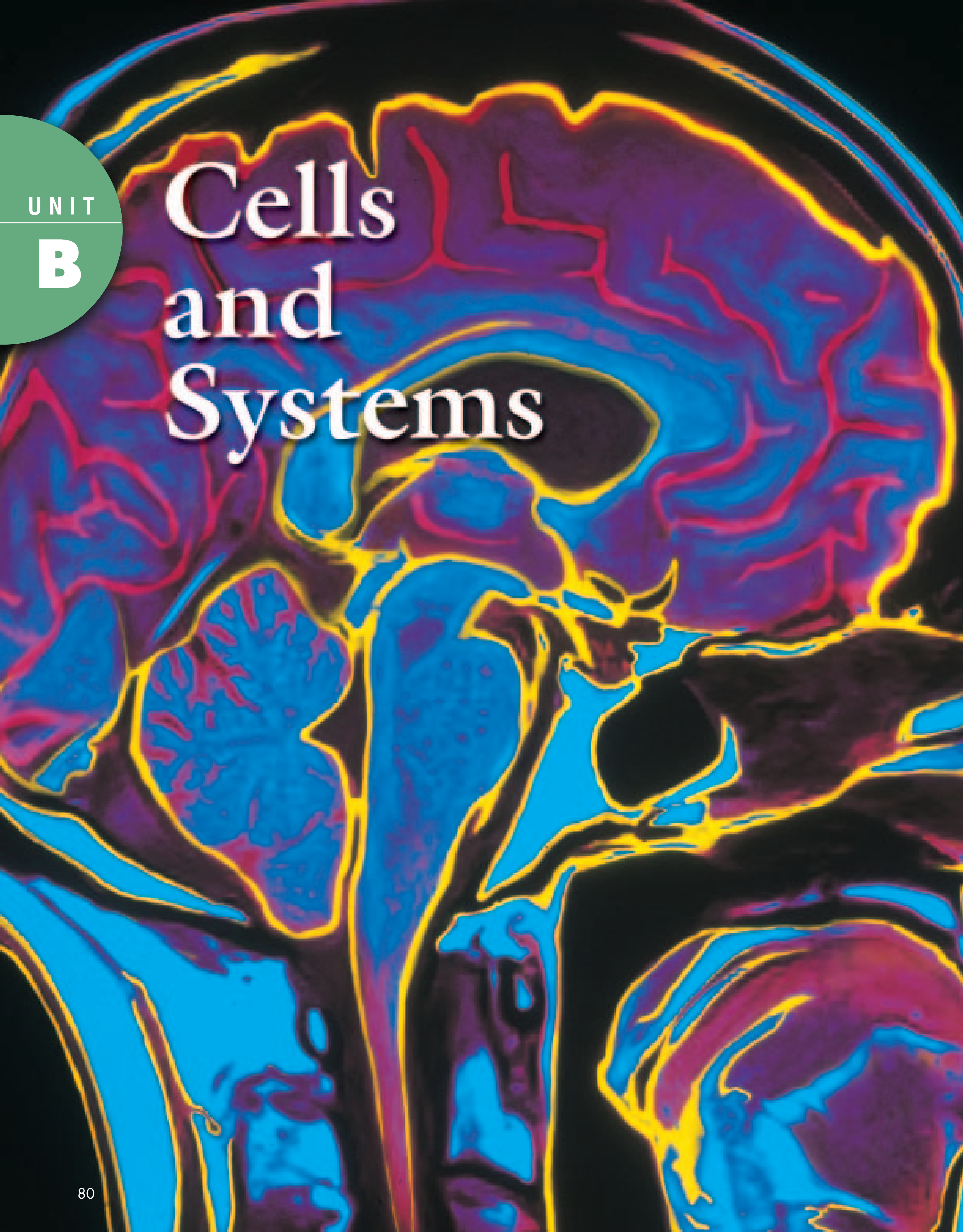
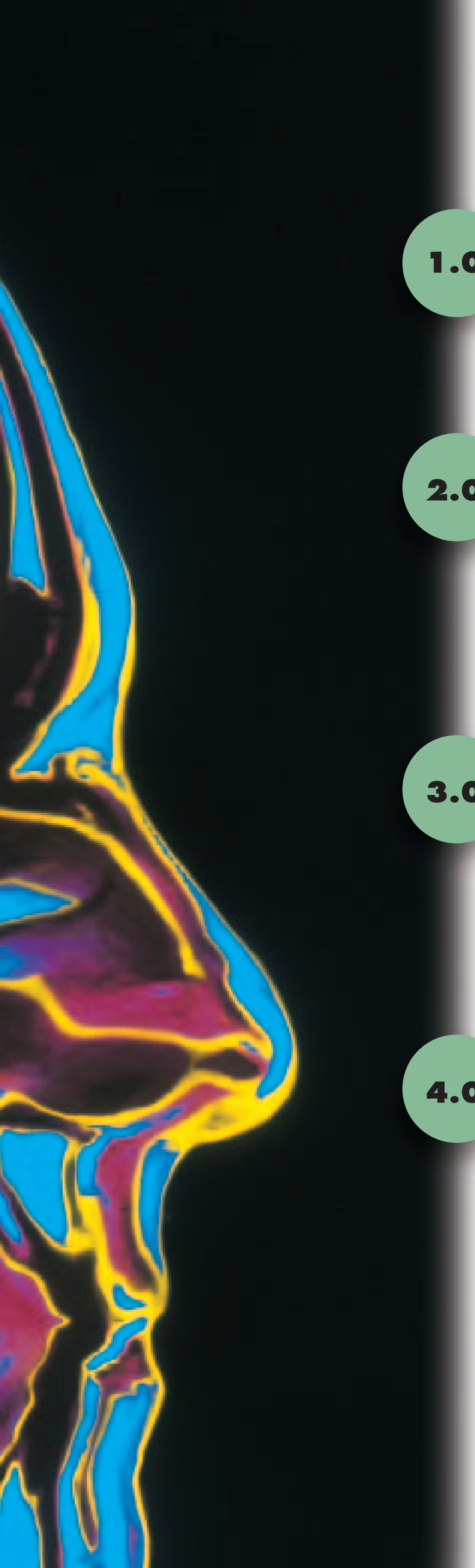
UNIT

B

Cells and Systems





In this unit, you will cover the following sections:

1.0 Living things share certain characteristics and have structures to perform functions.

1.1 The Characteristics of Living Things

1.2 Structure and Function

1.3 Organs and Organ Systems

2.0 Cells play a vital role in living things.

2.1 The Microscope Extends the Sense of Sight

2.2 The Cell Is the Basic Unit of Life

2.3 Organisms Can Be Single-Celled or Multicelled

2.4 How Substances Move Into and Out of Cells

2.5 Cells in Multicellular Organisms Combine to Form Tissues and Organs

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

3.1 Digestive System

3.2 Respiratory System

3.3 Circulatory System

3.4 Excretory System

3.5 Nervous System

4.0 Scientific investigation leads to new knowledge about body systems and new medical applications.

4.1 Developing a Theory for Disease

4.2 Factors That Affect the Healthy Function of Body Systems

Exploring

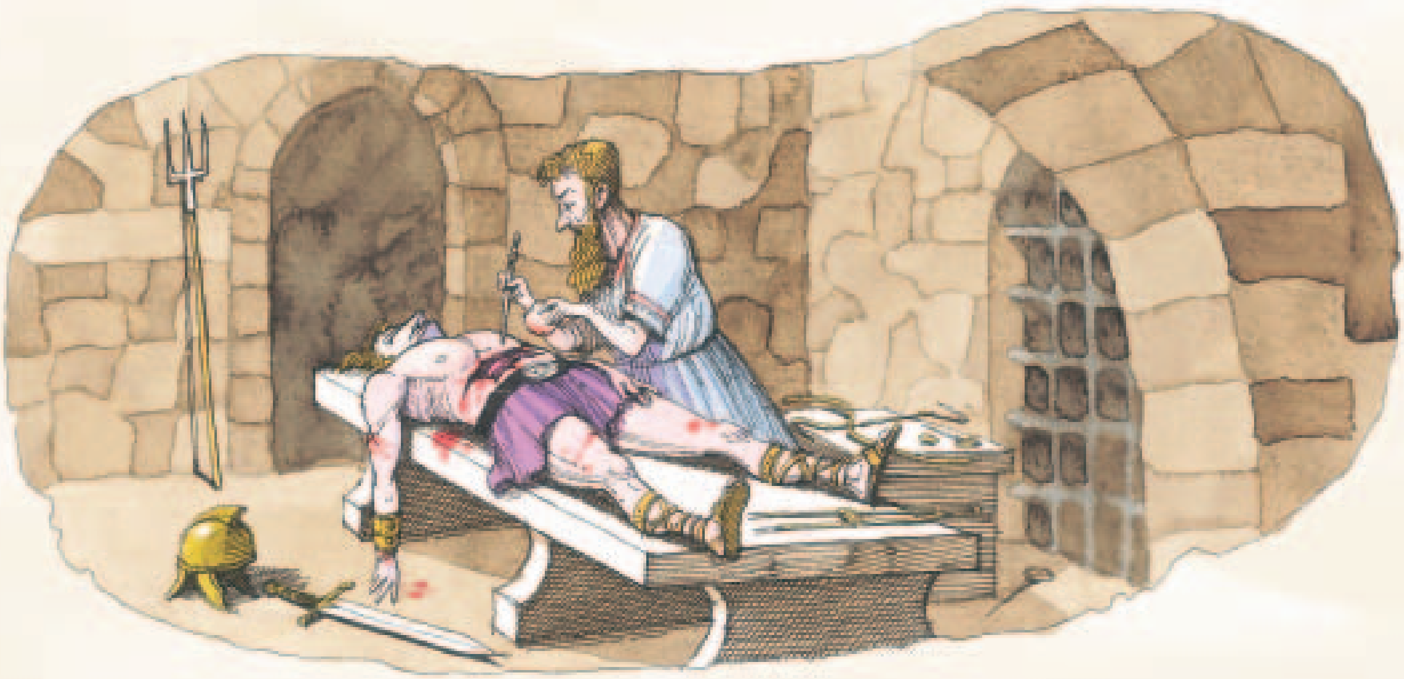
BLOOD AND GUTS

Galen lived from A.D. 129 to 216. He eventually became the emperor's doctor.

One of the first people to observe internal body structures and devise a scheme of how they worked was a Roman called Galen. He was a keen observer, which is an important quality for someone interested in studying the natural world.

Galen wanted to find out how the human body worked, but at the time, there were strict laws against opening up dead human bodies. Luckily, Galen's job allowed him to view the inner workings of the human body. He was the doctor to the gladiators! Roman gladiators had to fight each other to the death. As a result of these combats, the survivors were often injured badly. While he was trying to heal their gaping wounds, he could observe their internal organs. And because these wounds bled so much, he was able to observe how blood flowed in the body.

Through his observations and experiments, he did make some important discoveries. But his ideas about how body parts worked seem quite bizarre today. He mapped the major nerves of the body, but he thought they were hollow tubes through which flowed a "life force." He also thought that the liver was the most important structure in the body because it was so big and had lots of tubes coming out of it. He decided that its purpose was to heat the body.



Though these ideas might seem odd today, doctors accepted Galen's theories on how the body worked right up until the sixteenth century.

Give it a TRY ACTIVITY

PIECING TOGETHER THE BODY

You may think Galen's theories were absurd, but what do you know about the body's internal and external parts and how they work together? In this activity, you will have a chance to put your knowledge to the test.

Work with one or two of your classmates. Make a list of all the body parts that you can think of, both internal and external. Write each one on a small piece of paper. Try to figure out how they work together to keep you alive. Once your group has decided that there is a pattern, create a concept map showing how these body parts are linked.

- How many body parts could you name?
- Did you know the functions of the parts you named?
- Did you know how each part related to another?

Focus On THE NATURE OF SCIENCE

As you work through this unit, you will be reading and doing activities about cells and systems. You will encounter three major themes that are important to the study of life science: systems, cells, and structures and functions. You will need an understanding of these themes to do the project about investigating single-celled organisms.

Use the following questions to guide your reading as you learn about cells and systems.

1. **What do all living things have in common?**
2. **What types of systems do living things have, and how are they organized?**
3. **What are the functions of various structures found in living things?**

1.0 Living things share certain characteristics and have structures to perform functions.

Key Concepts

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

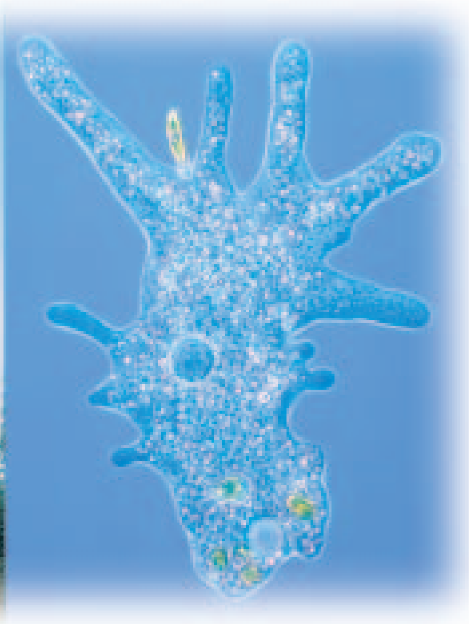
- organisms
- cells
- organs
- structure and function
- systems
- response to stimuli

Learning Outcomes

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

- describe the characteristics of living things
- analyze the general structure and function of living things
- explain how living things have different structures for similar functions
- show how the body is organized into systems

Giant sequoia



Amoeba

There are about 1.75 million different types of living things on Earth. They come in many different forms—from a single-celled bacteria that can be seen only with a microscope to a giant blue whale over 30 m long, to a giant sequoia tree that's over 100 m tall. Despite the differences among all the different life forms on this planet, there are similarities between them. All living things have features in common that distinguish them from non-living things.

Living things have an amazing variety of functioning parts. For example, some have leaves, some have wings. One way of making sense of this variety is to think about the function of the parts, or what they are used for. What do cats use their claws for? What does a tree use its roots for? Does the structure of these parts tell you something about how they work?

Any single living thing is made up of different structures. These structures work together to keep you, or any other plant or animal, alive. These parts work together as a single unit to keep a plant or animal running smoothly.

For Web links relating to 1.0, visit **www.pearsoned.ca/scienceinaction**

1.1 The Characteristics of Living Things

Before you can make sense of the millions of different living things on Earth, you have to be able to know what is alive and what is not. When trying to decide what is living and what is non-living, you have to find common characteristics for all forms of life. Although they are still debating, most scientists agree on these six characteristics of living things:

- are made of cells
- need energy
- grow and develop
- respond to the environment
- reproduce
- have adaptations for their environment

All living things, or **organisms**, have all of these characteristics. Non-living things may have some of these characteristics (for example, clouds may grow in size), but they will not have all of them.

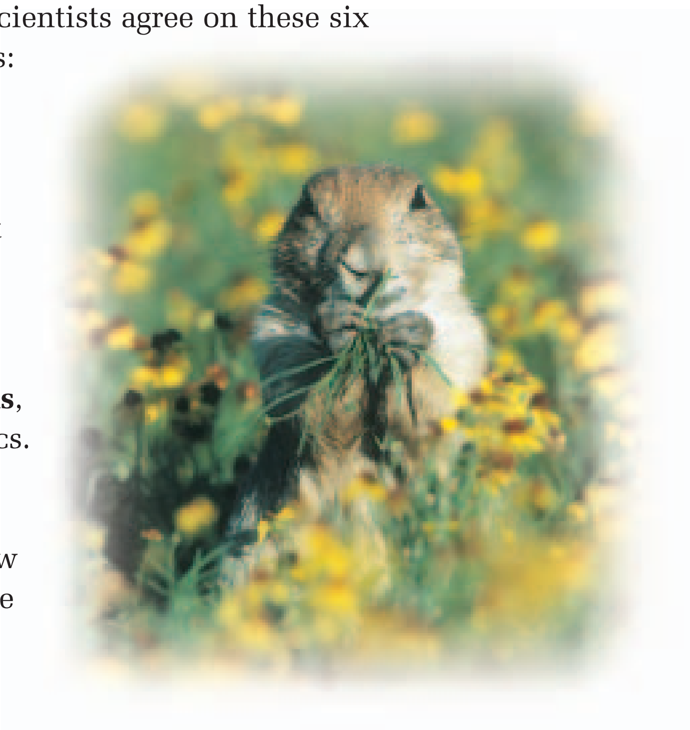


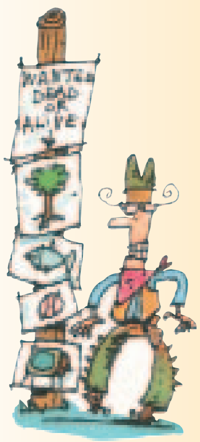
Figure 1.1 What is the energy source for the animal? What is the energy source for the plant?

Give it a TRY — Activity

Dead or Alive?

Draw a table with two columns, one headed *Living*, the other *Non-living*. Place each of the following items under the appropriate heading: radio, tree, mushroom, hair, fish, rain, bicycle, moss, skirt, soil, television, carrot, baseball, rock, seeds, air.

- Do all the things that you placed in the *Living* category meet the six characteristics of living things?
- Were there any items that you had trouble placing in either category?



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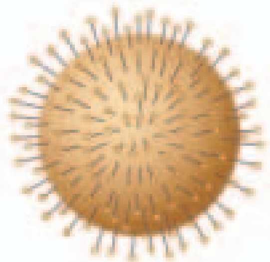
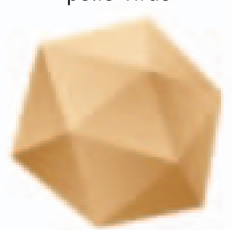
Viruses

Have you ever had a cold? Colds (and many other diseases) are caused by viruses. Viruses are extremely small and come in many different shapes. There is an entire branch of biology devoted to the study of viruses, even though most scientists don't consider them to be alive. This is because viruses can't reproduce by themselves. They depend on living cells of other living things to reproduce.



polio virus



flu virus

Cells

The cell is the basic unit of life. A cell can perform all the processes that life depends on. All organisms are made up of at least one cell, and every cell comes from another cell.

Cells are usually microscopic in size, so a single-celled organism is almost always tiny. A large organism, such as a tree, can be made of trillions of microscopic cells.

Non-living things are not made of cells. However, there are exceptions. Cells are found in non-living material if that material was alive at one time. For example, if you looked at a piece of wood under a microscope, you would see evidence of cells. This is because the wood came from a tree that was once alive.

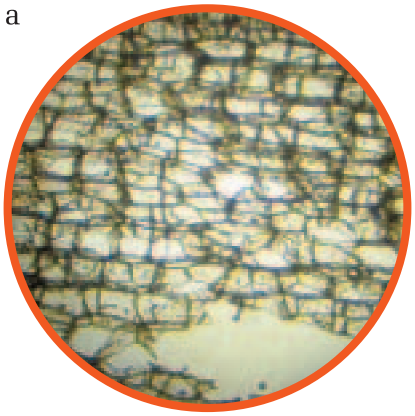


Figure 1.2 Cells from a cork

Energy

Everything an organism does requires energy. Think of all the things you did in the last few hours: you slept, had breakfast, walked to school or ran to catch the bus, and started school. All of these things required energy. Energy is the ability to make things move or change.

Organisms get energy from the environment. Plants and animals differ in how they get their energy. Plants use the energy from the sun to make their own food. Animals get their food from the environment around them. Plants and animals both obtain nutrients from their food and the environment. **Nutrients** are substances that provide the energy and materials that organisms need to grow, develop, and reproduce.

Many different chemical processes happen inside cells. Some of these processes create energy, and some of them use energy. For an organism to stay alive, there has to be a balance between these energy-using processes and the energy-creating processes. The sum of all the different processes that happen in an organism is called the organism's **metabolism**.

Responding to the Environment

You step out onto the street and suddenly you see a moving car barrelling toward you. What do you do? You jump out of the way. The sight of the moving car is actually a stimulus. A **stimulus** is anything that causes a response in an organism. Jumping out of the way of the car is a reaction, or **response**, to a stimulus.

Growth and Development

You may have grown a few centimetres taller in the past year. But growth is not just about getting bigger. It may also involve a change in structure. When you plant a seed, it grows roots and produces a stem and leaves. Once the plant gets to a certain size, it may not get any bigger, just as you will not grow beyond a certain height. But growth doesn't end there. Parts of any living thing wear out or get damaged. Every year, trees produce new leaves. Your skin keeps replacing itself as it gets worn away.

As some organisms grow, they change their body shape quite drastically. This is called development. Think of a frog. Adult frogs release eggs in the water. As each egg develops, it turns into a tadpole with a tail and gills. As the tadpole grows, it loses its gills and tail and develops lungs and limbs. Finally, it moves from the water onto the land.

Reproduction

All living things come from other living things. This process is called reproduction. Reproduction is not actually necessary for an organism to survive. But since all individual organisms die, reproduction is necessary for the survival of each type of organism.

Give it a **TRY** — **ACTIVITY**

Misinterpreting the Evidence

It seems pretty clear to us that living things come from living things, but this wasn't always so obvious. People noticed that mice often appeared from stacks of straw, and that flies and maggots appeared from rotting meat. People then assumed that the piles of straw and the rotting meat could create mice and flies. The idea that living things could come from non-living things was called **spontaneous generation**. But people had misinterpreted the evidence.

However, in the 1600s, an Italian doctor called Francisco Redi performed an experiment to test the idea of spontaneous generation. He put some meat into three jars. One he left open, another he sealed shut with a lid, and a third he covered with a mesh screen. He thought that if spontaneous generation actually happened, maggots would appear on the spoiled meat in all the jars. Figure 1.3 shows the results of the experiment.

Observe the results of the experiment. How did the experiment disprove spontaneous generation?

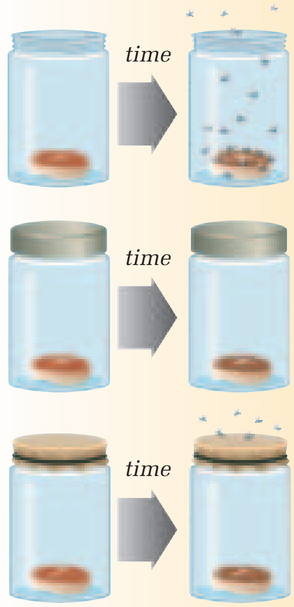


Figure 1.3

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Monarch Development
Monarch butterflies go through an amazing development in their life cycle. What are the stages of development of the butterfly? What happens at each stage?

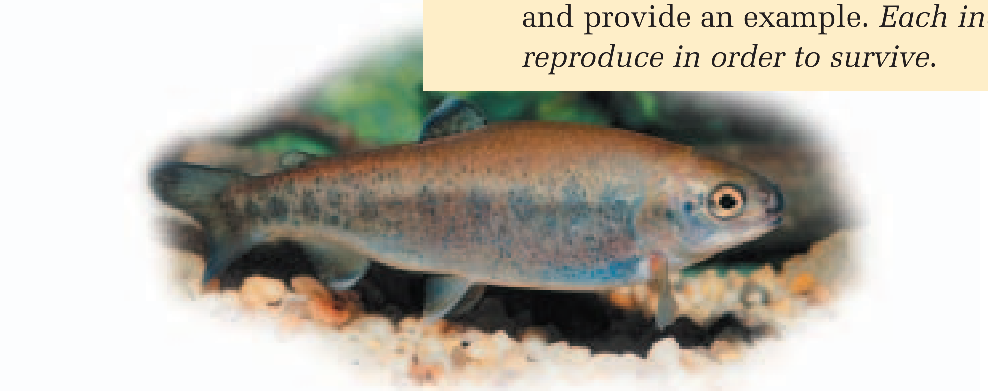
ADAPTATIONS

In the winter, snowshoe hares grow a white coat of fur. This allows them to blend in with their snowy surroundings and avoid being noticed by predators. This coloration is an example of an adaptation. An adaptation is a characteristic that allows an organism to live in its environment. Animals and plants have many adaptations. A cactus has spines to stop animals from eating it. A mountain goat has tiny feet to allow it to perch on steep cliffs.

Figure 1.4 Snowshoe hare in winter

CHECK AND REFLECT

1. List the characteristics of living things. Give an example of each characteristic.
2. What adaptations does a fish have for living in water?
3. Is skin a living thing?
4. Is the following statement true or false? Explain your answer and provide an example. *Each individual organism must reproduce in order to survive.*



1.2 Structure and Function

As well as having certain characteristics, living things have to do certain things to keep themselves alive. Some of the things animals do are to exchange gases, move, and gather food. Plants don't move like animals do, but they do exchange gases and gather nutrients. Organisms have developed many different ways of doing these tasks and have developed different body parts, or **structures**, to do them. Each structure is used for a specific **function**, which means it carries out a specific task.

Give it a **TRY** — ACTIVITY

WHICH STRUCTURE FOR WHAT FUNCTION?

List a number of functions an organism must perform in order to survive. Your list might include movement, food gathering, breathing, and so on. Make a table and place these functions in the first column, and place the organisms pictured in Figure 1.5 in the top row, as illustrated below.

