Chapter 2

Living Things

The BIG Idea

Structure and Function

How are cells important to the structure and function of living things?

Chapter Preview

Each transparent ball is a tiny freshwater organism known as a *Volvox*.

Discovery CHANNEL SCHOOL

Cell Structure and Function

- ▶ Video Preview
- Video Field Trip
- Video Assessment

Lab zone™ **Chapter Project**

Mystery Object

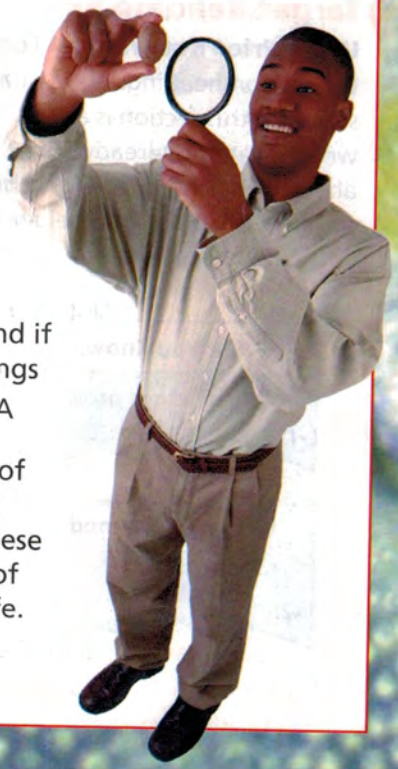
It's not always easy to tell whether something is alive. In this chapter, you will learn the characteristics of living things. As you study this chapter, your challenge will be to determine whether or not a mystery object is alive.

Your Goal To study a mystery object for several days to determine whether or not it is alive

To complete the project, you must

- care for your object following your teacher's instructions
- observe your object each day, and record your data
- determine whether your object is alive, and if so, to which domain and kingdom it belongs
- follow the safety guidelines in Appendix A

Plan It! Before you get started, create a list of characteristics that living things share. Think about whether nonliving things also share these characteristics. Also, think about what kind of tests you can carry out to look for signs of life. Create data tables in which to record your observations.



Section 1

What Is Life?

Reading Preview

Key Concepts

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

Key Terms

- organism • cell • unicellular
- multicellular • stimulus
- response • development
- spontaneous generation
- autotroph • heterotroph
- homeostasis

Target Reading Skill

Using Prior Knowledge Look at the section headings and visuals to see what this section is about. Then write what you already know about living things in a graphic organizer like the one below. As you read, write what you learn.

What You Know
1. Living things grow. 2.

What You Learned
1. 2.

Lab zone Discover Activity

Is It Living or Nonliving?

1. Your teacher will give you and a partner a wind-up toy.
2. One of you will look for evidence that the toy is alive and the other will look for evidence that the toy is not alive.
3. Observe the toy. List the evidence that supports your position about whether or not the toy is alive.
4. Share your lists with your classmates.

Think It Over

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

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

The Characteristics of Living Things

Living things share important characteristics. **All living things have a cellular organization, contain similar chemicals, use energy, respond to their surroundings, grow and develop, and reproduce.**

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. Cells are so small that you need a microscope to see them.

Organisms may be composed of only one cell or of many cells. **Unicellular,** or single-celled organisms, include bacteria (bak TIHR ee uh), the most numerous organisms on Earth. **Multicellular** organisms are composed of many cells that 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.

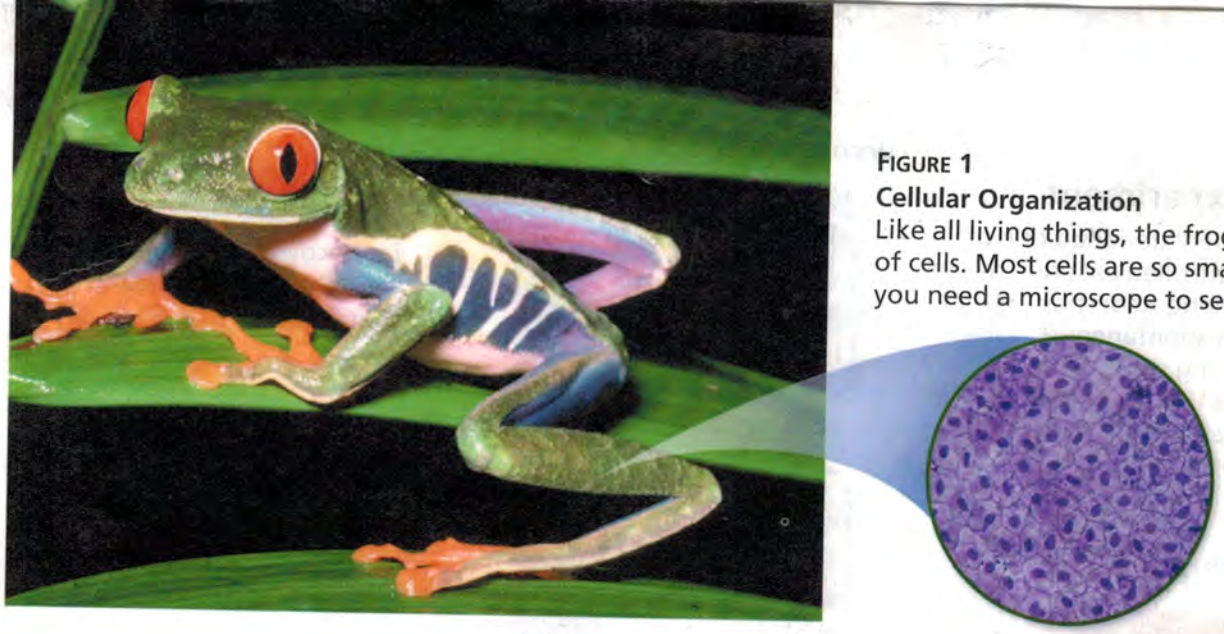


FIGURE 1
Cellular Organization
Like all living things, the frog is made of cells. Most cells are so small that you need a microscope to see them.

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 drayts), are a cell's main energy source. Two other chemicals, proteins (PROH teenz) and lipids, are the building materials of cells. Nucleic (noo KLEE ik) acids are the genetic material—the chemical instructions that direct the cell's activities.

Energy Use The cells of organisms use energy to do what living things must do, such as repairing injured parts. An organism's cells are always hard at work. For example, as you read this paragraph, your eye and brain cells are at work. Your blood cells are busy moving chemicals around your body.

Response to Surroundings Have you noticed that plant stems bend toward the light? Plants and all other 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. An organism reacts to a stimulus with a **response**—an action or change in behavior. For example, has the sound of a car horn ever startled you? The sound was a stimulus that caused your response.

Growth and Development Living things also 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.

Reproduction Another characteristic of organisms is the ability to reproduce, or produce offspring that are similar to the parents. For example, robins lay eggs that develop into young robins that closely resemble their parents.

Lab zone Try This Activity

React!

1. Have a partner clap his or her hands together about 10 centimeters 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.

FIGURE 2

Redi's Experiment

Francesco Redi designed one of the first controlled experiments. In his experiment, Redi showed that flies do not spontaneously arise from decaying meat.

Controlling Variables *What is the manipulated variable in this experiment?*

1. Redi placed meat in two identical jars. He left one jar uncovered. He covered the other jar with a cloth that let in air.

2. After a few days, Redi saw maggots (young flies) on the decaying meat in the open jar. There were no maggots on the meat in the covered jar.

3. Redi reasoned that flies had laid eggs on the meat in the open jar. The eggs hatched into maggots. Because flies could not lay eggs on the meat in the covered jar, there were no maggots there. Redi concluded that decaying meat did not produce maggots.

