SECTION 1
What Is Life?

Mr. Pierro

DISCOVER ACTIVITY

Is It Living or Nonliving?

1. Your teacher will give you and a partner a wind-up toy.
2. With your partner, decide who will find evidence that the toy is alive and who will find evidence that the toy is not alive.
3. Observe the wind-up toy. Record the characteristics of the toy that support your position about whether or not the toy is alive.
4. Share your lists of living and nonliving characteristics with your classmates.

Think It Over

Forming Operational Definitions Based on what you learned from the activity, create a list of characteristics that living things share.

GUIDE FOR READING

- What characteristics do all living things share?
- What do living things need to survive?

Reading Tip As you read, use the headings to make an outline of the characteristics and needs of living things.

Looking like the slimy creatures that star in horror movies, the "blobs" appeared in towns near Dallas, Texas, in the summer of 1973. Jellylike masses, like the ones in Figure 1, overran yards and porches all over the towns. The glistening blobs oozed slowly along the ground. Terrified homeowners didn't know what the blobs were. Some people thought that they were life forms from another planet. People around Dallas were worried until biologists, scientists who study living things, put their minds at ease. The blobs were slime molds—living things usually found on damp, decaying material on a forest floor. The unusually wet weather around Dallas that year provided ideal conditions for the slime molds to grow in people's yards.

The Characteristics of Living Things

If you were asked to name some living things, or **organisms,** you might name yourself, a pet, and maybe some insects or plants. But you would probably not mention a moss growing in a shady spot, the mildew on bathroom tiles, or the slime molds that oozed across the lawns in towns near Dallas. But all of these things are also organisms that share six important characteristics

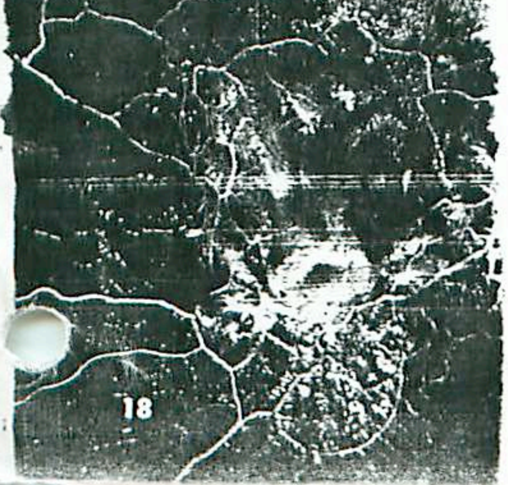
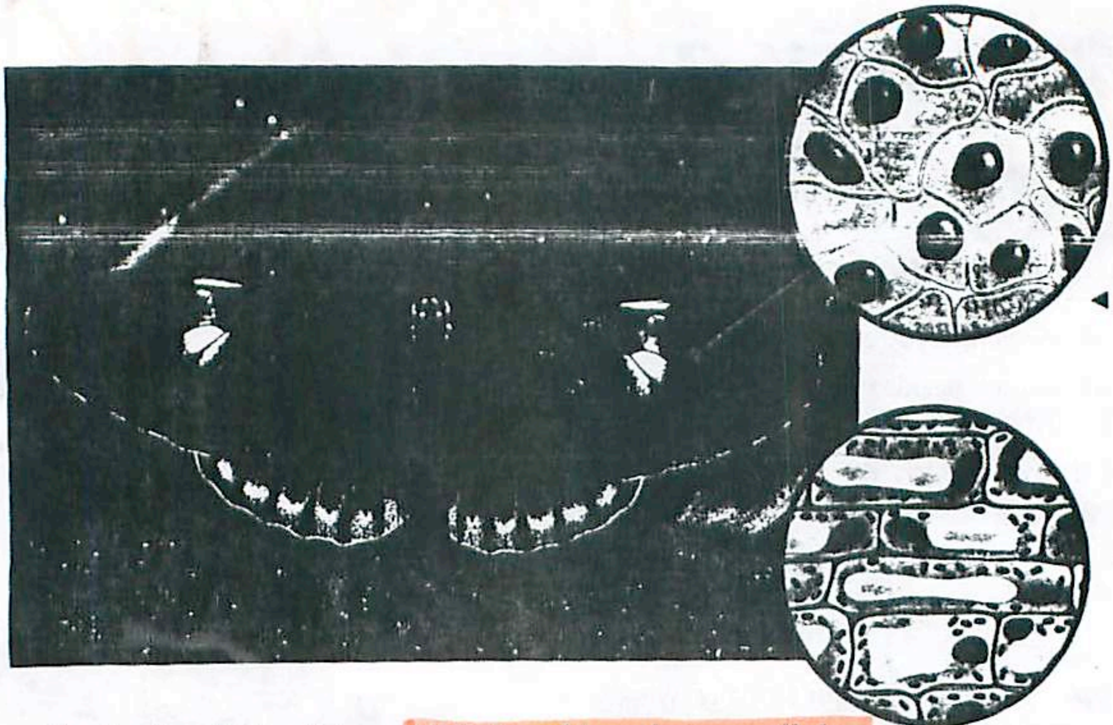


Figure 1 Slime molds similar to these grew in yards and porches in towns near Dallas, Texas.



with all other living things. **All living things have a cellular organization, contain similar chemicals, use energy, grow and develop, respond to their surroundings, and reproduce.**

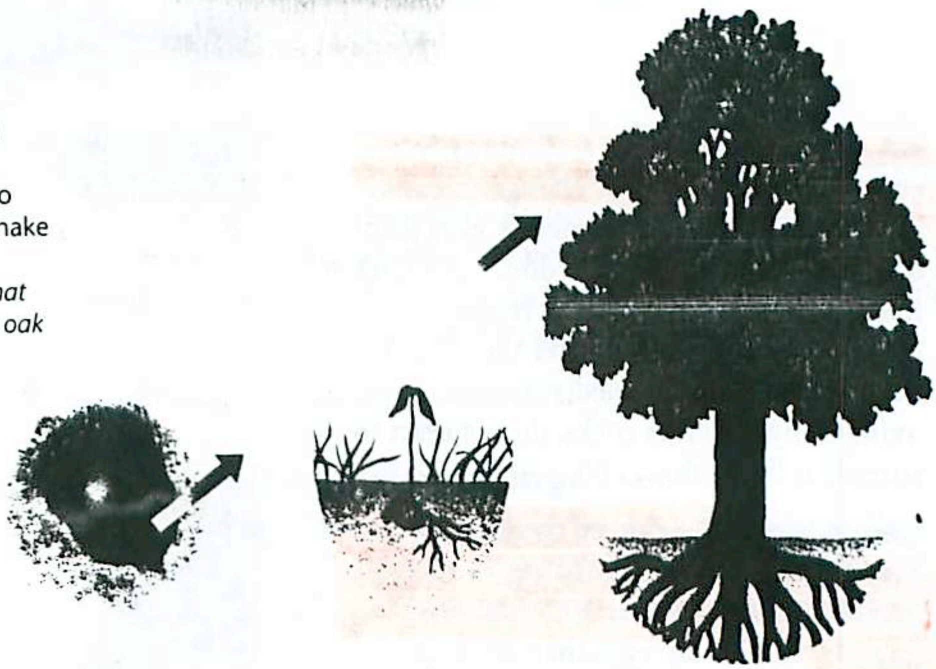
Figure 2 Like all living things, the butterfly and the leaf are made of cells. Although the cells of different organisms are not identical, they share important characteristics. ***Making Generalizations*** *In what ways are cells similar?*

Cellular Organization All organisms are made of small building blocks called cells. A **cell** is the basic unit of structure and function in an organism. The smallest cells are so tiny that you could fit over a million of them on the period at the end of this sentence. To see most cells, you need a microscope—a tool that uses lenses, like those in eyeglasses, to magnify small objects.

Organisms may be composed of only one cell or of many cells. **Unicellular,** or single-celled organisms, include bacteria (bak TEER ee uh), the most numerous organisms on Earth. A bacterial cell carries out all of the functions necessary for the organism to stay alive. **Multicellular** organisms are composed of many cells. The cells of many multicellular organisms are specialized to do certain tasks. For example, you are made of trillions of cells. Specialized cells in your body, such as muscle and nerve cells, work together to keep you alive. Nerve cells carry messages from your surroundings to your brain. Other nerve cells then carry messages to your muscle cells, making your body move.

The Chemicals of Life The cells of all living things are composed of chemicals. The most abundant chemical in cells is water. Other chemicals called carbohydrates (kahr boh HY drayt) are a cell's energy source. Two other chemicals, proteins (PROH teenz) and lipids (LIP idz), are the building materials of cells, much like wood and bricks are the building materials of houses. Finally, nucleic (noo KLEE ik) acids are the genetic material—the chemical instructions that direct the cell's activities.

Figure 3 Over time, a tiny acorn develops into a giant oak tree. A great deal of energy is needed to produce the trillions of cells that make up the body of an oak tree. ***Comparing and Contrasting*** *In what way does the seedling resemble the oak tree? In what ways is it different?*



Energy Use The cells of organisms use energy to do what living things must do, such as grow and repair injured parts. An organism's cells are always hard at work. For example, as you read this paragraph, not only are your eye and brain cells busy, but most of your other cells are working, too. The cells of your stomach and intestine are digesting food. Your blood cells are moving chemicals around your body. If you've hurt yourself, some of your cells are repairing the damage.

Growth and Development Another characteristic of living things is that they grow and develop. Growth is the process of becoming larger. **Development** is the process of change that occurs during an organism's life to produce a more complex organism. For example, as multicellular organisms develop, their cells differentiate, or become specialized. To grow and develop, organisms use energy to create new cells. Look at Figure 3 to see how an acorn develops as it grows into an oak tree.

You may argue that some nonliving things grow and change as they age. For example, a pickup truck rusts as it ages. Icicles grow longer as more water freezes on their tips. But pickup trucks and icicles do not use energy to change and grow. They also don't become more complex over time.

Response to Surroundings If you've ever seen a plant in a sunny window, you may have observed that the plant's stems have bent so that the leaves face the sun. Like a plant bending toward the light, all organisms react to changes in their environment. A change in an organism's surroundings that causes the organism to react is called a **stimulus** (plural *stimuli*). Stimuli include changes in temperature, light, sound, and other factors.

TRY THIS

React! ACTIVITY

In this activity, you will test your responses to three different stimuli.

1. Have a partner clap his or her hands together about six inches in front of your face. Describe how you react.
2. Look at one of your eyes in a mirror. Cover the eye with your hand for a minute. While looking in the mirror, remove your hand. Observe how the size of your pupil changes.
3. Bring a slice of lemon close to your nose and mouth. Describe what happens.

Classifying For each action performed, name the stimulus and the response.

same basic needs as you, they do. All organisms need four things to stay alive. **Living things must satisfy their basic needs for energy, water, living space, and stable internal conditions.**

Energy You read earlier that organisms need a source of energy to live. They use food as their energy source. Organisms differ in the ways they obtain their energy. Some organisms, such as plants, capture the sun's energy and use it along with carbon dioxide, a gas found in Earth's atmosphere, and water to make their own food. Organisms that make their own food are called **autotrophs** (AW tuh trawfs). *Auto-* means "self" and *-troph* means "feeder." Autotrophs use the food they make as an energy source to carry out their life functions.