Look at the organisms in Figure 1.5 and decide what structure each organism uses to perform each function. Then, fill in the table. When you are finished, compare your table with those of your classmates.

- Did they list important functions that you did not?
- Which function was listed by the most people?
- Did all the organisms have structures for all the functions you listed?

	Dolphin	Tree	Beetle	Tiger
movement				
food gathering				

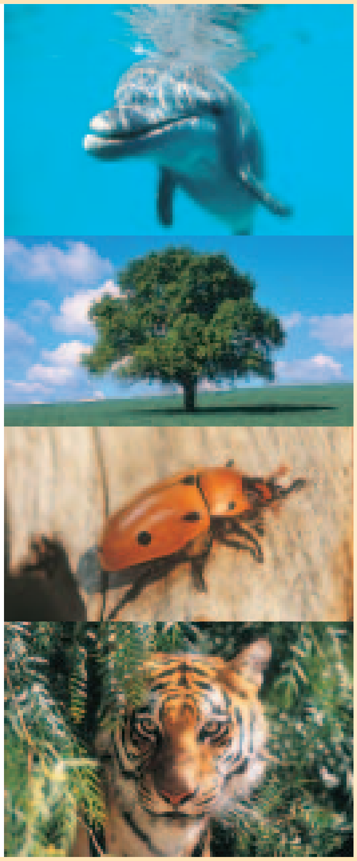


Figure 1.5

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Spiracles

Some animals have unusual ways of breathing! Insects have small holes in the sides of their abdomens called spiracles. Insects adjust the amount of air that enters their bodies by adjusting the size of their spiracles.

Spiracles are the dark spots on the side of the abdomen.

Figure 1.6 Gibbon using its arms to move

Different Structures for Similar Functions

All organisms have to perform certain tasks or functions to stay alive, but different plants and animals have developed different structures for doing similar functions. For example, most animals have to move about in order to find food. But animals have very different structures for performing this function. Birds have wings to fly through the air, and whales have tail flukes and flippers to swim through the water. We humans mostly use our legs to move around, but gibbons mostly use their arms. Can you think of other structures animals have for moving around?

Organisms have an amazing variety of food-gathering structures. Barnacles have tentacles that rake the seawater for tiny bits of food. Birds have bills. Insects have very complicated mouth parts. Mammals have different types of teeth to help them chew the food they eat. Teeth can vary from the sharp teeth of a lion to no teeth at all. An anteater has no teeth, just a long, sticky tongue that allows it to gather ants.

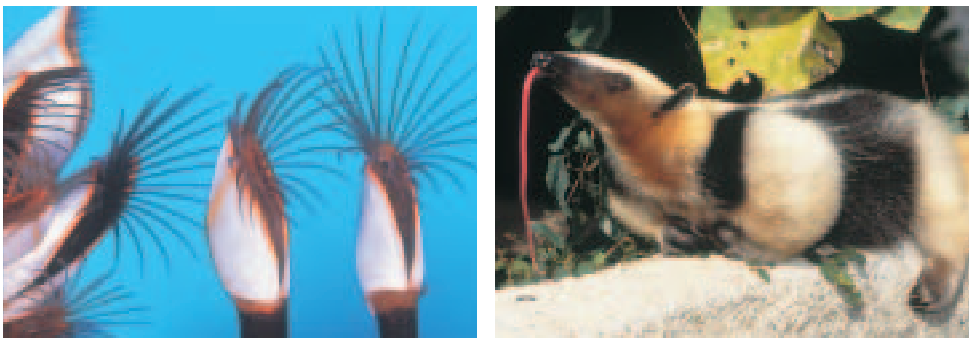

Figure 1.7 Feeding structures of barnacles and an anteater

Gills, lungs, spiracles, skin—all of these are breathing structures used by different animals. Plants use their leaves to exchange gases with the surrounding air. Leaves can vary widely in shape, from the tiny needles of spruce trees to enormous flat leaves up to 2 m wide! Conifers, like the spruce, have tiny needles to reduce the amount of water lost in their dry environment.

Figure 1.8 Leaves come in many shapes and sizes.

Variations in Structure

As you have seen, structures used for a certain function can be very different. But they aren't always wildly different. Similar organisms often have slight variations in their structures. These variations are often very easy to see in animals living on islands.

The Galapagos islands are located off the west coast of South America. On the islands, there are 13 closely related species of birds, commonly known as finches. They were discovered by the famous biologist Charles Darwin over 100 years ago. These finches, known as Darwin's finches, as well as many other birds, have different bill structures to perform the function of food gathering.

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Marine Iguanas

There are other species living on the Galapagos islands that have unique features. What structures does the marine iguana have to help it gather food? How is it different from other species of iguana?

Variations in Bill Shape

Three of Darwin's 13 species of finches are pictured in Figure 1.9. Finches are usually seed-eating birds with large bills adapted for crushing hard seeds. However, typical of island organisms, Darwin's finches have different structures for the function of feeding.

Study the different bird bills in Figure 1.9 and decide what kind of food-gathering functions each bill structure would be best suited for. One bird is a warbler-like finch that eats insects hiding within the bark of trees. Another is a ground-dwelling finch that eats seeds and nuts. The third type is a parrot-like finch that eats tree fruit.

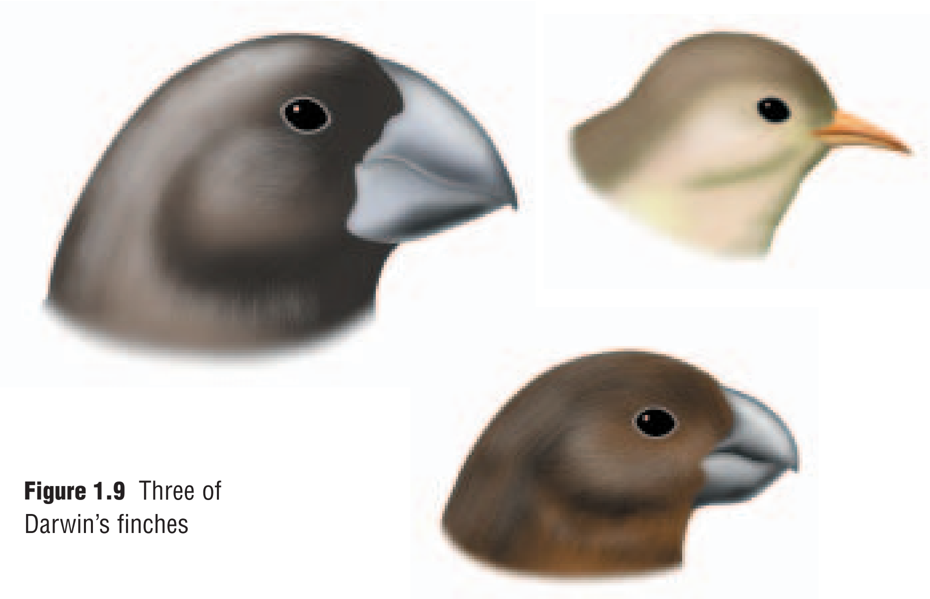

Figure 1.9 Three of Darwin's finches

Check and Reflect

1. Name as many functions as you can think of that an organism must carry out in order to survive.
2. Identify at least one type of structure that an organism would need to perform each of the above functions.
3. Why might similar organisms, such as birds, have different structures to perform the same function such as feeding?
4. What is the function of flowers? Why do you think they come in so many bright colours?

1.3 Organs and Organ Systems

So far, you have seen that you and other organisms have structures that allow you to survive and interact with your surroundings. But you have many other body structures that are constantly in use for other functions. These include your heart, lungs, brain, and kidneys. What other body parts can you think of? None of these body parts functions on its own. Each part is an **organ**. The organs that make up each **organ system** work together to perform a certain task or function. For example, the organs of your digestive system work together to break down food to supply your body with the energy and nutrients you need to survive. The following charts describe some of your body's organ systems.

Give it a **TRY** ACTIVITY

DRAWING SYSTEMS

Notice that some of the organ systems mentioned in the text to follow do not have illustrations. That's your job. On a piece of paper, draw a rough outline of the body. Study the list of structures of the circulatory system. Imagine what they look like and where in the body they are located. Draw these structures in your body outline. Repeat the process for the other organ systems.

CIRCULATORY SYSTEM (see subsection 3.3)

Structure	Function of System
heart arteries veins capillaries blood	• transport oxygen, food, and other substances throughout the body • transport some wastes to other organs for elimination • defend the body against diseases • connect all other organ systems

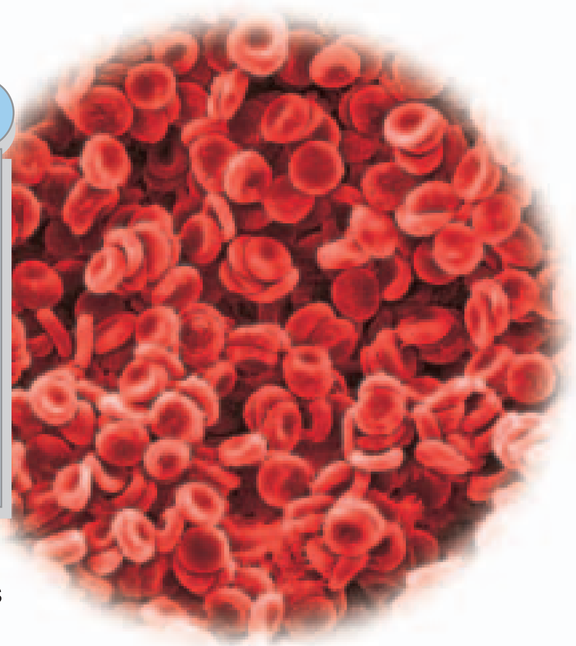

Figure 1.10 Red blood cells

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Only Skin Deep
The largest organ in the human body is the skin! It has a surface area of almost 2 m^2 and it weighs almost 3 kg.

RESPIRATORY SYSTEM (see subsection 3.2)

Structure	Function of System
nose mouth trachea diaphragm bronchi lungs	• transport oxygen from the outside air to the blood • transport carbon dioxide from the blood to the outside air

Figure 1.11 The digestion of food begins in your mouth.

DIGESTIVE SYSTEM (see subsection 3.1)

Structure	Function of System
salivary glands mouth esophagus stomach liver pancreas gall bladder small intestine large intestine	• break down food pieces into much smaller pieces (particles) so they can be absorbed and transported throughout the body

NERVOUS SYSTEM (see subsection 3.5)

Structure	Function of System
brain spinal cord nerves eyes, ears, and other sensing organs (hands, nose, etc.)	• coordinate and control the actions of all organs and organ systems • detect, process, and respond to changes in external and internal environments

Figure 1.12 The brain controls your nervous system.

EXCRETORY SYSTEM (see subsection 3.4)

Structure	Function of System
kidneys bladder lungs skin liver	• remove chemical and gaseous wastes from the blood

SKELETAL SYSTEM

Structure	Function of System
bones cartilage	• provide a movable support frame for the body • protect soft-tissue organs such as the heart and lungs

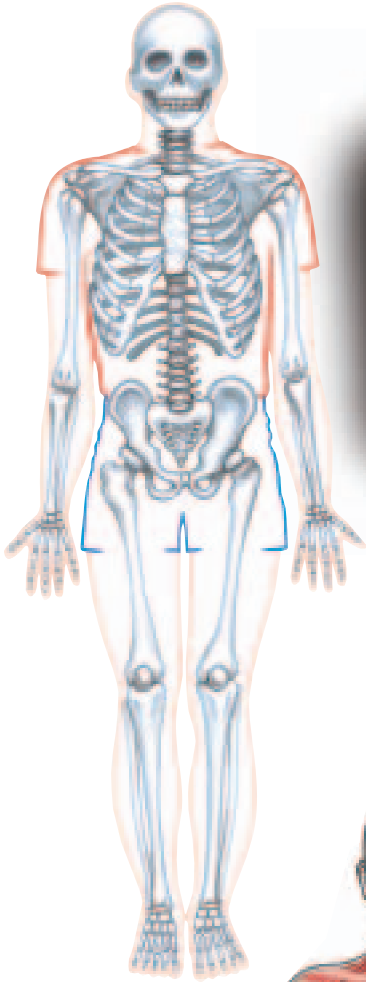
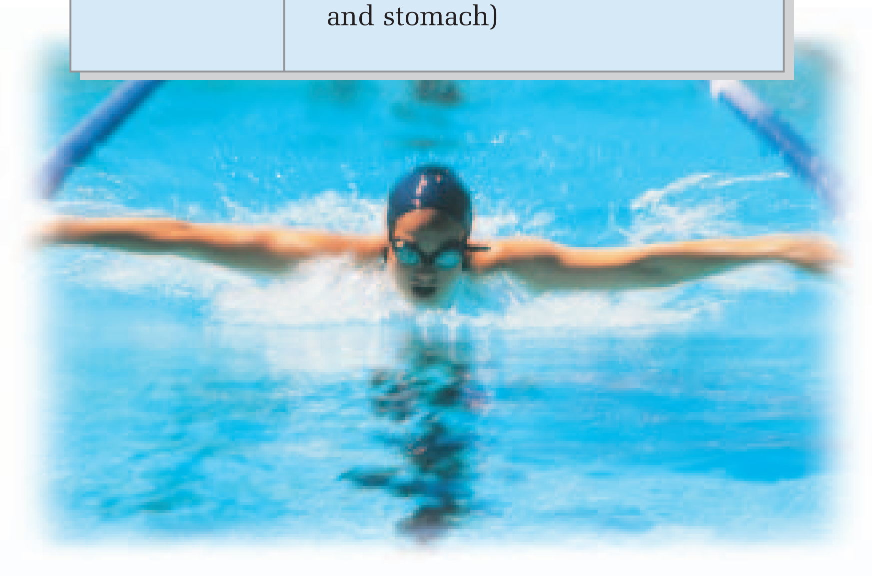


Figure 1.13 You have 206 bones in your body.

MUSCULAR SYSTEM

Structure	Function of System
muscles tendons	• move bones • move organs that contain muscle tissue (such as the heart and stomach)



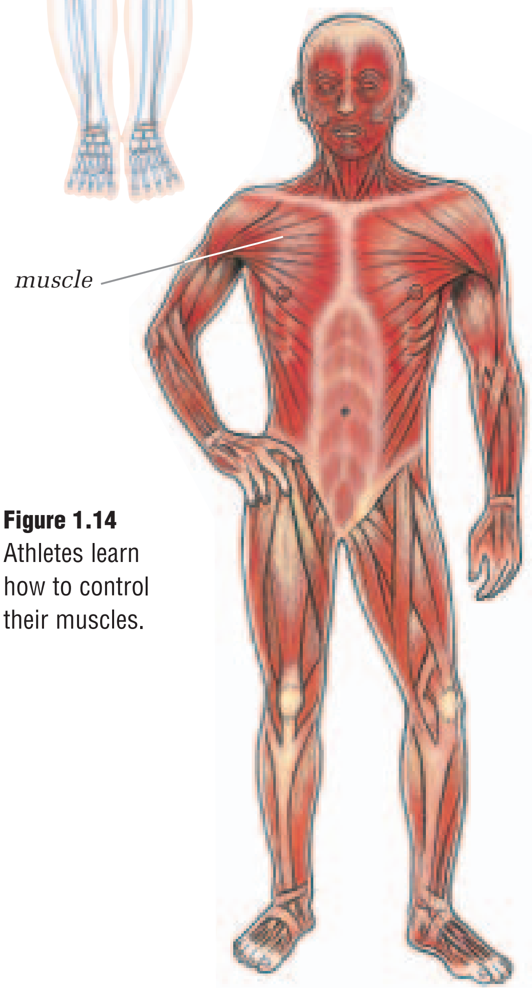


Figure 1.14 Athletes learn how to control their muscles.

Integumentary System

Structure	Function of System
skin	• protects the body's internal environment from the external environment • senses pain, pressure, and temperature

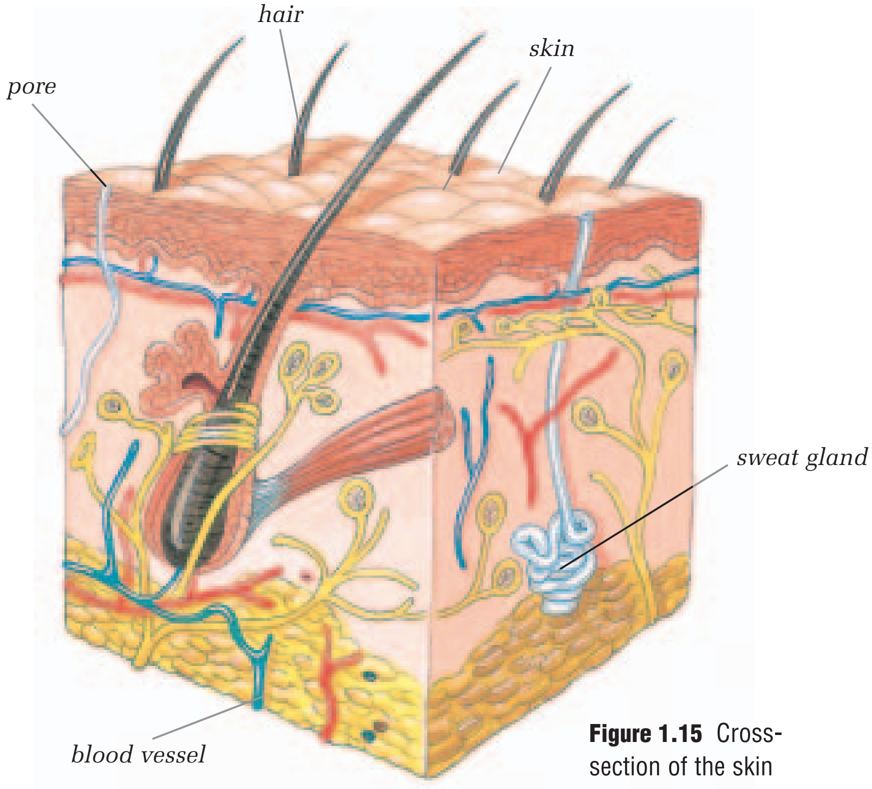


Figure 1.15 Cross-section of the skin

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Glands

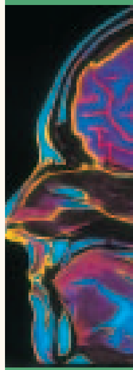
An organ system that has not been mentioned is the endocrine system. Find out what the endocrine system does. What is the role of each of its organs?

Check and Reflect

1. Why are organs grouped together into organ systems?
2. Could you do without any of your organ systems? Why or why not?
3. How do you think the systems studied in this subsection might work together to provide the requirements for a living organism?

Assess Your Learning

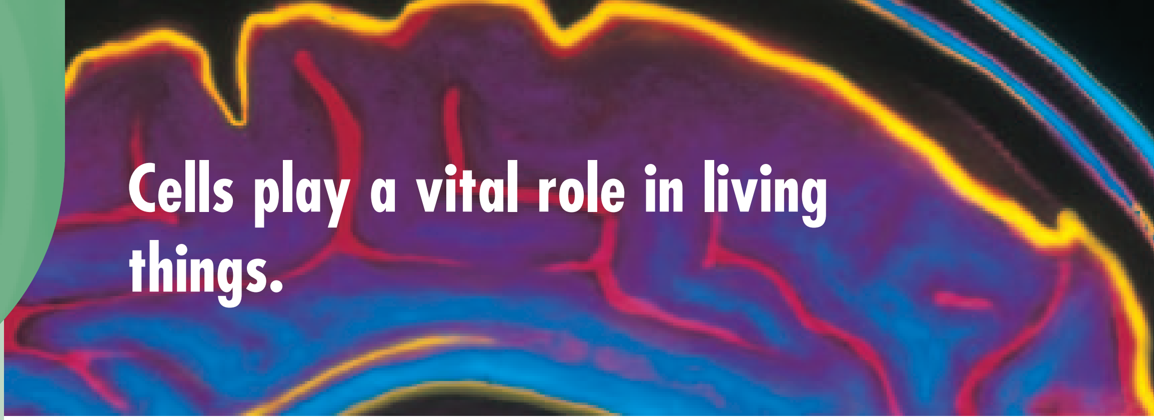
1. How are living things different from non-living things?
2. As you dive into a pool, you hold your breath. What characteristic of living things are you showing and why?
3. Choose two organisms found in your area and compare the structures each one uses for the same function (e.g., food gathering, breathing).
4. Define *structure* and *function*.
5. Make a labelled sketch of the organs of the digestive system.
6. A doctor has a patient complaining of shortness of breath when climbing stairs. Describe what body systems may be causing this problem and why.



Focus On THE NATURE OF SCIENCE

Scientific knowledge develops through observation, experimentation, and the discovery of patterns and relationships. Think back over what you've learned in this section.

1. What observations have people made about living things? What new information was developed from these observations?
2. What relationship did Redi's experiment establish?
3. Describe one relationship between human body systems that you discovered.



2.0 Cells play a vital role in living things.

Key Concepts

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

- cells
- tissues
- organs
- structure and function

Learning Outcomes

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

- use a microscope and prepare your own slides
- explain the role of cells as a basic unit of life
- identify plant and animal cells
- identify the differences between one-celled and multicelled organisms
- explain osmosis and diffusion
- recognize the roles of cells, tissues, and organs

For a long time, the circulatory system presented an unsolvable puzzle. People could easily observe the arteries and the veins. They could see that these blood vessels branched out into smaller and thinner vessels. Some observers suspected that blood from the arteries returned to the heart through the veins. However, they could not observe any linking structures between them. They had reached the limits of human sight.

In 1660, an Italian scientist named Marcello Malpighi solved the puzzle. He looked at an intricate network of thin, hair-like vessels connecting arteries and veins in the lung tissues of frogs. These blood vessels were later called **capillaries**, from the Latin word for "hair."

Malpighi's eyesight was no better than that of other scientists of his time. However, he lived during an exciting period in the history of modern science. By the early 1600s, a technological device had been invented that would change our understanding of life and living things. This device was the **microscope**.

The invention of the microscope allowed scientists to view the most basic element of life—the cell—for the first time. Later on in this section, you will learn more about the structure, function, and needs of cells.

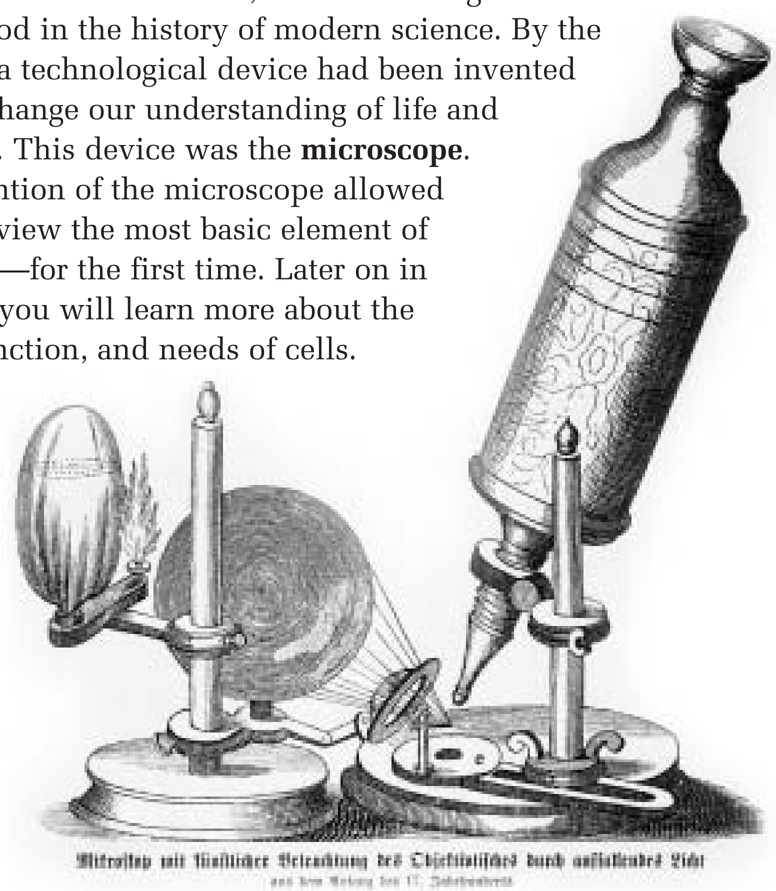


Figure 2.1 One of the earliest microscopes

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2.1 The Microscope Extends the Sense of Sight

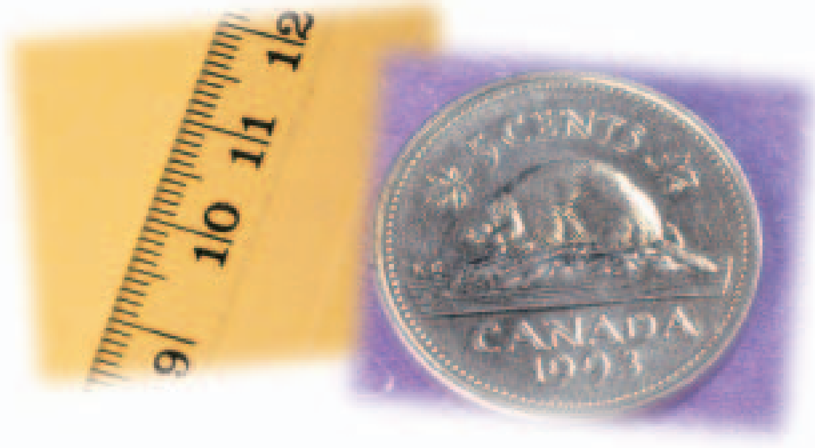


Figure 2.2 How close can your eyes come to an object and still see it clearly? Try it with a ruler and a coin.