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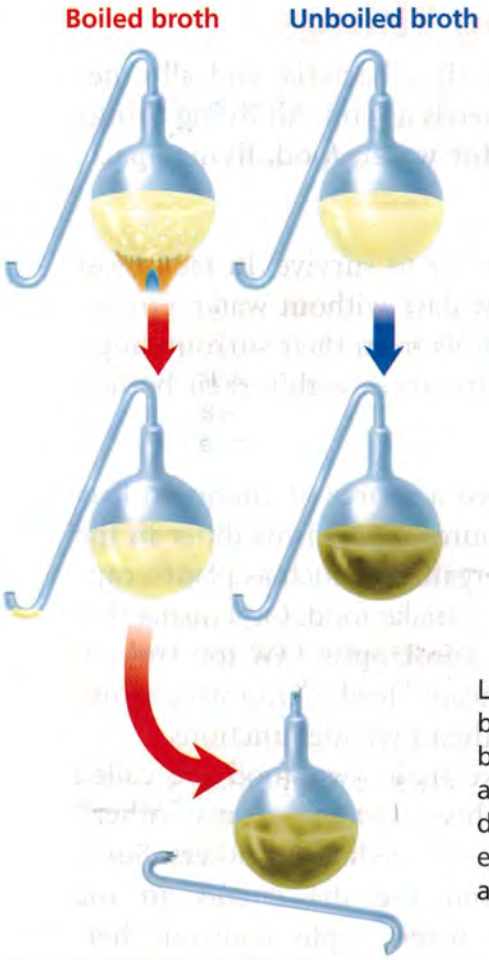
active art

For: Redi's and Pasteur's Experiments activity
Visit: PHSchool.com
Web Code: cep-1011

Life Comes From Life

Today, when people see moths fly out of a closet or weeds poking out of cracks in the sidewalk, they know that these organisms are the result of reproduction. **Living things arise from living things through reproduction.** However, four hundred years ago, people believed that life could appear from nonliving material. For example, they thought that flies could arise from rotting meat. The mistaken idea that living things can arise from nonliving sources is called **spontaneous generation.** It took hundreds of years of experiments to convince people that spontaneous generation does not occur.

Redi's Experiment In the 1600s, an Italian doctor named Francesco Redi helped to disprove spontaneous generation. Redi designed a controlled experiment to show that flies do not arise from decaying meat. Recall that in a controlled experiment, a scientist carries out two tests that are identical in every respect except for one factor. The one factor that a scientist changes is called the manipulated variable.



1 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.

Later, Pasteur took the flask with the broth that had remained clear and broke its curved neck. Bacteria from the air could now enter the flask. In a few days, the broth became cloudy. This evidence confirmed that new bacteria arise only from existing bacteria.

FIGURE 3
Pasteur's Experiment
Louis Pasteur's carefully controlled experiment demonstrated that bacteria arise only from existing bacteria.

▲ Pasteur in his laboratory

In Redi's experiment, shown in Figure 2, the manipulated variable was whether or not the jar was covered. Flies were able to enter the uncovered jar and lay their eggs on the meat inside. These eggs hatched into maggots, which developed into new flies. The flies could not enter the covered jar, however. Therefore, no maggots formed on the meat in the covered jar. Through his experiment, Redi was able to conclude that rotting meat does not produce flies.

Pasteur's Experiment Even after Redi's work, many people continued to believe that spontaneous generation could occur. In the mid-1800s, the French chemist Louis Pasteur designed some controlled experiments that finally rejected spontaneous generation. As shown in Figure 3, he demonstrated that new bacteria appeared in broth only when they were produced by existing bacteria. The experiments of Redi and Pasteur helped to convince people that living things do not arise from nonliving material.

Reading Checkpoint **What is a controlled experiment?**

Lab zone Skills Activity

Designing Experiments

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 hair dryer and a balance. Obtain your teacher's approval before carrying out your plan. How does your result compare with your prediction?

The Needs of Living Things

Though it may seem surprising, flies, bacteria, and all other organisms have the same basic needs as you. **All living things must satisfy their basic needs for water, food, living space, and stable internal conditions.**

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 obtain chemicals from their surroundings, break down food, grow, move substances within their bodies, and reproduce.

Food Recall that organisms need a source of energy to live. They use food as their energy source. Organisms differ in the ways they obtain energy. Some organisms, such as plants, capture the sun's energy and use it to make food. Organisms that make their own food are called **autotrophs** (AW toh trohfs). *Auto-* means "self" and *-troph* means "feeder." Autotrophs use the food they make to carry out their own life functions.

Organisms that cannot make their own food are called **heterotrophs** (HET uh roh trohfs). *Hetero-* means "other." Heterotrophs obtain their energy by feeding on others. Some heterotrophs eat autotrophs and use the energy in the autotroph's stored food. Other heterotrophs consume heterotrophs that eat autotrophs. Therefore, a heterotroph's energy source is also the sun—but in an indirect way. Animals, mushrooms, and slime molds are examples of heterotrophs.

Reading Checkpoint **Why are plants called autotrophs?**

FIGURE 4
Water, Food, and Living Space

This environment meets the needs of the many animals that live there. **Inferring** *How do plants meet their needs for food?*

The porcupine, a heterotroph, feeds on green plants.

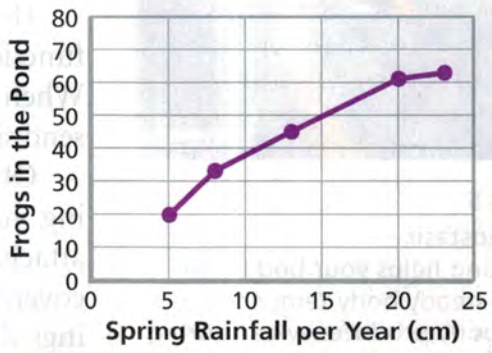
Math Analyzing Data

Frogs and Rainfall

Frogs need a moist environment, such as a pond, to survive. For five years, a scientist counted the frogs in a pond. The scientist also measured the spring rainfall.

1. **Reading Graphs** What data are plotted on the horizontal axis? What units were used?
2. **Interpreting Data** What was the greatest number of frogs that the scientist recorded? How much rain fell that spring?
3. **Making Generalizations** What is the relationship between the number of frogs and the amount of spring rain? What do you know about living things that might help explain that relationship?

Rainfall and Number of Frogs



Living Space All organisms need a place to live—a place to get food and water and find shelter. Whether an organism lives in the freezing Antarctic or the scorching desert, its surroundings must provide what it needs to survive.

Because there is a limited amount of space on Earth, some organisms must compete for space. Trees in a forest, for example, compete with other trees for sunlight above ground. Below ground, their roots compete for water and minerals.

FIGURE 5
Homeostasis
Sweating helps your body maintain a steady body temperature. Your body produces sweat during periods of strenuous activity. As the sweat evaporates, it cools your body down.

Stable Internal Conditions Organisms must be able to keep the conditions inside their bodies stable, even when conditions in their surroundings change significantly. For example, your body temperature stays steady despite changes in the air temperature. The maintenance of stable internal conditions is called **homeostasis** (hoh mee oh STAY sis).

Homeostasis keeps internal conditions just right for cells to function. Think about your need for water after a hard workout. When water levels in your body decrease, chemicals in your body send signals to your brain, causing you to feel thirsty.

Other organisms have different mechanisms for maintaining homeostasis. Consider barnacles, which as adults are attached to rocks at the edge of the ocean. At high tide, they are covered by water. At low tide, however, the watery surroundings disappear, and barnacles are exposed to hours of sun and wind. Without a way to keep water in their cells, they would die. Fortunately, a barnacle can close up its hard outer plates, trapping some water inside. In this way, a barnacle can keep its body moist until the next high tide.

Reading Checkpoint **What is homeostasis?**

Section 1 Assessment

Target Reading Skill **Using Prior Knowledge** Review your graphic organizer and revise it based on what you just learned in the section.

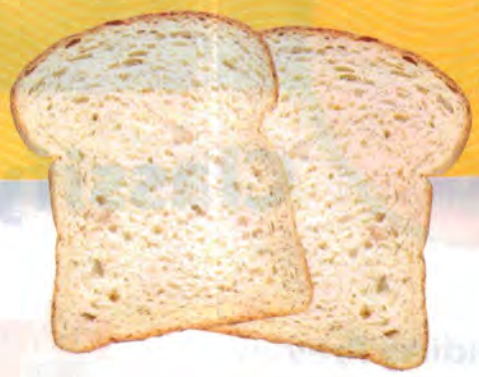
Reviewing Key Concepts

1. a. **Reviewing** List the six characteristics of living things.
   b. **Inferring** A bird sitting in a tree flies away as you walk by. Which of the life characteristics explains the bird's behavior?
   c. **Applying Concepts** Explain why the tree, which does not move away, is also considered a living thing.
2. a. **Defining** What was meant by the idea of *spontaneous generation*?
   b. **Explaining** Why is this idea incorrect?
   c. **Summarizing** How did Pasteur's experiment help show that spontaneous generation does not occur?
3. a. **Identifying** What four things do all organisms need to survive?
   b. **Describing** Which need is a fox meeting by feeding on berries?
   c. **Applying Concepts** The arctic fox has thick, dense fur in the winter and much shorter fur in the summer. How does this help the fox maintain homeostasis?

Lab zone **At-Home Activity**

Observing Life With a family member, observe a living thing, such as a family pet, a houseplant, or a bird outside your window. Record your observations as you study the organism. Prepare a chart that shows how the organism meets the four needs of living things discussed in this section.

