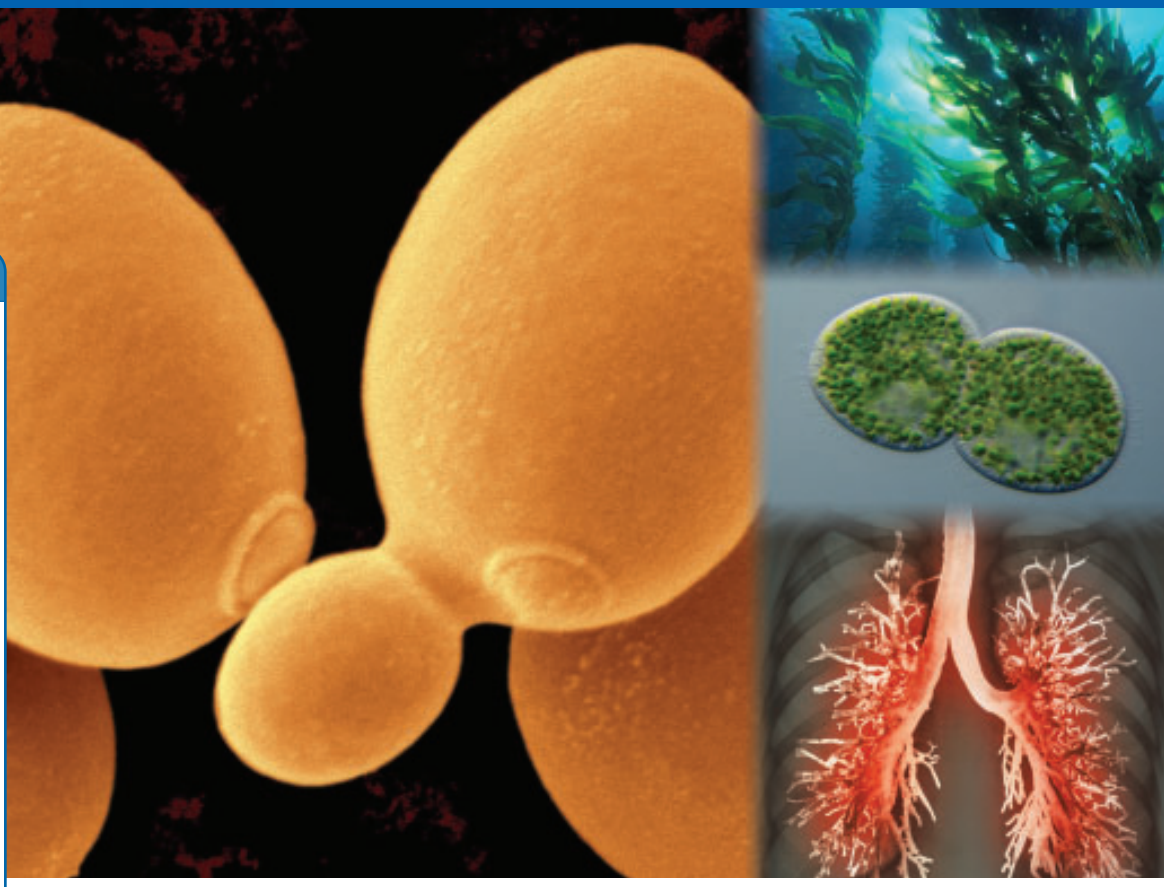
CHAPTER

2

Cells and Cell Systems



KEY IDEAS

- Unicellular organisms perform the same basic functions as multicellular organisms.
- Cells are specialized to carry out specific functions.
- Cells are generally more efficient when they work together to perform a specific function.
- Cells in the human body are organized into tissues.
- Groups of tissues are organized into organs. Groups of organs are referred to as organ systems.
- Some diseases are caused when cells are invaded by microscopic living things.
- Your health depends on how well your cell systems work together.

Some organisms, such as yeast, consist of a single cell and cannot be seen alone without the aid of a microscope. How do these organisms carry out the processes that characterize them as living things when other organisms require trillions of cells to carry out the same processes? If all those processes can be done in one cell, is it better to be a unicellular organism?

Do the trillions of cells in your body all look alike and have the same function? You will probably agree that they all do not look alike, so how are they different?

Would you notice if a few of your cells stopped working properly? Probably not. What if half of one type of cells in your body malfunctioned? What can cause cells to malfunction?

In this chapter, you will study how cells in multicellular organisms become specialized and organized into tissues, organs, and systems to carry out essential life processes.

LEARNING TIP

As you read these paragraphs, try to answer the questions using what you already know.

Cells and Cell Systems 2.1

Have you ever been part of a team? Successful teams are not always the ones with the most gifted players. Success depends on how well the players cooperate.

A multicellular organism like you can be compared to a team—all of your cells must work together. A cell that works on its own faster or more efficiently than other cells is not necessarily a better cell. It can even be life-threatening. For example, a cell that uses nutrients or reproduces faster than other cells could be a cancer cell.

Cell Organization

A group of cells that are all similar in shape and function is called a **tissue**. For example, skin that covers the outside surfaces of your body is epithelial tissue. Epithelial tissue also covers the inside surfaces of your body and provides support and protection for your body structures.

Tissues are often organized into larger structures called **organs.** Many organs are composed of several different types of tissues. Each organ has at least one function. For example, the heart is an organ that pumps blood through your body. It is made of several tissues (**Figure 1**). Each tissue is made of cells that are similar. For example, epithelial cells tend to be broad and flat. Cells from different tissues look different. Cells in nerve tissue do not look like cells in muscle tissue.

Organ systems are groups of organs that have related functions (**Figure 2**). The circulatory system includes the heart, arteries that carry blood from the heart to the tissues, capillaries where nutrients and waste are exchanged, and veins that carry blood and waste from the tissues back to the heart. Nerve tissue, blood, epithelial tissue, connective tissue, and muscle tissue are all found in the circulatory system. Many of the other organ systems in the body are described in **Table 1**.

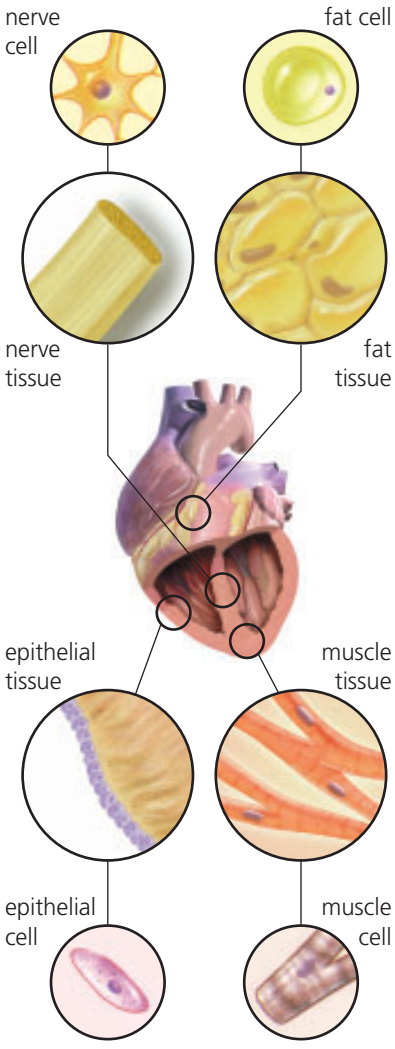


Figure 1
Your heart is an organ. It is made of several different kinds of tissue.

