Figure 3.31 Structure of two neurons showing the path of a message from one neuron to the next

How the Nervous System Is Organized

The nervous system consists of many divisions. Two of the most important are the central nervous system and the peripheral nervous system. The **central nervous system** is composed of the brain and spinal cord, while the **peripheral nervous system** is made up of the cranial (head) and spinal nerves. These nerves travel to all parts of your body.

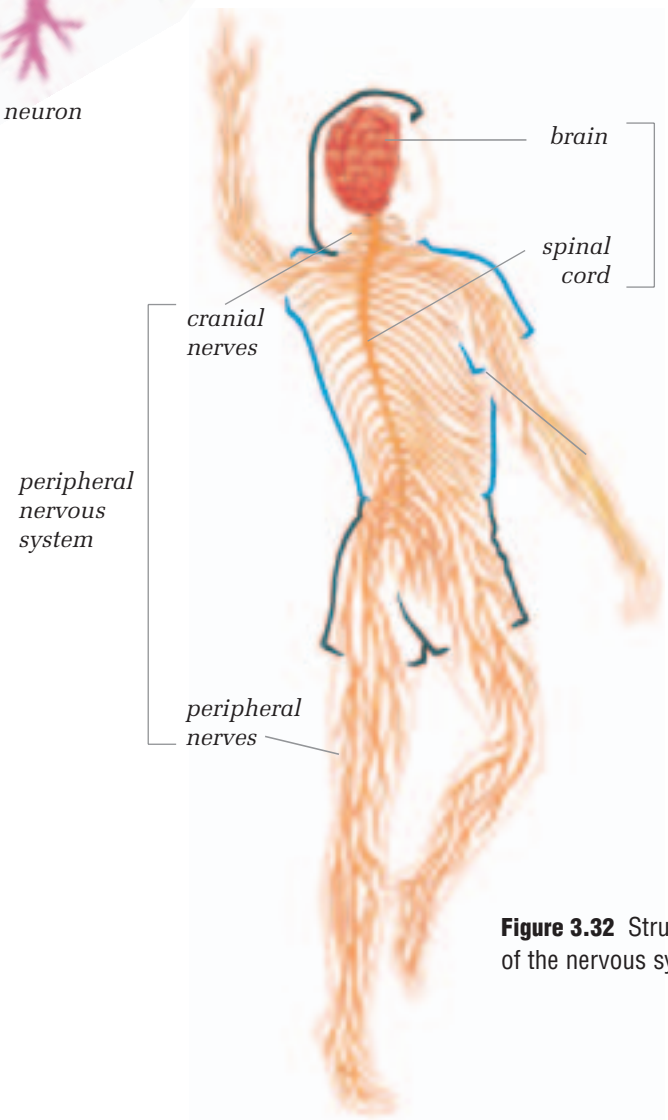

Figure 3.32 Structures of the nervous system

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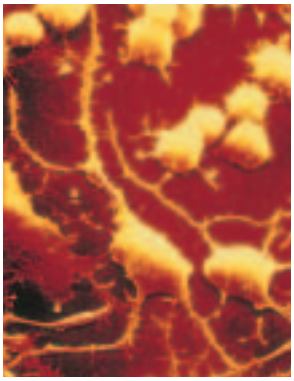
Making Connections

Humans have the most sophisticated brains of any organism. Our brains are composed of about 100 billion neurons. Interestingly, scientists think that we don't learn by growing new neurons, but rather by forming new connections between our existing neurons.



The Peripheral Nervous System

Each nerve of the peripheral nervous system is composed of two types of neurons. **Sensory neurons** carry information from the body to the central nervous system, and **motor neurons** carry information from the central nervous system to the muscles or organs.

The peripheral nervous system can be divided again. You may have conscious control over your responses to stimuli. For example, when you hear a noise, you can decide whether or not to turn your head to see what caused it. These voluntary responses are controlled by the **somatic nervous system**.