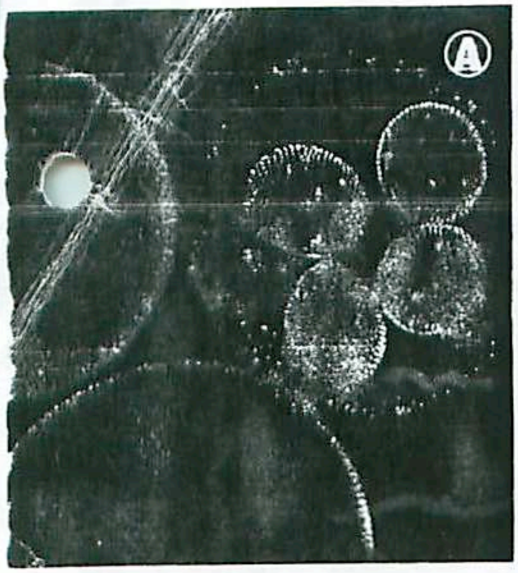
PASTEUR'S EXPERIMENT

1. In one experiment, Pasteur put clear broth into two flasks with curved necks. The necks would let in oxygen but keep out bacteria from the air. Pasteur boiled the broth in one flask to kill any bacteria in the broth. He did not boil the broth in the other flask.

2. In a few days, the unboiled broth became cloudy, showing that new bacteria were growing. The boiled broth remained clear. Pasteur concluded that bacteria do not spontaneously arise from the broth. New bacteria appeared only when living bacteria were already present.

LOUIS PASTEUR

Later, Pasteur took the curve-necked flask containing the broth that had remained clear and broke its long neck. Bacteria from the air could now enter the flask. In a few days, the broth became cloudy. This evidence confirmed Pasteur's conclusion that new bacteria appear only when they are produced by existing bacteria.



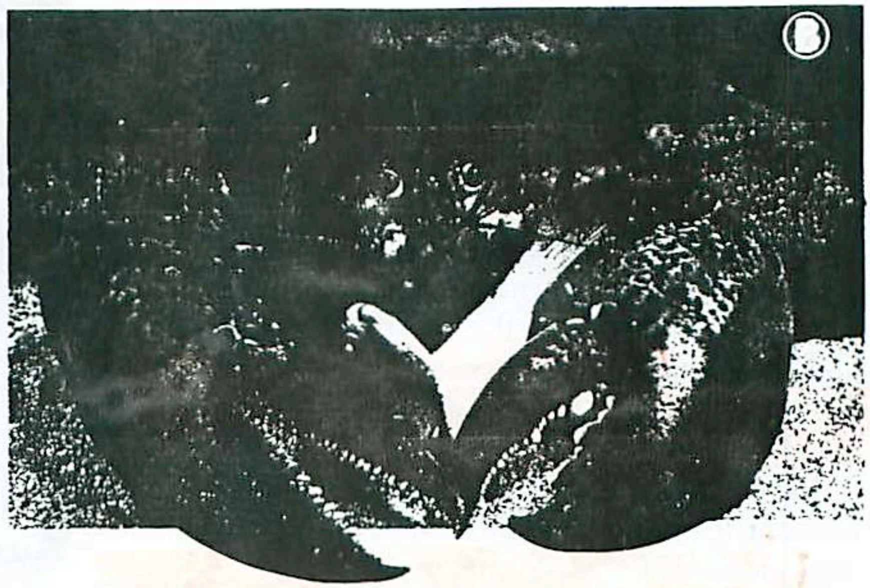


Figure 5 All organisms need a source of energy to live. **A.** *Volvox* is an autotroph that lives in fresh water, where it uses the sun's energy to make its own food. **B.** This American lobster, a heterotroph, is feeding on a herring it has caught. ***Applying Concepts*** *How do heterotrophs depend on autotrophs for energy?*

Organisms that cannot make their own food are called **heterotrophs** (HET uh roh trawfs). *Hetero-* means "other." A heterotroph's energy source is also the sun—but in an indirect way. Heterotrophs either eat autotrophs and obtain the energy in the autotroph's stored food, or they consume other heterotrophs that eat autotrophs. Animals, mushrooms, and slime molds are examples of heterotrophs.

Water All living things need water to survive—in fact, most organisms can live for only a few days without water. Organisms need water to do things such as obtain chemicals from their surroundings, break down food, grow, move substances within their bodies, and reproduce.

INTEGRATING CHEMISTRY One important property of water that is vital to living things is its ability to dissolve more chemicals than any other substance on Earth. In your body, for example, water makes up 92 percent of the liquid part of your blood. The oxygen and food that your cells need dissolve in the blood and are transported throughout your body. Carbon dioxide and other waste also dissolve in the blood. Your body's cells also provide a watery environment in which chemicals are dissolved. In a sense, you can think of yourself as a person-shaped sack of water in which other substances are dissolved. Fortunately, your body contains some substances that do not dissolve in water, so you hold your shape.

Sharpen your Skills

Designing an Experiment

ACTIVITY

Your teacher will give you a slice of potato. Predict what percentage of the potato's mass is water. Then come up with a plan to test your prediction. For materials, you will be given a hairdryer and a balance. Obtain your teacher's approval before carrying out your plan. How does your result compare with your prediction?

Living Space All organisms need a place to live—a place to get food and water and find shelter. Because there is a limited amount of living space on Earth, some organisms may compete for space. Plants, for example, occupy a fixed living space. Above the ground, their branches and leaves compete for living space with those of other plants. Below ground, their roots compete for water and minerals. Unlike plants, organisms such as animals move around. They may either share living space with others or compete for living space.

Stable Internal Conditions Because conditions in their surroundings can change significantly, organisms must be able to keep the conditions inside their bodies constant. The maintenance of stable internal conditions despite changes in the surroundings is called **homeostasis** (hoh mee oh STAY sis). You know that when you are healthy your body temperature stays constant despite temperature changes in your surroundings. Your body's regulation of temperature is an example of homeostasis.

Other organisms have different mechanisms for maintaining homeostasis. For example, imagine that you are a barnacle attached to a rock at the edge of the ocean. At high tide, the ocean water covers you. At low tide, however, your watery surroundings disappear, and you are exposed to hours of sun and wind. Without a way to keep water in your cells, you'd die. Fortunately, a barnacle can close up its hard outer plates, trapping droplets of water inside. In this way, the barnacle can keep its body moist until the next high tide.

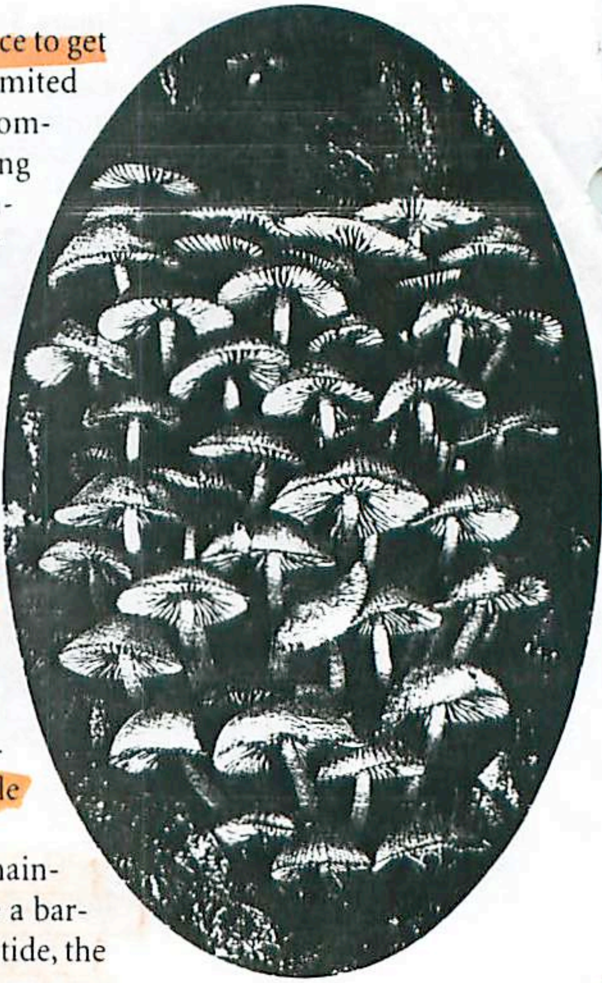


Figure 6 A tree trunk provides these mushrooms with food, water, and shelter.

Section 1 Review

1. Name six characteristics that you have in common with a tree.
2. List the four things that all organisms need to stay alive.
3. How did Pasteur's experiment show that bacteria do not arise spontaneously in broth?
4. **Thinking Critically Applying Concepts** You see a crowd of gulls fighting over an object on the wet sand at the ocean's edge. You investigate. The object is a pink blob about as round as a dinner plate. How will you decide if it is a living thing?

Check Your Progress

CHAPTER PROJECT

At this point, you should be ready to carry out your tests for signs of life following your teacher's directions. Before you start, examine your mystery object carefully, and record your observations. Also, decide whether you need to revise the list of life characteristics you prepared earlier. (*Hint:* Do not be fooled by the object's appearance—some organisms appear dead during a certain stage of their life.)

SECTION 2 Discovering Cells

DISCOVER — ACTIVITY

Is Seeing Believing?

1. Cut a black-and-white photograph out of a page in a newspaper. With your eyes alone, closely examine the photo. Record your observations.
2. Examine the same photo with a hand lens. Record your observations.
3. Place the photo on the stage of a microscope. Use the clips to hold the photo in place. Shine a light down on the photo. Focus the microscope on part of the photo. (See Appendix B for instructions on using the microscope.) Record your observations.

Think It Over

Observing What did you see in the photo with the hand lens and the microscope that you could not see with your eyes alone?

A majestic oak tree shades you on a sunny day at the park. A lumbering rhinoceros wanders over to look at you at the zoo. After a rain storm, mushrooms sprout in the damp woods. What do you think an oak tree, a rhinoceros, and a mushroom have in common? You might say that they are all living things. What makes all of these living things alike? If you said that they are made of cells, you are correct.

Cells are the basic units of structure and function in living things. Just as bricks are the building blocks of a house or school, cells are the building blocks of life. Since you are alive, you are made of cells, too. Look closely at the skin on your arm. No

GUIDE FOR READING

- How did the invention of the microscope contribute to scientists' understanding of living things?
- What is the cell theory?
- How does a lens magnify an object?

Reading Tip As you read, make a flowchart showing how the contributions of several scientists led to the development of the cell theory.

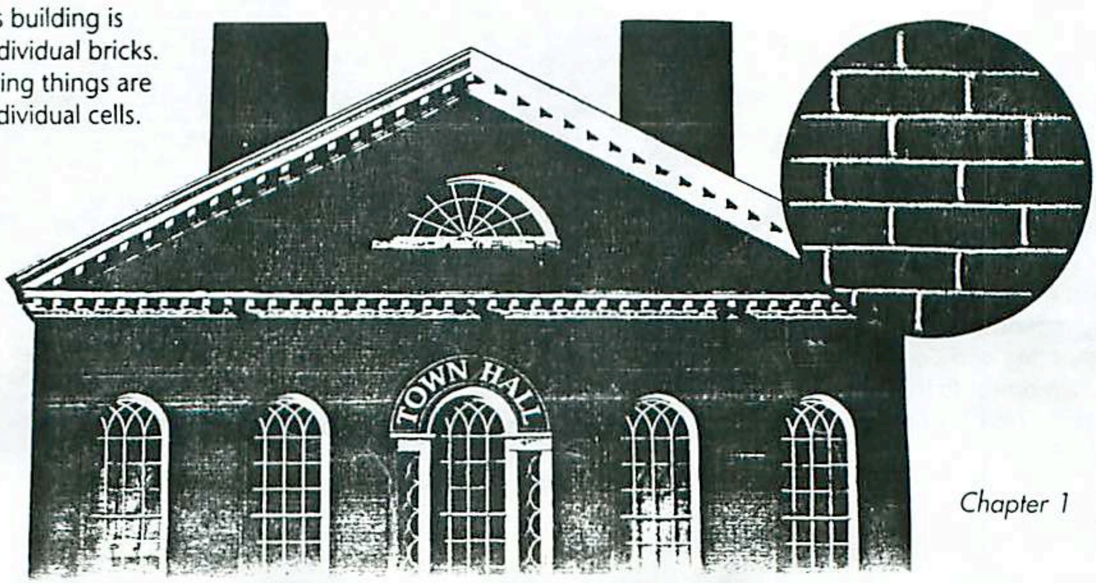


Figure 7 This building is made up of individual bricks. Similarly, all living things are made up of individual cells.

matter how hard you look with your eyes alone, you won't be able to see individual skin cells. The reason is that cells are very small. In fact, one square centimeter of your skin's surface contains over 100,000 cells.