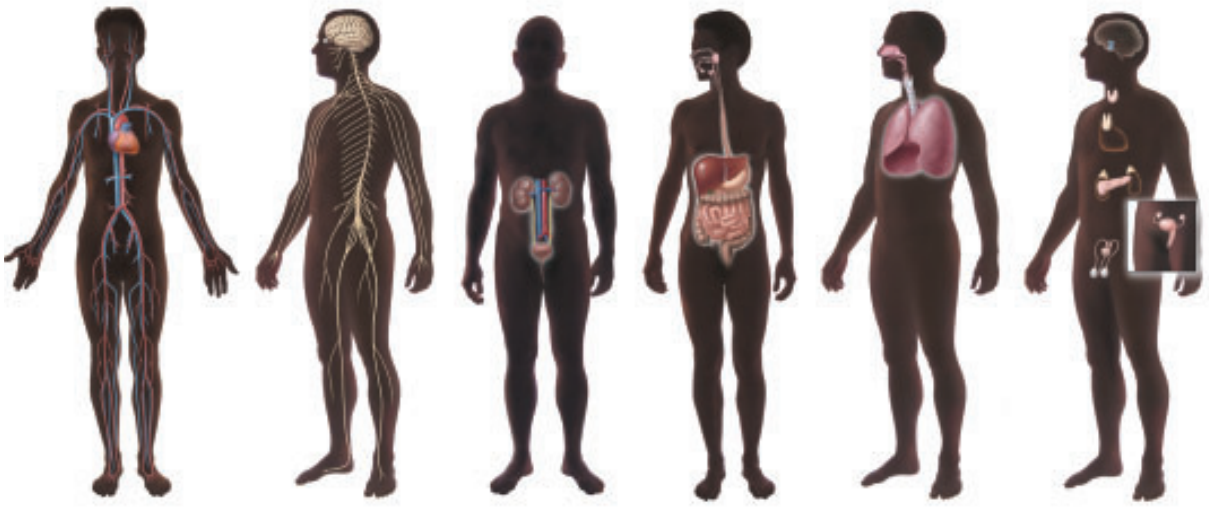


Figure 2
The organs in the bodies of all large organisms, including humans, are organized into organ systems.

Table 1 Levels of Cell Organization in the Human Body

Organ system	circulatory system	nervous system	excretory system	digestive system	respiratory system	endocrine system
Major organs in the system	heart, arteries, capillaries, veins	brain, spinal cord, eyes, ears, nerves to and from body parts	kidneys, bladder, ureters, urethra	esophagus, stomach, intestines, liver	lungs, trachea, blood vessels	pancreas, adrenal glands, pituitary gland
Major tissues in the system	epithelial, nerve, connective, muscle, blood	epithelial, nerve, connective	epithelial, nerve, connective, muscle	epithelial, nerve, connective, muscle	epithelial, nerve, connective, muscle	epithelial, nerve, connective
Major functions	transportation of nutrients, dissolved gases, and waste to and from body cells	response to environment and control of body activities	removal of waste	breakdown of food into molecules small enough to pass into cells	exchange of oxygen and carbon dioxide	coordination and regulation of body activities

LEARNING TIP

Tables play an important role in reader comprehension. As you study **Table 1**, ask yourself, "Why is this included? What am I supposed to notice and remember?"

2.1 CHECK YOUR UNDERSTANDING

1. Define *tissue*, *organ*, and *organ system*. Give an example of each.
2. Organize the following structures from smallest to largest and give an example of each: organ system, tissue, cell, organ, and molecule.
3. Make a table to compare the levels of cell organization with the levels in an organization that you are familiar with, such as a sports team.

Unicellular Organisms 2.2

You are a multicellular organism. You have many specialized cells that work together to carry out all of life's functions. Many living things are composed of just one cell, however. These unicellular organisms—called **micro-organisms** or microbes because they are only visible under a microscope—must also carry out all of life's functions. Thus, a single cell is responsible for feeding, digesting, excreting, and reproducing.

The Importance of Micro-organisms

LEARNING TIP

Headings and subheadings act as guidelines for reading. Check for understanding as you read. Turn each heading into a question and answer it.

Most people become aware of micro-organisms when they get sick (**Figure 1(a)**). However, it is unfair to think of micro-organisms just in terms of diseases. Although many of them cause diseases, most are harmless and many are even helpful (**Figure 1(b)**). Dairy products such as buttermilk, cottage cheese, and yogurt are produced by the action of micro-organisms.

(a) Each droplet that is sprayed into the air during a sneeze could contain thousands of micro-organisms.

(b) Micro-organisms decompose dead plants and animals into chemical building blocks, which can be recycled by plants into food for humans and other animals.

Figure 1
Some micro-organisms make us sick, but others are necessary for us to survive.

DID YOU KNOW ?

Bacteria Everywhere

It is estimated that there are more than 100 trillion bacteria inside and on the average human body. There are over 500 different types of bacteria in your mouth. Most of these are harmless but one species secretes plaque that builds up on your teeth.

Bacteria

Bacteria (singular is *bacterium*) are among the most primitive and also the most plentiful organisms on Earth (**Figure 2**). Bacteria are said to be very successful because they have survived and changed little over several billion years. Some, like plants, can make their own food. Others are parasites. (Parasites can live only by invading the body of an animal or a plant.) Still others can live with little or no oxygen. There are bacteria in every environment on Earth—even in hot springs.

Bacteria, which are prokaryotic cells, are different from animal and plant cells in that they have no nucleus, no mitochondria, and no ribosomes.

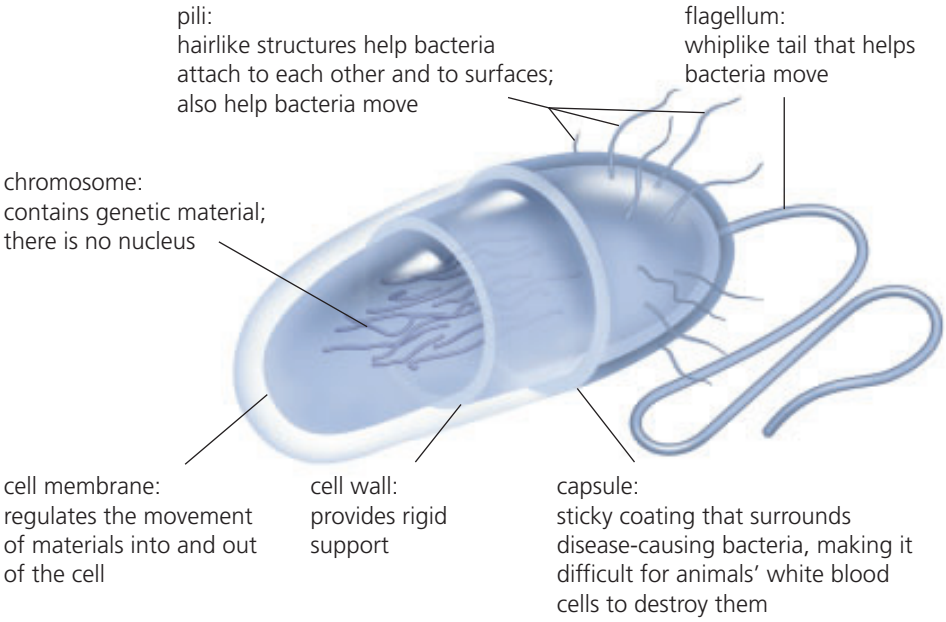


Figure 2
A typical bacterium

Protists

If you look into a drop of pond water, you will find an incredible collection of **protists**, unicellular organisms that are neither plants nor animals. Almost anywhere there is water, even in moist soil or rotting leaves, you will find protists. Unlike bacteria, protists are eukaryotic cells. They have a nucleus and contain organelles such as mitochondria, ribosomes, and lysosomes.

Plantlike Protists

We describe some protists as being plantlike because they are not true plants. They are similar to plants, however, because they contain chlorophyll and produce their own food by photosynthesis.

Figure 3
Each species of diatom has a unique shape. All species have symmetrical grooves and pores.

Diatoms

Diatoms are found in both fresh and salt water. They contain chlorophyll and can make their own food. Diatoms are encased in two thin shells, which are joined together. **Figure 3** shows some diatoms.

Euglena

Euglena (**Figure 4**) are similar to both plant and animal cells. If there is a lot of sunlight, euglena act like plants and make their own food. With reduced sunlight, euglena act like animals and begin feeding upon smaller cells.