Your brain also responds to certain stimuli unconsciously. This means you don't have to think about it. For example, your body automatically adjusts the size of your pupils, your heart rate, blood pressure, breathing rate, and peristalsis in your digestive system. It's a good thing you don't have to remember to do all these things; otherwise, you would have very little time to think of anything else! These automatic responses are controlled by the **autonomic nervous system**.

The Central Nervous System

The brain receives stimuli from the outside world, gathered by the sense organs: the eyes, ears, mouth, nose, and skin. What are the senses? The brain also receives internal stimuli from the body itself. It reacts to these stimuli and sends messages to the appropriate body parts. The brain is generally divided into three main sections: the cerebrum, the cerebellum, and the medulla. Figure 3.33 shows what each part of the brain does.

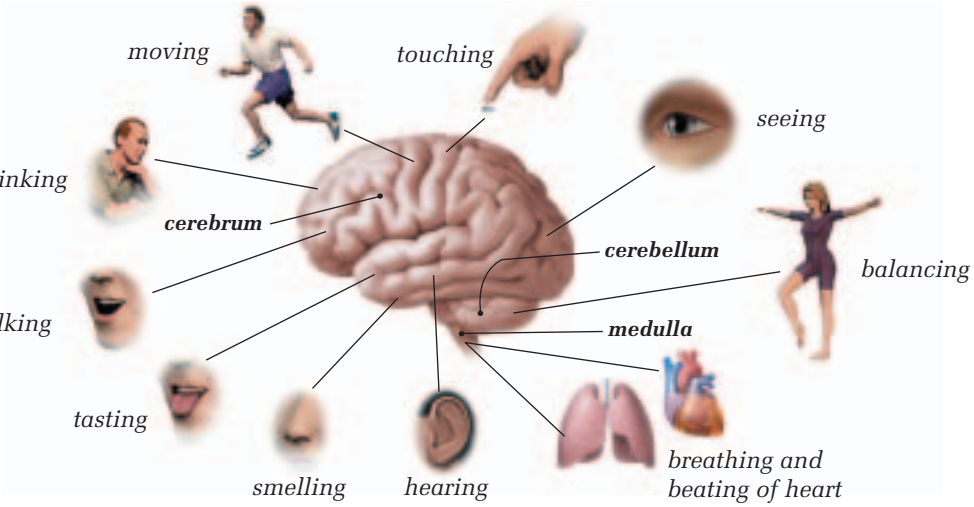


Figure 3.33 Functions of the brain

The spinal cord connects the brain to the peripheral nervous system, and it acts as a highway for messages between the brain and the body. It contains a type of neuron called an **interneuron**. These neurons connect one neuron to another.

The Reflex Response

In some situations, sensory and motor neurons may work together without involving the brain. This is known as a reflex. A **reflex** is an automatic response by the nervous system to an external stimulus.