Lab zone **Skills Lab**



Please Pass the Bread!

Problem

What factors are necessary for bread molds to grow?

Skills Focus

observing, controlling variables

Materials

- paper plates
- plastic dropper
- bread without preservatives
- sealable plastic bags
- tap water
- packing tape

Procedure

1. Brainstorm with others to predict which factors might affect the growth of bread mold. Record your ideas.
2. Place two slices of bread of the same size and thickness on separate, clean plates.
3. To test the effect of moisture on bread mold growth, add drops of tap water to one bread slice until the whole slice is moist. Keep the other slice dry. Expose both slices of bread to the air for one hour.
4. Put each slice into its own sealable bag. Press the outside of each bag to remove the air. Seal the bags. Then use packing tape to seal the bags again. Store the bags in a warm, dark place.
5. Copy the data table into your notebook.
6. Every day for at least five days, briefly remove the sealed bags from their storage place. Record whether any mold has grown. Estimate the area of the bread where mold is present. **CAUTION:** *Do not unseal the bags. At the end of the experiment, give the sealed bags to your teacher.*

Analyze and Conclude

1. **Observing** How did the appearance of the two slices of bread change over the course of the experiment?
2. **Inferring** How can you explain any differences in appearance between the two slices?
3. **Controlling Variables** What was the manipulated variable in this experiment? Why was it necessary to control all other variables except this one?
4. **Communicating** Suppose that you lived in Redi's time. A friend tells you that molds just suddenly appear on bread. How would you explain to your friend about Redi's experiment and how it applies to molds and bread?

Design an Experiment

Choose another factor that may affect mold growth, such as temperature or the amount of light. Set up an experiment to test the factor you choose. Remember to keep all conditions the same except for the one you are testing. *Obtain your teacher's permission before carrying out your investigation.*

Data Table

	Moistened Bread Slice		Unmoistened Bread Slice	
Day	Mold Present?	Area With Mold	Mold Present?	Area With Mold
1				
2				

Section 2

Classifying Organisms

Reading Preview

Key Concepts

- Why do biologists organize living things into groups?
- What do the levels of classification indicate about the relationship between organisms?
- What characteristics are used to classify organisms into domains and kingdoms?

Key Terms

- classification • taxonomy
- binomial nomenclature
- genus • species • prokaryote
- nucleus • eukaryote

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what*, *why*, or *how* question for each heading. As you read, write the answers to your questions.

Classifying Organisms

Question	Answer
Why do scientists classify?	Scientists classify because . . .

Lab zone Discover Activity

Can You Organize a Junk Drawer?

1. Your teacher will give you some items that you might find in the junk drawer of a desk. Your job is to organize the items.
2. Examine the objects and decide on three groups into which you can sort them.
3. Place each object into one of the groups, based on how the item's features match the characteristics of the group.
4. Compare your grouping system with those of your classmates.

Think It Over

Classifying Which of your classmates' grouping systems seemed most useful? Why?

Suppose you had only ten minutes to run into a supermarket to get what you needed—milk and tomatoes. Could you do it? In most supermarkets this would be an easy task. You'd probably find out where the dairy and produce sections are, and head straight to those areas. Now imagine if you had to shop for these same items in a market where things were randomly placed throughout the store. Where would you begin? You'd have to search through a lot of things before you found what you needed. You could be there for a long time!

FIGURE 6
Classifying Vegetables
Vegetables in the produce section of a supermarket are neatly organized.

FIGURE 7
Classifying Beetles
These beetles belong to a large insect collection in a natural history museum. They have been classified according to characteristics they share. **Observing** *What characteristics may have been used to group these beetles?*

Why Do Scientists Classify?

Just as shopping can be a problem in a disorganized store, finding information about a specific organism can also be a problem. So far, scientists have identified more than one million kinds of organisms on Earth. That's a large number, and it is continually growing as scientists discover new organisms. Imagine how difficult it would be to find information about one particular organism if you had no idea even where to begin. It would be a lot easier if similar organisms were placed into groups.

Organizing living things into groups is exactly what biologists have done. Biologists group organisms based on similarities, just as grocers group milk with dairy products and tomatoes with produce. **Classification** is the process of grouping things based on their similarities.

Biologists use classification to organize living things into groups so that the organisms are easier to study. The scientific study of how living things are classified is called **taxonomy** (tak SAHN uh mee). Taxonomy is useful because once an organism is classified, a scientist knows a lot about that organism. For example, if you know that a crow is classified as a bird, then you know that a crow has wings, feathers, and a beak.

Reading Checkpoint **What is the scientific study of how living things are classified called?**

The Naming System of Linnaeus

Taxonomy also involves naming organisms. In the 1750s, the Swedish naturalist Carolus Linnaeus devised a system of naming organisms that is still used today. Linnaeus placed organisms in groups based on their observable features. Based on his observations, Linnaeus gave each organism a unique, two-part scientific name. This naming system Linnaeus used is called **binomial nomenclature** (by NOH mee ul NOH men klay chur). The word *binomial* means "two names."

Genus and Species The first word in an organism's scientific name is its genus. A **genus** (JEE nus) (plural *genera*) is a classification grouping that contains similar, closely related organisms. For example, pumas, marbled cats, and house cats are all classified in the genus *Felis*. Organisms that are classified in the genus *Felis* share characteristics such as sharp, retractable claws and behaviors such as hunting other animals.

The second word in a scientific name often describes a distinctive feature of an organism, such as where it lives or its appearance. Together, the two words indicate a unique species. A **species** (SPEE sheez) is a group of similar organisms that can mate with each other and produce offspring that can also mate and reproduce.

Reading Checkpoint **What kind of name did Linnaeus give each organism?**

FIGURE 8 Binomial Nomenclature

These three species of cats belong to the same genus. Their scientific names, written in Latin, share the same first word, *Felis*. The second word of their names describes a feature of the animal. **Classifying** *What characteristics do these species share?*

Felis concolor (Puma)
Concolor means "the same color." Notice that this animal's coat is mostly the same color.

Felis marmorata (Marbled cat)
Notice the marbled pattern of this animal's coat. *Marmorata* means "marble."

Felis domesticus
(House cat)
Domesticus means "of the house."

Using Binomial Nomenclature Notice in Figure 8 that a complete scientific name is written in italics. Only the first letter of the first word is capitalized. Notice also that scientific names contain Latin words. Linnaeus used Latin because it was the language that scientists used during that time.

Binomial nomenclature makes it easy for scientists to communicate because everyone uses the same name for the same organism. Using different names can get confusing. For instance, people call the animal in Figure 9 a woodchuck, groundhog, or whistlepig. Fortunately, it has only one scientific name—*Marmota monax*.

Levels of Classification

The classification system that scientists use today is based on the contributions of Linnaeus. But today's classification system uses a series of many levels to classify organisms.

To help you understand the levels in classification, imagine a room filled with everybody from your state. First, all of the people from your town raise their hands. Then, those from your neighborhood raise their hands. Then, those from your street raise their hands. Finally, those from your house raise their hands. Each time, fewer people raise their hands. But you'd be in all of the groups. The most general group you belong to is the state. The most specific group is the house. The more levels you share with others, the more you have in common with them. Of course, organisms are not grouped by where they live, but rather by their shared characteristics.

The Major Levels of Classification Most biologists today classify organisms into eight levels. First, an organism is placed in a broad group, which in turn is divided into more specific groups. **The more classification levels that two organisms share, the more characteristics they have in common.**

Here are the eight classification levels that biologists commonly use.

- A domain is the highest level of organization.
- Within a domain, there are kingdoms.
- Within kingdoms, there are phyla (FY luh) (singular *phylum*).
- Within phyla are classes.
- Within classes are orders.
- Within orders are families.
- Each family contains one or more genera.
- Each genus contains one or more species.

FIGURE 9
Marmota monax
Although there are many common names for this animal, it has only one scientific name, *Marmota monax*.

Go Online
SCILINKS NSTA
For: Links on kingdoms
Visit: www.SciLinks.org
Web Code: scn-0113

Classifying an Owl Look at Figure 10 to see how the great horned owl is classified. The top row shows a wide variety of organisms that share the owl's domain. Notice that as you move down the levels, there are fewer kinds of organisms in each group. The organisms in each new group have more in common, however. For example, the class Aves includes all birds. The order Strigiformes includes only owls.