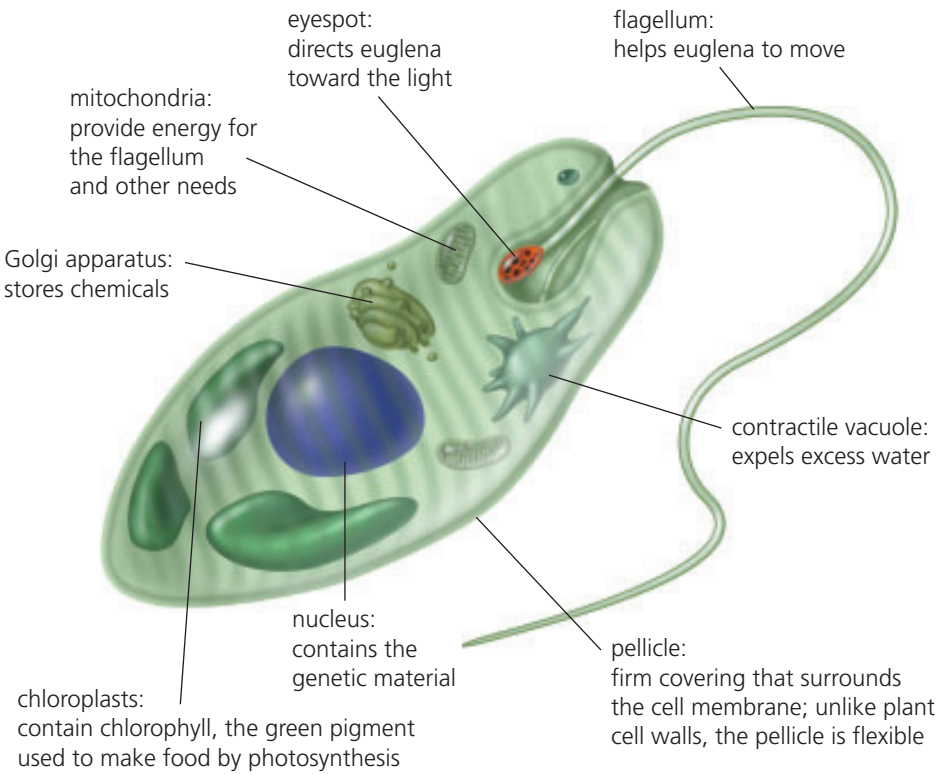


Figure 4
Euglena have features of both plant and animal cells. The photo inset shows a real euglena (magnified 600X).

Animal-like Protists

Animal-like protists cannot make their own food and must feed on things that are living or were once alive. They have all the organelles of an animal cell. Like euglena, they have a contractile vacuole.

Amoebae

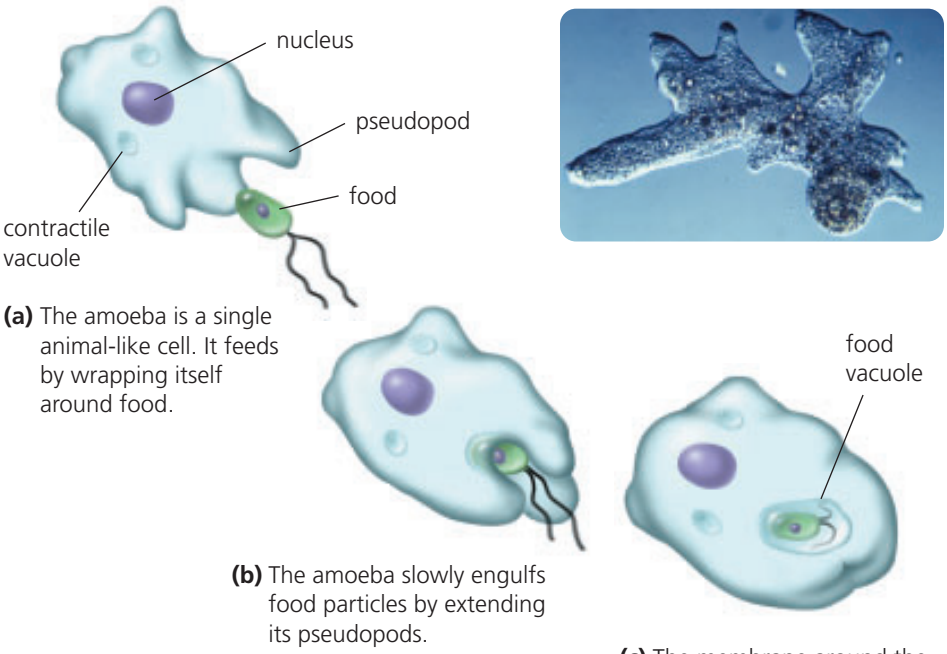
The amoeba (plural is *amoebae*) is a bloblike organism that changes shape as it moves (**Figure 5**). It moves by stretching out a branch of cytoplasm, called a **pseudopod** (false foot). The pseudopod anchors to an object, and the rest of the amoeba is dragged toward it. This method of movement is also used by the white blood cells of animals, including those in your blood vessels. The amoeba uses the pseudopod for feeding (refer to **Figure 5**).

Paramecia

The paramecium (plural is *paramecia*), like the amoeba, uses structures designed for movement to help it feed (**Figure 6**). Tiny hairlike structures, called cilia, beat in unison to create water currents that move the paramecium. Cilia around the paramecium's oral groove create a current that draws food into the groove. Bacteria and other smaller cells are the main food source for the paramecium.

LEARNING TIP

When analyzing diagrams, read the caption and look at the overall diagram to get a sense of what the diagram is about. Look for clues about how the diagram is organized, such as lines or arrows that show how the parts fit together.



(a) The amoeba is a single animal-like cell. It feeds by wrapping itself around food.

(b) The amoeba slowly engulfs food particles by extending its pseudopods.

(c) The membrane around the food forms a food vacuole. Digestion takes place inside the vacuole.

Figure 5
The amoeba crawls and feeds at the same time. The photo inset shows a real amoeba (magnified 63X).