Give it a **TRY** ACTIVITY

How Small Can It Be?

How small an object can you see with just your eyes? In your notebook, draw a line 1 mm long (or try making a circle that has a diameter of 1 mm). Have you ever seen an organism this small? Can you think of any organisms that are this small? Can you draw a line half a millimetre long?

Look closely at the dot pictures in Figure 2.3. All the dots in picture A are 1 mm in diameter. They are also 1 mm apart. (Use your ruler to verify this.) You can probably see each dot clearly. Can you see the dots in picture B clearly? What about in pictures C and D?

You probably can't see individual dots in picture D. This is normal. Most people with good eyesight can see only clear, defined images of things that are 0.1 mm or larger. This is a limitation of the human eye. To overcome this limitation and extend our sense of sight, we need the help of technology. We need a microscope.

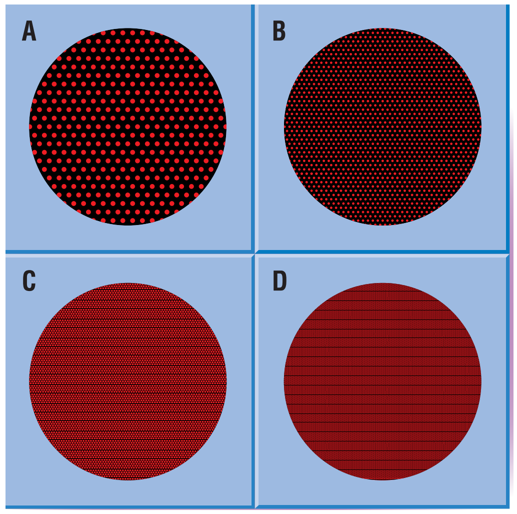


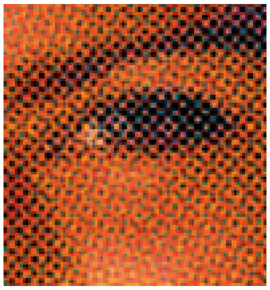
Figure 2.3 Dot pictures

infoBIT

A Closer Look

Look at this image close up. What do you see? Now look at it from a distance. What do you see?

Photographs in books, magazines, and newspapers are made up of tiny dots of colour and shade. This example has been exaggerated. The dots on a printed page are usually too small to see without magnification.



Introducing the Compound Light Microscope

A microscope magnifies (enlarges) the images of small objects. This magnification gives a clear, defined image that the human eye can see. The microscope you'll be using in class probably looks like the one shown in Figure 2.4. Take some time to study its parts and how they function. Then you'll be ready to take a closer look for yourself.

Microscope Parts and Their Functions

Any microscope that has two or more lenses is a *compound microscope*.

When you view an object with a microscope, you are looking through a thin slice of the object. You will see a lamp or other light source under the microscope's stage. That's why the full name for your microscope is **compound light microscope**. The light must travel through the thin object for you to see the object properly.

Microscopes are valuable precision instruments. Like all scientific equipment, they must be handled with care. As a class, develop a chart to summarize the proper care and handling of your microscopes. Use these questions as a starting point for your ideas.

- How should you prepare your work area before bringing the microscope to it?
- How should you carry the microscope to your work area?
- In what position (upright, tilted) should you keep the microscope? Why?
- What parts of the microscope should you keep clean? Why?
- How and where should you store the microscope when you've finished using it?

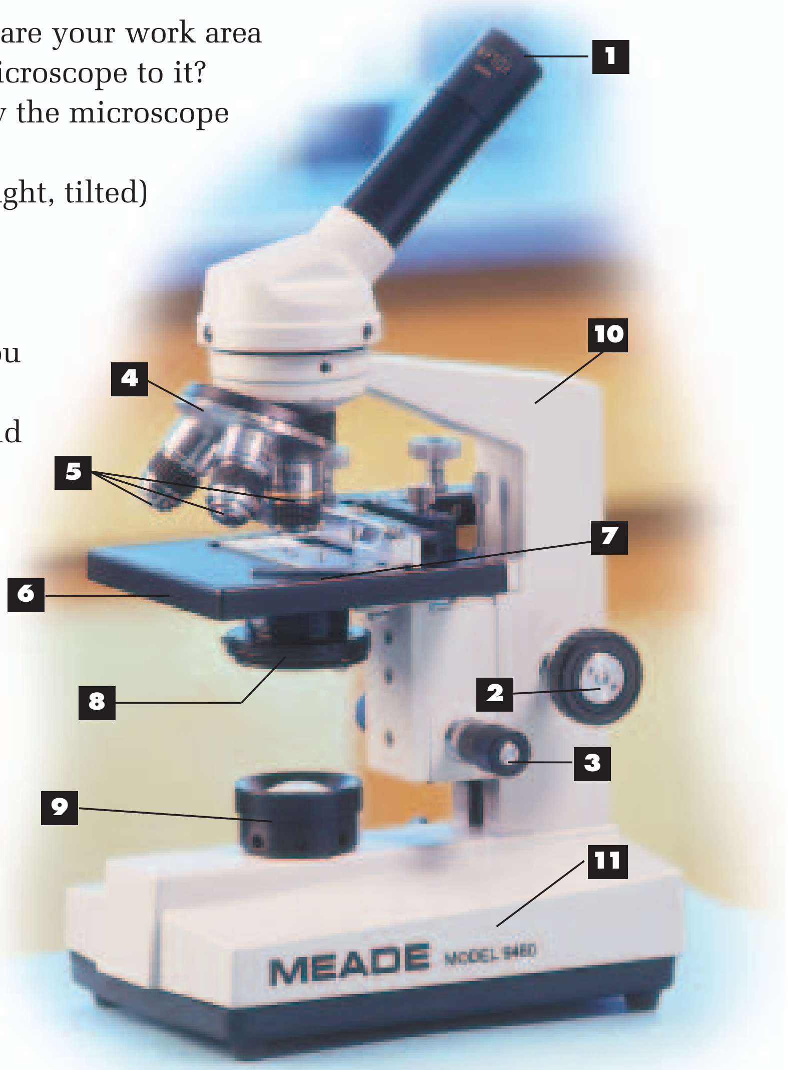


Figure 2.4
Compound light microscope

Compound Light Microscope

Part	Function	Handling Hints
1 eyepiece	contains the lens that magnifies	Try keeping both of your eyes open.
2 coarse adjustment knob	moves the stage up or down to focus on the object to produce a clear, sharp image	Use this only when you're using the lowest-power objective lens.
3 fine adjustment knob	brings the object into sharper focus	Use this with any objective lens, but mainly with the medium-power and high-power objective lenses.
4 revolving nosepiece	holds the three objective lenses	When you change any objective lenses, you'll feel or hear a "click" when the lens is in the right position.
5 objective lenses	provide different strengths (power) of magnification	Avoid getting fingerprints or dirt on the lenses. They should be cleaned with proper lens-cleaning paper only.
6 stage	supports the slide that holds the object you want to view	Keep the stage dry.
7 stage clips	hold the slide firmly on the stage	
8 diaphragm	has different-sized holes that let different amounts of light pass through the object you're viewing	
9 lamp	supplies the light that passes through the object you're viewing	If your microscope uses a mirror instead of a lamp, be careful not to reflect direct sunlight into the microscope. You could damage your eyes.
10 arm	allows you to carry the microscope securely	When you carry your microscope from one place to another, hold the arm with one hand. Support the microscope with your other hand under the base.
11 base	serves as a foundation for the rest of the microscope	When you carry your microscope from one place to another, support it with one hand under the base. Use your other hand to hold the arm.

Give it a **TRY** — ACTIVITY

TRYING OUT A MICROSCOPE

Now it's your turn to try out a microscope. For information on using a microscope, refer to Toolbox 11.

- Select a slide and place it on the microscope stage. Make sure that the lens is switched to the lowest power.
- Look through the microscope and focus the image using the coarse adjustment knob.
- When it's in focus, make a sketch of what you see.

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How Big Is It?
When you view something through a microscope, you can determine the actual size of the image. Ask your teacher how this is done.

PEEKING INSIDE

Microscopes come in many shapes and sizes. Fibre optics is a technology that allows light to travel down a flexible tube. Medical researchers have used fibre optics to create microscopes that can be used inside and outside the body. Some have parts that are tiny enough to be passed through a person's arteries. Other devices are used to help surgeons operate.

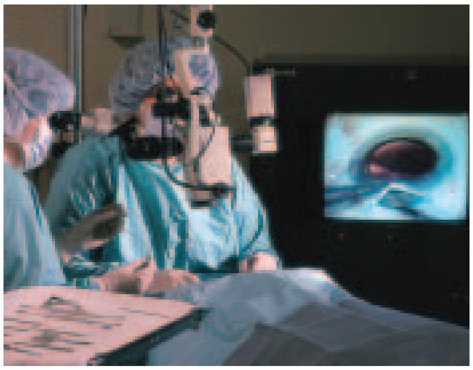

Figure 2.5 The image you see on the screen is actually the patient's eye!

CHECK AND REFLECT

1. a) Which of the following could you see without a microscope? Why would you need one to see the others?
  - a liver cell (about 0.02 mm)
  - the head of a pin (about 1 mm)
  - a red blood cell (about 0.007 mm)

b) Did any of these sizes surprise you? Which one, and why?

2. In your notebook, make a labelled sketch of a microscope. Briefly explain how you would use a microscope to look at a slide.

3. When using a microscope, why should you start with the lens in the lowest position and then move up? What would happen if you didn't?

2.2 The Cell Is the Basic Unit of Life

Cells are the smallest known functioning units of life. All organisms must be made of at least one cell. In most organisms, cells rarely work alone: cells with a similar structure and function are organized into **tissues**. Tissues that work together for a common purpose form **organs**, and an **organ system** is a group of organs that work together for a common purpose in order to keep you alive.

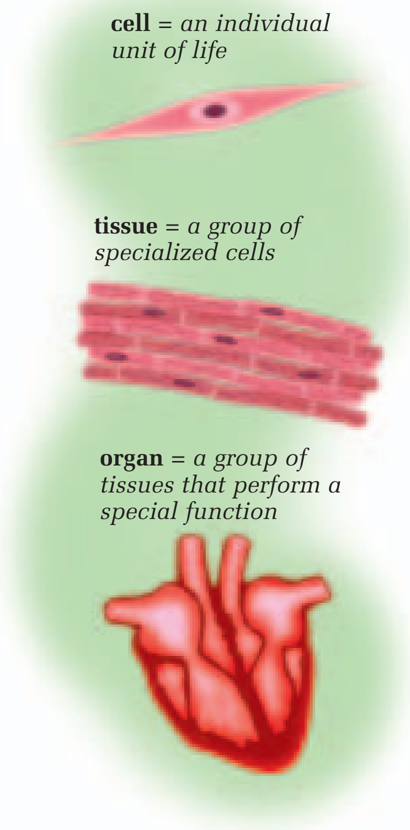

Figure 2.6 How cells, tissues, and organs are related

Looking at Cells

When you look at cells using a microscope, even at low power you will probably see more than one cell. So it helps to be able to identify where one cell stops and another starts.

Cell Structures You Can Usually See with a Classroom Light Microscope

Many things can affect your ability to see details of the internal parts of cells. These factors include:

- the type of microscope
- the power of the lenses
- the quality of the prepared slides

You are likely to find all of the cell structures listed in the table below if you look at slides of plant material as well as animal material. Not all of these structures will be found in any one cell.

Cell Structure	Feature That Can Help You Identify It
cell membrane	looks like a thin line that surrounds the whole cell
cell wall	a rigid, frame-like covering that surrounds the cell membrane
cytoplasm	a liquid inside the cell, which has grainy-looking bits in it
nucleus	a fairly large, dark, spherical structure that's usually near the centre of the cell
vacuoles	clear, liquid-filled spaces in various places within the cytoplasm

Inquiry
Activity

Comparing Plant and Animal Cells

The Question

How are cells from different living things alike and how are they different?

Procedure

1. Set up your microscope.
2. Get a prepared slide of plant cells, and put the slide on the stage. Position it so that your specimen is above the hole in the stage. Use the stage clips to hold the slide firmly in place.
3. When your glass slide is in place, look at the stage from the side. Make sure the low-power objective lens is above the slide.

Materials & Equipment

- compound microscope
- one or more prepared slides of plant cells (for example, cells from a lily leaf or hibiscus stem)
- one or more prepared slides of animal cells (for example, skin cells)

Figure 2.7 Using the coarse adjustment knob

4. Use the coarse adjustment knob shown in Figure 2.7 to bring the low-power objective lens as close as you can to the slide without touching it.
5. Look through the eyepiece. Use the coarse adjustment knob to bring your specimen into focus.
6. Use the fine adjustment knob, shown in Figure 2.8, to get a clear, sharp image.
7. Keep looking through the eyepiece. Gently move the glass slide in different directions—a bit to the left, to the right, up, down. See what effect this has on the image.
8. Move the specimen back to the centre of your view. Refocus using the coarse adjustment knob. Turn the revolving nosepiece to switch to the medium-power objective lens. (A “click” will tell you the lens is in place.) Focus the image with the fine adjustment knob.

Figure 2.8 Using the fine adjustment knob

9. Move the specimen to the centre. Refocus with the fine adjustment knob. Switch to the high-power objective lens.
10. Use the fine adjustment knob to focus the image.
11. Take your time to get familiar with what you can see at low, medium, and high power. In each case:
    a) Count or estimate the number of cells you observe in the field of view. The **field of view** is the entire area you can see when you look through the microscope.
    b) Notice the shapes of cells and how they're arranged.
    c) In your notebook, draw the view you see.
12. Remove the slide. Replace it with a prepared slide of animal cells. Again, observe at low, medium, and high power. Repeat step 11.

Caution!
Whenever you use the medium-power and the high-power objective lenses, focus your image using only the fine adjustment knob.

Hint!
When your specimen is in focus, try keeping both eyes open. If you concentrate on what you're looking at, all you'll see is your specimen. This method lets you relax your face muscles so you feel more comfortable. As a result, you can observe much longer.

Collecting Data

13 Look over all your cell drawings. Choose one plant cell and one animal cell. Then use the information about typical cell structures in the text to help you label your drawings.

Analyzing and Interpreting

14 What do you think are the differences between plant and animal cells? Give examples from what you observed.

15 What are the similarities you can identify between plant and animal cells?

Forming Conclusions

16 Write a summary paragraph that answers the question: "How are cells from different living things alike and how are they different?" Include diagrams in your explanation.

Applying and Connecting

In this activity, you looked at slides that were prepared by taking extremely thin slices of samples. When you look at them through the microscope, you are seeing two-dimensional views of the samples. Another method of preparing samples is called freeze-etching, which gives three-dimensional views of the parts of cells, as seen in Figure 2.9.

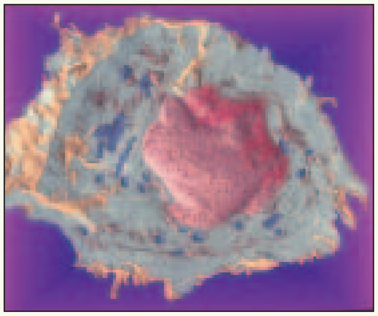

Figure 2.9 Freeze-etching shows parts of this cell in three dimensions.

PREPARING SLIDES

So far, you have looked at slides that have been prepared for you. In order to learn more about organisms, scientists have to be able to view living specimens. To do this, they must prepare their own slides. This is how it's done.

Figure 2.10 A finished wet mount being positioned on the microscope stage

Preparing a Wet Mount

Follow these steps to make a wet mount of a lowercase letter "e."

1. Gather the following: a clean glass slide and cover slip, an eyedropper, tweezers (or a toothpick), a small cup of water, and your specimen—a letter "e" taken from a newspaper page.
2. Pick up the glass slide by the edges and place it in front of you.
3. Using an eyedropper, place one drop of water in the centre of the slide. Then use tweezers or a toothpick to lay your specimen—right side up—on the drop of water.
4. Pick up the cover slip the same way you picked up the glass slide. Slowly lower it over your specimen as shown in Figure 2.11. Try not to trap air bubbles under the cover slip.

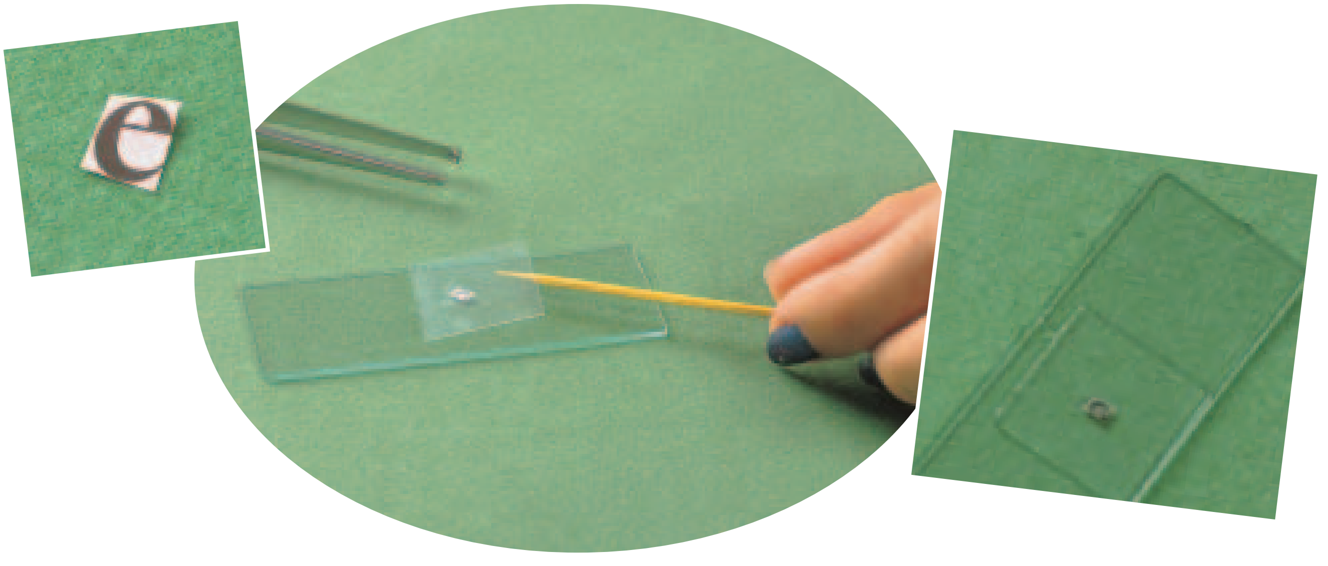

Figure 2.11 Placing a cover slip on a specimen

Preparing and Viewing a Cell Specimen

If you've ever looked closely at an onion, you may have noticed a thin, semi-transparent skin between the thicker layers. This skin is only one cell thick in most places, which makes it ideal for observing cells.

1. Remove this layer from a section of onion as shown in Figure 2.12 and carefully pick it up using tweezers or a toothpick. Hold the slide at a 45° angle and drape the specimen onto the middle of the slide. Try to avoid trapping air bubbles between the specimen and the slide.
2. Continue to prepare the wet mount as you did above.

Figure 2.12 Peeling off a thin layer of an onion section

Give it a **TRY** ACTIVITY

TESTING YOUR WET MOUNT

Prepare a wet mount of an "e" following the directions on the previous page. Pick up your wet mount slide by the edges and place it on the microscope stage. Before you view anything, make the following predictions. Then, make sketches to record your predictions.

- How will your specimen appear when you observe it with low power?
- How will it change when you move the slide to the left? to the right? up? down?
- How will it change when you view it with medium power? with high power?

View your slide under the microscope to test your predictions. Record your observations in your notebook.

Now, prepare a specimen of onion skin following the directions above. View your specimen under the microscope. Make a sketch of your observations.

VIEWING PLANT AND ANIMAL CELLS

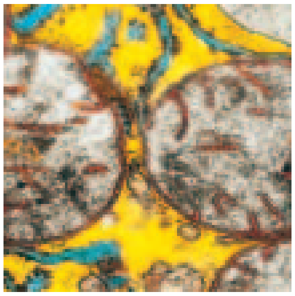

Figure 2.13 Part of a liver cell magnified 11 300× using an electron microscope. The circles are mitochondria.

Look at Figure 2.14. It is probably very difficult to see all the structures mentioned in the chart on page 103. Even the best light microscopes do not show all the structures found in a cell. For about 300 years, this was a major drawback to scientists studying cells. The electron microscope solved the problem. These microscopes use electrons instead of light. They allowed the discovery of new, smaller cell structures as shown in Figure 2.13.

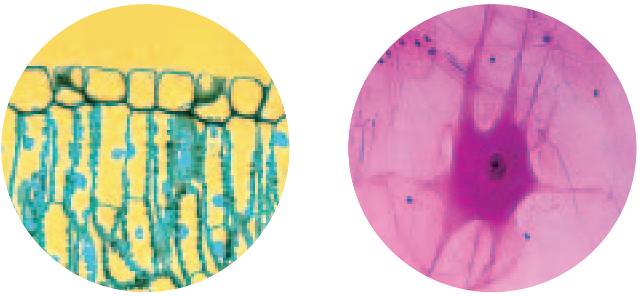

Figure 2.14 Plant and animal cells viewed through a light microscope. Which is which?

THE VITAL ROLES THAT CELL STRUCTURES PLAY

Within each cell there are a number of specialized structures called **organelles** that carry out specific functions. One way to think about cells' organization is to think of them as living factories, making all the things necessary for them to live. These factories have the following specialized areas.

Structure	Function
nucleus	a "command centre" that directs all cellular activities such as movement, growth, and other life functions
mitochondria	the "powerhouses" of the cell where chemical reactions occur that convert the energy the cell receives into a form it can use
cell membrane	a "controllable gateway" that lets needed materials in and waste materials out
vacuoles	the "storage rooms" where nutrients, water, or other substances can be stored by the cell. Plant cells tend to have just one big vacuole, and animal cells have many small vacuoles.
cytoplasm	the "kitchen" of the cell. It contains the nutrients required by the cell to maintain its life processes.
cell wall	the "frame" of the cell. Found in plant cells but not in animal cells, it provides strength and support to plants.
chloroplasts	the "solar panels" of the cell. They are found in the cells of the green parts of plants. They carry out photosynthesis, converting the sun's energy into food for the cell.

Most cells have these special structures. Because of this, scientists have constructed cell models like the ones shown in Figures 2.15–2.16. How does the function of each cell structure contribute to the overall health of the cell?

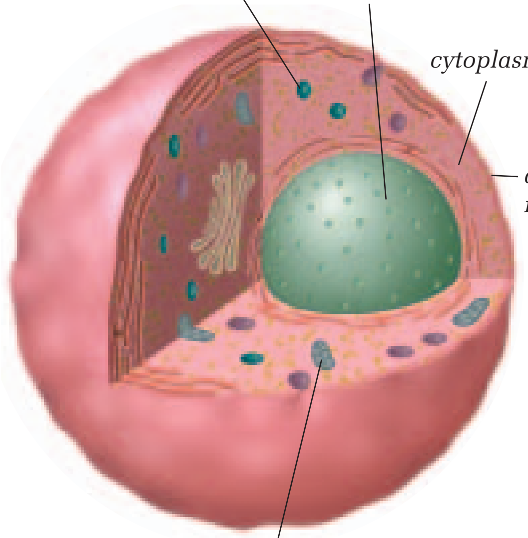

Figure 2.15 Model of an animal cell

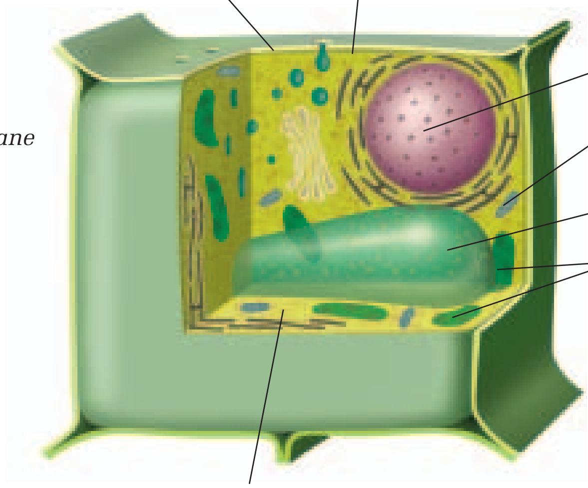

Figure 2.16 Model of a plant cell

Check and Reflect

1. Design a chart to record the following information:
   a) cell structures that you can see with a compound light microscope
   b) the functions of these cell structures
   c) whether these structures appear in animal cells, plant cells, or both
2. Scientists build generalized cell models based on organisms made of many cells. Do you think there's such a thing as a generalized single-celled organism? Make a sketch to record your ideas of what one might look like. Include labels to describe the functions of all the structures you include.
3. How would the health of a cell be affected if one or more of its organelles were damaged? Give reasons to support your opinion.