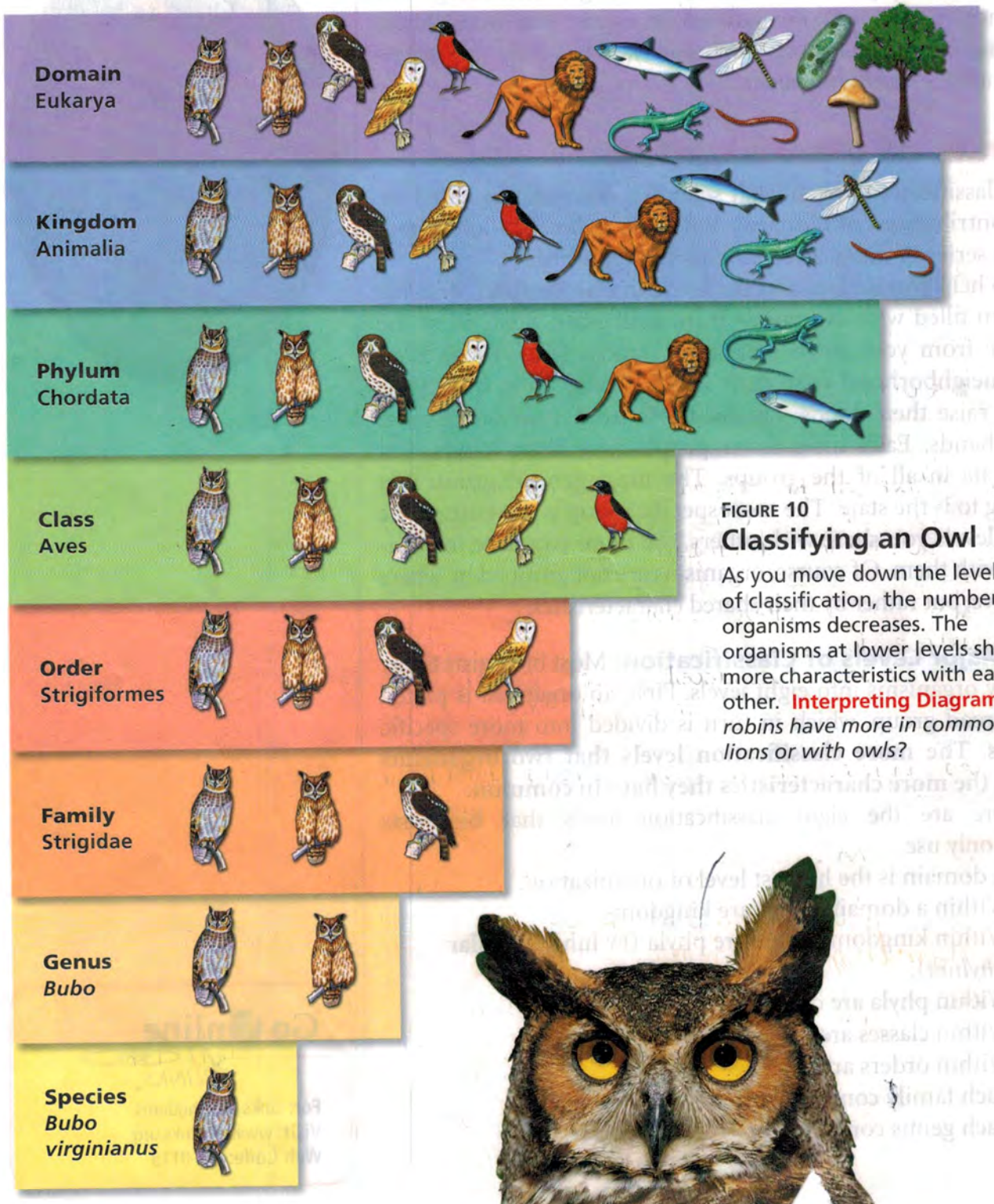


FIGURE 10
Classifying an Owl
As you move down the levels of classification, the number of organisms decreases. The organisms at lower levels share more characteristics with each other. **Interpreting Diagrams** *Do robins have more in common with lions or with owls?*

Domains and Kingdoms

Today, a three-domain system of classification is commonly used. Shown in Figure 11, the three domains are Bacteria, Archaea, and Eukarya. Within the domains are kingdoms. **Organisms are placed into domains and kingdoms based on their cell type, their ability to make food, and the number of cells in their bodies.**

Bacteria Although you may not know it, members of the domain Bacteria are all around you. You can find them in the yogurt you eat, on every surface you touch, and inside your body, both when you are healthy and sick. Some bacteria are autotrophs, while others are heterotrophs.

Members of the domain Bacteria are prokaryotes (proh KA ree ohtz). **Prokaryotes** are organisms whose cells lack a nucleus. A **nucleus** (NOO klee us) (plural *nuclei*) is a dense area in a cell that contains nucleic acids—the chemical instructions that direct the cell's activities. In prokaryotes, nucleic acids are not contained within a nucleus.

Archaea Deep in the Pacific Ocean, hot gases and molten rock spew out from a vent in the ocean floor. Surprisingly, a group of tiny organisms thrives there. They are members of the domain Archaea (ahr KEE uh), whose name comes from the Greek word for "ancient." Archaea can be found in some of the most extreme environments on Earth, including hot springs, very salty water, swamps, and the intestines of cows! Scientists think that the harsh conditions in which archaea live are similar to those of ancient Earth.

Like bacteria, archaea are unicellular prokaryotes. And like bacteria, some archaea are autotrophs while others are heterotrophs. Archaea are classified in their own domain, however, because their structure and chemical makeup differ from that of bacteria.

Reading Checkpoint What is a nucleus?

Lab zone Skills Activity

Classifying

Test your classifying skills using Figure 10. Look carefully at the organisms pictured together at the kingdom level. Make a list of the characteristics that the organisms share. Then make two more lists of shared characteristics—one for the organisms at the class level and the other for those at the genus level. How does the number of shared characteristics on your lists change at each level?

Three Domains of Life

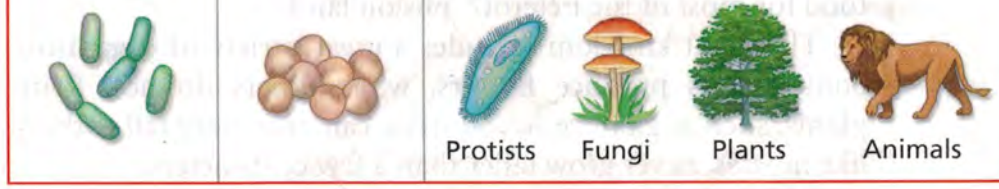


FIGURE 11
Three Domains
In the three-domain system of classification, all known organisms belong to one of three domains—Bacteria, Archaea, or Eukarya.

▲ **Protists:** Paramecium

▲ **Fungi:** Mushrooms

FIGURE 12

Domain Eukarya

You can encounter organisms from all four kingdoms of Eukarya on a hike through the woods.

Making Generalizations *What characteristic do all Eukarya share?*

Domain Eukarya

What do seaweeds, mushrooms, tomatoes, and dogs have in common? They are all members of the domain Eukarya. Organisms in this domain are **eukaryotes** (yoo KA ree ohtz)—organisms with cells that contain nuclei. **Scientists classify organisms in the domain Eukarya into one of four kingdoms: protists, fungi, plants, or animals.**

Protists A protist (PROH tist) is any eukaryotic organism that cannot be classified as an animal, plant, or fungus. Because its members are so different from one another, the protist kingdom is sometimes called the "odds and ends" kingdom. For example, some protists are autotrophs, while other protists are heterotrophs. Most protists are unicellular, but some, such as seaweeds, are large multicellular organisms.

Fungi If you have eaten mushrooms, then you have eaten fungi (FUN jy). Mushrooms, molds, and mildew are all fungi. Most fungi are multicellular eukaryotes. A few, such as the yeast you use for baking, are unicellular eukaryotes. Fungi are found almost everywhere on land, but only a few live in fresh water. All fungi are heterotrophs. Most fungi feed by absorbing nutrients from dead or decaying organisms.

Plants Dandelions on a lawn, mosses in a forest, and peas in a garden are familiar members of the plant kingdom. Plants are all multicellular eukaryotes and most live on land. In addition, plants are autotrophs that make their own food. Plants provide food for most of the heterotrophs on land.

The plant kingdom includes a great variety of organisms. Some plants produce flowers, while others do not. Some plants, such as giant redwood trees, can grow very tall. Others, like mosses, never grow taller than a few centimeters.

▲ **Plants:** Moss

▲ **Animals:** Salamander

Animals A dog, a flea on the dog's ear, and a cat that the dog chases have much in common because all are animals. All animals are multicellular eukaryotes. In addition, all animals are heterotrophs. Animals have different adaptations that allow them to locate food, capture it, eat it, and digest it. Members of the animal kingdom live in diverse environments throughout Earth. Animals can be found from ocean depths to mountaintops, from hot, scalding deserts to cold, icy landscapes.