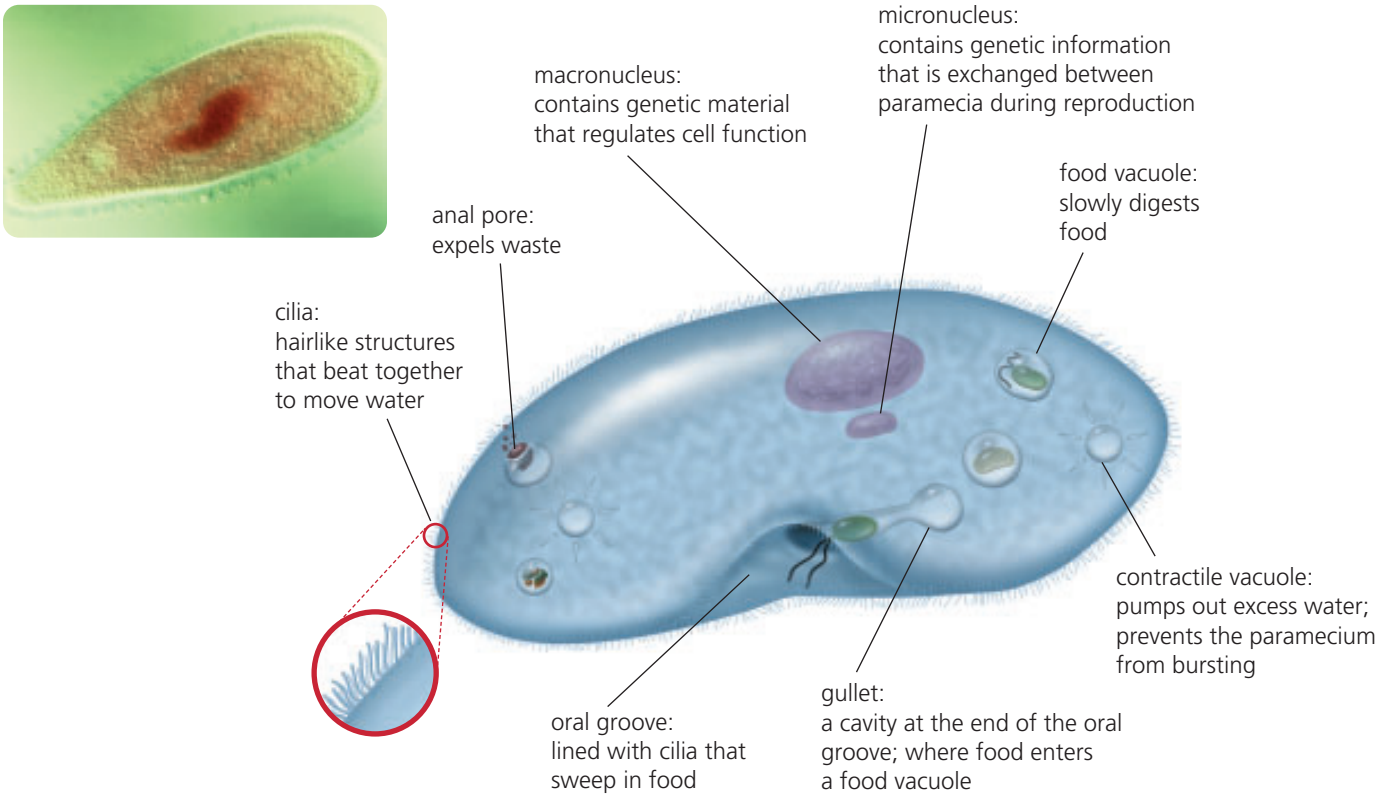


Figure 6
The paramecium is a single animal-like cell that performs most of the functions that your body performs. The photo inset shows a real paramecium (magnified 240X).

Fungi

Fungi (singular is *fungus*) include many organisms that are multicellular, as well as some that are unicellular. Bread mould, mushrooms, and puff balls are well-known fungi. Harmful fungi include those that cause ringworm, Dutch elm disease, and athlete's foot.

Yeast, the Unicellular Fungus

Yeast is one of the few unicellular fungi (**Figure 7**). There are many different species of yeast. Like animal cells, yeast cells do not have chlorophyll and must rely on other organisms as their source of energy.

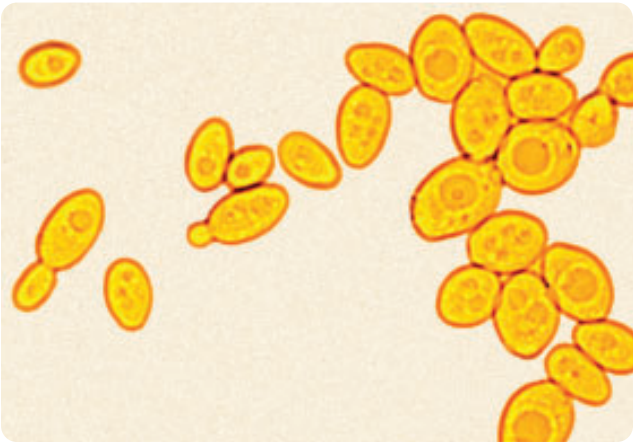


Figure 7
Even under a microscope, it is difficult to see that yeast cells are living.

2.2 CHECK YOUR UNDERSTANDING

1. Why are diatoms called plantlike protists?
2. Use a Venn diagram or a three-column table to compare euglena to plant cells.
3. Compare the process of feeding in a paramecium and an amoeba.
4. Why do you think bacteria are considered to be more primitive than other cells you have studied?
5. Why do many people associate micro-organisms with disease?
6. Using what you know about osmosis, explain why euglena, paramecia, and amoebae need contractile vacuoles.
7. Penicillin is an antibiotic that weakens the cell walls of bacteria. The concentrations of sugars and proteins in the cytoplasm of bacteria are in higher concentrations than outside the bacteria. Draw a series of diagrams to show how penicillin kills bacteria.

LEARNING TIP

For help with Venn diagrams, see **Using Graphic Organizers** in the Skills Handbook.

PERFORMANCE TASK

Cells in the tubes that lead to your lungs have cilia, much like those of paramecia. Human white blood cells, like amoebae, engulf and digest foreign particles. Examine the structures of the unicellular organisms carefully. Would any of these structures be useful in your model cell?

Nature's Oil Recyclers

Our society is very dependent on fossil fuels—oil, gas, and coal. Billions of litres of oil and gas are pumped from the ground every day. Around 30 % of the oil is pumped from under the ocean floor and transported by large oil tankers. While considerable care is taken, accidents happen occasionally, and crude oil is spilled into the ocean.

One of the most significant oil spills in history occurred in 1989. The oil tanker *Exxon Valdez* went aground in the Prince William Sound on the coast of Alaska and spilled over 40 million litres of crude oil (**Figure 1**). The impact on the environment was staggering—tens of thousands of birds and mammals were killed and their habitats destroyed.

The first response to an oil spill is to contain it and recover as much of the oil as possible. One recent approach to dealing with the remaining oil is called *bioremediation*, using living organisms to change hazardous pollution into less dangerous substances.

Figure 1
Oil from the Exxon Valdez coated the beaches of Prince William Sound.

One bioremediation method simply enhances a natural process. There are many species of bacteria that are able to digest or break down crude oil. A few are more effective than others (**Figure 2**). These bacteria are found naturally in the ocean. They require three elements to survive and reproduce—nitrogen, phosphorus, and carbon.

Most of the time, these bacteria are not plentiful because they have a limited food supply (carbon). During an oil spill the food supply is suddenly increased because crude oil consists of long chains of carbon atoms. Scientists discovered that the addition of fertilizers containing nitrogen and phosphorus created the right conditions for the bacteria to grow and reproduce rapidly, all the while munching on the crude oil and breaking it down into carbon dioxide, water, and other non-toxic substances. The bacteria continue to feed and reproduce until they run out of food, and then they die a natural death.

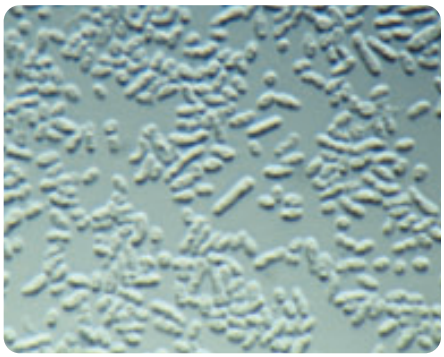


Figure 2
Many species of bacteria use oil as their food supply and break it down into less harmful substances (magnification 800X).

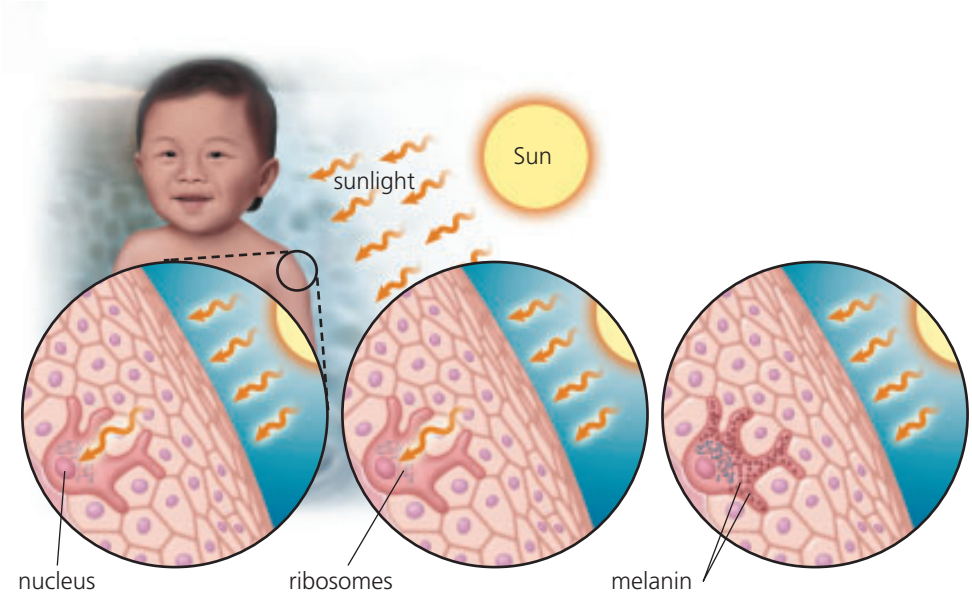
It is estimated that this method of bioremediation can help a shoreline recover in less than half the time it would require if left to natural processes. In addition, because it takes advantage of natural processes, bioremediation is generally less expensive than other clean-up methods.