First Sightings of Cells

Until the late 1500s there was no way to see cells. No one even knew that cells existed. Around 1590, the invention of the microscope enabled people to look at very small objects. **The invention of the microscope made it possible for people to discover and learn about cells.**

A **microscope** is an instrument that makes small objects look larger. Some microscopes do this by using lenses to focus light. The lenses used in light microscopes are similar to the clear curved pieces of glass used in eyeglasses. A simple microscope contains only one lens. A hand lens is an example of a simple microscope. A light microscope that has more than one lens is called a **compound microscope.**

Robert Hooke One of the first people to observe cells was the English scientist and inventor Robert Hooke. In 1663, Hooke observed the structure of a thin slice of cork using a compound microscope he had built himself. Cork, the bark of the cork oak tree, is made up of cells that are no longer alive. To Hooke, the cork looked like tiny rectangular rooms, which he called *cells.* Hooke described his observations this way: "These pores, or cells, were not very deep. . . ." You can see Hooke's drawings of cork cells in Figure 8. What most amazed Hooke was how many cells the cork contained. He calculated that in a cubic inch there were about 1.2 billion cells—a number he described as "most incredible."

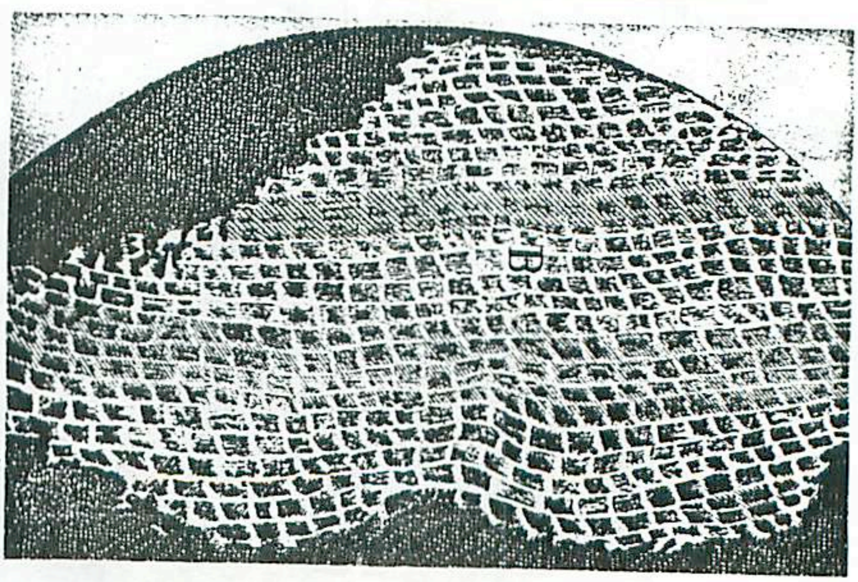


Figure 8 Robert Hooke made this drawing of dead cork cells that he saw through his microscope. Hooke called these structures *cells* because they reminded him of tiny rooms. ***Comparing and Contrasting*** *How are cells similar to the bricks in a building? How are they different?*

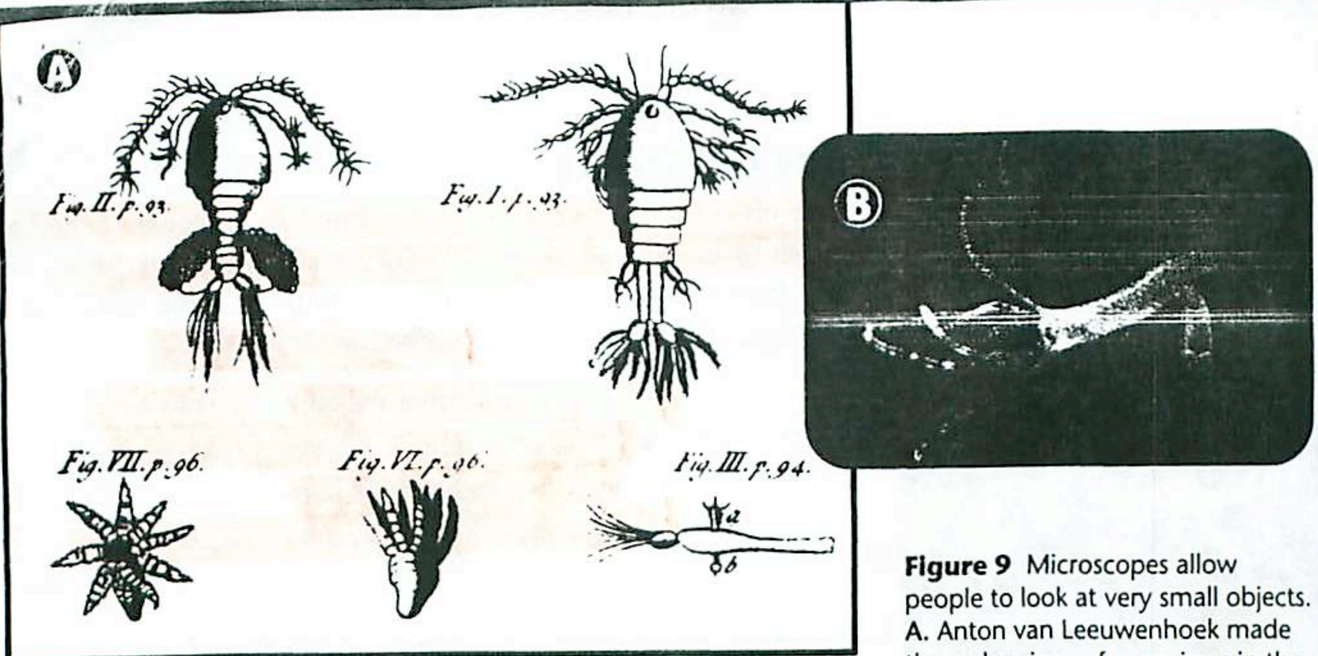


Figure 9 Microscopes allow people to look at very small objects. **A.** Anton van Leeuwenhoek made these drawings of organisms in the late 1600s after looking through a simple microscope. **B.** This is a hydra, a tiny water organism, as seen through a modern microscope. Compare this hydra to the one Leeuwenhoek drew, which is labeled Fig. III.

Anton van Leeuwenhoek At about the same time that Robert Hooke made his discovery, Anton van Leeuwenhoek (LAY vun hook) also began to observe tiny objects with microscopes. Leeuwenhoek was a Dutch businessman and amateur scientist who made his own lenses. He then used the lenses to construct simple microscopes.

One of the things Leeuwenhoek looked at was water from a pond. He was surprised to see one-celled organisms, which he called *animalcules* (an uh MAL kyoolz), meaning "little animals."

Leeuwenhoek looked at many other specimens, including scrapings from teeth. When Leeuwenhoek looked at the scrapings, he became the first person to see the tiny single-celled organisms that are now called bacteria. Leeuwenhoek's many discoveries caught the attention of other researchers. Many other people began to use microscopes to see what secrets they could uncover about cells.

Matthais Schleiden and Theodor Schwann Over the years, scientists have continued to use and improve the microscope. They have discovered that all kinds of living things are made up of cells. In 1838, a German scientist named Matthais Schleiden (SHLY dun) concluded that all plants are made of cells. He based this conclusion on his own research and on the research of others before him. The next year, another German scientist, Theodor Schwann, concluded that all animals are also made up of cells. Thus, stated Schwann, all living things are made up of cells. 1839

Schleiden and Schwann had made an important discovery about living things. However, they didn't understand where cells came from. Until their time, most people thought that living things could come from nonliving matter. In 1855, a German doctor, Rudolf Virchow (FUR koh) proposed that new cells are formed only from existing cells. "All cells come from cells," wrote Virchow.

☑ *Checkpoint What did Schleiden and Schwann conclude about cells?*

The Cell Theory

The observations of Hooke, Leeuwenhoek, Schleiden, Schwann, Virchow, and others led to the development of the **cell theory.** The cell theory is a widely accepted explanation of the relationship between cells and living things. The cell theory states:

- All living things are composed of cells.
- Cells are the basic unit of structure and function in living things.
- All cells are produced from other cells.

Science & History

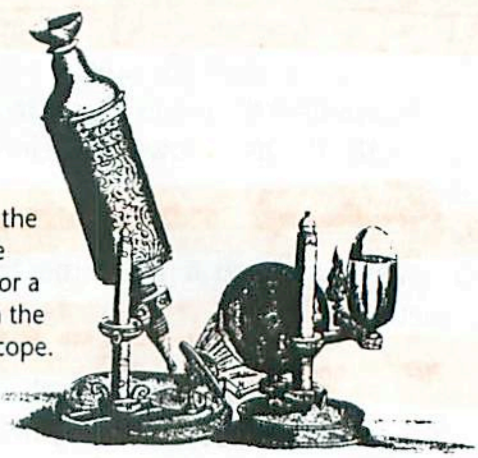
The Microscope—Improvements Over Time

The discovery of cells would not have been possible without the microscope. Microscopes have been improved in many ways over the last 400 years.

1660

Hooke's Compound Microscope

Robert Hooke improved on the compound microscope. The stand at the right holds oil for a flame, which shines light on the specimen under the microscope.



1600 **1750**

1590

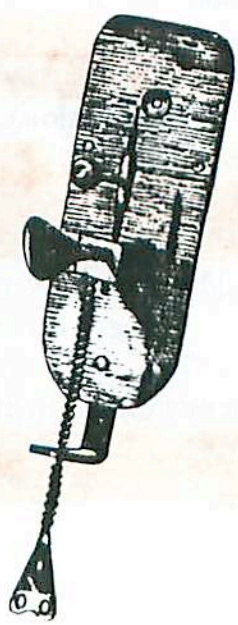
First Compound Microscope

Hans Janssen and his son Zacharias, Dutch eyeglass makers, made one of the first compound microscopes. Their microscope was simply a tube with a lens at each end.

1683

Leeuwenhoek's Simple Microscope

Although Leeuwenhoek's simple microscope used only one tiny lens, it could magnify a specimen up to 266 times. Leeuwenhoek was the first person to see many one-celled organisms, including bacteria.



The cell theory holds true for all living things, no matter how big or small, or how simple or complex. Since cells are common to all living things, they can provide information about all life. And because all cells come from other cells, scientists can study cells to learn about growth, reproduction, and all other functions that living things perform. By learning about cells and how they function, you can learn about all types of living things.