Reading Checkpoint **Which two kingdoms consist only of heterotrophs?**

Section 2 Assessment

Target Reading Skill **Asking Questions** Use the answers to the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. a. **Reviewing** Why do biologists classify?
   b. **Inferring** Suppose someone tells you that a jaguarundi is classified in the same genus as a house cat. What characteristics do you think a jaguarundi might have?
   c. **Predicting** What genus name would you expect a jaguarundi to have? Explain.
2. a. **Listing** List in order the levels of classification, beginning with domain.
   b. **Applying Concepts** Woodchucks are classified in the same family as squirrels, but in a different family than mice. Do woodchucks have more characteristics in common with squirrels or mice? Explain.
3. a. **Identifying** What are the three domains into which organisms are classified?
   b. **Classifying** Which two domains include only organisms that are prokaryotes?
   c. **Comparing and Contrasting** How do the members of the two domains of prokaryotes differ?

Lab zone **At-Home Activity**

Kitchen Classification With a family member, go on a "classification hunt" in the kitchen. Look in your refrigerator, cabinets, and drawers to discover what classification systems your family uses to organize items. Then explain to your family member the importance of classification in biology.

Section 3

• Tech & Design •

Discovering Cells

Reading Preview

Key Concepts

- What are cells?
- How did the invention of the microscope contribute to knowledge about living things?
- What is the cell theory?
- How do microscopes produce magnified images?

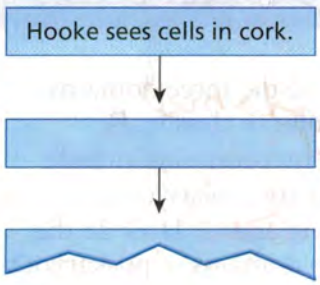
Key Terms

• cell • microscope • cell theory

Target Reading Skill

Sequencing A sequence is the order in which a series of events occurs. As you read, construct a flowchart showing how the work of Hooke, Leeuwenhoek, Schleiden, Schwann, and Virchow contributed to scientific understanding of cells.

Discovering Cells



Lab zone Discover Activity

Is Seeing Believing?

1. Cut a black-and-white photograph out of a page in a newspaper. With only your eyes, closely examine the photo. Record your observations.
2. Examine the same photo with a hand lens. Again, 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 that you could not see with only your eyes? What additional details could you see with the microscope?

A forest is filled with an amazing variety of living things. Some are easy to see, but you have to look closely to find others. If you look carefully at the floor of a forest, you can often find spots of bright color. A beautiful pink coral fungus grows beneath tall trees. Beside the pink fungus, a tiny red newt perches on a fallen leaf.

What do you think a fungus, a tree, and a red newt have in common? They are all living things, or organisms, and, like all organisms, they are made of cells.

FIGURE 13
Newt and Coral Fungus
All living things are made of cells, including this pink fungus and the red newt that perches next to it.

An Overview of Cells

You are made of cells. **Cells are the basic units of structure and function in living things.** This means that **cells** form the parts of an organism and carry out all of an organism's processes, or functions.

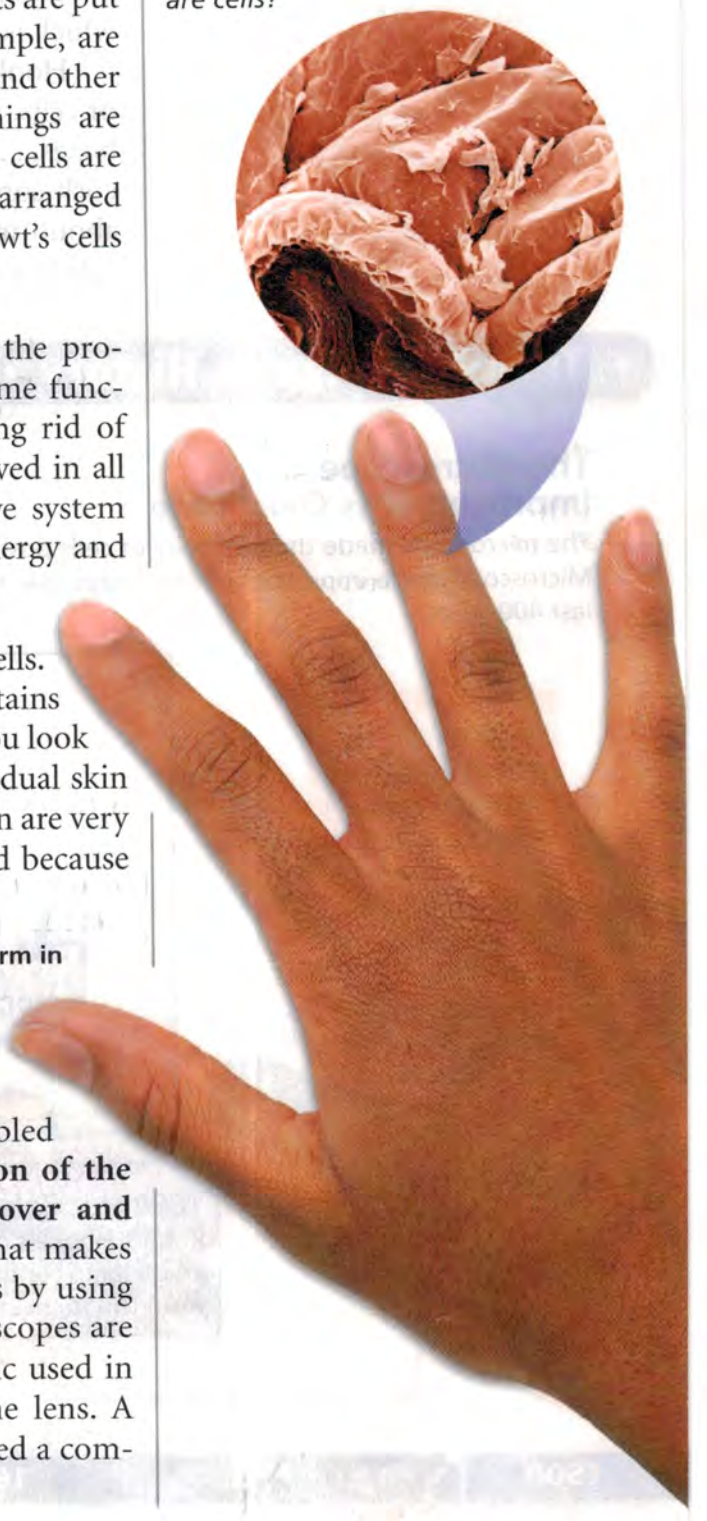
Cells and Structure When you describe the structure of an object, you describe what it is made of and how its parts are put together. The structures of many buildings, for example, are determined by the way in which bricks, steel beams, and other materials are arranged. The structures of living things are determined by the amazing variety of ways in which cells are put together. A tall tree, for example, consists of cells arranged to form a high trunk and leafy branches. A red newt's cells form a body with a head and four legs.

Cells and Function An organism's functions are the processes that enable it to stay alive and reproduce. Some functions in organisms include obtaining oxygen, getting rid of wastes, obtaining food, and growing. Cells are involved in all these functions. For example, cells in your digestive system absorb food. The food provides your body with energy and materials needed for growth.

Many and Small Figure 14 shows human skin cells. One square centimeter of your skin's surface contains more than 100,000 cells. But no matter how closely you look with your eyes alone, you won't be able to see individual skin cells. That is because, like most cells, those of your skin are very small. Until the late 1600s, no one knew cells existed because there was no way to see them.

Reading Checkpoint **What are some functions that cells perform in living things?**

FIGURE 14
Skin Cells
Your skin is made of cells such as these. **Applying Concepts** *What are cells?*



First Observations of Cells

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 or plastic used in eyeglasses. A simple microscope contains only one lens. A light microscope that has more than one lens is called a compound microscope.