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More Organelles

You have observed cell structures using a compound light microscope. Using the higher power of an electron microscope, scientists have discovered many more cell structures. Use print or electronic resources to find out about the following cell structures and their functions:

- endoplasmic reticulum
- Golgi bodies
- lysosomes
- ribosomes

Figure 2.18 Blue whale

Figure 2.17
Mycoplasma

2.3 Organisms Can Be Single-Celled or Multicelled

Figure 2.17 shows the smallest kind of organism scientists have discovered so far. It belongs to a group of organisms known as **mycoplasma**. These are so small that they had to be magnified over 18 000× to make this photo.

The organism in Figure 2.18 is the world's largest kind of animal, the blue whale. The whale is about 30 m in length. It's hard to believe that blue whales and mycoplasma have much in common. But they do. They have something in common with you, too, and with every other organism. They are made up of cells.

Cells are the individual, living units that make up all living organisms. Some organisms are **multicellular**. This means that they are made up of two or more cells. Plants and animals are examples of multicellular (many-celled) organisms.

Other organisms are **unicellular**. They are made up of only a single cell. Most microscopic organisms, or **micro-organisms**, such as mycoplasma, are examples of unicellular (single-celled) organisms.

UNICELLULAR VS. MULTICELLULAR

The little glass pill-boxes in Figure 2.19 are alive! They are called diatoms, and they are single-celled plants. They have chloroplasts just like the plants you see every day. They live in lakes, oceans, and moist soil, and are an important part of the food chain.

Figure 2.19 Diatoms

Although there is a tendency to consider unicellular organisms as simple because they lack the tissues and organs of more advanced creatures—they are not. A single-celled organism can do most things that we need trillions of cells to do: eat, move, react to stimuli, get rid of waste products, and reproduce. Unicellular organisms often develop specialized structures to help them perform these functions.

Instead of relying on a single cell to meet all of their needs, multicellular organisms rely on many very specialized cells to perform functions such as feeding, moving, and so on. As a result, all the cells within multicelled organisms react to one another (or interact). For example, in a multicelled animal such as a deer, there are cells specialized for the function of feeding. However, these cells are dependent on other specialized cells, such as muscle cells, to move the deer to new supplies of food.

Whether single-celled or multicelled, all plants and animals have most of the organelles you studied in the cell models.

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Colossal Cell

One of the world's largest unicellular organisms is so big that you can see it with the unaided eye. It's called *acetabularia*, and it's a member of the plant-like algae family. Acetabularia measures from 5 cm to 7 cm!

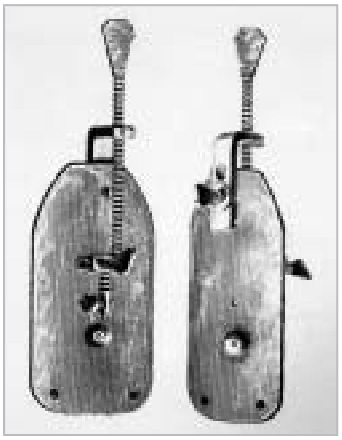
*re*SEARCH

The World's First Microscope

The person who first observed unicellular organisms was a Dutch amateur scientist named Antony van Leeuwenhoek [pronounced LAY-ven-hook].

Find out about Leeuwenhoek and his microscopic investigations.

- What kinds of organisms did he discover?
- How did he communicate his findings?



Inquiry
Activity

OBSERVING UNICELLULAR ORGANISMS

Materials & Equipment
- microscope
- glass slide
- cover slip
- eyedropper
- live, unicellular organisms (supplied by your teacher)
- small jar to carry the organisms to your viewing area
- methyl cellulose

Caution!
Be careful when handling microscopic organisms. Wash your hands thoroughly when you have finished this activity.

The Question

What cell structures can be seen using a simple light microscope?

Figure 2.20 A common unicellular organism

Procedure

1. Prepare a wet mount of the live organisms. Set up your slide on the microscope stage and position the low-power objective lens over your specimen. Observe your organisms.
Tip: Some organisms are fast! Take your time and concentrate on getting familiar with what you're observing, and on keeping your specimen in focus. After a little while, switch to medium power and observe. If you wish, try high power. Was this an improvement? Why or why not?
2. Observe your specimens. Record any features and actions you find interesting. With a partner, brainstorm some questions you would like answered about your specimens.

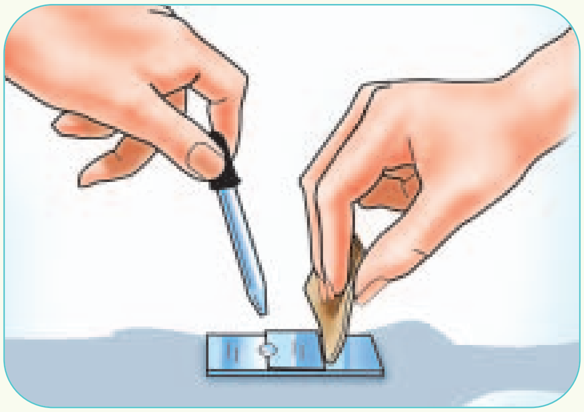


Figure 2.21 Use a piece of paper towel to "pull" the methyl cellulose under the cover slip.

3. *To slow down fast-moving specimens*: If you are viewing fast-moving organisms such as paramecia, slow them down by adding a tiny amount—less than a drop—of methyl cellulose. This is a syrupy liquid that thickens the water so it is harder for the paramecia to move rapidly. Figure 2.21 shows how to add methyl cellulose to your wet mount.

4 Observe your slowed-down specimen. Follow the instructions in step 5 for recording your observations.

Collecting Data

5 Make an accurate drawing of one organism. Try to draw what you really see, not what you think or imagine might be there. Include labels to identify or describe the following details:

- shape
- colour
- size (how much of your field of view it occupies)
- all the cell structures and organelles that you recognize
- any cell structures and organelles that you don't recognize
- the power of the objective lens you're using

Analyzing and Interpreting

6 Describe how your organisms move. Use an analogy to help you describe their movement.

7 a) If you observed paramecia, how did the methyl cellulose slow the paramecia's movements?

b) Suppose you didn't have any methyl cellulose available. Suggest another method you could use to slow the paramecia without harming them. Explain why you think it will work.

Forming Conclusions

8 Write a short story or draw a cartoon strip about a day in the life of your organism. Use your observations to help you include informative details such as how it moves, where it goes, what you think it eats, and what might eat it! Include as many cell structures and organelles as you can to support the details you include.

Applying and Connecting

Imagine Antony van Leeuwenhoek or the other microscope pioneers examining their drinking water and seeing unicellular organisms like those you have just observed. What do you think their reaction would be? What would yours be? While many micro-organisms are harmless, some cause disease. Do you know what steps have been taken to ensure your drinking water is safe from micro-organism contamination? Find out, if you don't know.

Figure 2.22 Antony van Leeuwenhoek

Common Unicellular Organisms

Amoeba

Amoebas are common unicellular organisms that live in water. They move around using foot-like projections called **pseudopods**. They extend a pseudopod and the cytoplasm streams into it. Amoebas also use these pseudopods to capture food. Figure 2.23 shows an amoeba engulfing food between two pseudopods. The ends of the pseudopods fuse together and create a vacuole around the food particle. The food in the vacuole is digested and absorbed into the cytoplasm.

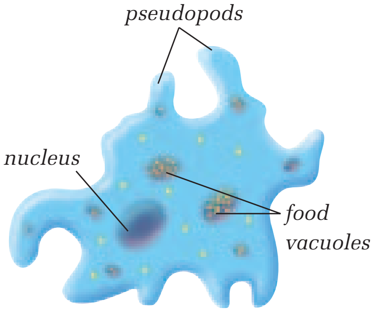
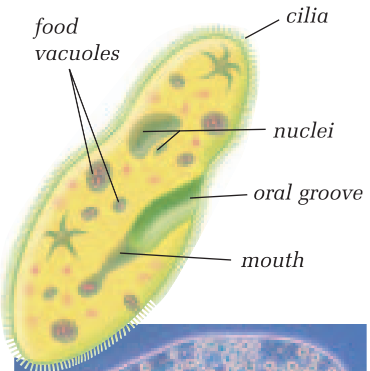


Figure 2.23 An amoeba keeps changing shape as it creates new pseudopods. Here, an amoeba extends pseudopods around a food particle.

Paramecium

Unlike amoebas, paramecia (plural form of paramecium) move swiftly through the fresh water where they live. They are covered in hair-like structures called **cilia**, which move back and forth like oars to move them through the water. Cilia also help them gather food. On one side of the cell is a channel called an oral groove. It's lined with cilia, which sweep food to the bottom of the groove. There, the food enters a food vacuole, which moves into the cytoplasm, and the food inside is digested.



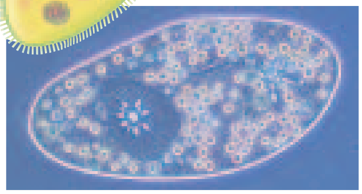
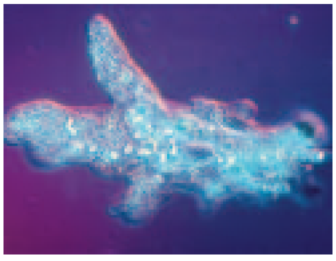


Figure 2.24 In the picture, the tiny circles with dark centres are food vacuoles. Can you see the cilia?

Check and Reflect

1. Unicellular organisms are simple. Agree or disagree with this statement and fully explain your answer.
2. Why can't the individual cells of a multicellular organism live on their own? Explain your answer.
3. Describe the steps you would follow to prepare amoeba specimens for observation.
4. Identify an amoeba's food-gathering structures and describe how they function.
5. Make up three questions about the behaviours of paramecia. Pick one of your questions and write a hypothesis that answers the question. (Remember: A hypothesis is a possible answer to a question. You usually phrase it so that it implies a way you could test it.)



2.4 How Substances Move Into and Out of Cells

Right now, every cell in your body is bringing in water, gases, and food inside itself. At the same time, each is removing waste products from inside itself. This bringing in and removal of substances is important to your survival. But it isn't unique to humans. These processes are also happening in the cells of every organism. The cell has a structure that permits this vital exchange of substances. It is the cell membrane. Many substances move through the cell membrane by a process called **diffusion**.

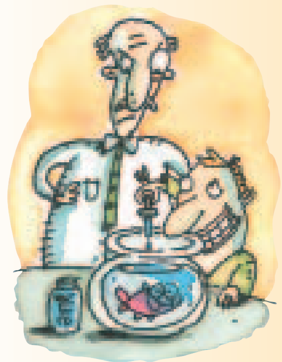
Give it a TRY — ACTIVITY

DIFFUSION IN ACTION

In this activity, you will observe the process of diffusion in action. Place a drop of food colouring into a beaker of room-temperature water. Make sketches in your notebook to show what the drop looks like

a) as soon as it is dropped in the water
b) about 20 s later
c) about 60 s later
d) about 10 min later

What happened to the drop of food colouring over time? How did it look after 10 min? Can you think of a sentence to explain diffusion?



THE CELL MEMBRANE AND DIFFUSION

Diffusion is the movement of particles from an area where there are more of them to an area where there are fewer of them. In other words, diffusion moves particles from a more concentrated area to a less concentrated area. It's a "balancing out" or "evening out" process that continues until the concentration of particles is the same everywhere.

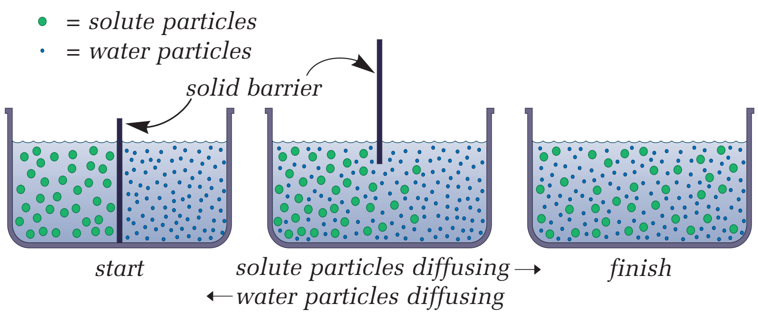


Figure 2.25 The process of diffusion

Figure 2.26 The tiny openings in this tea bag are large enough to allow water to pass through, along with the substances that make the flavour of the tea, but they are small enough to keep in the tea leaves themselves. How is a tea bag similar to a cell? How is it different?

Particles of many substances move in and out of cells by diffusion. The cell membrane acts like a filter with extremely tiny openings that allow some particles to pass through.

These openings are small enough to keep the cell's cytoplasm and organelles inside. They are also small enough to keep particles of most substances in the cell's external environment out. However, particles of some substances are able to pass from the outside in and from the inside out. So the cell membrane allows the particles of some substances to pass through it, but not others. Because of this fact, scientists say that the cell membrane is **selectively permeable**.

To do their jobs, mitochondria in cells need oxygen. Oxygen particles are small enough to pass through the cell's selectively permeable membrane into the cell. This movement of oxygen happens by diffusion. That's because the concentration of oxygen is usually higher outside the cell membrane than it is inside. As a result, oxygen simply diffuses into the cell. The cell doesn't have to do anything to make it happen.

The Cell Membrane and Osmosis

Water is another substance that has particles small enough to diffuse through the cell membrane. The amount of water inside a cell must stay fairly constant. If the water concentration inside the cell gets too low, water from outside the cell diffuses in. If the concentration gets too high, water diffuses out of the cell.

The diffusion of water is vital to the survival and health of cells. For this reason, scientists give it a special name: osmosis. **Osmosis**, then, is the diffusion of water particles through a selectively permeable membrane. The water particles move from an area of higher concentration (where there are more water particles) to an area of lower concentration (where there are fewer water particles).

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Vultures Find the Spot

Engineers once used diffusion to find a leak in a gas pipeline. They put a chemical that smells like rotting flesh into the pipeline, and then watched and waited. Turkey vultures can smell even tiny amounts of this gas. The circling vultures led the engineers to the location of the leak in the pipeline.

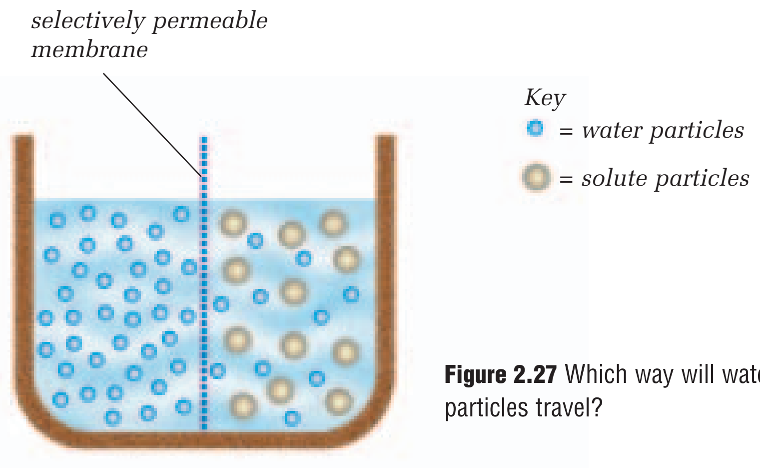

Figure 2.27 Which way will water particles travel?

Inquiry
Activity

Effects of Different Solutions on Cells

Materials & Equipment

- thin slice of onion
- compound microscope
- glass slide
- cover slip
- saltwater solution
- eyedropper
- paper towelling
- distilled (pure) water

The Question

How will a saltwater solution and pure water affect the appearance of a cell?

The Hypothesis

Form a hypothesis for this investigation describing the effect a saltwater solution will have on an onion cell. (See Toolbox 2 if you need help with this.)

Figure 2.28 Onion cells

Procedure

1. Prepare a wet mount of a small piece of onion skin. Lay the skin as flat as possible on the slide.
2. Position the slide under the microscope and make a drawing of one or two of the cells you observe. Remove the slide from the microscope.
3. Place several drops of saltwater solution on one side of the cover slip. Use a piece of paper towel to "pull" the saltwater solution under the cover slip (as shown in Figure 2.21 on page 112). Wait 30 to 60 s.
4. Position the slide under the microscope and make another drawing of one or two of the cells you observe. Remove the slide from the microscope.
5. Repeat steps 3 and 4, but this time use distilled water on your specimen.

Collecting Data

6. Assemble the three drawings you made in steps 2 to 5.

Analyzing and Interpreting

7. How did the saltwater solution and the pure water affect the appearance of onion cells?

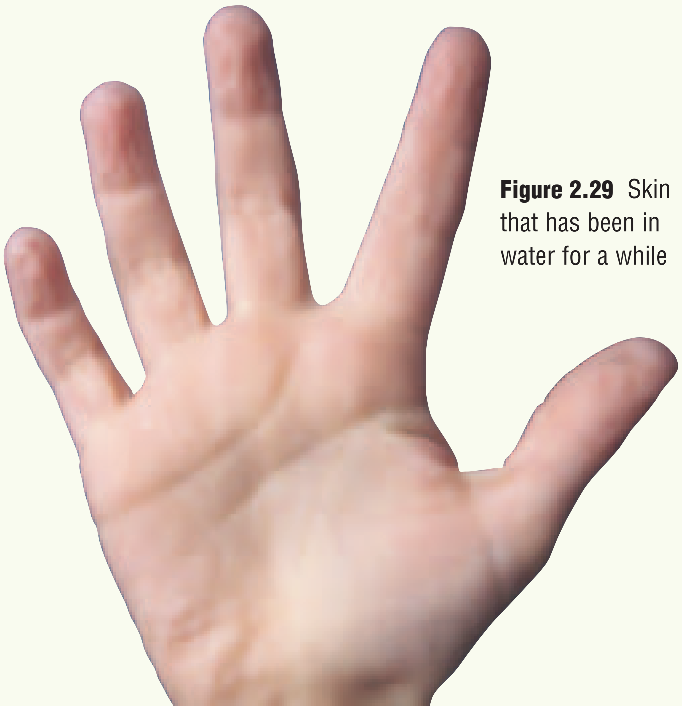

Figure 2.29 Skin that has been in water for a while

Forming Conclusions

8. Explain what happened in this activity.

Applying and Connecting

Have you ever noticed that when you've been in the water for a long time, your skin wrinkles, as in Figure 2.29? Why do you think this happens?

Experiment
ON YOUR OWN

How to Stop the Wilt


Figure 2.30 Fresh cut flowers

Before You Start ...

Have you ever given or received flowers from someone? How did they look at first? How did they change over time? Why did this happen?

Selling fresh, vibrant cut flowers, as in Figure 2.30, is big business. Flower shops use a variety of methods to keep plants fresh looking for as long as possible. What's the science behind these methods? Use your understanding of plant cells and tissues to help you solve the following problem.

The Question

Which substance, technique, or both, will keep flowers from wilting for as long as possible?

Design and Conduct Your Experiment

1 Make a hypothesis.
2 Decide what materials and equipment you'll need to test your hypothesis. For example:
   a) What kind of plant will you use, and how many will you need?
   b) What substances do you need to test your hypothesis?
   c) Where can you find what you need, and what substitutions could you make, if necessary?
   d) How will you troubleshoot for safety?
3 Plan your procedure. For example:
   a) What evidence are you looking for to support your hypothesis?
   b) How long will you run your experiment?
   c) How will you collect your data?
   d) What variables are you working with, and how would you define them?
   e) How can you make sure that your test is fair?
   f) How will you record your results?
4 Write up your procedure and show it to your teacher.
5 Carry out your experiment.
6 Compare your results with your hypothesis. Did your results support your hypothesis? If not, what possible reasons might there be?
7 How did you keep water moving through the plant's roots, stems, and leaves? Can you explain your results in terms of water moving through the plant?
8 Share and compare your experimental design and findings with your classmates. How do your results compare with theirs?

The Effect of Osmosis on Cells

In Figure 2.31, photo A shows a normal red blood cell. It has been in a solution in which the concentration of water was the same inside and outside the cell. In photo B, the cell was in a saltwater solution. The concentration of water was higher inside the cell than outside, so the water moved out of the cell by osmosis. This cell now has a shrunken appearance. In photo C, the cell was placed in almost pure water. The inside of the cell contains far less water than the outside of the cell, so the water moves into the cell by osmosis, causing the cell to swell.

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Reverse Osmosis
A process called reverse osmosis can be used to purify water. It is often used on ships to purify drinking water. Find out how it works.

Figure 2.31 Cells can be affected greatly by osmosis.

Check and Reflect

1. a) Use the term *selectively permeable* in a sentence that clearly demonstrates its meaning.
   b) What is the function of a cell's selectively permeable membrane?
   c) How does this function contribute to the health of the cell?
2. The terms *diffusion* and *osmosis* seem to have similar meanings. Explain how they are similar. Then give a reason why scientists use two separate terms.
3. Martin volunteered to carry drinks to the class hosting a surprise party for a retiring teacher. He isn't sure which classroom is the right one, but he does know the students plan to serve pizza and popcorn. Explain how Martin could use the smell of popcorn and pizza as a clue.
4. Alex accidentally left a bag of carrots in the warm car. When he found them, they had wilted and were soft. He decides to place them in a container of water and check on them every half-hour or so for several hours. Predict what will happen to the carrots and why.
5. Fish species that live in fresh water have to remove excess water as waste from their bodies. Fish species that live in salt water have bodies that keep as much water as possible. Using what you know about osmosis, explain these observations.

2.5 Cells in Multicellular Organisms Combine to Form Tissues and Organs

Figure 2.32 Have you wondered why unicellular organisms are so small? Does it surprise you that there aren't any single-celled creatures the size of a dog or elephant?

Unicellular organisms are tiny because there are limits to how large they can grow. One of the reasons involves diffusion and osmosis. These vital processes work well only over very short distances. For example, it takes an oxygen particle a fraction of a second to diffuse over a distance of 10 μm (0.01 mm). To diffuse over a distance of 1 mm takes several minutes! Do you see how unicellular organisms benefit by being microscopic?

Cells Reproduce

Like all organisms, unicellular organisms grow and develop. When they reach the limits of their size, like the amoeba shown here, they reproduce. Amoeba do this by dividing into two, which results in two smaller, identical copies of each organism.

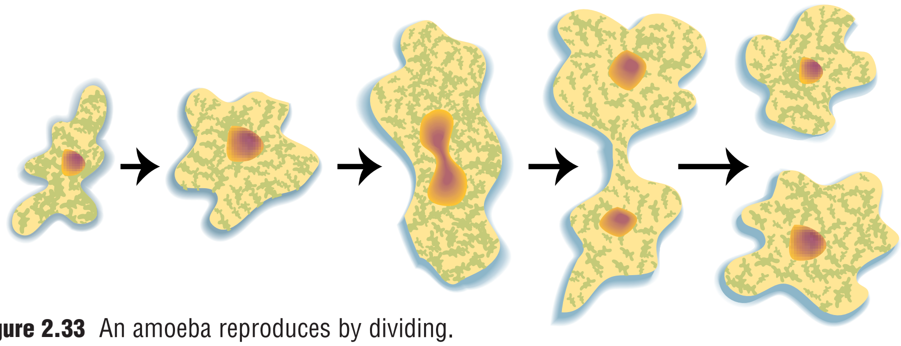

Figure 2.33 An amoeba reproduces by dividing.

Your cells reproduce this way, too. That's how, for example, your body replaces the 50 000 000 or so skin cells that it naturally loses each day! Your body cells also reproduce to repair tissues that get damaged. For example, if you scrape your elbow, your skin cells reproduce to form new skin tissue.

Multicellular Organisms Have Specialized Cells

Your skin cell can do this because it's specialized for this function. You and most other multicellular organisms are made up of **specialized cells**. This means that there are various kinds of cells, and each kind carries out a specific function or functions needed to support life. Each kind of cell has specific structures that enable it to carry out its function. For example, the function of your **red blood cells** is to carry oxygen to all cells of your body. To do this, the red blood cells often must travel through extremely small blood vessels. Their thin, pliable disc shape enables them to do this.

Red blood cells do not reproduce in the same way as skin cells. When red blood cells mature into the shape shown here, they lose their nucleus. Since the nucleus controls cell division (among other functions), red blood cells can't reproduce by simply dividing to make more of themselves. The only way your body can make more red blood cells is by relying on specialized tissues in another body system. Most bones of the skeletal system contain a type of connective tissue called **marrow**, with specialized cells that make red blood cells.