☑ ***Checkpoint*** *Which scientists contributed to the development of the cell theory?*

In Your Journal

Choose one of the microscopes. Write an advertisement for it that might appear in a popular science magazine. Be creative. Emphasize the microscope's usefulness or describe the wonders that can be seen with it.

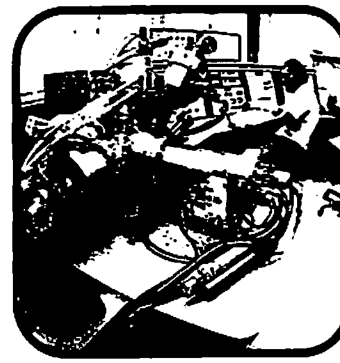
1933

Transmission Electron Microscope (TEM)

The German physicist Ernst Ruska created the first electron microscope. TEMs make images by sending electrons through a very thinly sliced specimen. They can only examine dead specimens, but are very useful for viewing internal cell structures. TEMs can magnify a specimen up to 500,000 times.

1981

Scanning Tunneling Microscope (STM)



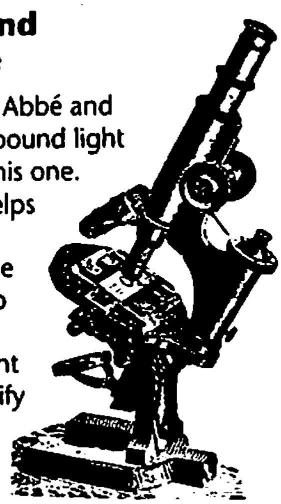
A STM measures electrons that leak, or "tunnel," from the surface of a specimen. With a STM, scientists can see individual molecules on the outer layer of a cell. STMs can magnify a specimen up to 1,000,000 times.

1900 **2050**

1886

Modern Compound Light Microscope

German scientists Ernst Abbé and Carl Zeiss made a compound light microscope similar to this one. The horseshoe stand helps keep the microscope steady. The mirror at the bottom focuses light up through the specimen. Modern compound light microscopes can magnify a specimen up to 1,000 times.



1965

Scanning Electron Microscope (SEM)

The first commercial SEM is produced. This microscope sends a beam of electrons over the surface of a specimen, rather than through it. The result is a detailed three-dimensional image of the specimen's surface. SEMs can magnify a specimen up to 150,000 times.

Sharpen your Skills

Observing ACTIVITY

1. Place a prepared slide of a thin slice of cork on the stage of a microscope.
2. Observe the slide under low power. Draw what you see.
3. Place a few drops of pond water on another slide and cover it with a coverslip.
4. Observe the slide under low power. Draw what you see. Wash your hands after handling pond water.

Observing How does your drawing in Step 2 compare to Hooke's drawing in Figure 8? Based on your observations in Step 4, why did Leeuwenhoek call the organisms he saw "little animals"?

How a Light Microscope Works

INTEGRATING PHYSICS Microscopes use lenses to make small objects look larger. But simply enlarging a small object is not useful unless you can see the details clearly. For a microscope to be useful to a scientist, it must combine two important properties—magnification and resolution.

Magnification The first property, **magnification,** is the ability to make things look larger than they are. **The lens or lenses in a light microscope magnify an object by bending the light that passes through them.** If you examine a hand lens, you will see that the glass lens is curved, not flat. The center of the lens is thicker than the edges. A lens with this curved shape is called a **convex lens.** Look at Figure 10 to see how light is bent by a convex lens. The light passing through the sides of the lens bends inward. When this light hits the eye, the eye sees the object as larger than it really is.

Because a compound microscope uses more than one lens, it can magnify an object even more. Light passes through a specimen and then through two lenses. Figure 10 also shows the path that light takes through a compound microscope. The first lens near the specimen magnifies the object. Then a second lens near the eye further magnifies the enlarged image. The total magnification of the microscope is equal to the magnifications of the two lenses multiplied together. For example, if the first lens has a magnification of 10 and the second lens has a magnification of 40, then the total magnification of the microscope is 400.

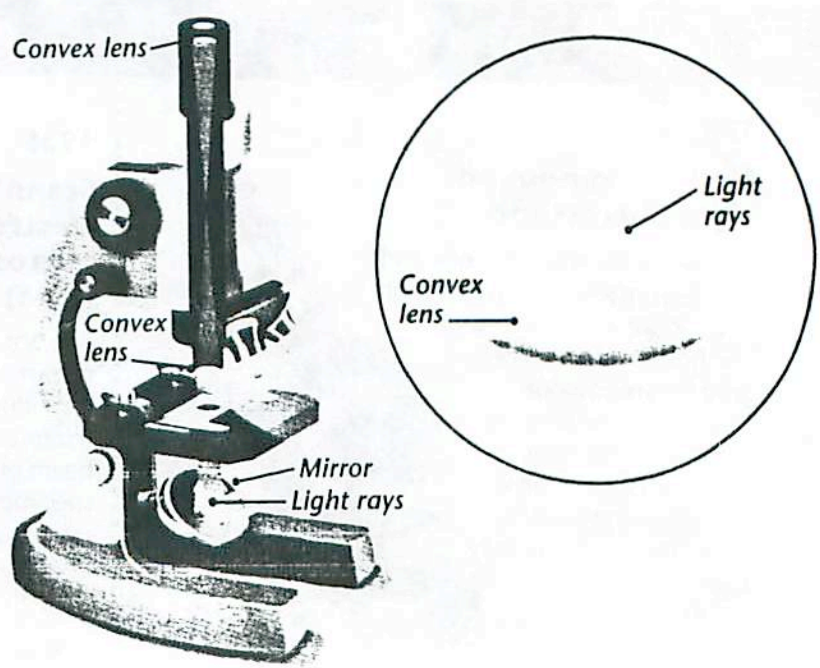
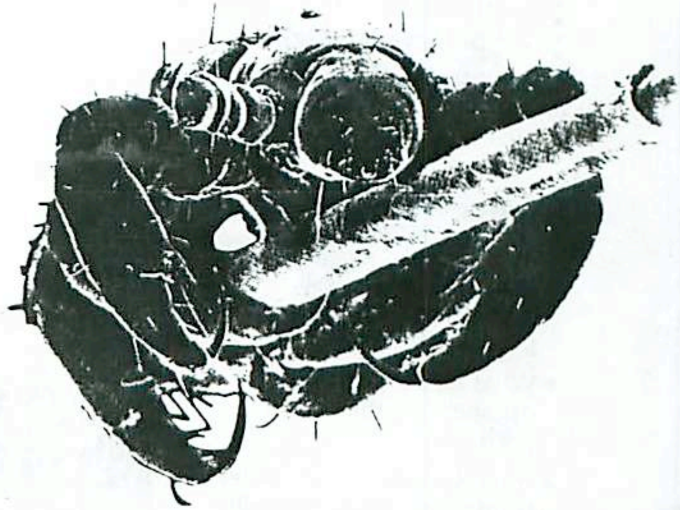


Figure 10 Microscopes use lenses to make objects look larger. A compound microscope has two convex lenses. Each convex lens bends light, making the image larger. *Calculating If one lens had a magnification of 10, and the other lens had a magnification of 50, what would the total magnification be?*

Resolution To create a useful image, a microscope must also help you see individual parts clearly. The ability to clearly distinguish the individual parts of an object is called **resolution**. Resolution is another term for the sharpness of an image.

For example, when you use your eyes to look at a photo printed in a newspaper, it looks like a complete picture from one side to the other. That picture, however, is really made up of a collection of small dots. To the unaided eye, two tiny dots close together appear as one. If you put the photo under a microscope, however, you can see the dots. You see the dots not only because they are magnified but also because the microscope improves resolution. Good resolution—being able to see fine detail—is not needed when you are reading the newspaper. But it is just what you need when you study cells.

Figure 11 This head louse, shown clinging to a human hair, was photographed through a scanning electron microscope. It has been magnified to about 80 times its actual size.



Electron Microscopes

The microscopes used by Hooke, Leeuwenhoek, and other early researchers were all light microscopes. Since the 1930s, scientists have developed a different type of microscope called an electron microscope. Electron microscopes use a beam of electrons instead of light to examine a specimen. Electrons are tiny particles that are smaller than atoms. The resolution of electron microscopes is much higher than the resolution of light microscopes. As the technology of microscopes keeps improving, scientists will continue to learn more about the structure and function of cells.

Section 2 Review

1. How did the invention of the microscope affect scientists' understanding of living things?
2. Explain the three main ideas of the cell theory.
3. How does a compound microscope use lenses to magnify an object?
4. Explain why both magnification and resolution are important when viewing a small object with a microscope.
5. **Thinking Critically Applying Concepts** Why do scientists learn more about cells each time the microscope is improved?

CHAPTER PROJECT

Check Your Progress

Observe your object at least once a day. Record your observations in a data table. Draw accurate diagrams. (*Hint:* Measuring provides important information. Take measurements of your object regularly. If you cannot measure it directly, make estimates.)

SECTION

3 Looking Inside Cells

DISCOVER ACTIVITY

How Large Are Cells?

1. Look at the organism in the photo. The organism is an ameba, a large single-celled organism. This type of ameba is about 1 millimeter (mm) long.
2. Multiply your height in meters by 1,000 to get your height in millimeters. How many amebas would you have to stack end-to-end to equal your height?
3. Many of the cells in your body are about 0.01 mm long—one hundredth the size of an ameba. How many body cells would you have to stack end-to-end to equal your height?

Think It Over

Inferring Look at a metric ruler to see how small 1 mm is. Now imagine a distance one-hundredth as long, or 0.01 mm. Why can't you see your body's cells without the aid of a microscope?