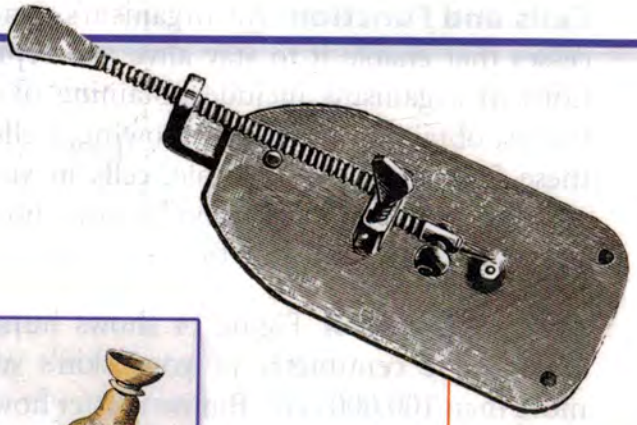
Robert Hooke One of the first people to observe cells was the English scientist and inventor Robert Hooke. Hooke built his own compound microscope, which was one of the best microscopes of his time. In 1663, Hooke used his microscope to observe the structure of a thin slice of cork. Cork, the bark of the cork oak tree, is made up of cells that are no longer alive. To Hooke, the empty spaces in the cork looked like tiny rectangular rooms. Therefore, Hooke called the empty spaces *cells*, which is a word meaning "small rooms."

Hooke described his observations this way: "These pores, or cells, were not very deep, but consisted of a great many little boxes. . . ." What most amazed Hooke was how many cells the cork contained. He calculated that in a cubic inch there were about twelve hundred million cells—a number he described as "almost incredible."

• Tech & Design in History •

The Microscope: Improvements Over Time

The microscope made the discovery of cells possible. Microscopes have improved in many ways over the last 400 years.



1590 First Compound Microscope
Dutch eyeglass makers Zacharias and Hans Janssen made one of the first compound microscopes. It was a tube with a lens at each end.

1660 Hooke's Compound Microscope
Robert Hooke's compound microscope included an oil lamp for lighting. A lens focuses light from the flame onto the specimen.

1674 Leeuwenhoek's Simple Microscope
Although Anton van Leeuwenhoek's simple microscope used only one tiny lens, it could magnify a specimen up to 266 times.

1500 | 1600 | 1700

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 who sold cloth. In his spare time, he built simple microscopes.

Leeuwenhoek looked at drops of lake water, scrapings from teeth and gums, and water from rain gutters. In many materials, Leeuwenhoek was surprised to find a variety of one-celled organisms. Leeuwenhoek noted that many of these tiny organisms moved. Some whirled, some hopped, and some shot through water like fast fish. He called these moving organisms *animalcules* (an ih MAL kyoolz), meaning "little animals."

Reading Checkpoint **Which type of microscope—simple or compound—did Leeuwenhoek make and use?**

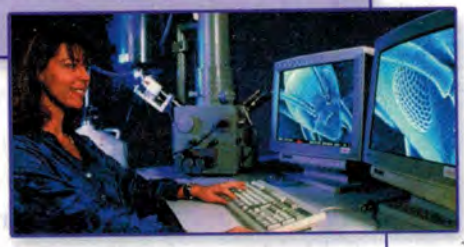
Writing in Science

Research and Write Find out more about one of the microscopes. Then 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.

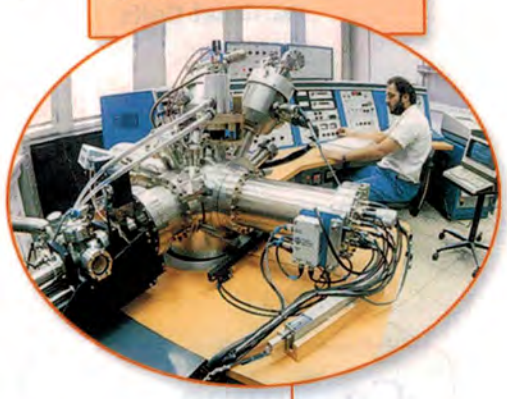
1886 Modern Compound Light Microscope
German scientists Ernst Abbé and Carl Zeiss made a compound light microscope with complex lenses that greatly improved the image. A mirror focuses light up through the specimen. Modern compound microscopes can effectively magnify a specimen up to 1,000 times.

1933 Transmission Electron Microscope (TEM)
German physicist Ernst Ruska created the first electron microscope. TEMs send electrons through a very thinly sliced specimen. TEMs can magnify a specimen up to 500,000 times.

1965 Scanning Electron Microscope (SEM)
An SEM sends electrons over the surface of a specimen, rather than through it. The result is a three-dimensional image of the specimen's surface. SEMs can magnify a specimen up to 150,000 times.



1981 Scanning Tunneling Microscope (STM)
An STM measures electrons that leak, or "tunnel," from the surface of a specimen. STMs can magnify a specimen up to 1,000,000 times.



1800 1900 2000

Plant Cells

Animal Cells

FIGURE 15
Monarch and Milkweed
The monarch butterfly caterpillar and the milkweed leaf that the caterpillar nibbles on are both made of cells.

Development of the Cell Theory

Leeuwenhoek's exciting discoveries caught the attention of other researchers. Like Hooke, Leeuwenhoek, and all good scientists, these other researchers were curious about the world around them, including things they couldn't normally see. Many other people began to use microscopes to discover what secrets they could learn about cells.

Schleiden, Schwann, and Virchow Three German scientists made especially important contributions to people's knowledge about cells. These scientists were Matthias Schleiden (SHLY dun), Theodor Schwann, and Rudolf Virchow (FUR koh). In 1838, Schleiden 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, Theodor Schwann concluded that all animals are also made up of cells. Thus, stated Schwann, all living things are made up of cells.

Schleiden and Schwann had made an important discovery about living things. However, they didn't explain where cells came from. Until their time, most people thought that living things could come from nonliving matter. In 1855, Virchow proposed that new cells are formed only from cells that already exist. "All cells come from cells," wrote Virchow.

What the Cell Theory Says Schleiden, Schwann, Virchow, and others helped develop the cell theory. The **cell theory** is a widely accepted explanation of the relationship between cells and living things. **The cell theory states the following:**

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

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The cell theory holds true for all living things, no matter how big or how small. Since cells are common to all living things, they can provide information about the functions that living things perform. Because all cells come from other cells, scientists can study cells to learn about growth and reproduction.

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

Light and Electron Microscopes

The cell theory could not have been developed without microscopes. For a microscope to be useful, it must combine two important properties—magnification and resolution. Scientists today use two kinds of microscopes: light microscopes and electron microscopes.

Magnification and Lenses The first property, magnification, is the ability to make things look larger than they are. **The lenses in light microscopes magnify an object by bending the light that passes through them.** If you examine a hand lens, such as the one in Figure 16, you will see that the lens is curved, not flat. The center of the lens is thicker than the edge. A lens with this curved shape is called 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.

Lab zone Skills Activity

Observing

1. Read about using the microscope (Appendix B) before beginning this activity.
2. Place a prepared slide of a thin slice of cork on the stage of a microscope.
3. Observe the slide under low power. Draw what you see.
4. Place a few drops of pond water on another slide and cover it with a coverslip.
5. Observe the slide under low power. Draw what you see. Wash your hands after handling pond water.

How does your drawing in Step 3 compare to Hooke's description of cells on page 52? Based on your observations in Step 5, why did Leeuwenhoek call the organisms he saw "little animals"?

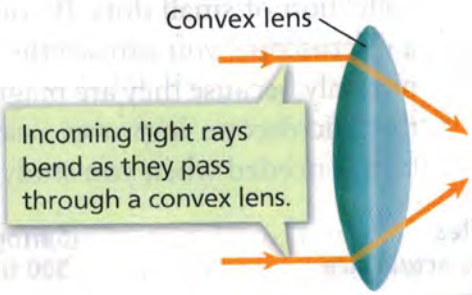


FIGURE 16
A Convex Lens
A magnifying glass is a convex lens. The lines in the diagram represent rays of light, and the arrows show the direction in which the light travels.
Interpreting Diagrams *Describe what happens to light rays as they pass through a convex lens.*