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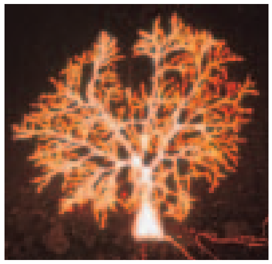
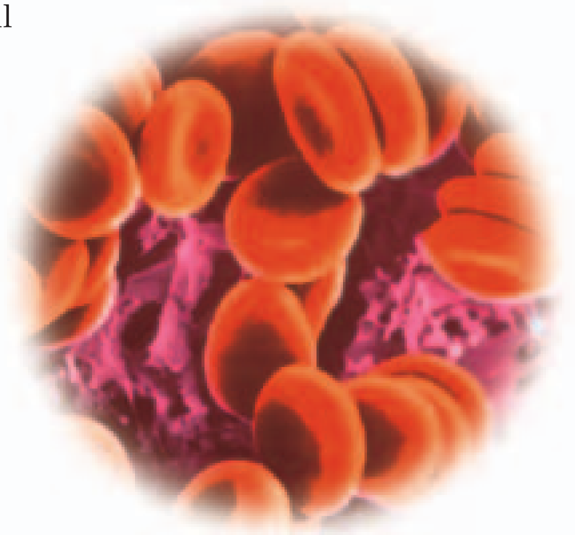
The Body's Nerve Centre



This strange-looking tree is actually a nerve cell. It's called a *purkinje cell*, and it is a very specialized cell from a part of your brain called the cerebellum. Your brain and nervous system are made of billions of nerve cells. These cells are what let you think, touch, taste, move, and see.

Figure 2.34 Red blood cells



Specialization means that the cells of a multicellular organism must work together to support their own lives, as well as the life of the whole individual. For example, the cells that make up the tissue of your liver rely on other organ systems to provide them with oxygen and nutrients by diffusion.

Similar Cells Combine to Form Tissue

In humans, as well as in many other animals, the cells are organized into four different tissue types: connective, epithelial, nervous, and muscle tissues.

As you may recall, organs are made of tissues. Almost all of your organs are made up of different combinations of these four types of tissue.

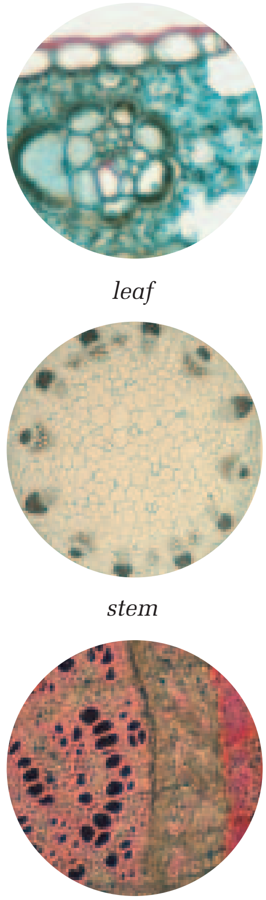
Figure 2.35 Your body contains four types of tissue.

Tissues in Plants

Plant cells are also organized into tissues, but plants have three tissue types: photosynthetic/storage, protective, and transport. These tissues are organized into the three organs that make up plants: the leaves, the roots, and the stems. Unlike animals, though, the organs of a plant are not organized into organ systems. However, the organs of a plant still interact—one organ, such as the leaf, cannot live without the substances provided by the other two organs.

As you look at Figures 2.37, 2.38, and 2.39, observe how each of the tissues are organized in each of the organs.

Figure 2.36 Cross-sections of a leaf, stem, and root seen through a microscope



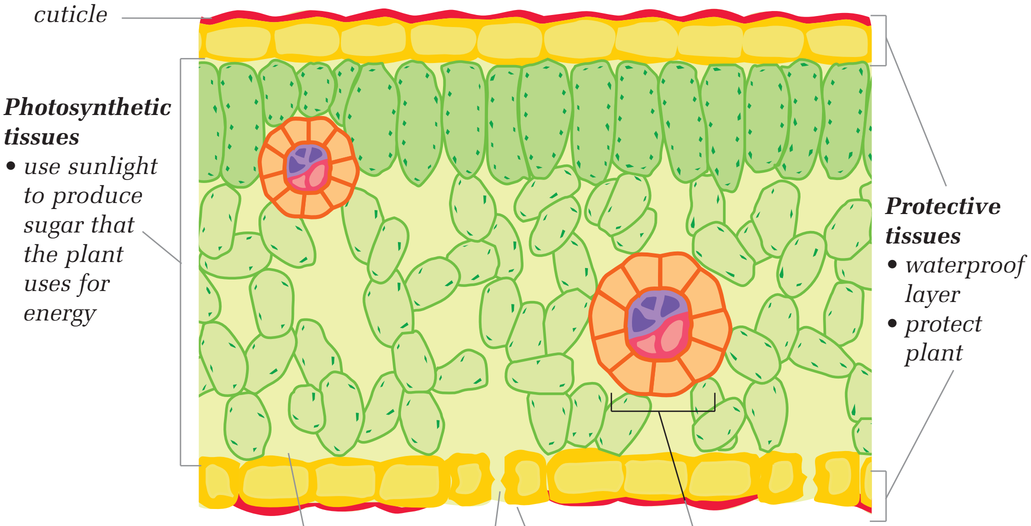


Figure 2.37 Tissues and cells of the leaf

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Water Bears

Not all multicellular animals are large. For example, the members of one group of microscopic animals fondly referred to as "water bears" are multicellular. They range in size from 0.05 mm to 1.2 mm. (So the largest water bears are just in the range of your unaided sight.) These animals are amazing survivors. Find out more about water bears. How do they withstand extreme conditions?

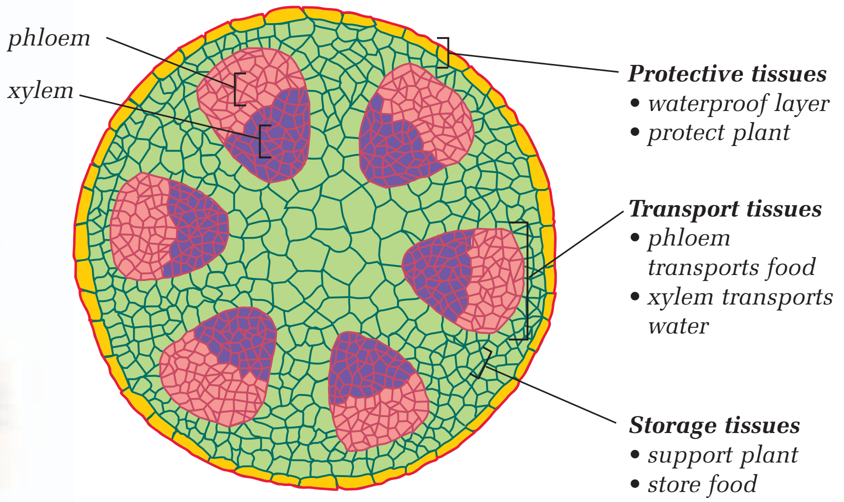


Figure 2.38 Tissues and cells of the stem

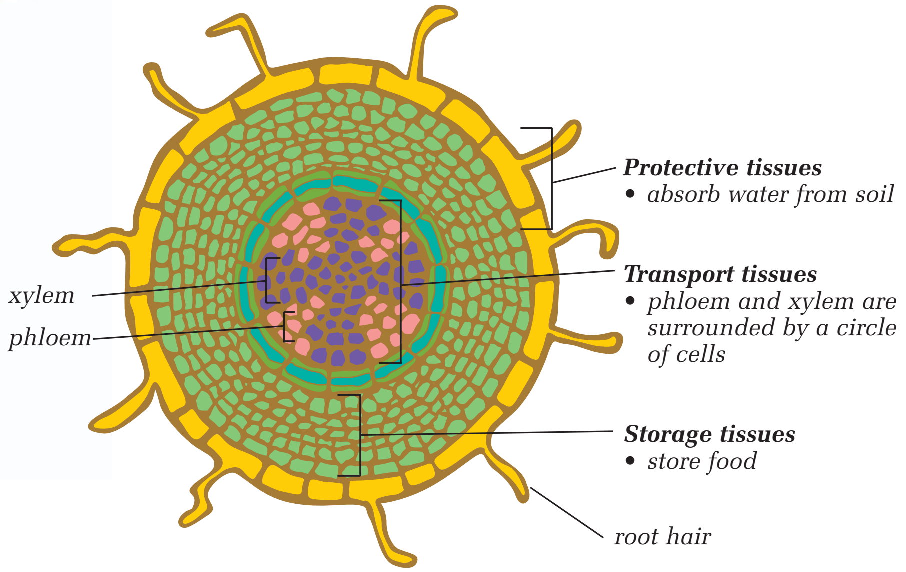


Figure 2.39 Tissues and cells of the root

Check and Reflect

1. For what reasons do the cells that make up multicellular organisms need to reproduce?

2. Is a red blood cell more specialized than an amoeba, or is it the other way round?

3. What are the advantages of having specialized cells? Are there any disadvantages? Explain your answer.

4. a) Name a plant organ.

b) Identify the tissues that make up this organ.

c) Describe the cells that make up each of the tissues in these organs.

Assess Your Learning

1. Identify the organisms in Figure 2.40 as unicellular or multicellular. Give reasons for your answers in each case.

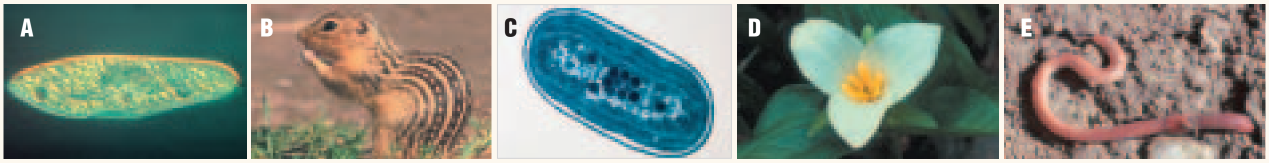
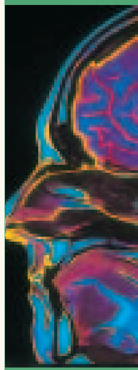


Figure 2.40



2. a) Sketch a plant cell and identify, using labels, the organelles and other cell structures.
   b) Do the same for an animal cell.
   c) Describe the key differences between plant cells and animal cells.
3. What is the function of a compound light microscope?
4. In your opinion, which structure or organelle is the most important to the health of a cell? Give reasons for your answer.
5. Choose one of the items below. Using words, pictures, or both, explain how you would prepare it to view with a microscope. Also, make a sketch showing what you think it would look like under low, medium, and high power. (Ask your teacher if you can set up a microscope to verify, and, if necessary, modify your sketches.)
   a) a hair from your hand
   b) a fleck of dandruff
   c) a grain of pepper
   d) a grain of salt
6. Imagine that an amoeba is placed in a solution of salty water. The concentration of salt in the solution is greater than the salt concentration of the amoeba's watery cytoplasm. What will happen, and why? Be sure to use the proper science terms to communicate your understanding.

Focus On THE NATURE OF SCIENCE

A goal of science is to provide knowledge of the natural world. Think back on what you have learned about cells.

1. Why do you think it's important to know how cells work?
2. How has the microscope helped us to improve our understanding of the natural world?
3. What do plants and animals have in common?

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.

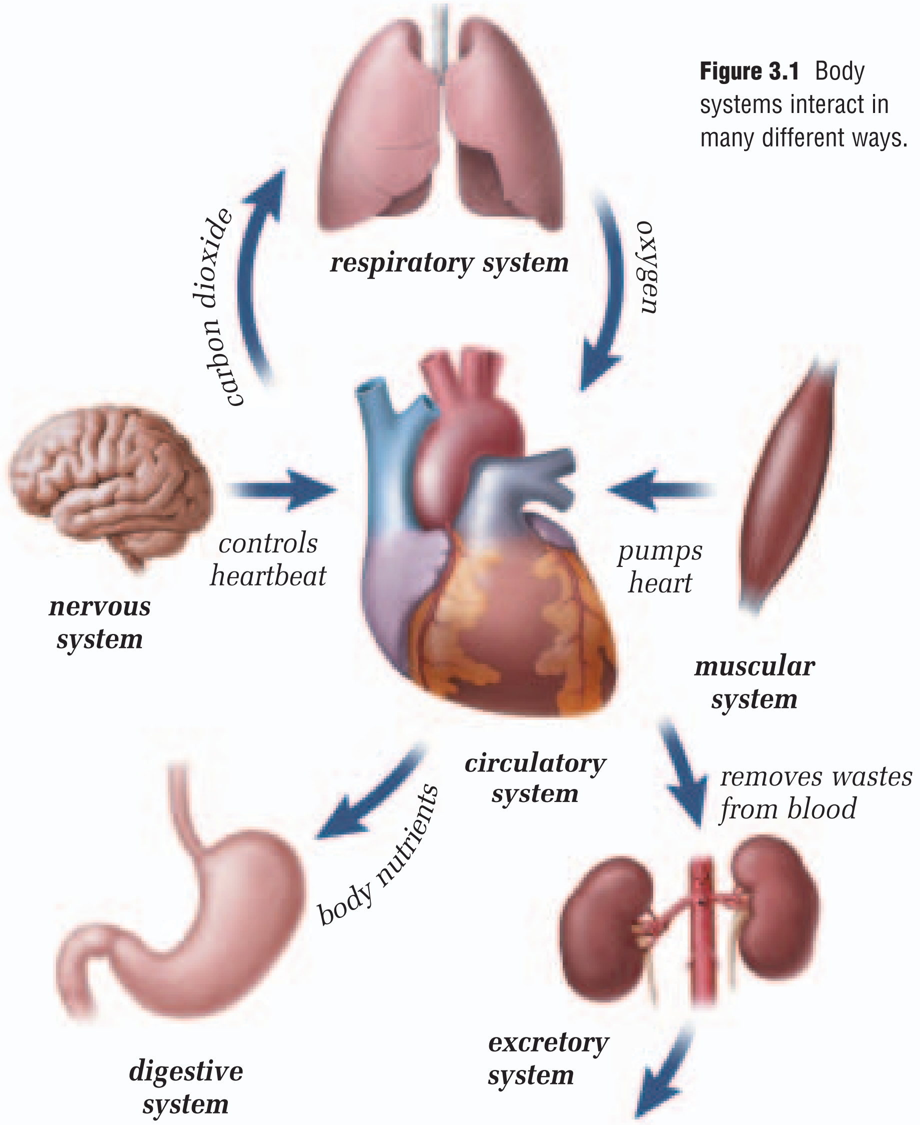


Figure 3.1 Body systems interact in many different ways.

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.

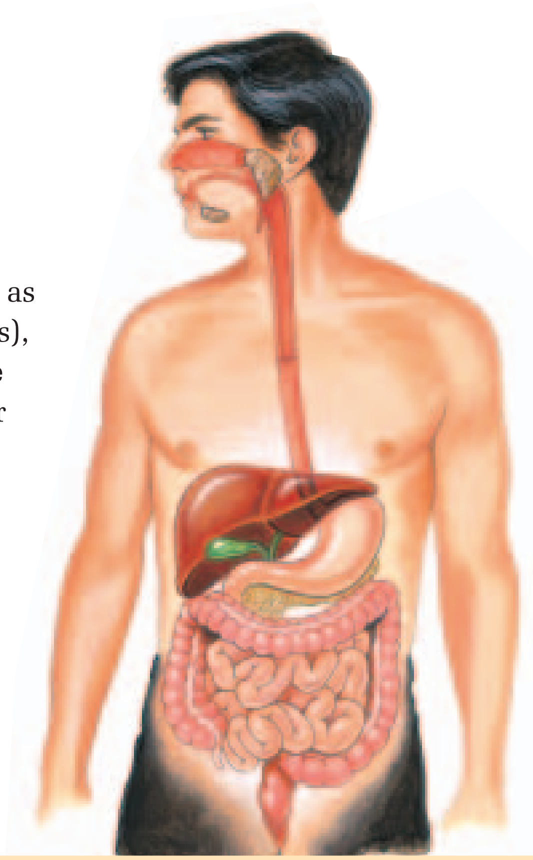


Figure 3.2 Organs of the digestive system

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.

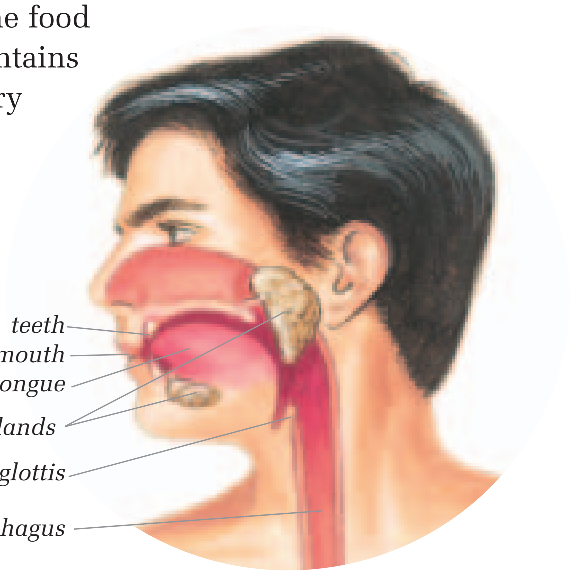


Figure 3.3 Saliva from salivary glands moistens food in the mouth.

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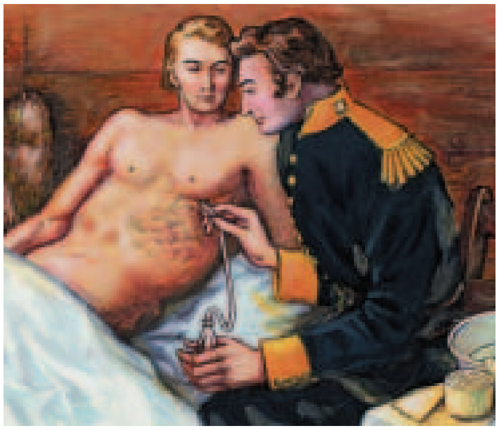
Accident Advances Science!

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.

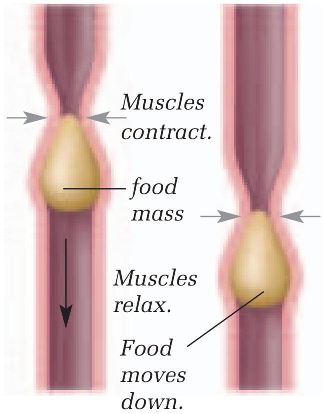


Figure 3.4 Peristalsis in the esophagus

The Stomach

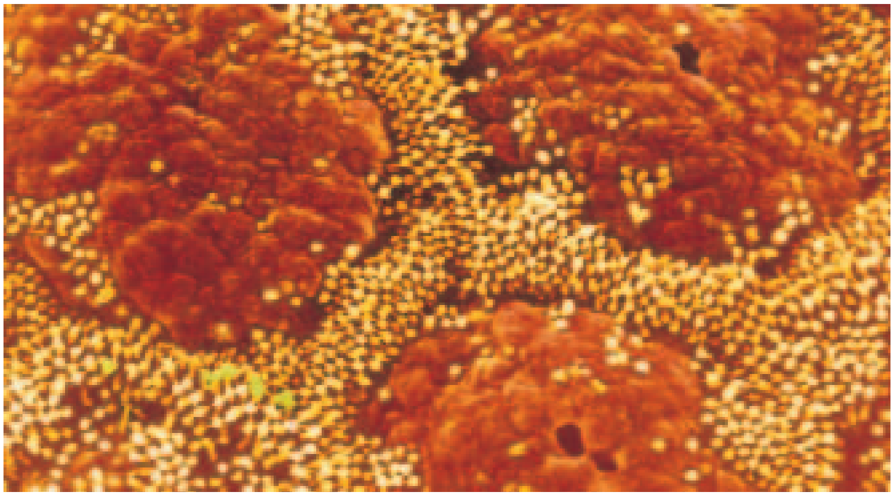


Figure 3.5 The yellow dots are droplets of mucus produced by the stomach wall.

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.

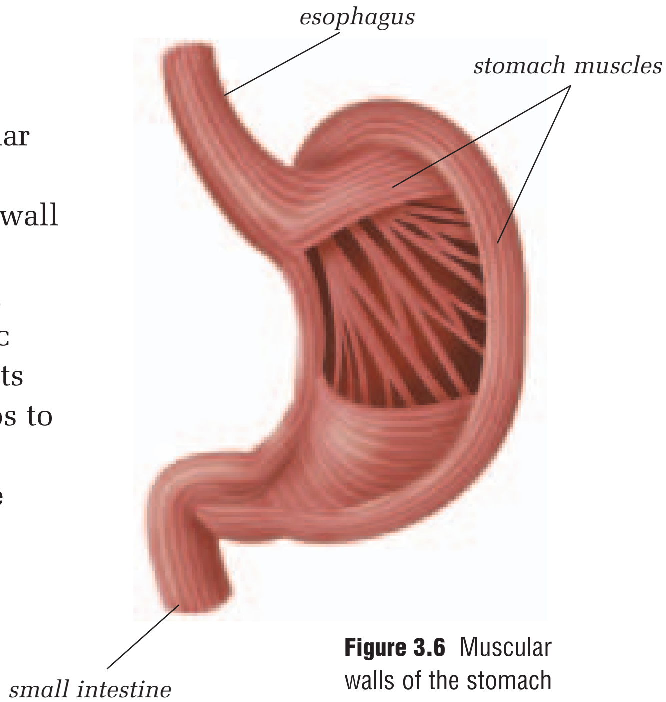


Figure 3.6 Muscular walls of the stomach

The Small Intestine, Pancreas, Liver, and Gall Bladder

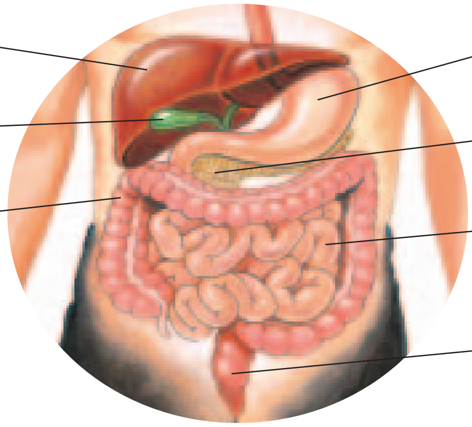


Figure 3.7 The lower part of the digestive system

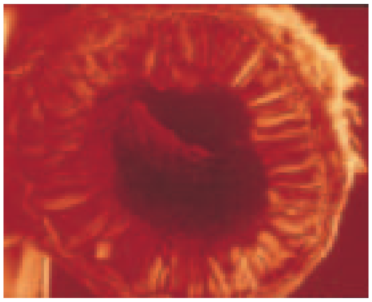


Figure 3.8 A cross-section of the small intestine showing villi on the inner surface

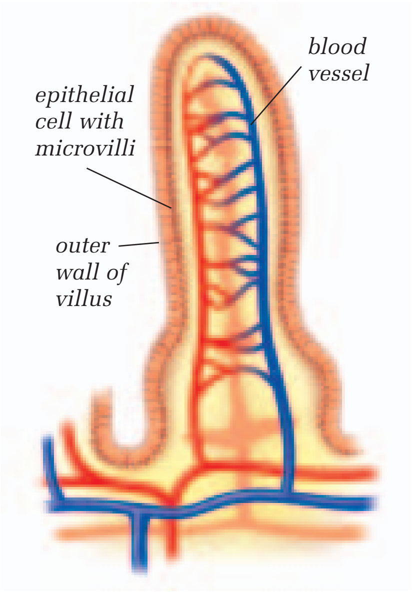


Figure 3.9 The inner structure of a villus

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.

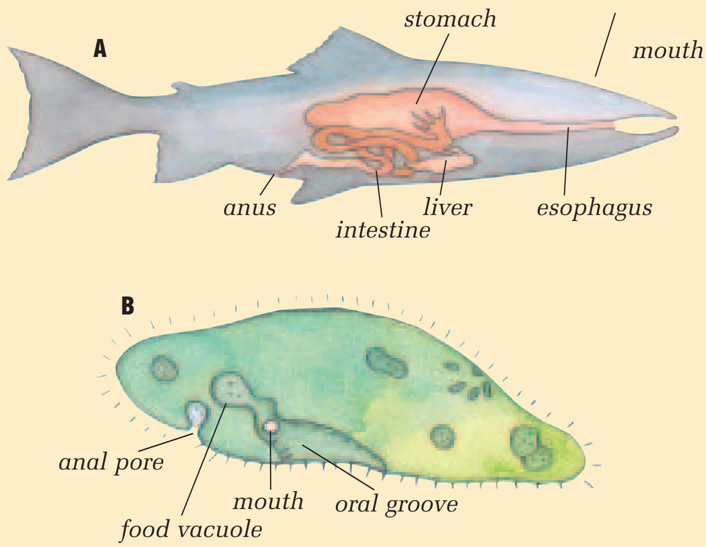


Figure 3.10

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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.

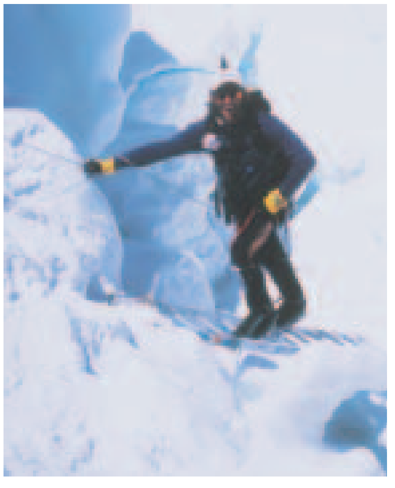
- Add 10 mL of water and a few drops of bromothymol blue to each of 2 test tubes.
- Label the first test tube "A" and the second test tube "B."
- Use a straw to gently blow 5 big breaths into the liquid of test tube A, and note any changes you observe.