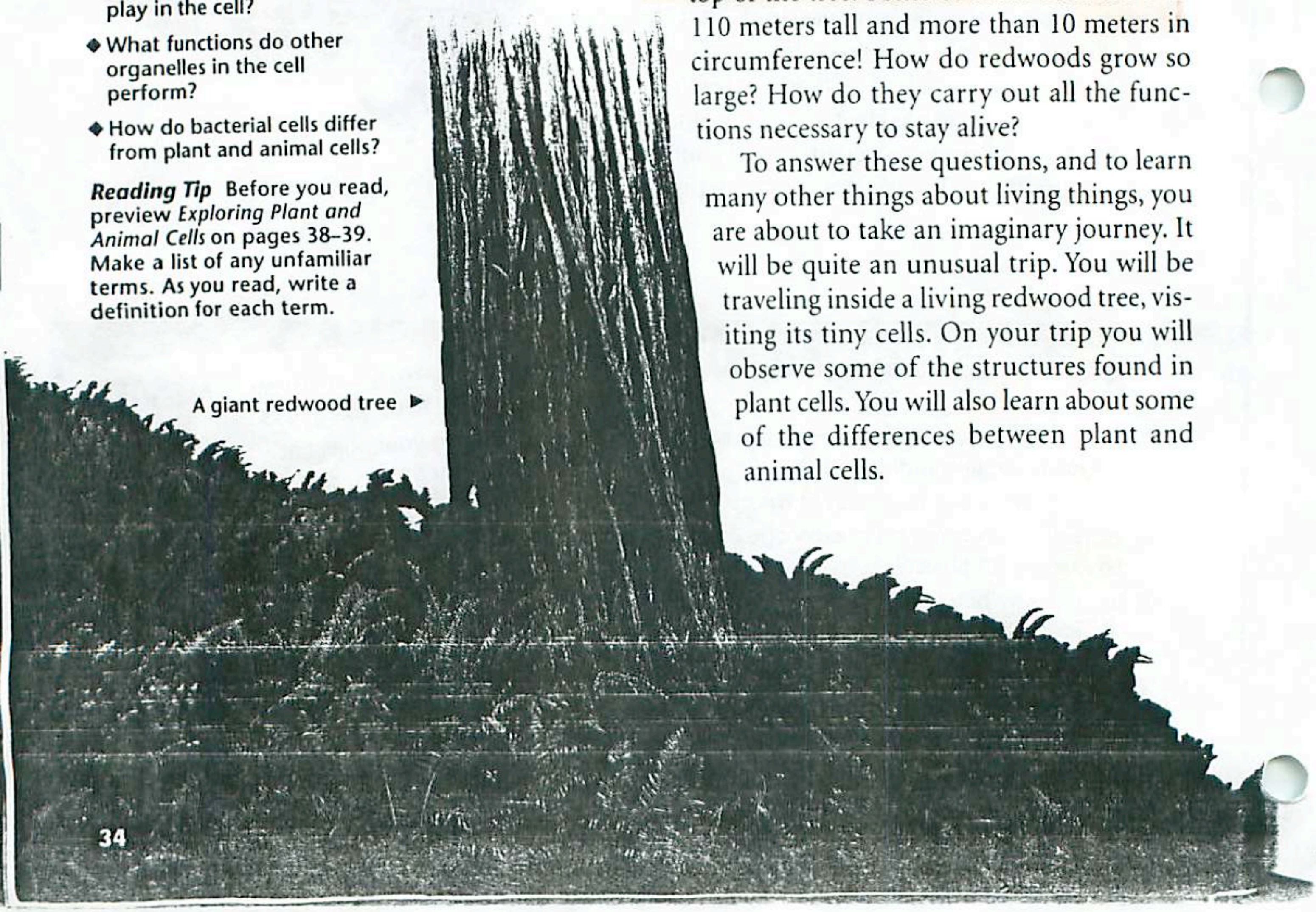
GUIDE FOR READING

- What role do the cell membrane and nucleus play in the cell?
- What functions do other organelles in the cell perform?
- How do bacterial cells differ from plant and animal cells?

Reading Tip Before you read, preview *Exploring Plant and Animal Cells* on pages 38–39. Make a list of any unfamiliar terms. As you read, write a definition for each term.

Imagine you're in California standing next to a giant redwood tree. You have to bend your head way back to see the top of the tree. Some of these trees are over 110 meters tall and more than 10 meters in circumference! How do redwoods grow so large? How do they carry out all the functions necessary to stay alive?

To answer these questions, and to learn many other things about living things, you are about to take an imaginary journey. It will be quite an unusual trip. You will be traveling inside a living redwood tree, visiting its tiny cells. On your trip you will observe some of the structures found in plant cells. You will also learn about some of the differences between plant and animal cells.



A giant redwood tree ▶

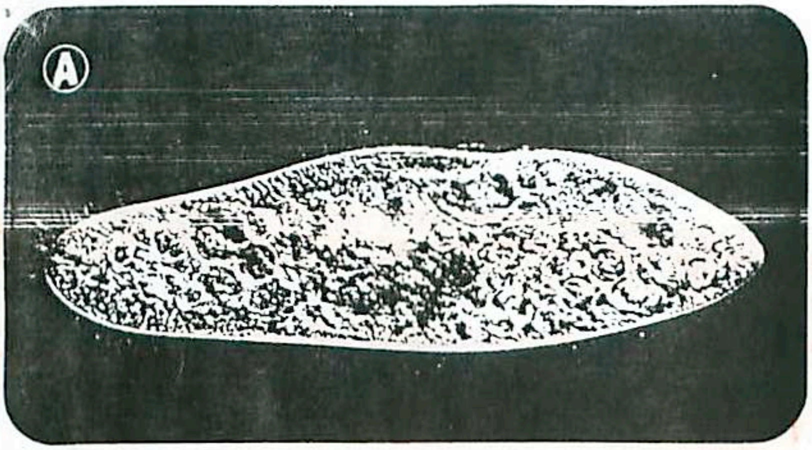


Figure 12 All cells have cell membranes, but not all cells have cell walls. **A.** The cell membrane of this single-celled paramecium controls what substances enter and leave the cell. **B.** The cell walls of these onion root cells have been stained green so you can see them clearly. Cell walls protect and support plant cells.

As you will discover on your journey, cells themselves contain even smaller structures. These tiny cell structures, called **organelles,** carry out specific functions within the cell. Just as your stomach, lungs, and heart have different functions in your body, each organelle has a different function within the cell. You can see the organelles found in plant and animal cells in *Exploring Plant and Animal Cells* on pages 38 and 39. Now it's time to hop aboard your imaginary ship and prepare to enter a typical plant cell.

Cell Wall

Entering a plant's cell is a bit difficult. First you must pass through the cell wall. The **cell wall** is a rigid layer of nonliving material that surrounds the cells of plants and some other organisms. The cell wall is made of a tough, yet flexible, material called cellulose. If you think of a wooden desk, you will have a good idea of what cellulose is. Wood contains a lot of cellulose.

The cells of plants and some other organisms have cell walls. In contrast, the cells of animals and some other organisms lack cell walls. A plant's cell wall helps to protect and support the cell. In woody plants, the cell walls are very rigid. This is why giant redwood trees can stand so tall. Each cell wall in the tree adds strength to the tree. Although the cell wall is stiff, many materials, including water and oxygen, can pass through the cell wall quite easily. So sail on through the cell wall and enter the cell.

☑ *Checkpoint* *What is the function of the cell wall?*

Cell Membrane

After you pass through the cell wall, the next structure you encounter is the **cell membrane.** All cells have cell membranes. In cells with cell walls, the cell membrane is located just inside the cell wall. In other cells, the cell membrane forms the outside boundary that separates the cell from its environment.

Language Arts CONNECTION

Writers often use analogies to help readers understand unfamiliar ideas. In an analogy, a writer explains something by comparing it to something similar with which the reader is more familiar. For example, the author of this textbook describes the cell membrane by making an analogy to a window screen. This analogy helps the readers understand that the cell membrane is a boundary that separates the cell from the outside environment.

In Your Journal

Identify other analogies used by the author. Then choose two cell parts from this section. Write an analogy for each part that helps explain its structure or function.

As your ship nears the edge of the cell membrane, you notice that there are tiny openings, or pores, in the cell membrane. You steer toward an opening. Suddenly, your ship narrowly misses being stuck by a chunk of waste material passing out of the cell. **You have discovered one of the cell membrane's main functions: the cell membrane controls what substances come into and out of a cell.**

Everything the cell needs—from food to oxygen—enters the cell through the cell membrane. Harmful waste products leave the cell through the cell membrane. For a cell to survive, the cell membrane must allow these materials to pass into and out of the cell. In a sense, the cell membrane is like a window screen. The screen keeps insects out of a room. But holes in the screen allow air to enter and leave the room.

Nucleus

As you sail inside the cell, a large, oval structure comes into view. This structure, called the **nucleus** (NOO klee us), acts as the "brain" of the cell. **You can think of the nucleus as the cell's control center, directing all of the cell's activities.**

Nuclear Membrane Notice in Figure 13 that the nucleus is surrounded by a nuclear membrane. Just as the cell membrane protects the cell, the nuclear membrane protects the nucleus. Materials pass in and out of the nucleus through small openings, or pores, in the nuclear membrane. So aim for that pore just ahead and carefully glide into the nucleus.

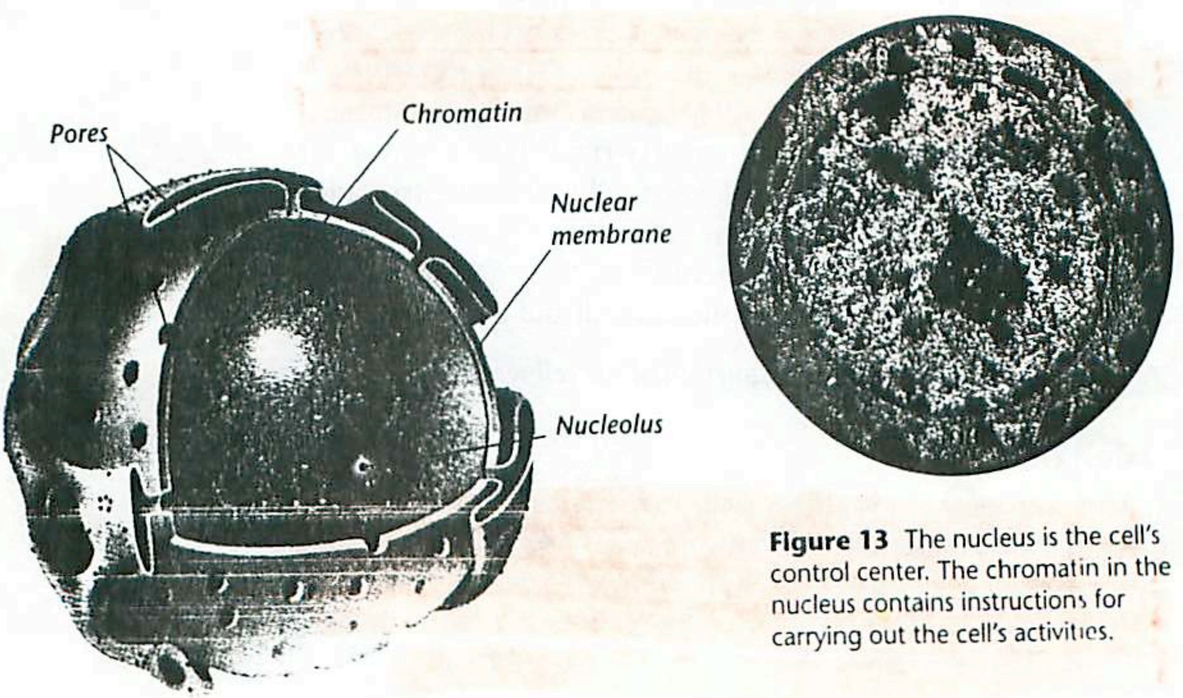


Figure 13 The nucleus is the cell's control center. The chromatin in the nucleus contains instructions for carrying out the cell's activities.

Chromatin You might wonder how the nucleus "knows" how to direct the cell. The answer lies in those thin strands floating directly ahead in the nucleus. These strands, called **chromatin,** contain the genetic material, the instructions that direct the functions of a cell. For example, the instructions in the chromatin ensure that leaf cells grow and divide to form more leaf cells. The genetic material is passed on to each new cell when an existing cell divides. You'll learn more about how cells divide in Chapter 2.

Nucleolus As you prepare to leave the nucleus, you spot a small object floating by. This structure, the nucleolus, is where ribosomes are made. Ribosomes are the organelles where proteins are produced.

☑ ***Checkpoint*** *Where in the nucleus is genetic material found?*

Organelles in the Cytoplasm

As you leave the nucleus, you find yourself in the **cytoplasm,** the region between the cell membrane and the nucleus. Your ship floats in a clear, thick, gel-like fluid. The fluid in the cytoplasm is constantly moving, so your ship does not need to propel itself. Many cell organelles are found in the cytoplasm. **The organelles function to produce energy, build and transport needed materials, and store and recycle wastes.**

Mitochondria As you pass into the cytoplasm, you see rod-shaped structures looming ahead. These organelles are called **mitochondria** (my tuh KAHN dree uh) (singular *mitochondrion*). Mitochondria are called the "powerhouses" of the cell because they produce most of the energy the cell needs to carry out its functions. Muscle cells and other very active cells have large numbers of mitochondria.