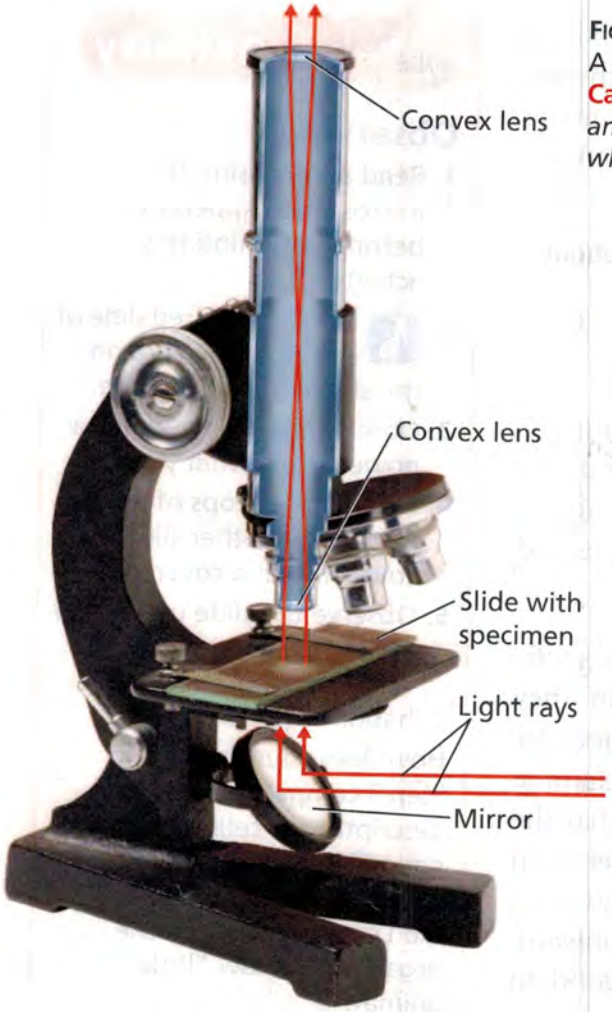


FIGURE 17 A Compound Microscope
A compound microscope has two convex lenses.
Calculating *If one lens has a magnification of 10, and the other lens has a magnification of 50, what is the total magnification?*

Compound Microscope Magnification

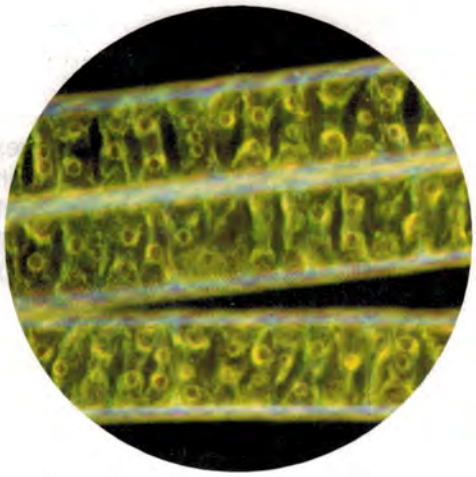
A compound microscope uses more than one lens. As a result, it can magnify an object more than one lens by itself. Light passes through a specimen and then through two lenses, as shown in Figure 17. The first lens, near the specimen, magnifies the object. Then a second lens, near the eye, further magnifies the enlarged image. The total magnification of the microscope is equal to the magnifications of the two lenses multiplied together. For example, suppose the first lens makes an object look 10 times bigger than it actually is, and the second lens makes the object look 40 times bigger than it actually is. The total magnification of the microscope is 10×40, or 400.

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, a photograph in a newspaper is really made up of a collection of small dots. If you put the photo under a microscope, you can see the dots. You see the dots not only because they are magnified but also because the microscope improves resolution. Good resolution is needed when you study cells.

FIGURE 18
Light Microscope Photos
The pictures of the water flea and the threadlike *Spirogyra* were both taken with a light microscope.

Water flea
40 times actual size

Spirogyra
300 times actual size



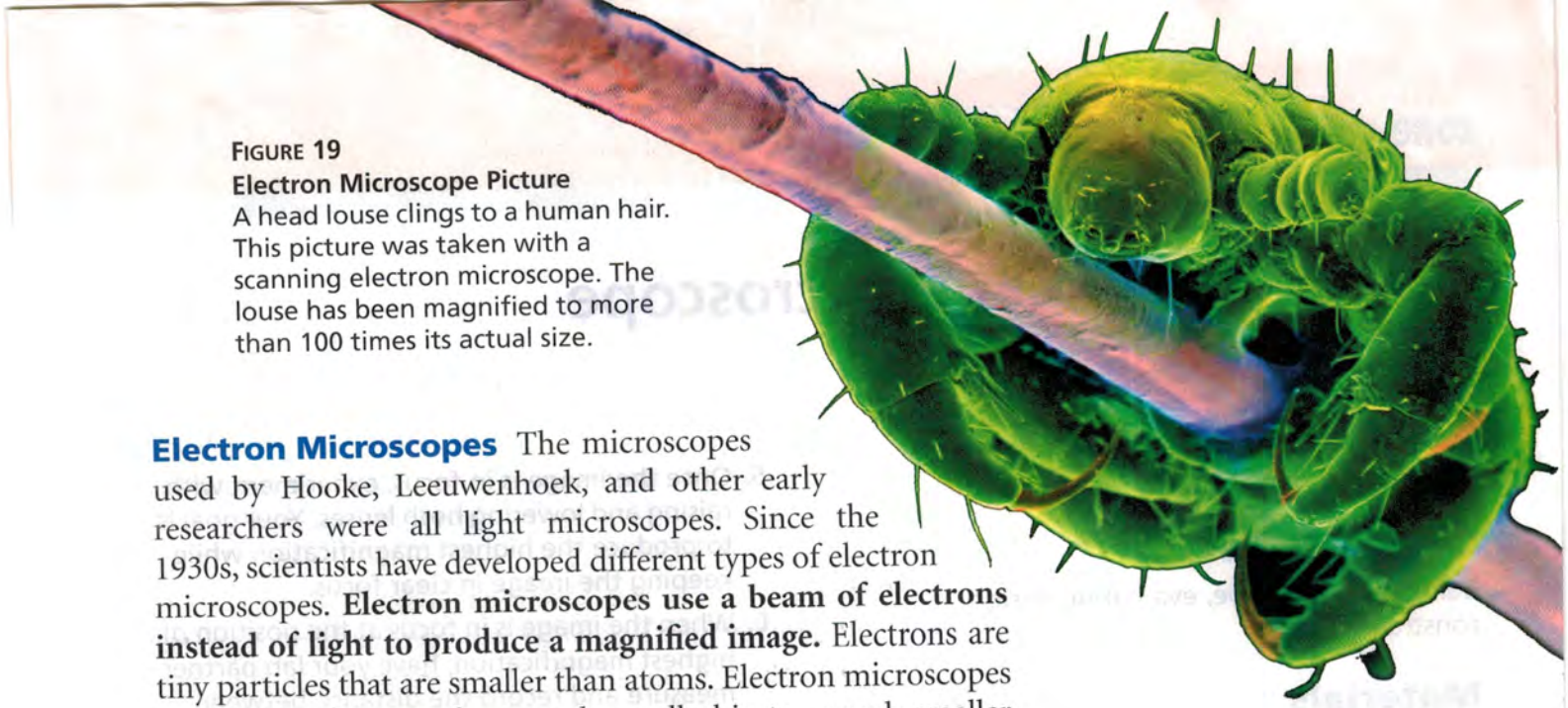


FIGURE 19
Electron Microscope Picture
A head louse clings to a human hair. This picture was taken with a scanning electron microscope. The louse has been magnified to more than 100 times its actual size.

Electron Microscopes The microscopes used by Hooke, Leeuwenhoek, and other early researchers were all light microscopes. Since the 1930s, scientists have developed different types of electron microscopes. **Electron microscopes use a beam of electrons instead of light to produce a magnified image.** Electrons are tiny particles that are smaller than atoms. Electron microscopes can obtain pictures of extremely small objects—much smaller than those that can be seen with light microscopes. The resolution of electron microscopes is much better than the resolution of light microscopes.

Reading Checkpoint **What do electron microscopes use to produce magnified images?**

Section 3 Assessment

Target Reading Skill **Sequencing** Review your flowchart and use it to answer Questions 2 and 3 below.

Reviewing Key Concepts

1. a. **Defining** Define *structure* and *function*.
   b. **Explaining** Explain this statement: Cells are the basic units of structure and function in organisms.
   c. **Applying Concepts** In what important function are the cells in your eyes involved?
2. a. **Reviewing** What does a microscope enable people to do?
   b. **Summarizing** Summarize Hooke's observations of cork under a microscope.
   c. **Relating Cause and Effect** Why would Hooke's discovery have been impossible without a microscope?
3. a. **Reviewing** What are the main ideas of the cell theory?
   b. **Explaining** What did Virchow contribute to the cell theory?
   c. **Applying Concepts** Use the ideas of Virchow to explain why plastic plants and stuffed animals are not alive.
4. a. **Defining** What is magnification?
   b. **Comparing and Contrasting** Contrast the way light microscopes and electron microscopes magnify objects.

Writing in Science

Writing an Award Speech Suppose you are a member of a scientific society that is giving an award to one of the early cell scientists. Choose the scientist, and write a speech that you might give at the award ceremony. Your speech should describe the scientist's accomplishments.

Lab zone

Technology Lab

• Tech & Design •

Design and Build a Microscope

Problem

How can you design and build a compound microscope?