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?

*info*BIT

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?

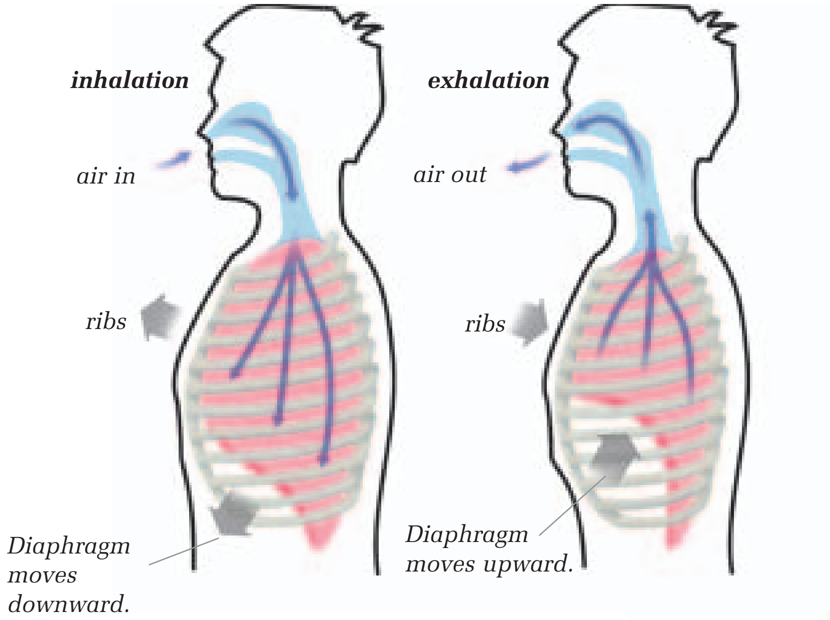


Figure 3.11 Movement of the ribs and diaphragm during breathing

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.

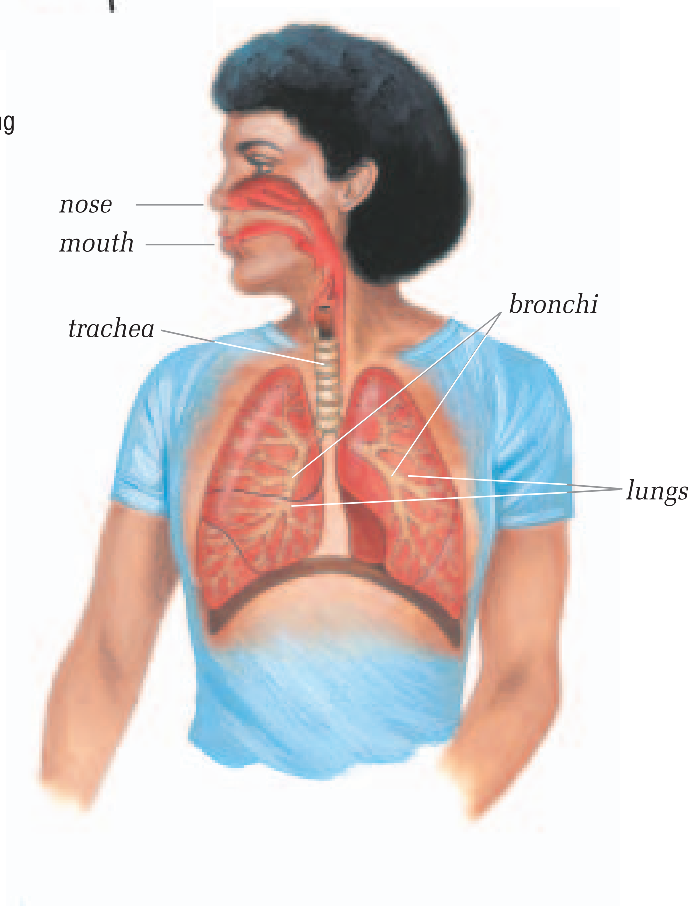


Figure 3.12 The pathway of air into the lungs

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.

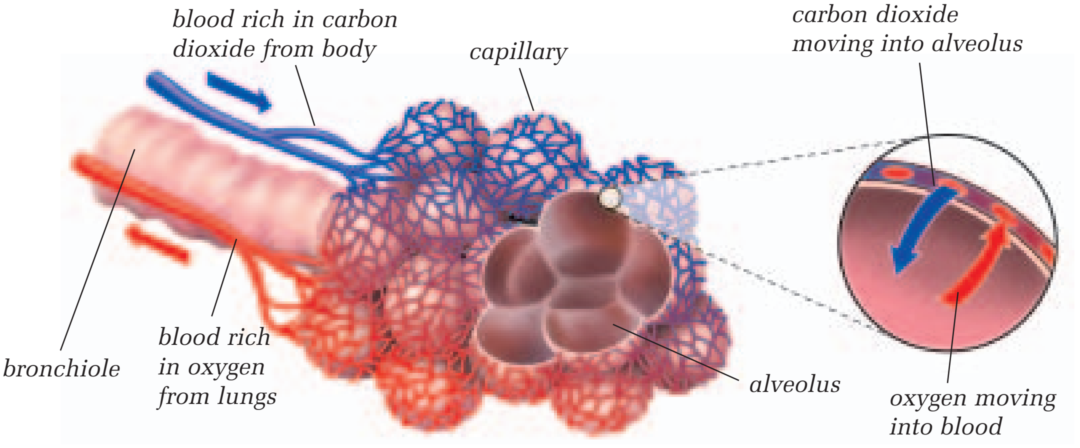


Figure 3.13 Alveoli are hollow sacs surrounded by capillaries. Gas exchange happens in the alveoli.

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?

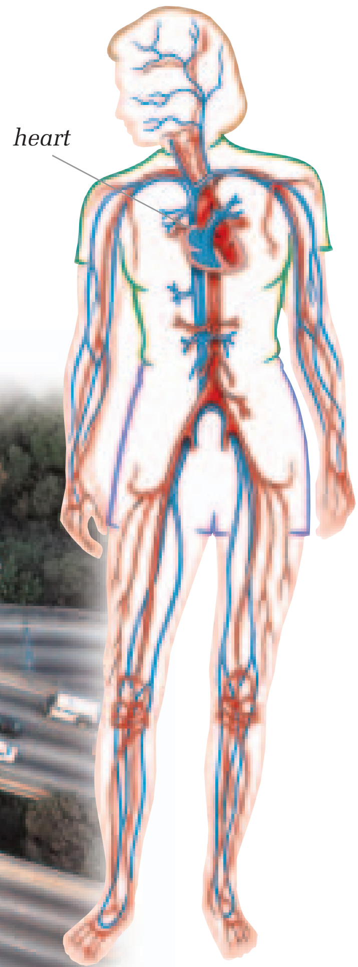


Figure 3.15 Arteries are in red; veins are in blue.

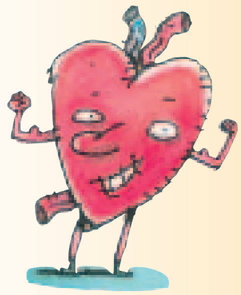
Give it a **TRY** ACTIVITY

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.

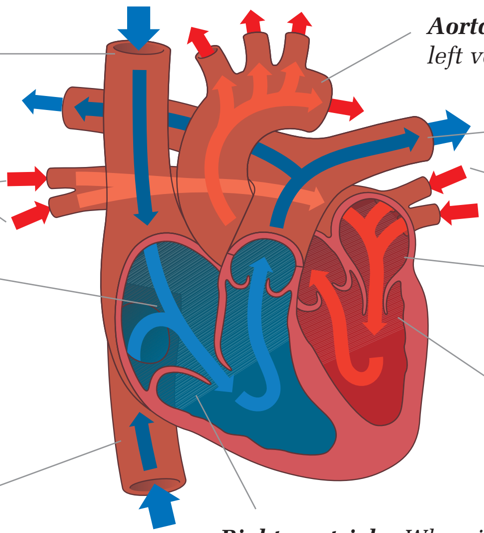


Figure 3.16 Blood flow through the heart. Blue arrows show the path of blood low in oxygen; red arrows show the path of blood high in oxygen.

*info***BIT**

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.

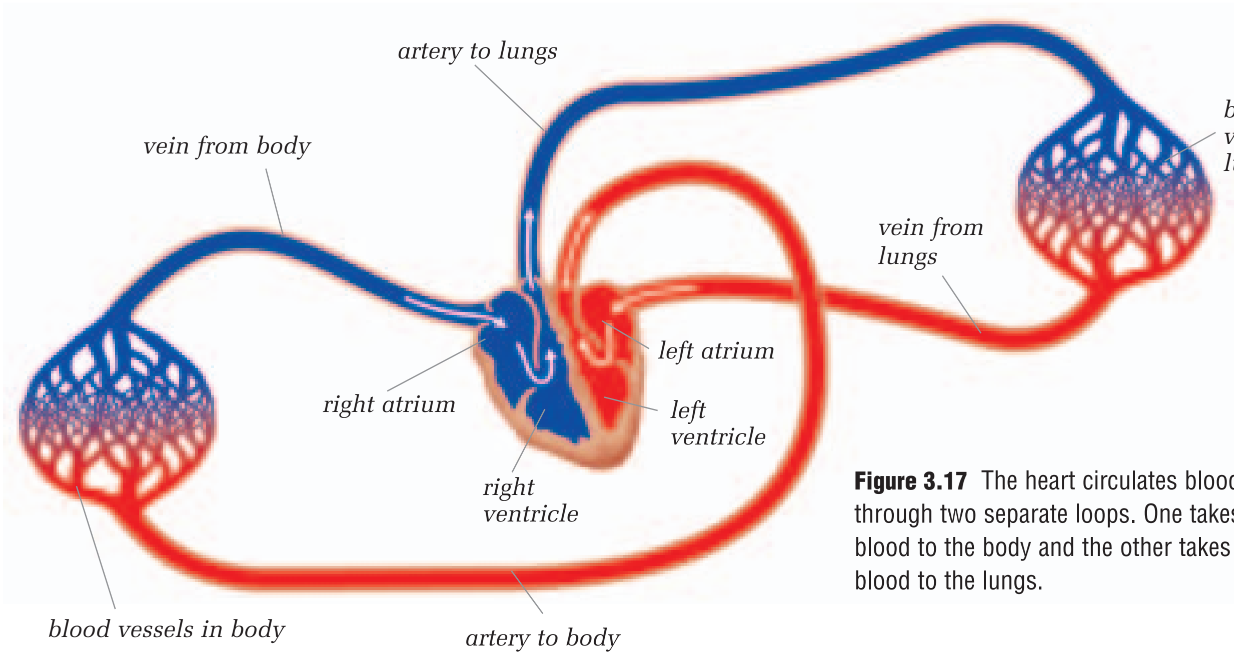


Figure 3.17 The heart circulates blood through two separate loops. One takes blood to the body and the other takes blood to the lungs.

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.

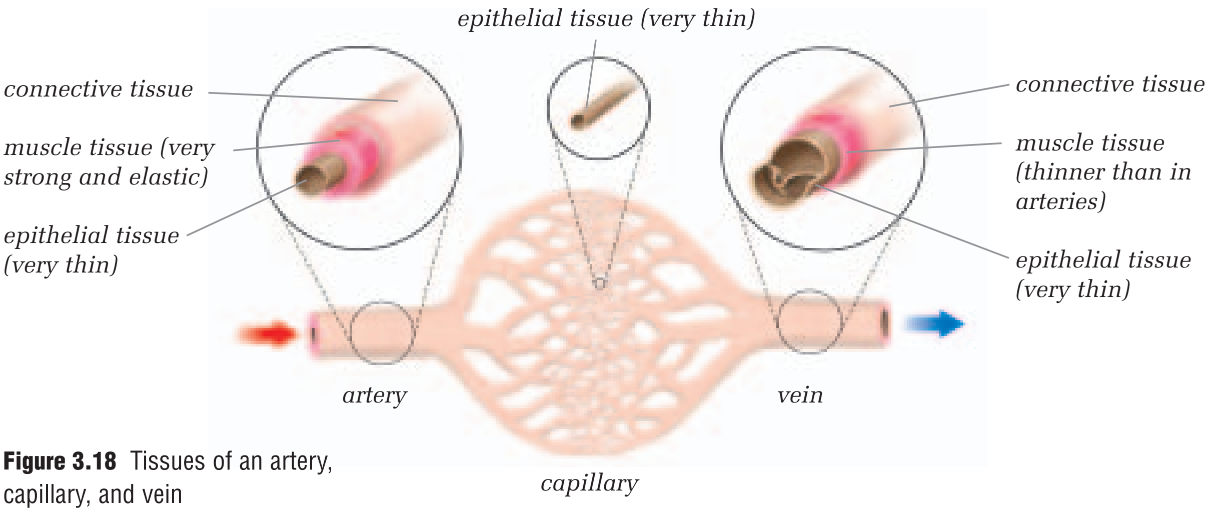


Figure 3.18 Tissues of an artery, capillary, and vein

Inquiry Activity

Changes in Heart Rate

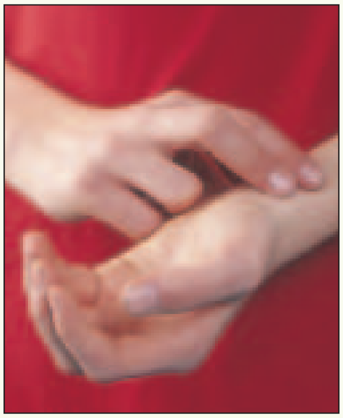


Figure 3.19 Two ways to measure your pulse

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?

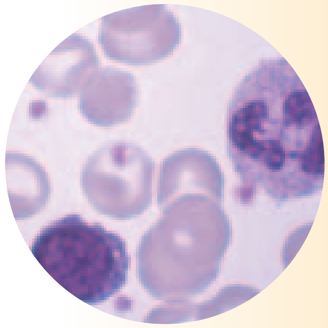


Figure 3.21 Human blood cells

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.

reSEARCH

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.

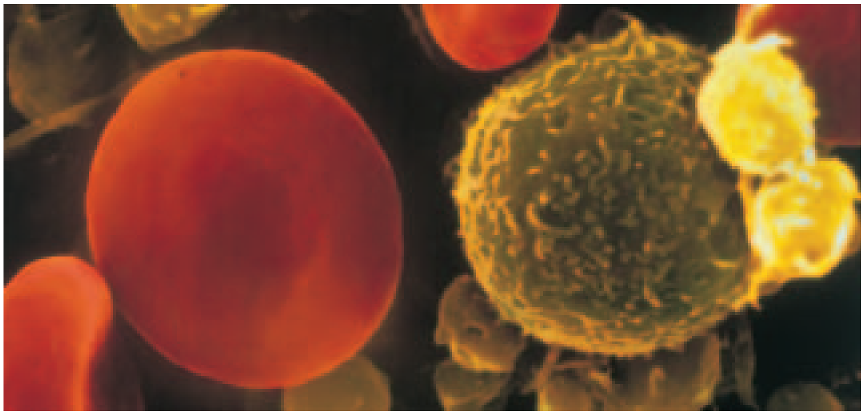


Figure 3.23 Red blood cell (left), white blood cell (right), and two platelets (far right)

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?

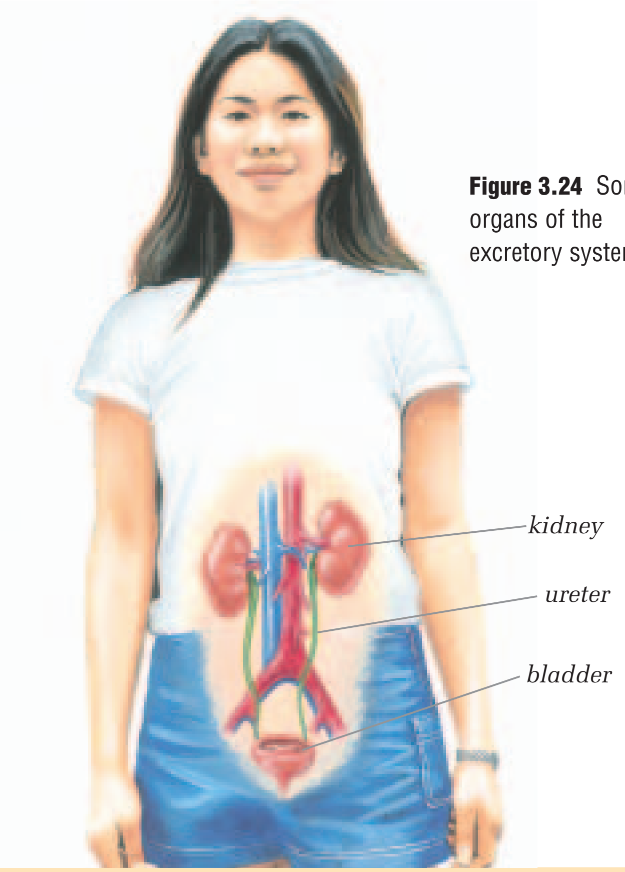


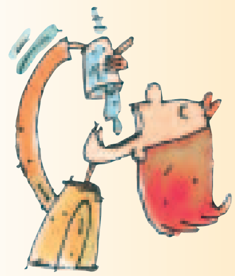
Figure 3.24 Some organs of the excretory system

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.

*info***BIT**

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.

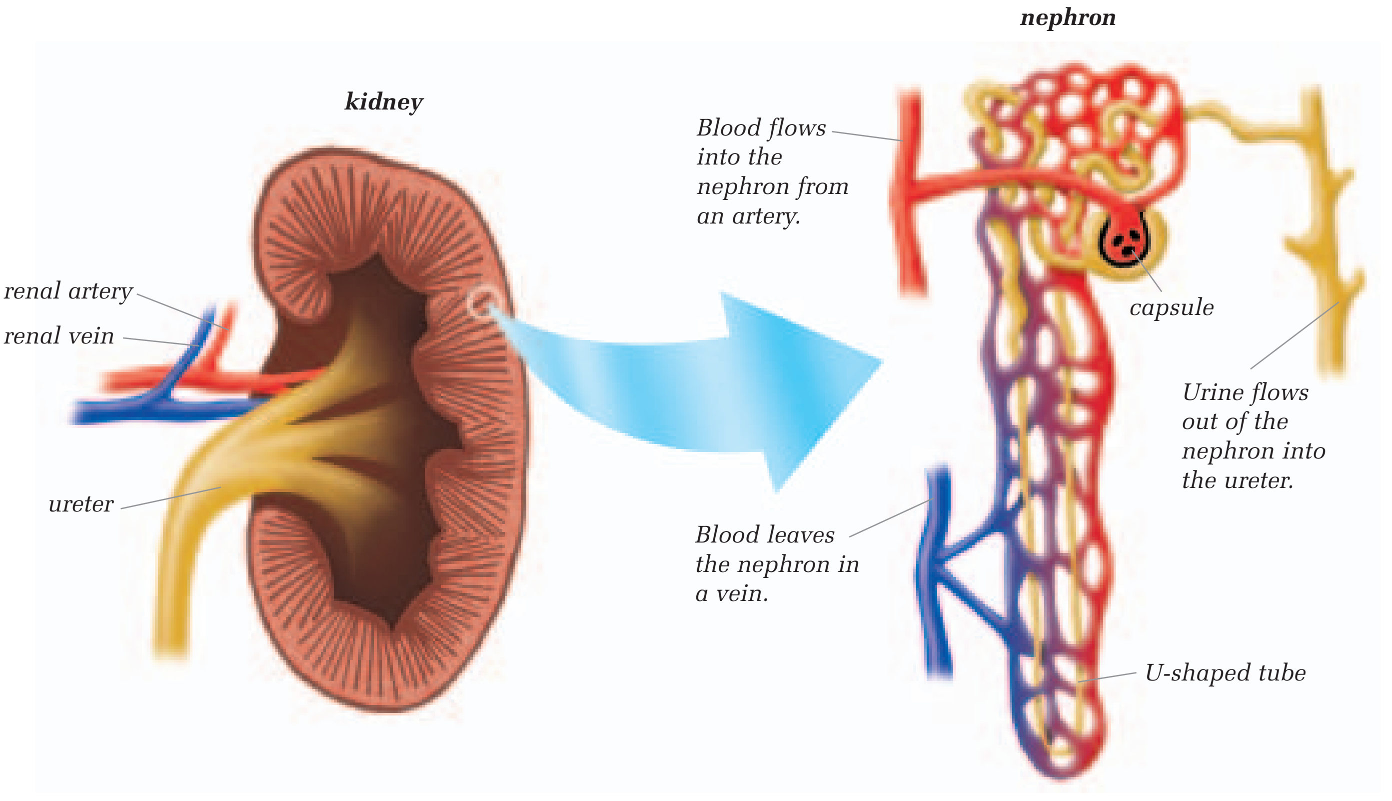


Figure 3.25 The structures of the excretory system

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.

reSEARCH

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.

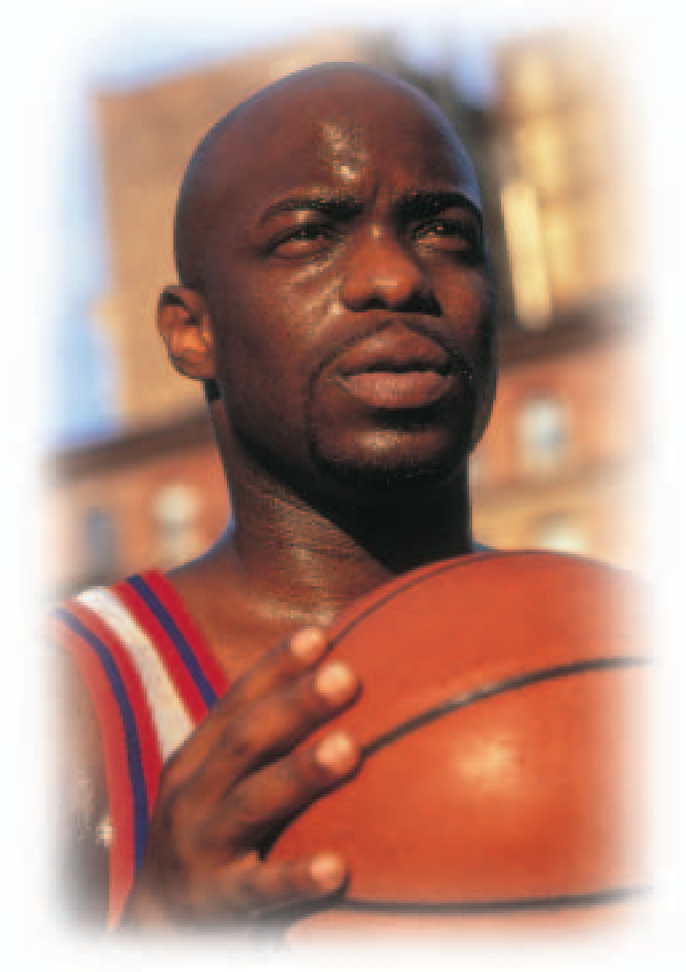


Figure 3.26 This athlete is excreting salt.

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.

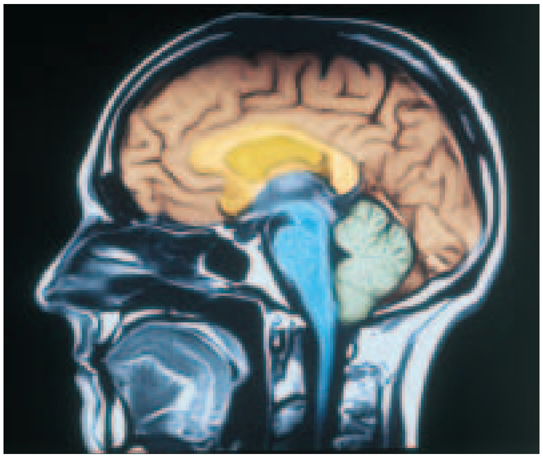


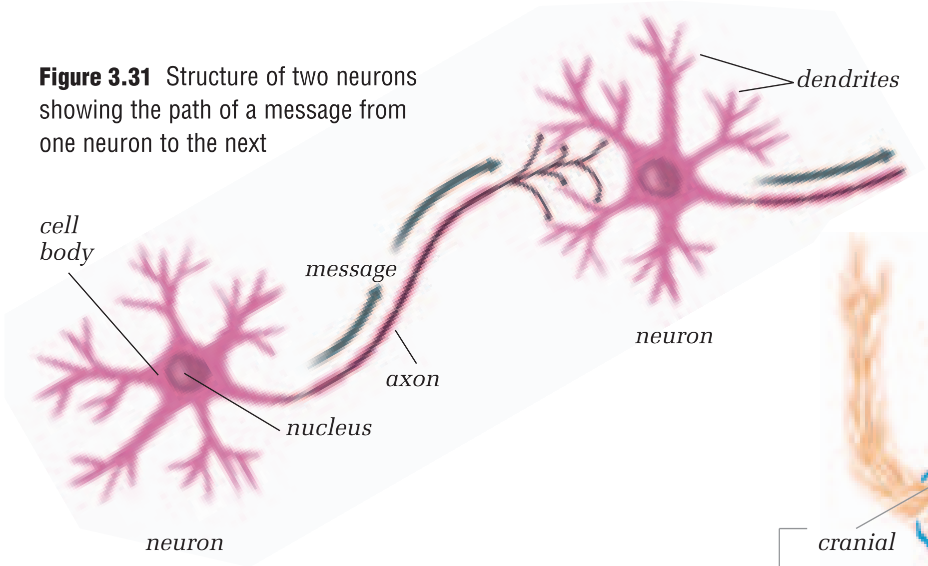
Figure 3.30 MRI scan showing the structures of the human brain

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.