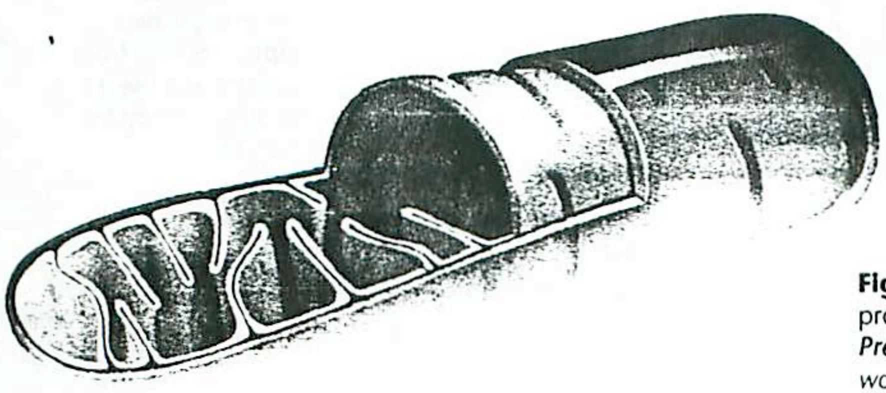
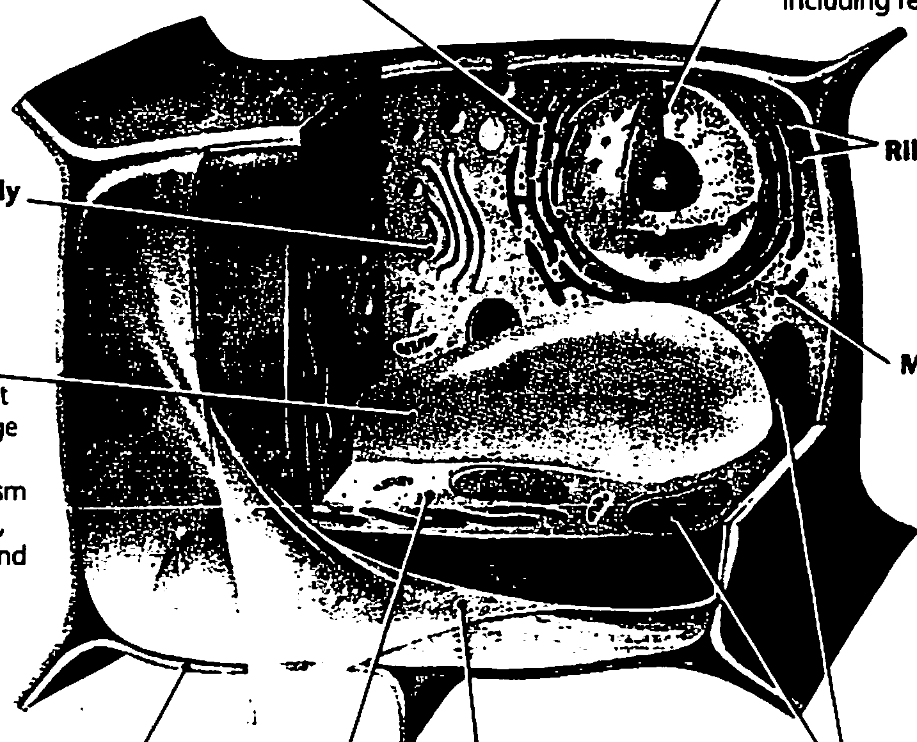


Figure 14 The mitochondria produce most of the cell's energy. ***Predicting*** *In what types of cells would you expect to find a lot of mitochondria?*

EXPLORING *Plant and Animal Cells*

On these pages, you can compare structures found in two kinds of cells: plant cells and animal cells. As you study these cells, remember that they are generalized cells. In living organisms, cells vary somewhat in shape and structure.

PLANT CELL



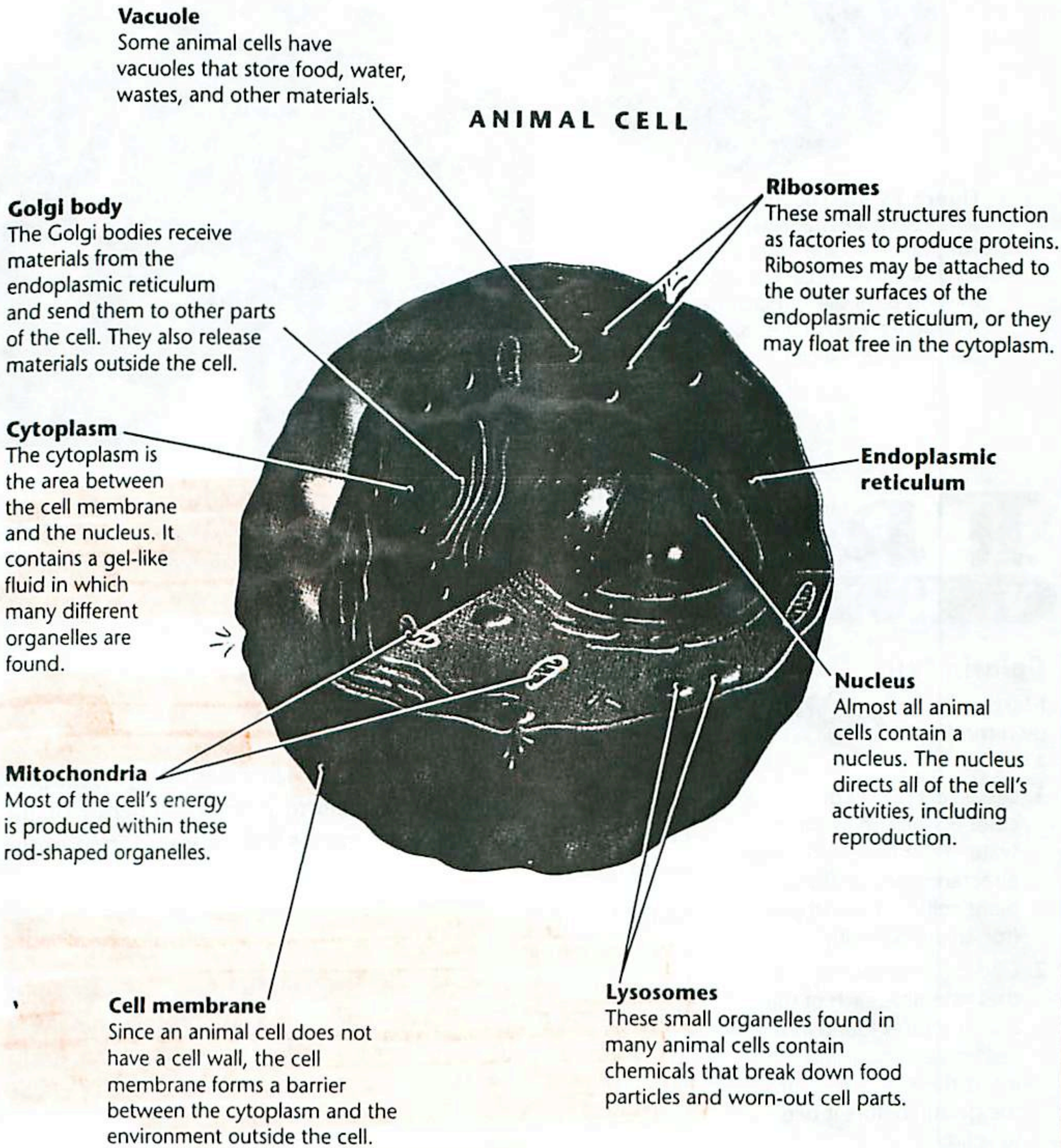

ANIMAL CELL
Vacuole
Some animal cells have vacuoles that store food, water, wastes, and other materials.
Golgi body
The Golgi bodies receive materials from the endoplasmic reticulum and send them to other parts of the cell. They also release materials outside the cell.
Cytoplasm
The cytoplasm is the area between the cell membrane and the nucleus. It contains a gel-like fluid in which many different organelles are found.
Mitochondria
Most of the cell's energy is produced within these rod-shaped organelles.
Cell membrane
Since an animal cell does not have a cell wall, the cell membrane forms a barrier between the cytoplasm and the environment outside the cell.
Ribosomes
These small structures function as factories to produce proteins. Ribosomes may be attached to the outer surfaces of the endoplasmic reticulum, or they may float free in the cytoplasm.
Endoplasmic reticulum
Nucleus
Almost all animal cells contain a nucleus. The nucleus directs all of the cell's activities, including reproduction.
Lysosomes
These small organelles found in many animal cells contain chemicals that break down food particles and worn-out cell parts.

Figure 15 The endoplasmic reticulum is a passageway through which proteins and other materials move within the cell. The spots on the outside of the endoplasmic reticulum are ribosomes, structures that produce proteins.

TRY THIS

Gelatin Cell

ACTIVITY

Make your own model of a cell.

1. Dissolve a packet of colorless gelatin in warm water. Pour the gelatin into a rectangular pan (for a plant cell) or a round pan (for an animal cell).
2. Choose different materials that resemble each of the cell structures found in the cell you are modeling. Insert these materials into the gelatin before it begins to solidify.

Making Models On a sheet of paper, develop a key that identifies each cell structure in your model. Describe the function of each structure.

Endoplasmic Reticulum As you sail farther into the cytoplasm, you find yourself in a maze of passageways called the **endoplasmic reticulum** (en duh PLAZ mik rih TIK yuh lum). These passageways carry proteins and other materials from one part of the cell to another.

Ribosomes Attached to the outer surface of the endoplasmic reticulum are small grainlike bodies called **ribosomes.** Other ribosomes are found floating in the cytoplasm. Ribosomes function as factories to produce proteins. The ribosomes pass the proteins to the endoplasmic reticulum. From the interior of the endoplasmic reticulum, the proteins will be transported to the Golgi bodies.

Golgi Bodies As you move through the endoplasmic reticulum, you see structures that look like a flattened collection of sacs and tubes. These structures, called **Golgi bodies,** can be thought of as the cell's mailroom. The Golgi bodies receive proteins and other newly formed materials from the endoplasmic reticulum, package them, and distribute them to other parts of the cell. The Golgi bodies also release materials outside the cell.

Chloroplasts Have you noticed the many large green structures floating in the cytoplasm? Only the cells of plants and some other organisms have these structures. These organelles, called **chloroplasts,** capture energy from sunlight and use it to produce food for the cell. It is the chloroplasts that give plants their green color. You will learn more about chloroplasts in Chapter 2.

Vacuoles Steer past the chloroplasts and head for that large, round, water-filled sac floating in the cytoplasm. This sac, called a **vacuole** (VAK yoo ohl), is the storage area of the cell. Most plant cells have one large vacuole. Some animal cells do not have vacuoles; others do.

Vacuoles store food and other materials needed by the cell. Vacuoles can also store waste products. Most of the water in plant cells is stored in vacuoles. When the vacuoles are full of water, they make the cell plump and firm. Without much water in the vacuoles, the plant wilts.

Lysosomes Your journey through the cell is almost over. Before you leave, take another look around you. If you carefully swing your ship around the vacuole, you may be lucky enough to see a lysosome. **Lysosomes** (LY suh sohmz) are small round structures that contain chemicals that break down large food particles into smaller ones. Lysosomes also break down old cell parts and release the substances so they can be used again. In this sense, you can think of the lysosomes as the cell's cleanup crew. Lysosomes are found in both animal cells and plant cells.