The Need for Cell Division 2.3

All large plants and animals are composed of many cells rather than one large cell. Why? Cells can grow, but there is a limit. Eventually, every cell reaches a size at which it must divide.

Is Smaller Better?

Think about how far chemical messages travel in a large cell compared with a small cell. Before the nucleus can tell the organelles in the cytoplasm what to do, it must receive messages from the cell's surroundings. The bigger the cell is, the longer messages take to reach the nucleus, and for the rest of the cell to receive instructions. Cells must be small for these messages to travel quickly, so the cells can react to changes in their environment. For example, exposure to sunlight triggers a chemical message in a child's skin cell. The message travels to the nucleus of the skin cell (**Figure 1(a)**). The nucleus sends a message to the ribosomes, telling them to make melanin (**Figure 1(b)**). The melanin blocks sunlight, preventing sunlight from damaging cells below (**Figure 1(c)**).



(a) Sunlight triggers a chemical message.

(b) Ribosomes make melanin.

(c) The melanin blocks sunlight.

Figure 1
Exposure to sunlight makes the skin of most people darker.

LEARNING TIP

Critical thinking is a helpful reading strategy. Look at **Figure 1** and ask yourself, "What would happen if it took a long time for the nuclear message to reach the ribosomes?"

Cells also need a constant supply of nutrients and waste must be removed. Molecules enter into and pass out of cells through the cell membrane. The more cell membrane there is compared with the

volume of a cell, the more efficiently the cell can take in nutrients and eliminate waste. The amount of cell membrane can be described in terms of the surface area of the cell.

TRY THIS: Comparing Surface Areas

Skills Focus: observing, predicting, inferring, measuring

You will need nine sugar cubes and a ruler for this activity.

1. Predict whether many small cells or one large cell would be more effective at exchanging nutrients and waste. Record your prediction.
2. Measure the length and width of a sugar cube in millimetres. The sugar cube represents a small cell. Record your measurements.

(a) Calculate the surface area of a single cube. To do this, find the area of one face and then multiply by the number of faces (**Figure 2**).

(b) Calculate the surface area of nine sugar cubes by multiplying the surface area of the single cube by nine. Record your calculations.

3. Arrange nine cubes to form a large cube. This block of cubes represents one large cell. (The ninth cube will be in the centre and will not contribute any surface area to the large cube.)

(c) Measure the length and width of the large cube. Calculate the surface area of the large cube. Record your calculation.

(d) Compare the total surface area of the nine individual cubes with that of the large cube. Which is greater?

(e) Which has more cell membrane for nutrients and waste to pass through: one large cell or nine small cells?

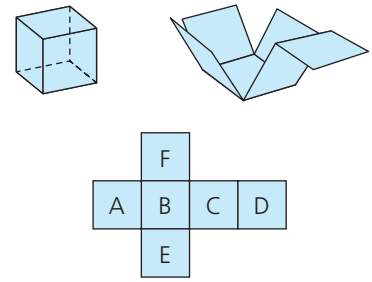


Figure 2
area of A = length × width
surface area of cube = 6 × area of A

Some Large, Some Small

Some cells in your body are larger than others. For example, cells in fat tissue are larger than cells in muscle tissue. If you compare the sizes of cells and their functions, you will find that cells that do a lot of work are usually smaller than cells that are not as active. The more active a cell is, the more nutrients it needs and the more waste it produces. Many small cells are more efficient at exchanging nutrients and waste than one large cell. This is because a group of small cells has a greater surface area than a single large cell of the same volume.

2.3 CHECK YOUR UNDERSTANDING

1. Which size of cell, large or small, is more efficient at
   (a) transferring chemical messages from its surroundings to its nucleus?
   (b) transporting nutrients into and waste materials out?
2. Explain why highly active cells tend to be small.
3. What is the advantage of a highly folded cell membrane?

Cell Specialization 2.4

Imagine how difficult life would be without specialists, people who are experts at performing certain tasks. Could you build your own television or grow your own food?

Unicellular organisms are not specialists. Each cell must carry out all the functions of life. Multicellular organisms, such as you, benefit from **cell specialization**. We have many different types of cells, each designed to carry out a special function.

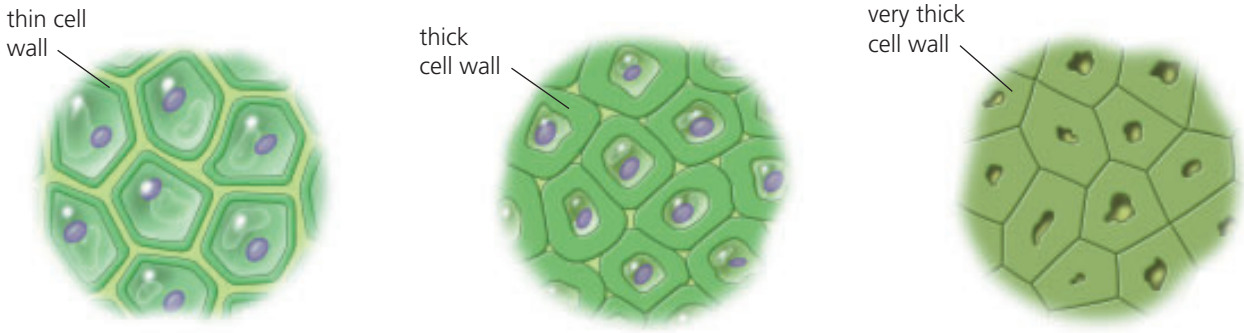
Specialized Plant Cells

The long strings in a celery stalk, the pit in an apricot, and the thin leaves in a head of lettuce are all evidence that there are different types of plant cells.

Thin-walled plant cells are found in the flexible tissues of leaves, flowers, fruits, and roots (**Figure 1(a)**). Most edible plant roots, such as potatoes and radishes, are composed of these cells.

Thick-walled plant cells are specialized for support (**Figure 1(b)**). Their thick cell walls are stretchable and flexible. The tough strings of a celery stalk are made of these cells.

Plants with very thick cell walls provide rigid support (**Figure 1(c)**). The cell walls can get so thick, as the plant matures, that nutrients have difficulty entering the cells. The cells usually die, leaving empty chambers surrounded by thick walls. Most of a tree trunk is made up of hollow cells, with only the very thick cell walls remaining.



(a) Plant cells with thin walls

(b) Plant cells with thick walls

(c) Plant cells with very thick walls

Figure 1
Plants, like animals, are made of tissues and organs. Each kind of tissue contains a special type of cell.

The cell wall is one very noticeable feature of plant cells. As plants develop, a primary cell wall is formed around each cell. Once the plant stops growing, a secondary cell wall may form inside the primary cell wall. The secondary cell wall provides added strength.

The spaces between plant cells, referred to as the middle lamellae, contain a sticky, sugary substance called pectin. Pectin acts like cement, sticking the plant cells together. The sticky syrup that often forms on the top of a baked apple pie is pectin.

Specialized Animal Cells

The shape and structure of an animal cell provides a clue to its function. Many of the features of unicellular organisms can be found in individual animal cells.

Nerve Tissue

Nerve cells conduct electrical signals from one location to another in the body. These cells tend to be long and thin (**Figure 2**). Many nerve cells are protected by a coating of fatty material that helps insulate the nerves and speeds up the conduction of electrical signals.

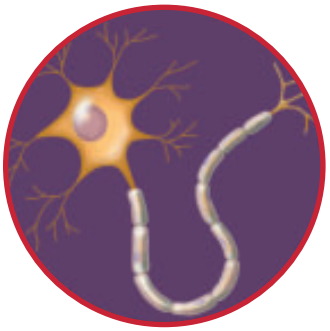


Figure 2
Nerve cells are designed to transmit messages from one location to another in the body.

Respiratory System

Lung cells are very thin (**Figure 3(a)**). This allows gases to exchange rapidly between the air and the blood. Particles that attempt to enter the lungs are trapped in **mucus**, a slippery substance that coats many cells, and then swept away from the lungs by cells with cilia (**Figure 3(b)**).