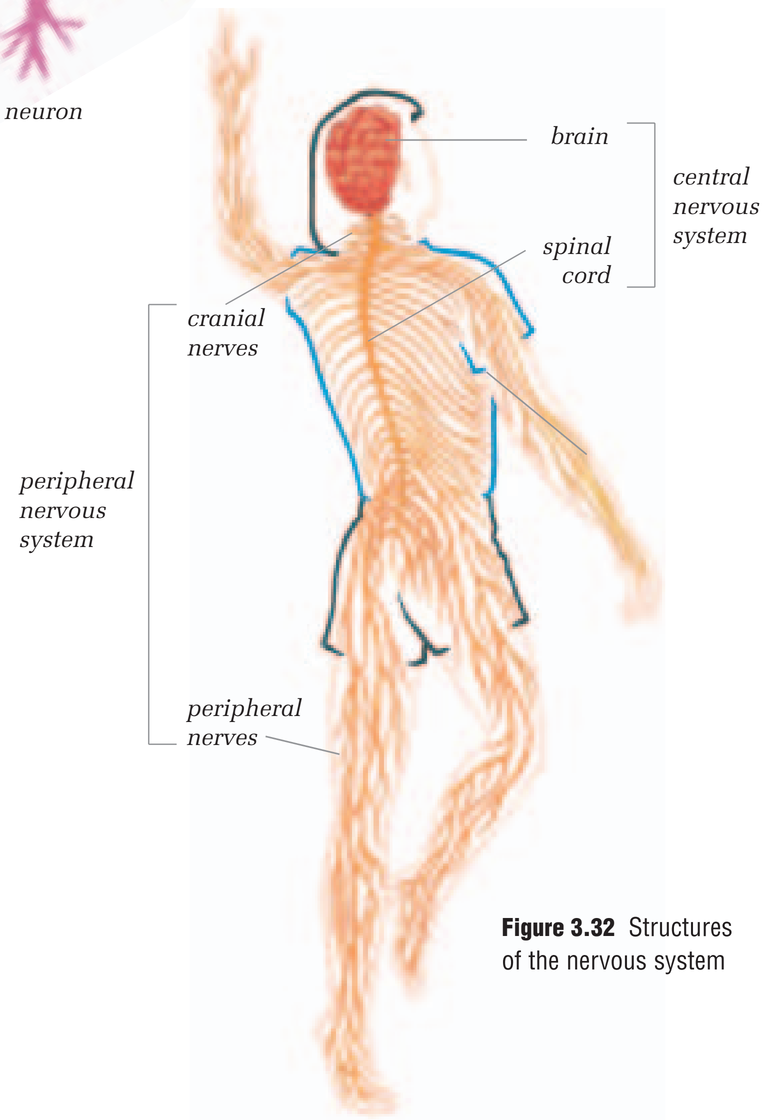


Figure 3.32 Structures of the nervous system

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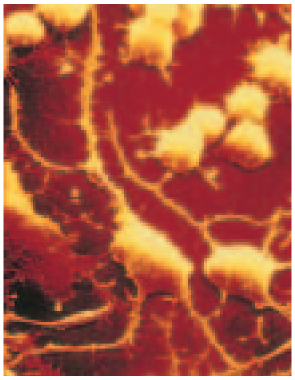
Making Connections
Humans have the most sophisticated brains of any organism. Our brains are composed of about 100 billion neurons. Interestingly, scientists think that we don't learn by growing new neurons, but rather by forming new connections between our existing neurons.



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.

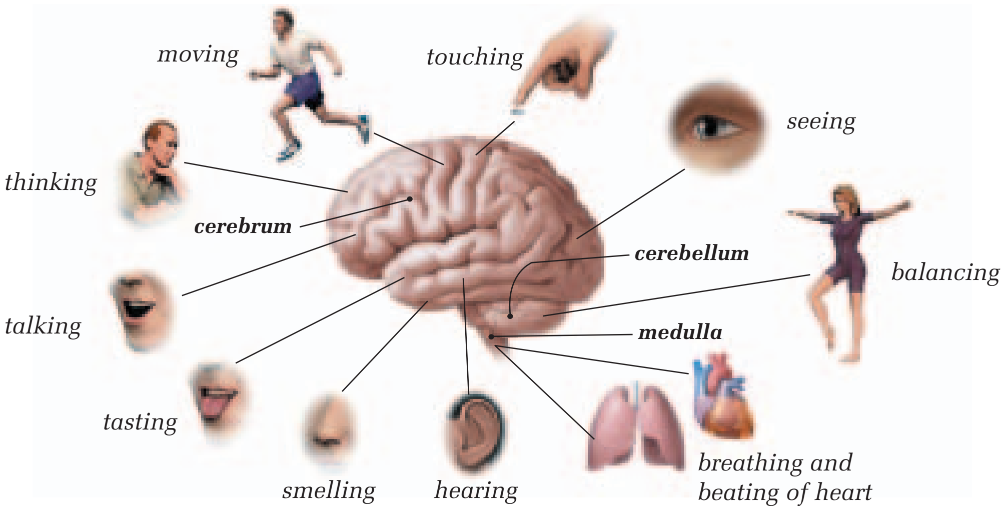


Figure 3.33 Functions of the brain

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.

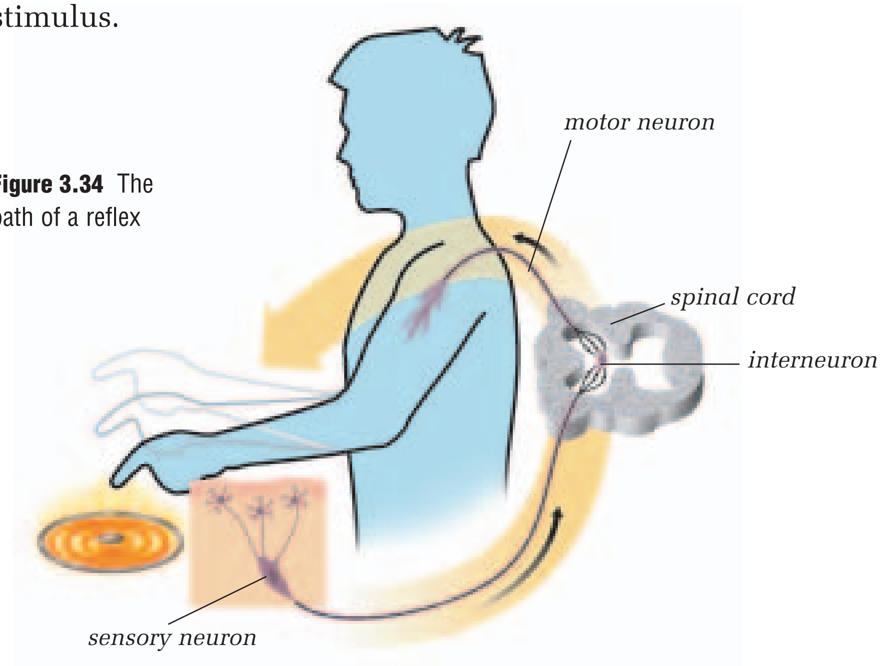


Figure 3.34 The path of a reflex

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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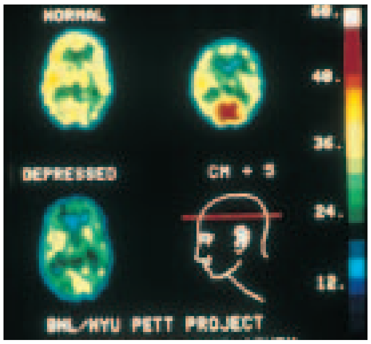
Watching the Brain at Work

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?

The Hypothesis

Create a hypothesis based on the question.

Materials & Equipment

- drafting divider, or 2 straightened paper clips
- ruler

Procedure

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.

Body Area	Distance between Points (mm)
fingertip	

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.

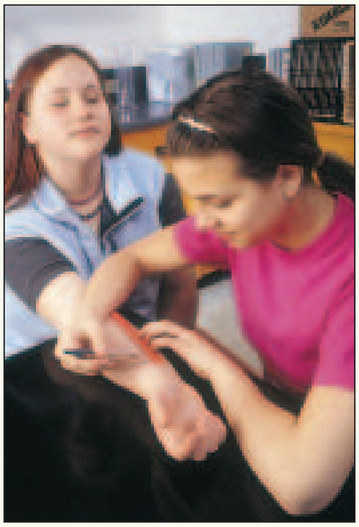


Figure 3.35 Step 3

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?

An Uneven Sense of Touch

Unlike other senses such as vision, hearing, smell, and taste, the sense of touch is not found in one specific place. The sense of touch is found in all areas of your skin, making it the largest sense organ.

When blind people read, they pass their fingertips over tiny bumps that form the braille letters. There is a reason they use their fingertips: they are loaded with touch receptors. But not all parts of the body have the same amount of touch receptors. Think of your body surface. Which areas are the most sensitive?

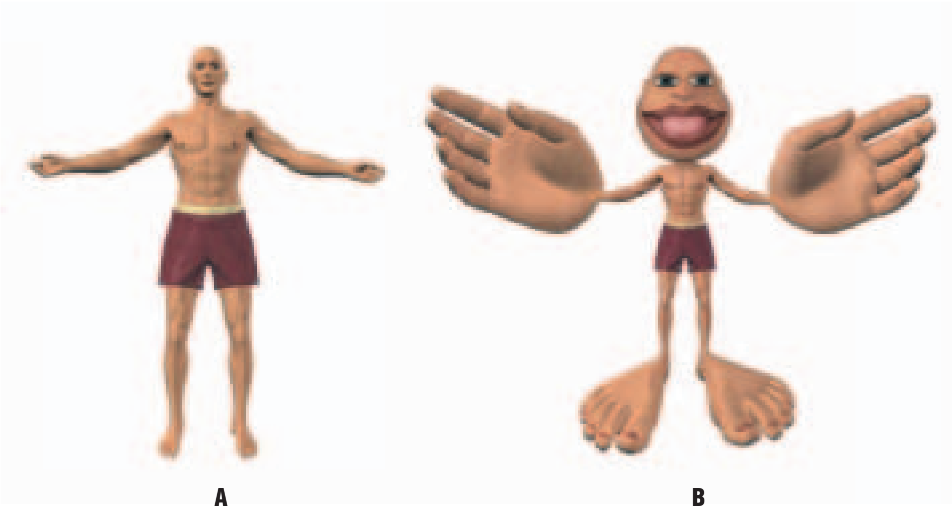


Figure 3.36 Drawing A represents the human body drawn to normal proportions. Drawing B represents the body when each area of the skin is drawn in proportion to its sensitivity to touch.

Check and Reflect

1. Add the nervous system to the systems concept map you started previously.
2. List at least six stimuli you have experienced so far today and which sense was responsible for experiencing each of them.
3. What is the role of the nervous system?
4. Describe the similarities and differences between the central and peripheral nervous systems.
5. Current brain research suggests that the more a particular set of neurons is used in the brain, the more automatic the response becomes. Use this information to explain why practising is so important in learning to play a musical instrument or in playing a sport.
6. How does the structure of a neuron help it to carry out its function?

TRY This at Home | **ACTIVITY**

CELLS IN 3-D!

Actual cells look much more exciting than the two-dimensional representations you see in photos or through a microscope. Using your current understanding of cell structures, design a three-dimensional model of a cell that is made from common household items.

Make a chart or mind map listing all the household items that you would use to make your cell model. Which cell structures did you include? Why did you choose the item to represent each structure?

Careers and Profiles

MEDICAL LAB TECHNOLOGIST

How would you like a job that saves people's lives? A job that helps people get better from sickness? Most people think only doctors and nurses have jobs like this, but there's another important life-saving job—that of a lab technologist.

Figure 3.37 Technologist testing a blood sample

When doctors see a sick patient, they sometimes have an idea of what the problem is from the symptoms, but they are not totally sure. To find out exactly what's wrong, the doctor sends the patient's specimen (such as a blood or urine sample) to a medical laboratory. At the medical laboratory, a lab technologist takes the specimen and tests it. Infections, such as strep throat, and many serious diseases are often hard to identify without a lab technologist's help.

1. How does a medical lab technologist contribute to human well-being?
2. Does being a lab technologist seem like an interesting career? Why or why not?

Section Review

Assess Your Learning

1. Imagine you have just eaten a meal containing the sugar, glucose. Using a concept map or flowchart, plot the path and roles for glucose in the body. You should be able to include almost all of the body systems you have studied in your flowchart.
2. a) Which two body systems work together during the process of gas exchange?
   b) Describe how they work together in this process.
   c) Is this an example of interaction? Why or why not?
3. What is the difference between an artery and a vein?
4. Draw and label the parts of the heart.
5. If you were lost in the desert and you hadn't had any water for a day, how would your body respond?
6. What is the role of skin in your excretory system?
7. What is the difference between the somatic nervous system and the autonomic nervous system?
8. Are there any body systems that a person could live without? Give reasons to explain your answer.

Focus On The Nature of Science

Scientific ideas help organize, interpret, and explain findings. Review the information you have learned in this section.

1. Models are often used in interpreting and explaining observations. What models have you been introduced to that help explain how parts of the body work?
2. Scientific language is precise and uses specific terms. What are some new terms you have encountered in this section?
3. Why do you think these terms are necessary?

4.0 Scientific investigation leads to new knowledge about body systems and new medical applications.

Key Concepts

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

- health and environmental factors

Learning Outcomes

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

- describe examples of research into how the body does or doesn't work
- understand how research has led to improvements in health and nutrition
- describe factors that affect different body systems

Surgeons rely on scientific knowledge about body systems.

Scientific research and modern medicine have improved many aspects of our lives. Humans are now living longer and leading healthier lives than ever before. Even those people who, against the advice of their doctors, continue self-destructive activities—such as smoking cigarettes—can do so knowing what the health effects of this decision may be. Others, who decide to live healthier lifestyles, have the benefit of sound advice on how to maintain good health through proper diet, exercise, and lifestyle choices.

For Web links relating to 4.0, visit **www.pearsoned.ca/scienceinaction**

4.1 Developing a Theory for Disease

Have you ever fallen off a bike and received a wound that needed attention in the hospital? Have you ever cut yourself with a knife so that you needed stitches? Have you or has anyone you know ever seriously broken a bone?

If you answer "yes" to any of these questions, consider yourself lucky. Why? Because you're alive. If you had lived before the mid-1800s, you would probably have died from your injury. In those days, 50% of people who had some kind of punctured wound and went to the hospital died of infection. That means that if you and your friend lived before that time, and you both cut yourselves and went to the hospital for treatment, the chances were that *one of you would be dead within a week!*

The First Vaccine

That's quite a startling fact. Doctors long ago were really quite helpless when it came to treating their patients for some illnesses and injuries.

During the 1600s and 1700s, people in Europe and the rest of the world suffered and died from a disease called **smallpox**. Victims broke out in a rash filled with pus (called pox). They developed chills, high fever, nausea, and muscle aches. Up to 40% of those infected died and many of the survivors were left blind.

Then in the late 1700s, Edward Jenner, an English country doctor, noticed an interesting coincidence. Milkmaids who had had cowpox, a mild and related form of smallpox, rarely got smallpox. He concluded that contracting the milder cowpox made them immune to the more serious smallpox. Jenner began infecting people with cowpox on purpose. These people became immune to smallpox. Jenner had created the world's first **vaccine**.

Figure 4.1 Edward Jenner (1749–1823) discovered how to prevent smallpox. He called his procedure *vaccination*, from the Latin word *vacca*, which means "cow." Here he is pictured vaccinating a small boy.

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The End of Smallpox

The last recorded case of smallpox occurred in Merca, Somalia, in 1977. The World Health Organization has considered the disease eradicated from the planet since 1979.

Watch Out for Germs!

But what caused disease and infection? That's what doctors and scientists couldn't figure out. Jenner and others tried for nearly 90 years to come up with at least one other vaccine that would prevent disease. They failed, because they just didn't understand what they were dealing with.

The French chemist, Louis Pasteur, did. He was the first person to identify living micro-organisms (organisms too small to be seen with the naked eye) as "germs." He suggested and later proved that germs were the cause of most infectious diseases. Using his knowledge, he found a way to prevent and cure many common but deadly diseases.

Louis Pasteur and the Beginning of Modern Medicine

Figure 4.2 Louis Pasteur (1822–1895) was originally a chemist. His first "great" discovery was finding out why wine and beer spoiled. He proved that yeast was actually a micro-organism and not a chemical, which is what people had thought. More importantly, he showed that it was a micro-organism floating in the air that made the wine and beer go bad.

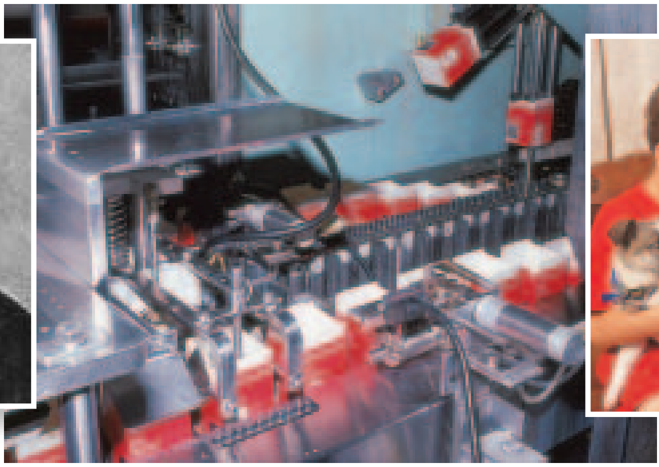

Figure 4.3 Pasteur realized he needed to kill the harmful micro-organisms in wine and beer to keep them from spoiling. His solution was simple but effective. He heated the wine and beer to 60°C, which killed the micro-organisms but didn't change the taste. This process of heating food became known as **pasteurization**. It is still used today for fruit juices, milk, wine, and beer.

Figure 4.4 Pasteur worked tirelessly to produce vaccines and cures for cholera, anthrax, swine erysipelas, and rabies. Now each year, pet owners take their dogs and cats to veterinarians for annual rabies vaccination shots.

Cleaning Up the Germs

Pasteur's discovery of germs led to other discoveries in medicine. For example, Joseph Lister (1827–1912) was an English surgeon. Many of his patients died of infection even though their operations were successful. He thought that these infections were caused by Pasteur's "germs" entering the surgical wounds. So he introduced the practice of cleanliness and sterilization to medical procedures. Before Lister, doctors and nurses never thought about keeping themselves or their patients' wounds and incisions clean.

Inquiry Activity

Tracking Down Disease

Materials & Equipment

- clean test tubes
- labels for test tubes
- eyedroppers
- protective gloves
- standard solution
- phenol red solution

Figure 4.6
- If your test tube turned red, you are disease-free!
- If your test tube turned yellow, you are infected!

Before You Start ...

Long before modern medicine, people realized that certain diseases were spread from person to person. It was important then to find the source and isolate the person or persons until the disease had run its course.

This simulation models how an infectious disease might spread in a group. Your job is to find out which of your classmates is the source of the disease.

The Question

How difficult is it to find the source of a disease?

The Hypothesis

Form a hypothesis based on the question.

Procedure

1. Write your name on a label to place on your test tube.
2. Don't allow the solutions to touch your skin. Remember, you are simulating an infectious disease!
3. Obtain from your teacher 5 mL of a standard solution in a test tube.
4. Label your test tube.
5. Choose a partner. Put one drop of your solution into your partner's test tube. Have your partner add a drop of solution to your test tube. Gently shake the test tube to mix the solution.

Figure 4.5 Step 5

Collecting Data

6. Record the name of your partner in your notebook.
7. Repeat steps 5 and 6 with two other partners.
8. Add 1 drop of phenol red solution to your test tube. Record the colour of your solution.

Analyzing and Interpreting

9. What colour was your test tube? Were you infected or are you disease-free?
10. If you were infected, from whom did you get the disease? How many in the class became infected?
11. As a class, try to track the transmission of the disease. Who was its source?

Forming Conclusions

12. What inferences can you make about the way diseases are spread?

Nutritional Research

Figure 4.7 Early expeditions to find the Northwest Passage took months and sometimes even years.

When early sailors went on voyages of discovery to find the Northwest Passage, the only foods they could take with them were those that would not spoil on the long journey: salt beef, hard bread, dried peas, and cheese. After months at sea, many sailors developed scurvy. They had sores that would not heal, bleeding gums, loose teeth, and an unsteady gait. But in 1747, a British naval surgeon called James Lind successfully treated sailors by feeding them oranges and lemons. It wasn't until very much later that the cause of scurvy was discovered: a lack of vitamin C in the diet.

By studying various diseases such as heart and liver disease, researchers have determined that diet affects the human body. Too much of some foods and too little of others can interfere with the proper functioning of all the body systems. Canada's Food Guide has been developed to show you how much of certain foods you should eat on a regular basis.

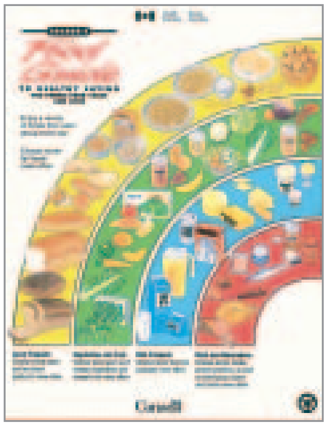

Figure 4.8 Canada's Food Guide

Check and Reflect

1. In your opinion, how important is scientific research in solving problems of human health? Give reasons to justify your answer.
2. How does the smallpox vaccine work?
3. Describe how Joseph Lister contributed to human health.
4. Give an example of how nutritional research on cells, organs, or body systems has brought improvement to human health.

4.2 Factors That Affect the Healthy Function of Body Systems

Figure 4.9 Asthma can be managed with medication.

You are outside skating on a frozen pond when all of a sudden your friend stops. He is doubled over and is having trouble breathing. You skate over and ask him what's wrong, but he is having trouble getting enough air to tell you. What do you do?

Luckily, you know your friend has asthma. You notice that he has dropped his inhaler. You pick up the device and give it to him immediately. After taking the medication, your friend feels weak and tired, but he's all right.

Asthma is a condition where the airways become narrowed temporarily. About half a million Canadian children under the age of 19 have asthma. An asthma attack can be triggered by a variety of environmental factors including colds, allergies, dust, cold air, pets, and pollution.

Give it a TRY ACTIVITY

IMITATING ASTHMA

You've just read about the effects of asthma. Now you will have a chance to know what having asthma feels like. Breathe normally, first through your nose, then through your mouth. Observe what it feels like. Then, put one end of a drinking straw into your mouth and pinch your nose so that you cannot breathe through it. Now try inhaling air through the straw for 10 s.

- How did your breathing pattern change when you breathed through the straw? Did you feel short of breath?

Caution!
Do not perform this activity if you have any medical condition that could be worsened by temporary shortness of breath.

FACTORS THAT AFFECT HUMAN HEALTH

Scientific research has shown that many factors affect the health of your cells and, therefore, your body systems. These factors include:

- diseases or conditions that you have inherited from your family
- sensitivity to environmental conditions, such as smog, or specific substances such as pollen, dust, or dairy products
- how you respond to physical, emotional, and psychological stresses
- how you treat your body in general (for example, the choices you make about diet, exercise, sleep, and whether or not to smoke)

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How Old Are You?
Smokers are more likely to show signs of aging prematurely and get deeper wrinkles than non-smokers.

Decision Making Activity

The Science of Health

The Issue

What is the best way to maintain the health of our body systems?