Although lysosomes contain powerful chemicals, you need not worry about your ship's safety. The membrane around a lysosome keeps these harsh chemicals from escaping and breaking down the rest of the cell.

Bacterial Cells

The plant and animal cells that you just learned about are very different from the bacterial cell you see in Figure 16. First, bacterial cells are usually smaller than plant or animal cells. A human skin cell, for example, is about 10 times as large as an average bacterial cell.

There are several other ways in which bacterial cells are different from plant and animal cells. **While a bacterial cell does have a cell wall and a cell membrane, it does not contain a nucleus.** Organisms whose cells lack a nucleus are called **prokaryotes** (proh KAR ee ohtz). The bacterial cell's genetic material, which looks like a thick, tangled string, is found in the cytoplasm. Bacterial cells contain ribosomes, but none of the other organelles found in plant or animal cells. Organisms whose cells contain a nucleus and many of the organelles you just read about are called **eukaryotes** (yoo KAR ee ohtz).

Figure 16 This single-celled organism is a type of bacteria. Bacterial cells lack a nucleus and some other organelles. ***Applying Concepts*** *Where is the genetic material in a bacterial cell found?*

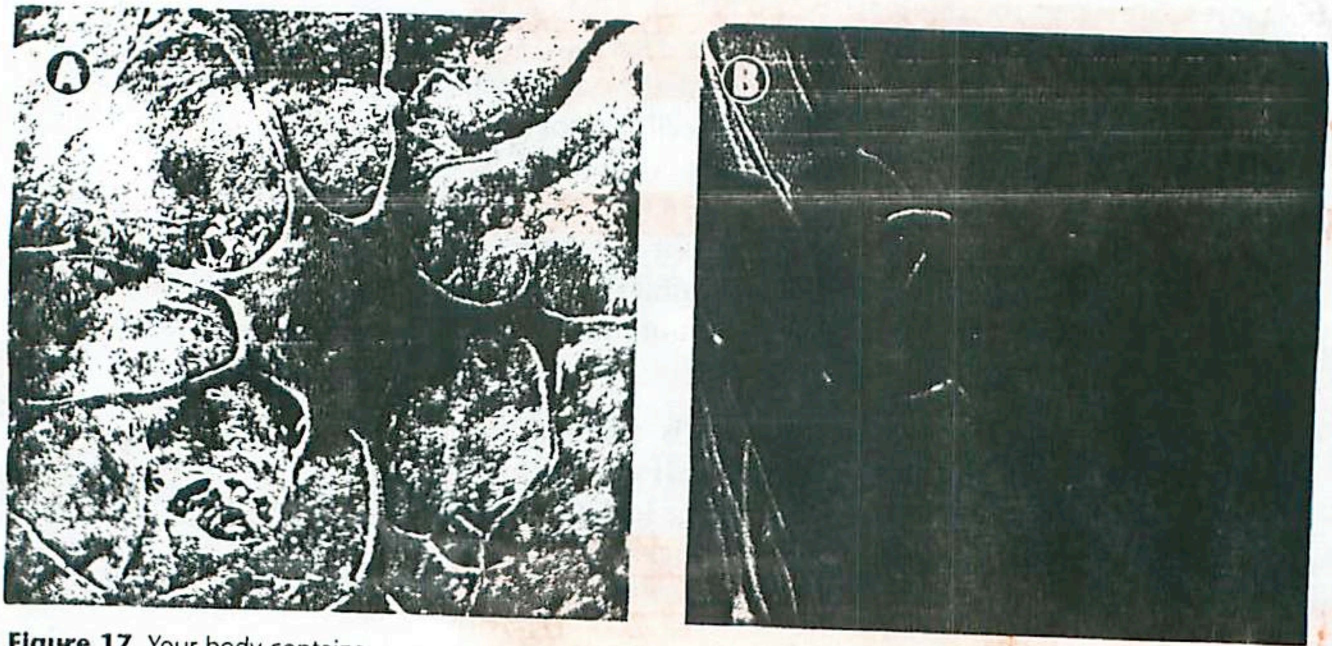


Figure 17 Your body contains a variety of different types of cells. **A.** Nerve cells have long projections through which messages are sent throughout the body. **B.** Red blood cells are thin and flexible, which allows them to fit through tiny blood vessels.

Specialized Cells

Unlike bacteria and other single-celled organisms, plants, animals (including yourself), and other organisms contain many cells. In a many-celled organism, the cells often vary greatly in size and structure. Think of the different parts of your body. You have skin, bones, muscles, blood, a brain, a liver, a stomach, and so on. Each of these body parts carries out a very different function. Yet all of these body parts are made up of cells.

Figure 17 shows two examples of different kinds of cells in your body—nerve cells and red blood cells. The structure of each kind of cell is suited to the unique function it carries out within the organism.

Section 3 Review

1. What is the function of the cell membrane?
2. Why is the nucleus sometimes called the control center of the cell?
3. Name two plant cell parts that are not found in animal cells. What is the function of each part?
4. How do the cells of bacteria differ from those of other organisms?
5. **Thinking Critically Comparing and Contrasting** Compare the functions of the cell wall in a plant cell and the cell membrane in an animal cell. How are the functions of the two structures similar and different?

Science at Home

Building Blocks Ask family members to help you find five items in your house that are made of smaller things. Make a list of the items and identify as many of their building blocks as you can. Be sure to look at prepared foods, furniture, and books. Discuss with your family how these building blocks come together to make up the larger objects. Do these objects or their building blocks possess any characteristics of living things?

Skills Lab

Observing

A Magnified View of Life

In this lab, you will use your observation skills to compare plant and animal cells.

Problem

How are plant and animal cells alike and different?

Materials

plastic dropper
water
microscope slide
microscope
colored pencils
prepared slide of animal cells
Elodea leaf
forceps
coverslip

Procedure

1. Before you start this lab, read *Using the Microscope* (Appendix B) on pages 802–803. Be sure you know how to use a microscope correctly and safely.

Part 1 Observing Plant Cells

2. Use a plastic dropper to place a drop of water in the center of a slide. **CAUTION:** *Slides and coverslips are fragile. Handle them carefully. Do not touch broken glass.*
3. With forceps, remove a leaf from an *Elodea* plant. Place the leaf in the drop of water on the slide. Make sure that the leaf is flat. If it is folded, straighten it with the forceps.
4. Holding a coverslip by its edges, slowly lower it onto the drop of water and *Elodea* leaf. If any air bubbles form, tap the slide gently to get rid of them.
5. Use a microscope to examine the *Elodea* leaf under low power. Then, carefully switch to high power.
6. Observe the cells of the *Elodea* leaf. Draw and label what you see, including the colors of the cell parts. Record the magnification.
7. Discard the *Elodea* leaf as directed by your teacher. Carefully clean and dry your slide and coverslip. Wash your hands thoroughly.

Part 2 Observing Animals Cells

8. Obtain a prepared slide of animal cells. The cells on the slide have been stained with an artificial color.
9. Observe the animal cells with a microscope under both low and high power. Draw and label the cell parts that you see. Record the magnification.

Analyze and Conclude

1. How are plant and animal cells alike?
2. How are plant and animal cells different?
3. What natural color appeared in the plant cells? What structures give the plant cells this color?
4. **Think About It** Why is it important to record your observations while you are examining a specimen?

More to Explore

Observe other prepared slides of animal cells. Look for ways that animal cells differ from each other. Obtain your teacher's permission before carrying out these observations.

Section 4 The Origin of Life

DISCOVER — ACTIVITY

How Can the Composition of Air Change?

1. Your teacher will give you two covered plastic jars. One contains a plant and one contains an animal.
2. Observe the organisms in each jar. Talk with a partner about how you think each organism affects the composition of the air in its jar.
3. Write a prediction about how the amount of oxygen in each jar would change over time if left undisturbed.
4. Return the jars to your teacher.

Think It Over

Inferring Scientists hypothesize that Earth's early atmosphere was different from today's atmosphere. What role might early organisms have played in bringing about those changes?

GUIDE FOR READING

- How was the atmosphere of early Earth different from today's atmosphere?
- How do scientists hypothesize that life arose on early Earth?

Reading Tip Before you read, write a paragraph stating what you already know about early life on Earth. As you read this section, make changes and additions to your paragraph.

You stare out the window of your time machine. You have traveled back to Earth as it was 3.6 billion years ago. The landscape is rugged, with bare, jagged rocks and little soil. You search for a hint of green, but there is none. You see only blacks, browns, and grays. Lightning flashes all around you. You hear the rumble of thunder, howling winds, and waves pounding the shore.

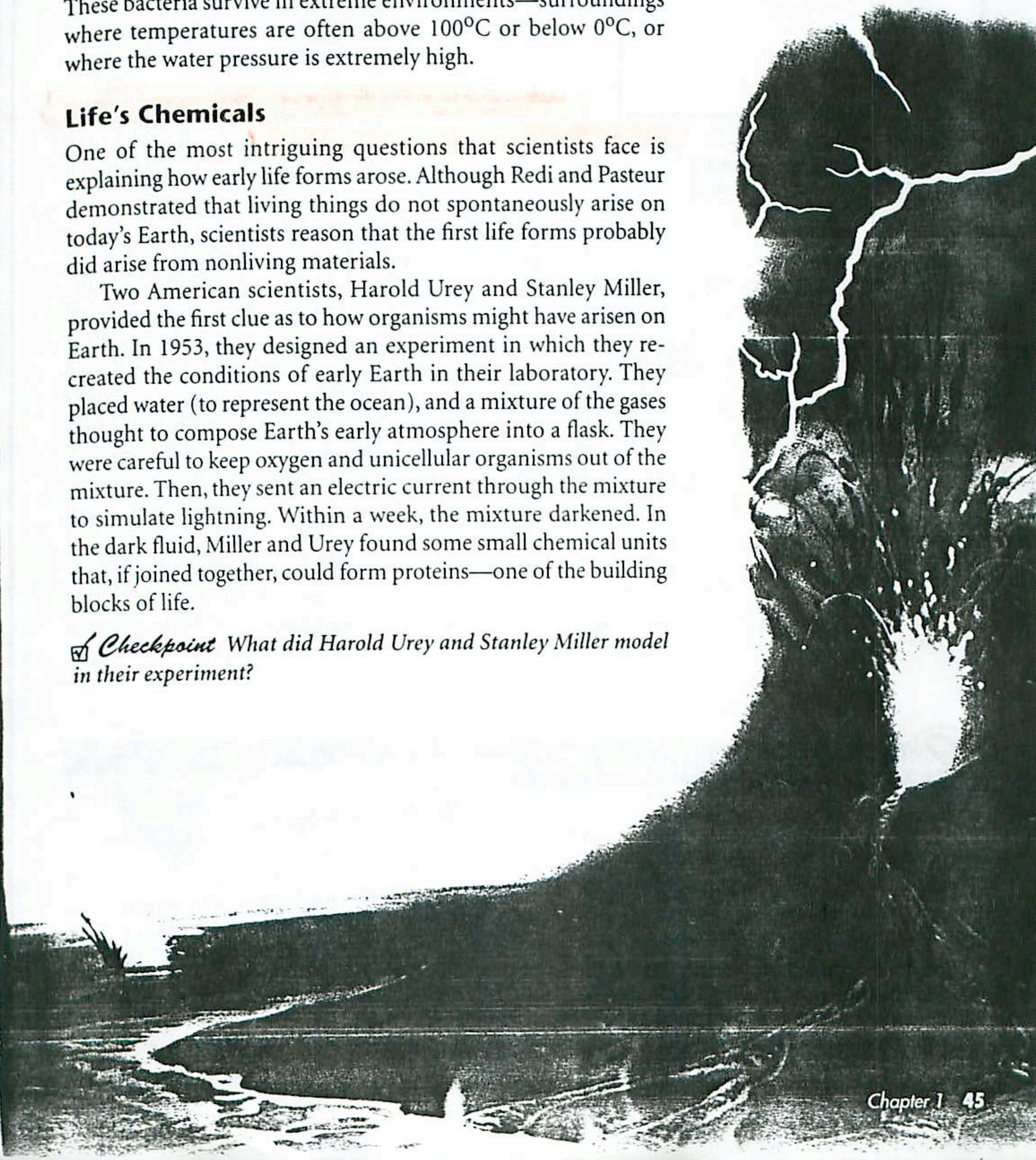
You neither see nor hear any living things. However, you know that this is the time period when scientists think that early life forms arose on Earth. You decide to explore. To be safe, you put on your oxygen mask. Stepping outside, you wonder what kinds of organisms could ever live in such a place.