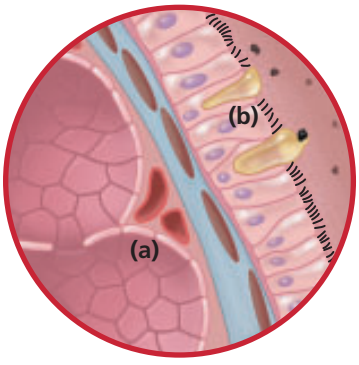


Figure 3
(a) The cells in the airways act as an air purification system.
(b) Oxygen diffuses into the bloodstream and carbon dioxide diffuses out through the cells of the lungs.

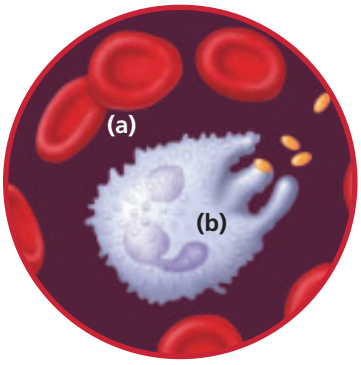


Figure 4
(a) Oxygen molecules attach to the hemoglobin in red blood cells.
(b) White blood cells move like amoebae to find and destroy invaders.

Blood Tissue

Red blood cells carry oxygen in a special protein called **hemoglobin** (**Figure 4(a)**). White blood cells protect the body from invaders by engulfing and digesting them, or by killing them with antibodies (**Figure 4(b)**).

Stomach

Your stomach contains a powerful acid that is necessary for digestion to take place. The cells that make up the lining of the stomach are protected from this acid by a layer of mucus (**Figure 5**). These cells have many Golgi apparatuses to produce and store the proteins that break down food.

Fat Tissue

Most of the cytoplasm in a fat cell is occupied by vacuoles (**Figure 6**). Extra nutrients that the body does not need are converted to fat and stored in vacuoles.

Small Intestine

Cells that line the small intestine absorb essential nutrients from food. Finger-like projections, called **villi**, increase the surface area for absorption (**Figure 7**).

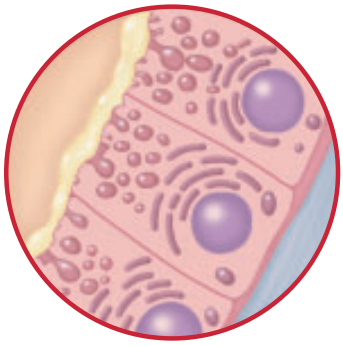


Figure 5
Mucus protects the stomach cells from the strong acid.

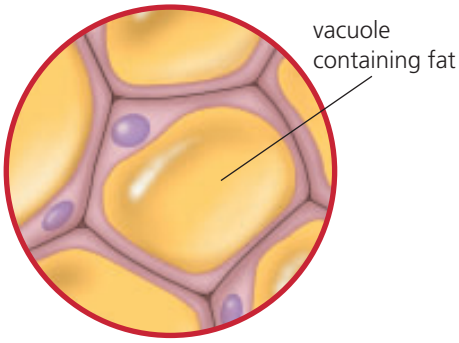


Figure 6
Vacuoles are used to store fat molecules.

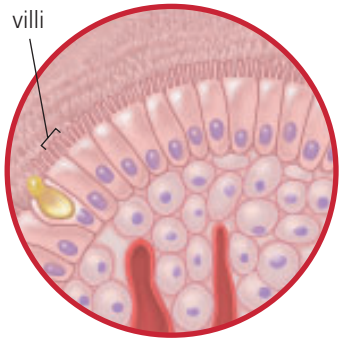


Figure 7
Villi increase the surface area for absorption.

2.4 CHECK YOUR UNDERSTANDING

1. What advantage does a thick, flexible plant cell wall provide over a thick, rigid plant cell wall?
2. Predict what might happen to multicellular plants if a micro-organism that digested pectin was accidentally released from a laboratory.
3. Identify body cells with a structure that is similar to that of a unicellular organism.

PERFORMANCE TASK

Is the structure of your model cell suitable for its special function? What changes should you make in your design, now that you know more about specialized cells?

2.5 Cell Wars

A **disease** is any condition that is harmful to or interferes with the well-being of an organism. Many years ago, tens of thousands of people died during epidemics of diseases, yet no one knew what caused the diseases. Imagine how frightening it was to face invisible killers!

The Invaders

Today we know that many diseases are caused by agents that invade the body and interfere with the normal activities of cells. The invasion is called **infection**. Some of the invaders are living things, such as bacteria, fungi, or parasitic worms. These invaders either rob cells of their nutrients or produce waste products that poison cells. In either case, the invaders can kill the cells.

Figure 1
Streptococcus pneumonia, the bacteria that causes pneumonia, invades the lungs.

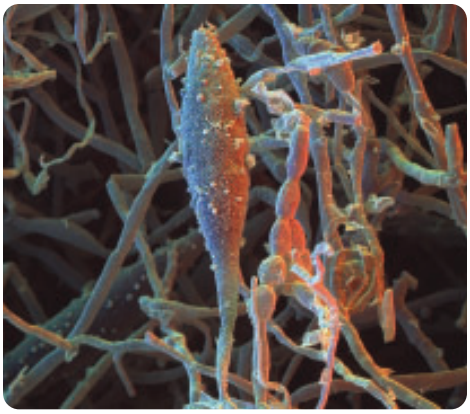
Bacteria

While there are many helpful bacteria, there are numerous diseases and harmful effects caused by bacteria that invade the human body. Tetanus, strep throat, and pneumonia (**Figure 1**), are a few of the more common conditions. Bacteria are also responsible for food spoilage and contamination of drinking water.

Fungi

Several human diseases are caused by fungi. Athlete's foot is one common problem (**Figure 2**). Most of these diseases are just annoying, but some can be deadly.

(a) Athlete's foot is an annoying condition named because it is often picked up from dirty shower floors or running shoes.



(b) The fungus that causes athlete's foot can be eliminated with proper treatment.

Figure 2

Protists

Malaria is caused by an animal-like protist called *Plasmodium,* which is transmitted by mosquitoes. The protists are transmitted when infected female mosquitoes bite humans. Despite efforts to control mosquito populations, malaria continues to be a widespread disease in tropical countries. A disease commonly known as beaver fever is caused by a protist called *Giardia lamblia*. A common source of this infection is drinking untreated stream or pond water. Beaver fever usually causes an upset stomach and diarrhea, but it can also have more serious effects on some people.

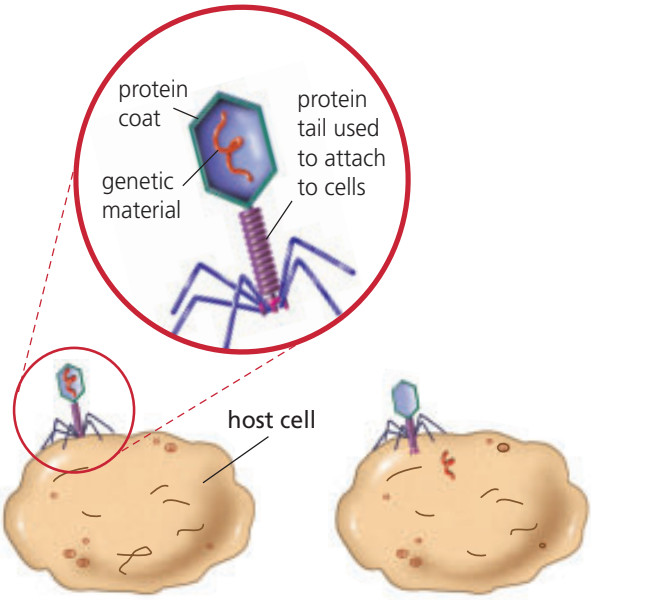
LEARNING TIP

Are you able to explain how a virus infects a cell in your own words? If not, re-read the main ideas, and look at **Figure 3** again.