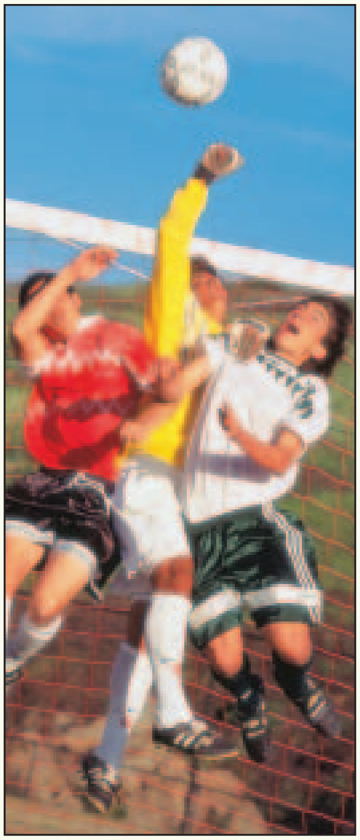


Figure 4.10 Maintaining a healthy body

Background Information

1 To make your recommendations, you need more information. Working in groups of three, have each group member choose one of the following body systems to investigate further:

a) circulatory system

b) digestive system

c) respiratory system

2 Use the guidelines below to focus your investigation. Record the process and results of your research with notes, diagrams, flowcharts, tables, and graphs. (Some of these may not apply in all cases. Use your judgment to choose the best methods for recording your data and information.)

a) List the system's main organs, tissues, and cells. Give examples of key features or specializations of the cells that contribute to the healthy functioning of the system.

b) List other body systems that support this system. Briefly describe how they support it.

c) List at least three examples of scientific developments that have improved our understanding of this system and its cells. Briefly describe each example.

d) Describe at least three ways that we have used our new understanding to improve or safeguard human health.

e) Identify at least two helpful and two harmful substances that alter the way the cells of this system function. Describe the impact of these changes on its tissues and organs. Include possible effects on other body systems and on the body as a whole.

3 Share your discoveries with other members of your group. Consult with other groups as well. You may have gathered information that they can benefit from, and they may have done the same for you.

Support Your Opinion

4 What do you think is the best way to maintain your body's health? Develop a plan and outline your recommendations. For example:

- Describe the kind of exercise you would like to maintain for your body and body systems.
- Write up a balanced diet plan that provides you with the nutrition you need.
- List the things you can do to reduce stress and enjoy each day.

5 Think back to when you worked in your group. What did you do well as a group? What would you improve upon next time?

Factors Affecting the Respiratory System

You have already read that asthma is a disease that affects the proper functioning of the respiratory system. The decision to smoke is an example of a behaviour that can influence how your respiratory system functions.

The Contents of Cigarettes

Because cigarettes have such huge effects on the respiratory system, it's worth taking a closer look at them. There are over 4000 different chemicals in a cigarette. Tar, carbon monoxide, and nicotine are the most destructive. **Tar** is a dark, sticky substance that forms as a cigarette burns. When a smoker inhales, the tar in the smoke settles on the surface of all the organs of the respiratory system. There are small hair-like projections called cilia on the lining of the respiratory tract. Their function is to move mucus from the lungs and nasal passages to the throat. Research has shown that tar makes the cilia clump together and prevents the movement of mucus.

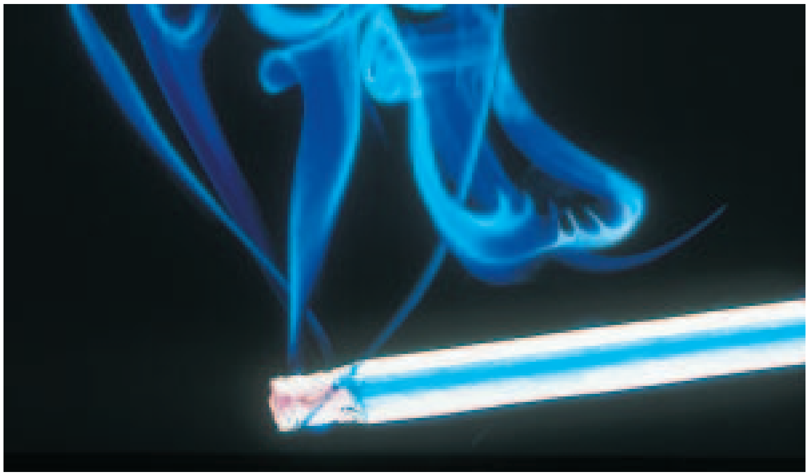


Figure 4.11 Smoke from a cigarette contains over 4000 chemicals.

Carbon monoxide is a colourless, odourless gas that is released when a cigarette burns. In the gas exchange process, carbon monoxide gets absorbed by red blood cells instead of oxygen, so smokers then get less oxygen into their bodies. This causes their hearts to beat faster.

Another chemical found in cigarettes is **nicotine**. Nicotine is a drug that speeds up the heart, and raises the blood pressure. Nicotine is also addictive. Even though tar is more damaging to the body, it's nicotine that keeps smokers smoking.

Smoking-Related Diseases

Smoking can cause a number of serious respiratory diseases including **bronchitis**, **emphysema**, and **lung cancer**. Bronchitis occurs when mucus builds up in the bronchi and causes them to become narrower. People with bronchitis have a hard time breathing. Infections and permanent damage to the lungs can occur if left untreated. Smokers are five to ten times more likely than non-smokers to develop bronchitis.

Figure 4.12 A healthy lung and a damaged lung caused by smoking

Emphysema occurs when the smoke from a cigarette damages lung tissue. The damaged tissue is unable to function properly and breathing becomes difficult. People with emphysema have trouble breathing and are always short of breath. The damage is permanent.

Of the 4000 chemicals in a cigarette, 40 are known to cause cancer. When people develop lung cancer, a tumour or cancerous growth starts to form in the lungs. As the tumour grows, it takes up space in the lungs and makes it harder for the person to breathe. Unfortunately, these tumours are very difficult to locate early on. As the cancer spreads, it becomes much harder to treat. In 1999, 17 400 Canadians died of lung cancer.

Factors Affecting the Circulatory System

Diet can affect the healthy functioning of the circulatory system. One reason why French fries and chocolate taste so good is that they contain lots of fats. (Recall that oils and fats together are called lipids.) When you eat these fatty foods, these fats are turned into cholesterol, a lipid that is found in the blood. The more fat you eat, the more cholesterol enters the bloodstream. Over time, it builds up on the walls of arteries. Look at Figure 4.13. Notice how much narrower the diameter of the artery on the left is.

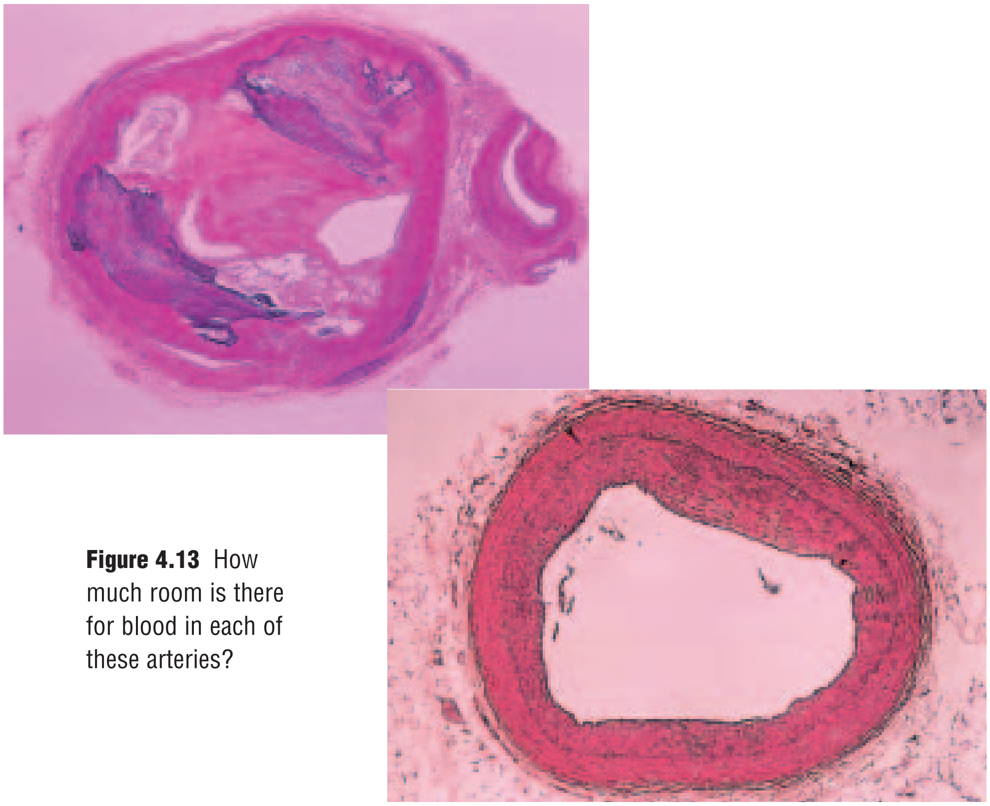


Figure 4.13 How much room is there for blood in each of these arteries?

reSEARCH

Hypertension and Strokes

High blood pressure, or hypertension, is often called "the silent killer." Find out more about hypertension and why it can be so dangerous.

Another factor that can affect the circulatory system is having a stroke. Find out what strokes are and how they can be prevented.

This build-up of cholesterol in the arteries is called **atherosclerosis**. As the arteries become narrower, the heart has to pump harder to move blood through them. If the arteries that feed the heart become blocked, the heart muscle can't get enough oxygen to do its work. This can lead to a heart attack. During a heart attack, heart cells begin to die through lack of oxygen. If people with heart attacks aren't treated immediately, they can die. Sometimes hearts that have been damaged by heart attacks or other diseases can be replaced with heart transplants.

Factors Affecting the Digestive System

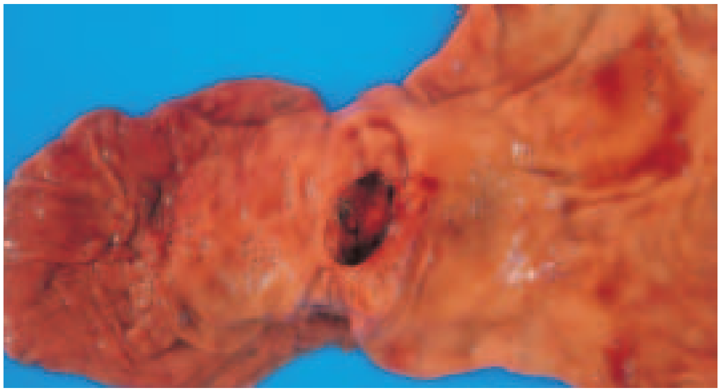


Figure 4.14 Stomach ulcers can be very painful.

There are a variety of factors that can affect the healthy function of the digestive system. A common problem of this system is **ulcers**. They are painful sores of the stomach lining. For a very long time, it was believed stomach ulcers were caused by stress. When a person was under stress, the stomach wouldn't produce enough mucus to protect the lining of the stomach. The gastric juice would then attack the stomach lining causing a painful sore. Now researchers have found that stomach ulcers are caused by a bacteria called *Helicobacter pylori* (or *H. pylori*). Unlike other bacteria you swallow with your food, *H. pylori* is not killed by the strong acidic digestive juices. When this bacteria is present in the stomach, it can break down the mucus layer in the stomach wall. For some reason not yet understood by researchers, not everyone who is infected with *H. pylori* gets a stomach ulcer. Because the cause has been found, the treatment is quite straightforward: taking antibiotics to kill the bacteria.

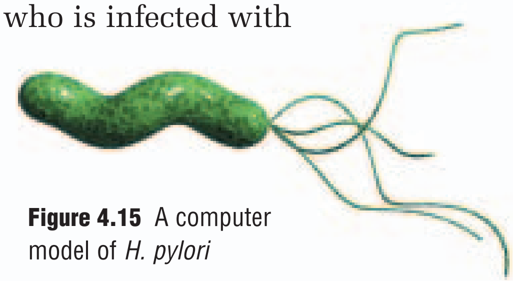
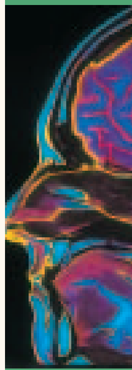


Figure 4.15 A computer model of *H. pylori*

Check and Reflect

1. Give an example of research involving the study of functional or dysfunctional body systems.
2. What are three diseases caused by smoking?
3. What is atherosclerosis?
4. What is a stomach ulcer and what causes it?
5. What is one thing you learned in this subsection you didn't know before?



Assess Your Learning

1. Identify and describe two environmental factors that can affect the health of your cells, organs, or body systems.
2. Name three people whose research led to our early understanding of diseases and how they can be prevented. What did each of those individuals discover?
3. What is pasteurization? Describe a food that has to be pasteurized.
4. Why is it important to know how nutrition affects human health?
5. Describe three chemicals found in cigarettes and explain their effect on the human body.

Focus On THE NATURE OF SCIENCE

Scientific knowledge results from the shared work of many people over time. Scientific knowledge also changes as new evidence is gathered.

1. What scientific knowledge did Jenner discover, and what evidence did he interpret?
2. How did Pasteur's work build on Jenner's discoveries?
3. Why did Lister need to know about Pasteur's work in order for him to make his discoveries?

Do Energy Bars Boost Performance?

The Issue

Out training for that next track-and-field or triathlon event? Do you wish there were a way you could boost your performance to give you that edge over the competition? Why not reach for the latest in athletic food supplements, an energy bar! You've seen the ads. They claim these bars give you a superhuman burst of energy, allowing you to run faster, jump higher, and throw farther. As a result, athletes are gobbling up energy bars at an unprecedented rate. But are the claims true? Can you believe everything you read? Do energy bars really work?

Should you eat energy bars to boost your athletic performance?

Yes, you should.	No, you shouldn't.
Energy bars are loaded with carbohydrates. Your body uses carbohydrates as fuel to do strenuous activities, like running a marathon. If you run out of carbs during an athletic event, your performance drops. Eating more carbs boosts your performance.	**Other foods like rice, pasta, and bread contain carbohydrates.** Recent scientific studies have shown that a bowl of oatmeal provides the same amount of carbohydrate energy as a typical energy bar.
Energy bars have been endorsed by famous athletes. If famous athletes are endorsing these bars, they must boost your performance.	**Energy bars are expensive.** A bowl of oatmeal costs a lot less than an energy bar.
Energy bars are convenient. An energy bar fits neatly into your pocket so that you can take it with you and eat it on the go. You could not do this with a bowl of oatmeal.	**There is no need for energy bars if you exercise for only a short time.** The body can store enough fuel from carbohydrates to give you about two hours of non-stop, strenuous activity.

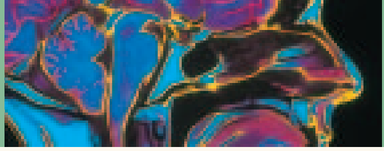
Go Further

Now it's your turn. Look into the following resources to help you form your opinion.

- Look on the Web: Check out energy bars and nutrition on the Internet.
- Ask the Experts: Try to find an expert such as a nutritionist or exercise physiologist. Experts can be found in all sorts of places: your community's health department, universities, hospitals, and government agencies.
- Look It Up in Newspapers and Magazines: Look for articles about energy bars or nutrition.
- Check Out Scientific Studies: Look for scientific studies about exercise and sports nutrition.

In Your Opinion

Write a memo to your coach or local athletic association stating your point of view, and don't forget to support your opinion with facts.



Unit Summary: Cells and Systems

Key Concepts / Section Summaries

1.0

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

1.0 Living things share certain characteristics and have structures to perform functions.

- All living things share certain characteristics. They are made of cells, require energy, grow and develop, respond to their environment, reproduce, and have adaptations for their environment.
- Organisms have structures that allow them to do functions needed to keep them alive. These structures can be very different in different plants and animals. The structures can be slightly different in closely related plants and animals.
- Most animals have organs. Different organs that work together to perform a common function are organized into organ systems.

2.0

- cells
- tissues
- organs
- structure and function

2.0 Cells play a vital role in living things.

- The microscope is an important scientific tool. It allows scientists to see extremely small structures, such as cells.
- The cell is the basic unit of life, and all organisms have at least one cell. Cells have structures in them called organelles, which carry out specific functions. The cells of plants and animals are similar, but plant cells have some organelles that animal cells don't have.
- Organisms can be made of a single cell or many cells. Multicelled organisms have specialized cells.
- Substances move in and out of cells by diffusion and osmosis. Diffusion is the movement of particles from areas of high concentration to areas of low concentration. All cells have a selectively permeable membrane. Diffusion of water through this membrane is called osmosis.
- In multicelled organisms, cells combine to form four tissue types in animals and three tissue types in plants. These tissues combine to form organs.

3.0

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

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

- Organs in organ systems all interact to perform certain functions, such as digestion, circulation of the blood, breathing, getting rid of wastes, and responding to stimuli.
- All these organ systems interact to keep the body functioning normally. All the systems react to internal stimuli in the body. The nervous system monitors external and internal stimuli and responds to them.

4.0

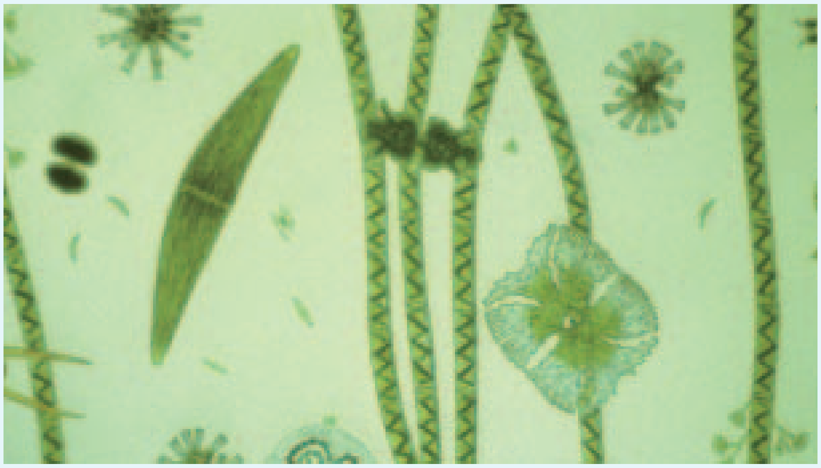
- health and environmental factors

4.0 Scientific investigation leads to new knowledge about body systems and new medical applications.

- Research into diseases such as smallpox has led to an understanding about what causes diseases. These discoveries have led to improvements in health and nutrition.
- Human health is affected by a variety of factors. Any of these factors can lead to the poor health of cells, organs, or organ systems.

PROJECT

WHAT IS NEEDED?



Getting Started

Experiments offer many opportunities for making new discoveries for yourself. In this activity, you will plan and carry out an experiment based on your own "what if" questions. Using a unicellular organism, you will try to determine what its basic needs for survival are. You may wish to refer to Toolbox 2 for further information on planning an experiment.

Your Goal

To determine what ways unicellular organisms meet their basic needs.

What You Need to Know

This activity involves asking your own questions about unicellular organisms, planning your own experiments to investigate one of these questions, and drawing your own conclusions from them.

Use the question, "In what ways do unicellular organisms meet their basic needs?" to help you brainstorm all the questions you have about the lives and behaviours of unicellular organisms. Then, review your questions to see which one intrigues you enough to investigate further. Do you see opportunities for experiment that could help you answer your questions?

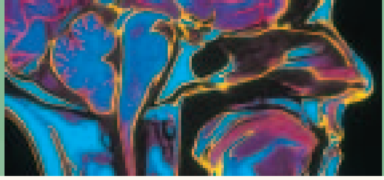
Steps to Success

1. Select a question and write a hypothesis to answer it. Then, plan an experiment to test your hypothesis.
2. Make sure your experiment is a fair test of your hypothesis. How will you know?
3. Decide what equipment and materials you will need. Ask your teacher what live unicellular organisms are available.
4. Write up the procedure you'll follow to perform your experiment. Obtain your teacher's approval, and carry it out.
5. Decide how you will record your results in a clear, meaningful manner. Examples include diagrams, data tables, graphs, and flowcharts. The method or methods you use will depend on the kind of experiment you design.
6. Explain how you decided on the experiment you planned. Which variable did you consider changing? Did you have a control?
7. What do the data you collect mean? Are there other ways to interpret them?

Caution!
Be careful when handling microscopic organisms. Wash your hands thoroughly when you've finished this activity.

How Did It Go?

Based on the experiment you planned and carried out, write a summary statement that answers a question that you have asked. Remember to use your data and observations to support your answer.



Unit Review: Cells and Systems

Unit Vocabulary

1. Create a mind map that illustrates your understanding of the following terms.

   cell
   diffusion
   organ
   multicellular
   organelle
   osmosis
   tissue
   selectively permeable
   system
   unicellular

2. Explain the following terms: enzyme, peristalsis, arteries, atrium, capillaries, digestion, nervous system

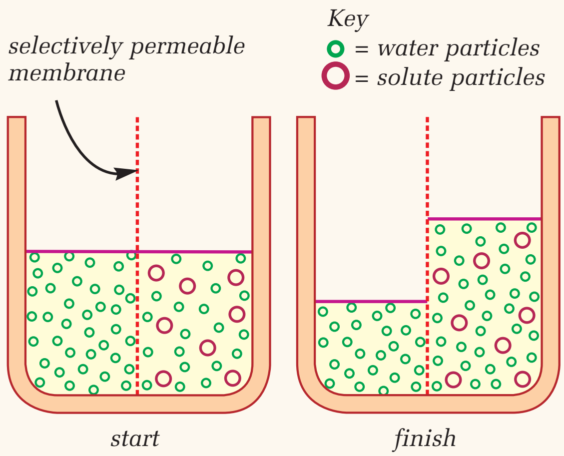
Check Your Knowledge

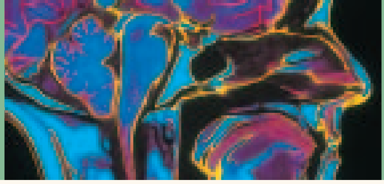
1.0

3. What is an organism?
4. Are your fingernails a living thing? Why or why not?
5. Name three different structures animals use for the same function.
6. What is an organ? Name six different organs.

2.0

7. a) Which of these terms do scientists use to describe the most basic unit of all living things: *tissues*, *organs*, *cells*, *body systems*?
   b) Explain how the other three terms are related to the one you chose in a).
8. a) Draw a labelled diagram comparing a typical plant cell and a typical animal cell.
   b) Explain any differences between the cells you drew.
9. Different kinds of specialized cells have different shapes. They often have different organelles, or different numbers of them. For example, the cells that make up muscles have many mitochondria, while the cells that make up skin have very few. Infer a reason why.
10. a) In the illustration below, which particles can move through the selectively permeable membrane? Explain why.
    b) Is this an example of diffusion or osmosis? How do you know?
    c) Look closely at this illustration. What do you notice? Why do you think this happened?





3.0

11. a) What do these terms have in common, and how are they different: *artery*, *capillary*, *vein*?

b) The layer of muscle tissue that surrounds your arteries is much thicker than the layer that surrounds your veins. How does this difference in structure suit the function of arteries and veins?

12. Agree or disagree with this statement, and give two examples to support your decision: *The organs of humans interact*.

13. Infer from the following information which person could have emphysema.

a) Marta is breathing (inhaling and exhaling) 12 times a minute. She is filling her air sacs with 4200 mL of oxygen-rich air each minute.

b) Douglas is breathing 20 times a minute. He is filling his air sacs with 3000 mL of oxygen-rich air each minute.

c) Cathy is breathing 30 times a minute. She is filling her air sacs with 1500 mL of oxygen-rich air each minute.

14. How does the structure of a villus help the small intestine absorb nutrients?

15. You are playing soccer and you are running to kick the ball. What parts of the brain are active, and what are they doing?

4.0

16. What was Pasteur's contribution to our understanding of disease?

17. What is scurvy?

18. List some of the factors that can affect your health.

19. What is tar, and how does it affect the health of your cells?

Connect Your Understanding

20. Explain how the four sections that you have explored are related to one another. Your explanation can be in the form of a mind map, an illustration, or a written summary.

21. When scientists think about the possibility of life on another planet, they want to know if that planet has water. In fact, scientists find it hard to imagine life without water. Why might that be?

22. Explain the similarities and differences between a cell organelle and an organ system.

23. Meat and fish are sometimes preserved from spoiling by salting them or by placing them in a salty solution. What effect do you think the salt has on these foods?

24. Choose three types of cells in your body. For each, describe how it contributes to your health.

25. Your friend has a bad cold, and has been coughing and sneezing around you. Several days later, you develop a cold. Explain how this could have happened.

26. Identify at least two things that you can do to improve your health. Describe the impact and effect of each of your choices.

27. Based on what you have learned, give two examples of ways that research has improved human health.

28. Give two examples of substances that change the way cells function. Describe their effect, and the consequences of their effect.

Practise Your Skills

29. Your classmate is viewing a specimen using high power and is about to refocus using the coarse adjustment knob. What would you recommend your classmate do and why?

30. A neighbour has brought in a water sample from a nearby pond. He would like you to check the sample for any microscopic organisms. Describe how you would prepare the sample.

Self Assessment

31. Describe one idea that you learned in this unit you would like to explore further.

32. When you did activities in groups, what did your group do well? What did your group need to improve?

33. During this unit, what did you learn about the role, contributions, and limits of science and technology?

34. Do you think that the choices you make about your lifestyle affect the environment?

Focus On The Nature of Science

In this unit, you have investigated the nature of science in relation to cells and systems. Consider the following questions.

35. Turn back to the Focus on the Nature of Science on page 83 of this unit. Use a creative way to demonstrate your understanding of one of the questions.

36. Describe the process of doing a scientific investigation. What are the steps involved?

37. Do you think we know everything there is to know about cells and organ systems? Explain your answer.