Earth's Early Atmosphere

You were smart to put on your oxygen mask before exploring early Earth. Scientists think that early Earth had a different atmosphere than it has today. **Nitrogen, water vapor, carbon dioxide, and methane were probably the most abundant gases in Earth's atmosphere 3.6 billion years ago. Although all these gases are still found in the atmosphere today, the major gases are nitrogen and oxygen.** You, like most of today's organisms, could not have lived on Earth 3.6 billion years ago, because there was no oxygen in the air. Scientists think, however, that the first forms of life on Earth appeared at that time.

No one can ever be sure what the first life forms were like, but scientists have formed hypotheses about them. First, early life forms did not need oxygen to survive. Second, they were probably unicellular organisms. Third, they probably lived in the oceans. Many scientists think that the first organisms resembled the bacteria that live today in places without oxygen, such as the polar ice caps, hot springs, or the mud of the ocean bottoms. These bacteria survive in extreme environments—surroundings where temperatures are often above 100°C or below 0°C, or where the water pressure is extremely high.

Figure 18 The atmosphere of early Earth had little oxygen. There were frequent volcanic eruptions, earthquakes, and violent weather. ***Inferring*** *What conditions on early Earth would have made it impossible for modern organisms to survive?*



Life's Chemicals

One of the most intriguing questions that scientists face is explaining how early life forms arose. Although Redi and Pasteur demonstrated that living things do not spontaneously arise on today's Earth, scientists reason that the first life forms probably did arise from nonliving materials.

Two American scientists, Harold Urey and Stanley Miller, provided the first clue as to how organisms might have arisen on Earth. In 1953, they designed an experiment in which they re-created the conditions of early Earth in their laboratory. They placed water (to represent the ocean), and a mixture of the gases thought to compose Earth's early atmosphere into a flask. They were careful to keep oxygen and unicellular organisms out of the mixture. Then, they sent an electric current through the mixture to simulate lightning. Within a week, the mixture darkened. In the dark fluid, Miller and Urey found some small chemical units that, if joined together, could form proteins—one of the building blocks of life.

☑ ***Checkpoint*** *What did Harold Urey and Stanley Miller model in their experiment?*

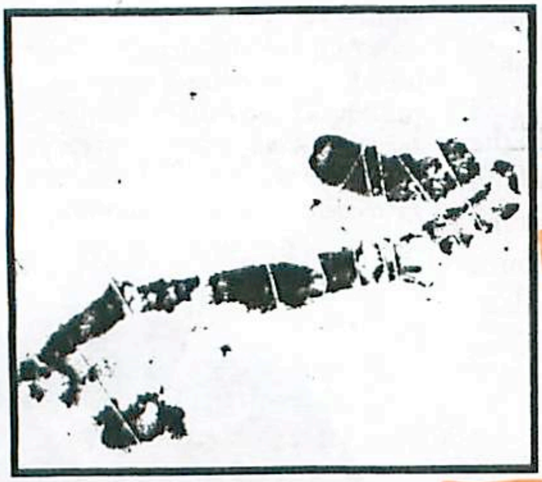


Figure 19 This fossil of bacteria-like cells was found in western Australia. It is the oldest fossil known—about 3.5 billion years old.

The First Cells

In experiments similar to Miller and Urey's, other scientists succeeded in producing chemical units that make up carbohydrates and nucleic acids. **From the results of these experiments, scientists hypothesized that the small chemical units of life formed gradually over millions of years in Earth's waters.** Some of these units joined to form the large chemical building blocks that are found in cells. Eventually, some of these large chemicals accumulated and became the forerunners of the first cells.

These hypotheses are consistent with evidence from fossils. **Fossils** are traces of ancient organisms that have been preserved in rock or other substances. The fossils in Figure 19 are of bacteria-like organisms that were determined to be between 3.4 and 3.5 billion years old. Scientists think that these ancient cells may be evidence of Earth's earliest life forms.

The first cells could not have needed oxygen to survive. They probably were heterotrophs that used the chemicals in their surroundings for energy. As they grew and reproduced, their numbers increased. In turn, the amount of chemicals available to them decreased. At some point, some of the cells may have developed the ability to make their own food. These early ancestors of today's autotrophs had an important effect on the atmosphere. As they made their own food, they produced oxygen as a waste product. As the autotrophs thrived, oxygen accumulated in Earth's atmosphere. Over many, many millions of years, the amount of oxygen increased to its current level.

No one will ever know for certain how life first appeared on Earth. However, scientists will continue to ask questions, construct models, and look for both experimental and fossil evidence about the origin of life on Earth.

Section 4 Review

1. Explain why you could not have survived in the atmosphere of early Earth.
2. Describe how scientists think that life could have arisen on Earth.
3. Describe Urey and Miller's experiment.
4. **Thinking Critically Inferring** How is the existence of organisms in hot springs today consistent with the scientific hypothesis of how life forms arose on Earth?

Check Your Progress

Now that you have completed your observations, analyze your data. Arrange your data in a chart or diagram. Find another object that is familiar to you and similar to your mystery object. Compare the two objects. Conclude whether your object is alive.

CHAPTER 1 STUDY GUIDE

Section 1 What Is Life?

Key Ideas

- All living things are made of cells, contain similar chemicals, use energy, grow and develop, respond to their surroundings, and reproduce.
- All living things must satisfy their basic needs for energy, water, living space, and stable internal conditions.

Key Terms

organism
cell
unicellular
multicellular
development
stimulus
response
reproduce
spontaneous generation
controlled experiment
variable
autotroph
heterotroph
homeostasis

Section 2 Discovering Cells

Key Ideas

- The invention of the microscope made the discovery of the cell possible.
- The cell theory explains the relationship between cells and living things.

Key Terms

microscope
compound microscope
cell theory
magnification
convex lens
resolution

Section 3 Looking Inside Cells

Key Ideas

- The cell membrane protects the cell and controls what substances enter and leave it.
- The nucleus is the cell's control center.
- Organelles in the cytoplasm perform many different vital functions.

Key Terms

organelle
cell wall
cell membrane
nucleus
chromatin
cytoplasm
mitochondrion
endoplasmic reticulum
ribosome
Golgi body
chloroplast
vacuole
lysosome
prokaryote
eukaryote

Section 4 The Origin of Life

INTEGRATING EARTH SCIENCE

Key Ideas

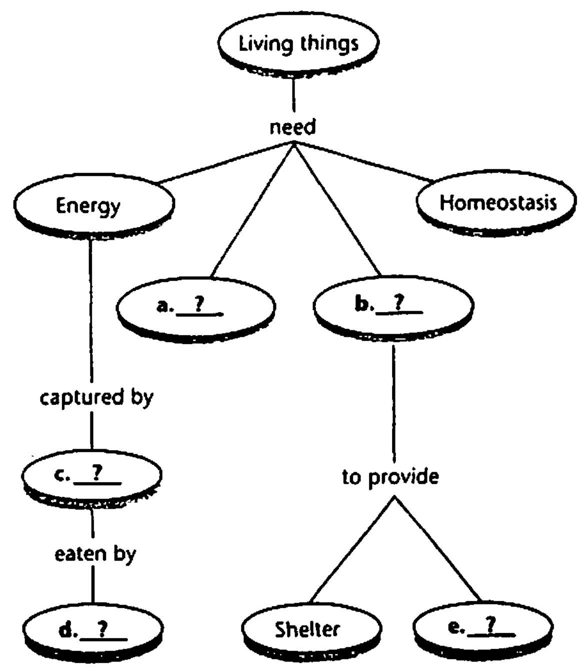
- Nitrogen, water vapor, carbon dioxide, and methane were probably the most abundant gases in Earth's atmosphere 3.6 billion years ago. Today the major gases are nitrogen and oxygen.
- Scientists hypothesize that over millions of years, the small chemical units of life formed in Earth's oceans. Over time, some of these units joined to form the large chemical building blocks found in cells.

Key Term

fossil

Organizing Information

Concept Map Copy the concept map about the needs of organisms onto a separate sheet of paper. Then complete it and add a title. (For more on concept maps, see the Skills Handbook.)



Reviewing Content

For more review of key concepts, see the Interactive Student Tutorial CD-ROM.

Multiple Choice

Choose the letter of the best answer.

1. The idea that life could spring from nonliving matter is called
   a. development.
   b. spontaneous generation.
   c. homeostasis.
   d. evolution.
2. The ability of microscopes to distinguish fine details is called
   a. resolution.
   b. bending.
   c. magnification.
   d. active transport.
3. In plant and animal cells, the control center of the cell is the
   a. chloroplast.
   b. ribosome.
   c. nucleus.
   d. Golgi body.
4. The storage compartment of a cell is the
   a. cell wall.
   b. lysosome.
   c. endoplasmic reticulum.
   d. vacuole.
5. Which gas was not part of Earth's atmosphere 3.6 billion years ago?
   a. methane
   b. nitrogen
   c. oxygen
   d. water vapor

True or False

If the statement is true, write true. If it is false, change the underlined word or words to make the statement true.

6. When you eat salad, you are acting like an <u>autotroph</u>.
7. Cells were discovered using <u>electron</u> microscopes.
8. <u>Vacuoles</u> are the "powerhouses" of the cell.
9. Bacterial cells differ from the cells of plants and animals in that they lack a <u>nucleus</u>.
10. The first organisms on Earth were probably <u>heterotrophs</u>.

Checking Concepts

11. Your friend thinks that plants are not alive because they do not move. How would you respond to your friend?
12. What role did the microscope play in the development of the cell theory?
13. Describe the function of the cell wall in the cells that have these structures.
14. Describe where Earth's early organisms lived, and how they obtained food.
15. **Writing to Learn** Suppose you had been a reporter assigned to cover early scientists' discoveries about cells. Write a brief article for your daily newspaper that explains one scientist's discoveries. Be sure to explain both how the discoveries were made and why they are important.

Thinking Critically

16. **Classifying** How do you know that a robot is not alive?
17. **Relating Cause and Effect** When people believed that spontaneous generation occurred, there was a recipe for making mice: Place a dirty shirt and a few wheat grains in an open pot; wait three weeks. List the reasons why this recipe might have worked. How could you demonstrate that spontaneous generation was not responsible for the appearance of mice?
18. **Applying Concepts** Explain how the cell theory applies to a dog.
19. **Predicting** Could a cell survive without a cell membrane? Give reasons to support your answer.
20. **Comparing and Contrasting** How are plant and animal cells similar? How are they different? To answer these questions, make a list of the different organelles in each cell. Explain how each organelle is vital to the life and function of a plant or animal.