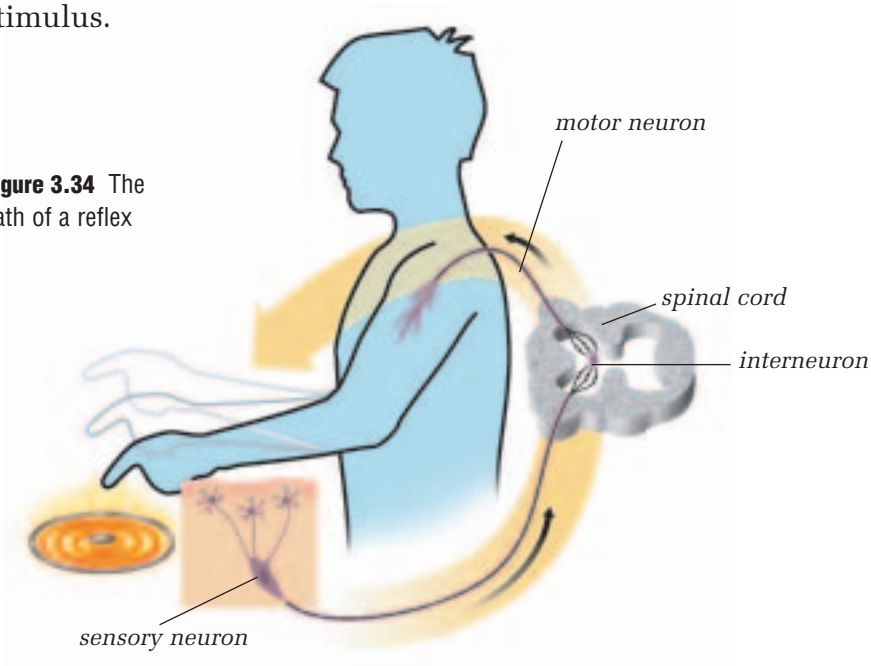


Figure 3.34 The path of a reflex

Suppose you accidentally touch a red-hot element on the stove. The stimulus is the intense heat. Sensory nerves in your hand react to the stimulus by sending nerve impulses to the spinal cord. Interneurons relay the message to the motor neurons. The impulse travels to the muscles of your arm, which quickly contract to remove your hand from the element.

The sensory neurons also send a message to your brain. But, by the time the message gets there and your brain decides to change your facial expression to a grimace and have you cry out in pain, your hand is already off the element. Reflexes protect you from injury by reducing the time it takes to react to harmful stimuli.

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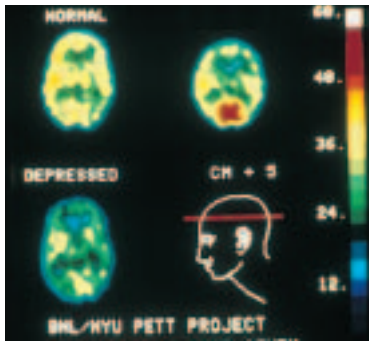
Watching the Brain at Work

Brain researchers have always wanted to be able to look inside the brain to find out which part of a person's brain is working when solving a math problem or reading a book. Researchers now have a tool that allows them to do this. It's called a PET scanner (PET is short for "positron emission tomography"). Use your school library or the Internet to find out how a PET scanner works, and what it has revealed about the brain.



Inquiry Activity

A Soft Touch

The Question

Sensory receptors in your skin that detect heat, cold, pain, pressure, and touch are distributed over the surface of your body. Are touch receptors distributed evenly over the surface of the body?

Materials & Equipment

- drafting divider, or 2 straightened paper clips
- ruler

The Hypothesis

Create a hypothesis based on the question.

Procedure

Body Area	Distance between Points (mm)
fingertip	

1. Copy the data table into your notebook.
2. In this activity, you will act as a tester, and your partner will be the subject. At the end of the activity, you will switch roles.
3. Have your partner sit down and close his or her eyes. With the divider about 4 cm apart, gently touch the person's fingertip with both points of the divider, as shown in Figure 3.35. Ask the subject whether they feel one point or two. If the subject says two, then decrease the distance between the points and repeat the test. Continue decreasing the distance between the points until the subject can feel only one point.
4. Repeat step 3 for the following areas: centre of palm, back of hand, inner forearm, back of neck, upper arm, and lower back.
5. Before you start, predict which body parts are the most sensitive to touch.

Figure 3.35 Step 3

Collecting Data

6. Measure the shortest distance between the points with a ruler and record it in the data table.
7. Repeat the test on the remaining areas listed on the data table. You may occasionally want to touch the subject with only one point to test the accuracy of their responses.

Analyzing and Interpreting

8. Look at your data and rank the seven areas tested from most sensitive to least sensitive.

Forming Conclusions

9. Does your data support the hypothesis? Explain why or why not.

Applying and Connecting

It is important for certain areas of your body to have a keen sense of touch and not so important for other areas. Look at the areas of the body that you found are well supplied with touch receptors. Why do you think these body parts require extra sensitivity?