Viruses

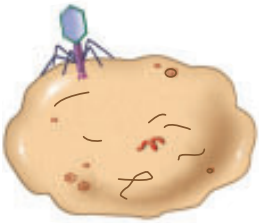
Viruses are often grouped with living invaders; however, viruses are not living things because they are not true cells. A virus contains no nucleus, cytoplasm, organelles, or cell membrane. A virus is a small strand of genetic information covered by a protein coat.

Viruses are only active once they invade a living cell. They take over the cell and turn it into a factory for making more viruses (**Figure 3**). Viruses are responsible for many diseases, including colds, cold sores, influenza, and HIV/AIDS.

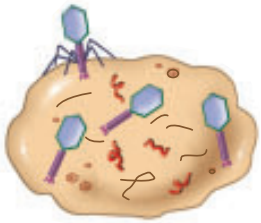


(a) The virus attaches to the cell.

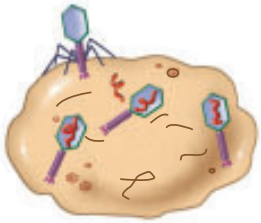
(b) The genetic information from the virus is injected into the cell.



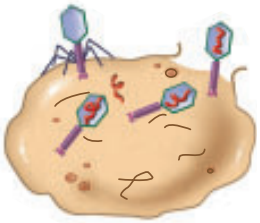
(c) The viral genetic information enters the nucleus of the cell.



(d) The genetic information takes over the cell and forces the cell to start making many protein coats and copies of the viral genetic information.



(e) New viruses are assembled.



(f) The cell bursts, and a new wave of invading viruses is released.

Figure 3
A virus infects a cell and uses it reproduce more viruses.

Figure 4
White blood cells engulf and digest invading bacteria.

The Defenders

Your immune system defends you by destroying invaders. One defence is to attack the invaders directly with white blood cells (**Figure 4**). Once the invaders are engulfed by the cells, the white blood cells' lysosomes release special chemicals that destroy the invaders, but also destroy the white blood cell. **Pus** is made of the strands of protein and cell fragments that remain after invaders have been attacked by white blood cells. As well as attacking and killing bacteria, white blood cells kill body cells that have been damaged by bacteria, viruses, or poisonous chemicals. Only healthy cells remain.

Antibodies

Another way that your immune system defends you is by using **antibodies.** Antibodies are made by a special type of white blood cell. Antibodies are large molecules that lock onto invading organisms.

Invading cells all have distinctive molecules, called **markers,** on their cell membranes or protein coats. These markers have a specific shape, and the antibodies are designed to fit that shape and lock onto them (**Figure 5**). Each type of antibody works on only one type of invader. You will learn more about antibodies in Section 3.6.

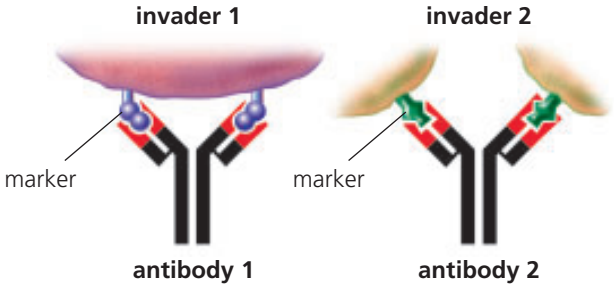


Figure 5
Each antibody can combine with only one marker.

2.5 CHECK YOUR UNDERSTANDING

1. What types of invaders cause infection in humans? Given an example of each type.
2. Why are viruses not considered to be living things?
3. In your own words, explain what disease is.
4. Identify two ways in which white blood cells protect the body from diseases.

DECISION-MAKING SKILLS

- Defining the Issue
- Researching
- Identifying Alternatives
- Analyzing the Issue
- Defending a Decision
- Communicating
- Evaluating

Experimenting with Cells

Biologists know that, with a few exceptions, sperm from one animal will not successfully fertilize the egg of another species. Advances in cell biology, however, have opened the door to the possibility of organisms like the rabirdoo in **Figure 1**.

While the rabirdoo may be an imaginary creature, some actual combinations have produced animals that have the characteristics of two related animals. For example, **Figure 2** shows the result of combining genetic material from a sheep and a goat.

The Issue: Combining Living Things

Because of advances in scientific knowledge and developments in technological processes, scientists are able to combine the genetic material from two different organisms. Some view this capability as having the potential to solve many of society's problems—from diseases to pollution and fuel shortages. Others see an industry that will create risks to human health and potential damage to the natural environment.

Statement

Scientists should not be permitted to combine genetic information from different organisms to create new life forms. This kind of research should be banned in Canada.

Background to the Issue

In 1970, Herbert Boyer and Stanley Cohen discovered a process for transplanting genetic information from a frog into a common bacterium (**Figure 3**). They observed that the genetic information from the frog began telling the bacterial cell what proteins to make, as if it had always been there. Two organisms that would never exchange genetic information in nature had been joined. Using this process, bacteria can become natural factories to produce valuable substances.

Figure 1
A rabirdoo has the feet and ears of a rabbit, the pouch of a kangaroo, and the feathers and beak of a bird. There is no such animal now, but maybe one day…

Figure 2
This animal contains genetic material from both a sheep and a goat. The thin white fur is produced from the goat's genetic information, and the thick grey wool is produced from the sheep's genetic information.

(a) A cell is taken from a frog.

(b) A chromosome is removed and split into smaller pieces by a chemical.

(c) One of the pieces is connected to the bacterium's chromosome.

(d) The new bacterium now contains frog DNA and makes frog proteins.

Figure 3
Genetic information from the cell of a frog is inserted into a bacterial cell.

Genetic Engineering

LEARNING TIP

Active readers know when they learn something new. Read the section on genetic engineering. Ask yourself, "What have I learned that I didn't know before?"

The exchange or modification of genetic material in cells is part of a relatively new area of science and technology, commonly known as **genetic engineering**. Genetic engineering is part of a growing industry, called biotechnology. Biotechnology uses medical and agricultural knowledge and skills to change the characteristics of plants or animals in ways that improve their usefulness to people—for example, by creating plants that are resistant to disease or insects. A natural form of genetic engineering, called selective breeding, has been used for centuries by farmers to produce plants and animals that have the most favourable characteristics.

More Crosses

Figure 4
These two mice are the same age, but one of them contains human genetic information—its cells make human growth hormone. Which mouse do you think has the modified cells?

Scientists have not restricted themselves to frogs and bacteria. Using the process discovered by Boyer and Cohen, bacterial genetic information has been transferred into plants, and plant genetic information has been transferred into animals. Human genetic information has also been placed in bacteria and mouse cells. Nonhuman cells with human genetic information can produce hormones such as human insulin or human growth hormone, which makes the human body grow larger (**Figure 4**). Boyer and Cohen's process is widely used today. Many substances have been produced as a result of their research, including insulin used to treat people with diabetes, a substance for dissolving blood clots in people who have had heart attacks, and a growth hormone for underdeveloped children.

Make a Decision

1. Carefully read the statement and the background information. Consider each of the sample opinions provided in **Table 1**.

Table 1 Viewpoints on Combining Genetic Information

Point	Counterpoint
Genetic engineering is not natural, and any unnatural modification of living things could cause problems for the natural environment.	Genetic engineering is basically no different than selective breeding, which has been done by farmers for centuries.
The new organisms that are created may not be safe. If they ever get loose, they may be dangerous to other living things or to human beings.	New combinations of genetic information provide many benefits. Modified cells make feed for pigs, fuel for cars, and vaccines for humans.
Companies now apply for patents on the life forms they create. No one should be able to own an organism.	Biotechnology is a multibillion-dollar industry that employs many people. If research is banned, jobs will be lost, and Canada will fall behind other countries.

2. In your group discuss the statement, and then decide whether you agree or disagree with it.
3. Search for information on genetic engineering or biotechnology that supports your position. You may find information in newspapers, a library periodical index, a CD-ROM directory, or on the Internet.

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4. Gather relevant information and prepare to defend your position in a class debate. You should also prepare to respond to challenges to your position.

Communicate Your Decision

Your teacher will organize a classroom debate for you to present your position and listen to the presentations of the opposing position. Each group should choose one of its members as their spokesperson.

At the end of the debate, each member of the class will vote on the issue. Be open-minded and willing to change your position. You should vote for the most convincing arguments. Your teacher will conduct the vote and announce the results.

LEARNING TIP

For help with debating and voting on an issue, see "Debating" in the Skills Handbook section **Oral Presentations**.

2.6 CHECK YOUR UNDERSTANDING

1. What is the result if sperm from one species is used to fertilize an egg from another species?
2. How can genetic information be transferred from one organism to another?

CHAPTER 2

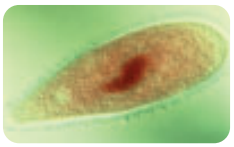
Review Cells and Cell Systems

Key Ideas

Unicellular organisms perform the same basic functions as multicellular organisms.

- Many unicellular organisms are also called micro-organisms. Some micro-organisms are harmful while others are helpful.
- Unicellular organisms obtain food and get rid of excess water and waste.






Cells are specialized to carry out specific functions.

- Plant cells with thick cell walls provide support and strength.
- Cell cilia allow movement of cells or movement of material outside cells.
- Red blood cells can carry oxygen to all the cells of the body. Special white blood cells can engulf invaders.



Cells are generally more efficient when they work together to perform a specific function.

- Nutrients move into a cell and waste is removed from a cell through the cell membrane.
- Several smaller cells are more efficient than one large cell because the ratio of surface area to volume is greater.

Cells in the human body are organized into tissues.

- Nerve, muscle, blood, connective, and epithelial are types of tissues that are found throughout the body.

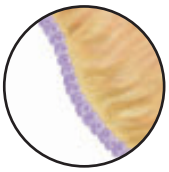
Vocabulary

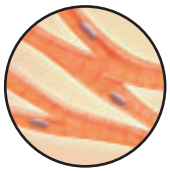
tissue, p. 41
organs, p. 41
organ systems, p. 41
micro-organisms, p. 43
bacteria, p. 43
protists, p. 44
pseudopod, p. 45
fungi, p. 47
cell specialization, p. 51
mucus, p. 52
hemoglobin, p. 53
villi, p. 53
disease, p. 54
infection, p. 54
viruses, p. 55
pus, p. 56
antibodies, p. 56
markers, p. 56
genetic engineering, p. 58

- The cells in tissues are all alike or very similar and have the same function.


nerve tissue

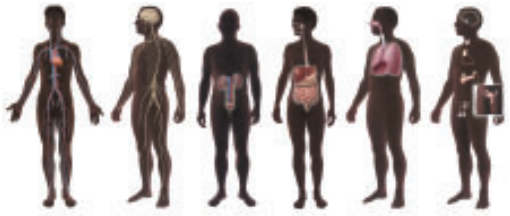

fat tissue


epithelial tissue


muscle tissue

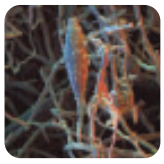
Groups of tissues are organized into organs. Groups of organs are referred to as organ systems.

- The brain, heart, kidneys, lungs, and stomach are examples of organs that have one or more types of tissue.
- The circulatory, nervous, excretory, digestive, respiratory, and endocrine systems are each composed of different organs that have related functions.



Some diseases are caused when cells are invaded by microscopic living things.

- Some micro-organisms, such as bacteria, protists, and fungi, cause illnesses or diseases in humans.
- Viruses, which are not living organisms, also cause diseases and illness by invading cells.



Your health depends on how well your cell systems work together.

- The human body produces special white blood cells and antibodies that are designed to protect the body against invaders.
- Genetic engineering involves modifying the genetic material of an organism to improve the organism or to make helpful products.

Review Key Ideas and Vocabulary

1. Copy **Table 1** into your notebook, and write each of the following words in the correct column.

respiratory	esophagus	fat
intestines	heart	digestive
lungs	circulatory	blood
connective	stomach	muscle
trachea	nerve	epithelial

Table 1

Organ system	Organs contained	Tissues contained

2. What type of tissue is found in the heart?
(a) epithelial
(b) muscle
(c) connective
(d) nerve
(e) all of these

3. Which one of the following is not a unicellular organism?
(a) amoeba
(b) moss
(c) paramecium
(d) euglena
(e) diatom

4. What kind of cell contains hemoglobin?
(a) red blood cell
(b) white blood cell
(c) bone cell
(d) stomach cell
(e) lung cell

5. How do white blood cells control diseases?
(a) by making antibodies
(b) by engulfing and digesting bacteria
(c) by secreting enzymes into the blood
(d) by coating bacteria with mucus
(e) two of these

6. Explain why unicellular organisms are often called micro-organisms.

7. (a) Describe three harmful effects of unicellular organisms.
(b) Describe three ways in which unicellular organisms are useful.

8. (a) Calculate the volume of cell A and of cell B in **Figure 1**. (Both are cubes.)
(b) Calculate the surface area of cell A and of cell B.
(c) Determine the ratio of surface area to volume for cell A and for cell B.
(d) Which cell should be better at absorbing nutrients and removing waste? Explain your answer.

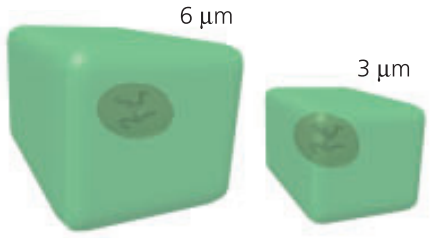


Figure 1

9. If cells are the basic unit of life, why are tissues, organs, and organ systems required in large multicellular organisms?

10. What are the advantages of cell specialization for an organism?

11. Explain how a living cell can become a virus factory.

12. Will an antibody produced against the influenza virus lock onto a common cold virus? Explain.

Use What You've Learned

13. All multicellular organisms start off as one cell. All cells in a given organism have the same genetic makeup (DNA). Describe what must happen to that single cell.
14. Heartburn, or acid indigestion, occurs when stomach acids back up into the esophagus, burning its lining. What can you infer about the type of cells that line the esophagus? How are they different from the cells that line the stomach?
15. A vaccine works by introducing dead or weakened invaders into the body. The body develops antibodies against the weak invaders. If strong invaders of the same kind enter the body later, the antibodies can be used to destroy them before they take over any cells. Using diagrams, show how a vaccine protects the body from invaders.
16. Based on what you have learned about the common source of the fungus that causes athlete's foot, what do you think are the ideal conditions for the growth of the fungus?
17. Examine the shapes of the cells in **Figure 8**.
    (a) Which shape is most suitable for an egg cell? Explain.
    (b) Which shape is most suitable for movement? Explain.
    (c) Which shape is most suitable for covering an organ? Explain.

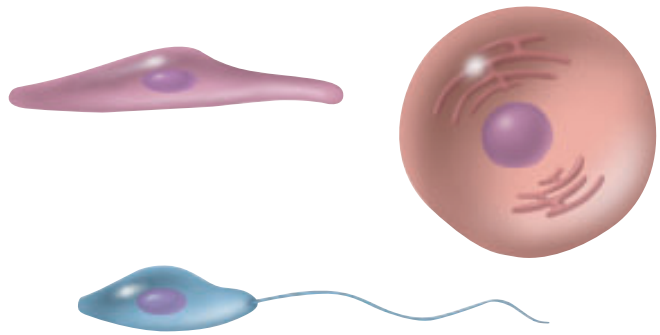


Figure 8

Think Critically

18. What do you think is the biggest advantage of being a multicellular organism? Explain.
19. Imagine you lived long before scientists had figured out that some micro-organisms caused diseases. Propose an idea that might have been used to explain why healthy people suddenly got sick and died. Use the Internet and other resources to research early explanations of diseases.

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20. Influenza or flu vaccines are available each fall. Identify the groups of people for whom the vaccine is recommended and explain why. Do you think the flu vaccine should be mandatory for some groups of people, for example, hospital workers? Explain why or why not.

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21. "Bacteria can affect people directly and indirectly." Write a short essay describing what you think this statement means.

Reflect on Your Learning

22. Genetic engineering can be a blessing or a curse. Write a letter to the federal government explaining why you think it should or should not support research into genetic engineering.
23. How did the discussion of genetic engineering change your opinion about the benefits or risks of the technology?

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