Design Skills

building a prototype, evaluating design constraints

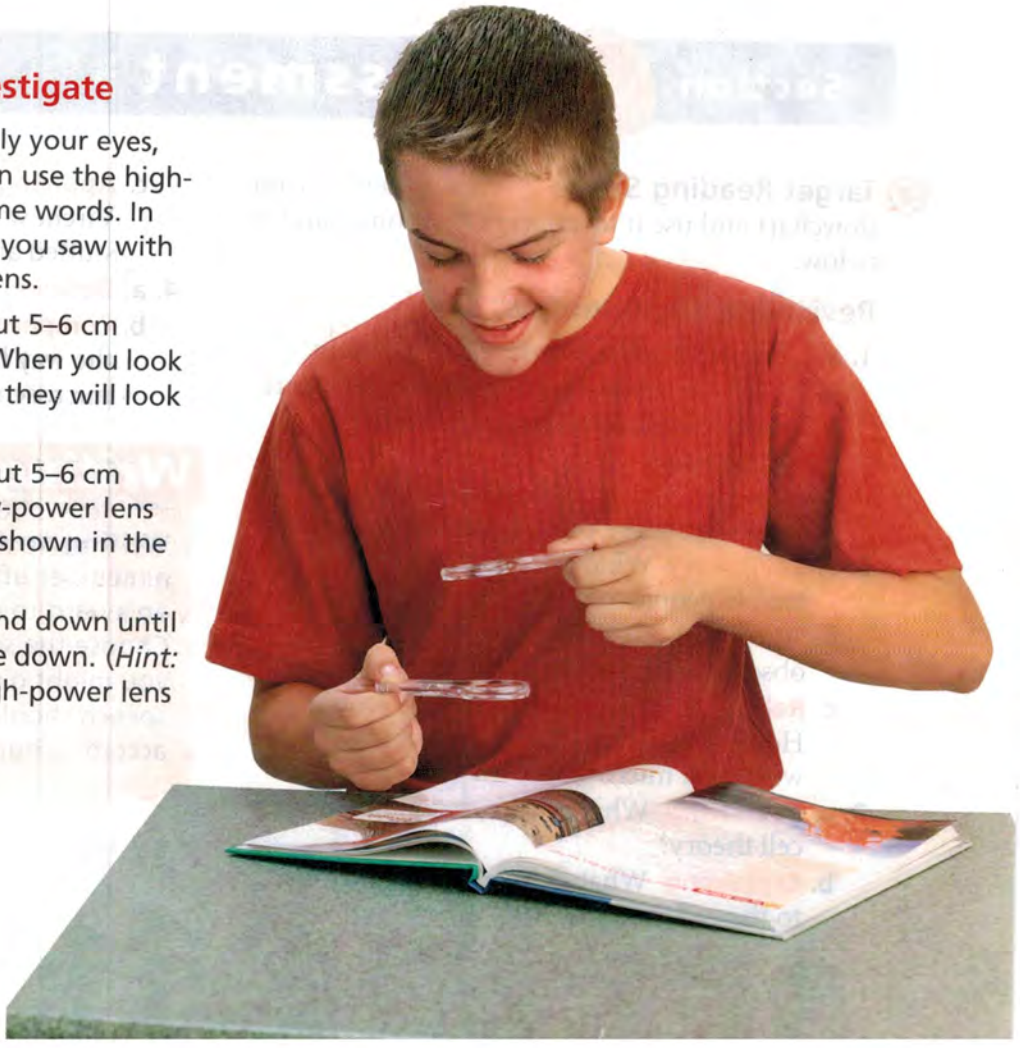
Materials

- book
- 2 dual magnifying glasses, each with one high-power and one low-power lens
- metric ruler
- 2 cardboard tubes from paper towels, or black construction paper
- tape

Procedure

PART 1 Research and Investigate

1. Work with a partner. Using only your eyes, examine words in a book. Then use the high-power lens to examine the same words. In your notebook, contrast what you saw with and without the magnifying lens.
2. Hold the high-power lens about 5–6 cm above the words in the book. When you look at the words through the lens, they will look blurry.
3. Keep the high-power lens about 5–6 cm above the words. Hold the low-power lens above the high-power lens, as shown in the photograph on the right.
4. Move the low-power lens up and down until the image is in focus and upside down. (*Hint:* You may have to move the high-power lens up or down slightly too.)
5. Once the image is in focus, experiment with raising and lowering both lenses. Your goal is to produce the highest magnification while keeping the image in clear focus.
6. When the image is in focus at the position of highest magnification, have your lab partner measure and record the distance between the book and the high-power lens. Your lab partner should also measure and record the distance between the two lenses.
7. Write a description of how the magnified words viewed through two lenses compares with the words seen without magnification.



PART 2 Design and Build

8. Based on what you learned in Part 1, work with a partner to design your own two-lens (compound) microscope. Your microscope should
   - consist of one high-power lens and one low-power lens, each attached to a tube of paper or rolled-up cardboard
   - allow one tube to fit snugly inside the other tube so the distance between the two lenses can be easily adjusted
   - focus to produce a clear, enlarged, upside-down image of the object
   - be made from dual magnifying glasses, cardboard tubes, and tape
9. Sketch your design on a sheet of paper. Obtain your teacher's approval for your design. Then construct your microscope.

PART 3 Evaluate and Redesign

10. Test your microscope by examining printed words or a printed photograph. Then, examine other objects such as a leaf or your skin. Record your observations. Did your microscope meet the criteria listed in Step 8?
11. Examine microscopes made by other students. Based on your tests and your examination of other microscopes, list ways you could improve your microscope.

Analyze and Conclude

1. **Observing** Compare the images you observed using one lens with the image from two lenses.
2. **Evaluating** When you used two lenses, how did moving the top lens up and down affect the image? What was the effect of moving the bottom lens up and down?
3. **Building a Prototype** Describe how you built your microscope and explain why you built it that way.
4. **Evaluating the Impact on Society** Describe some of the ways that microscopes have aided scientists in their work.

Communicate

Imagine it is 1675. Write an explanation that will convince scientists to use your new microscope rather than the single-lens variety used by Leeuwenhoek.

Section 4

Looking Inside Cells

Reading Preview

Key Concepts

- What role do the cell wall and cell membrane play in the cell?
- What are the functions of cell organelles?
- How are cells organized in many-celled organisms?

Key Terms

- organelle
- cell wall
- cell membrane
- cytoplasm
- mitochondria
- endoplasmic reticulum
- ribosome
- Golgi body
- chloroplast
- vacuole
- lysosome

Target Reading Skill

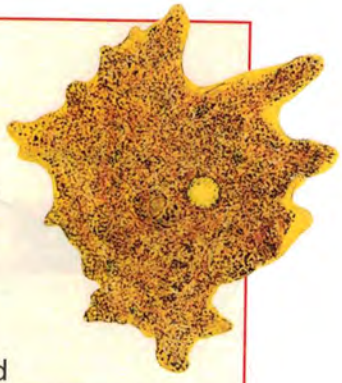
Previewing Visuals Before you read, preview Figure 24. Then write two questions that you have about the illustrations in a graphic organizer like the one below. As you read, answer your questions.

Plant and Animal Cells

Q. How are animal cells different from plant cells?
A.
Q.

Lab zone Discover Activity

How Large Are Cells?



1. Look at the organism in the photo. The organism is an amoeba (uh MEE buh), a large single-celled organism. This type of amoeba is about 1 mm long.
2. Multiply your height in meters by 1,000 to get your height in millimeters. How many amoebas 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 amoeba. How many body cells would you have to stack end-to-end to equal your height?

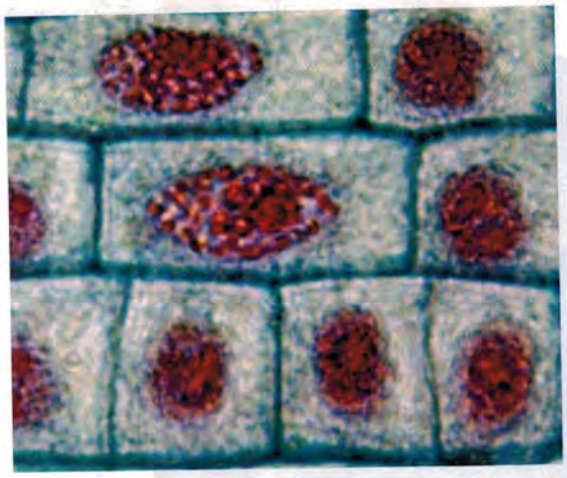
Think It Over

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

Nasturtiums brighten up many gardens with green leaves and colorful flowers. How do nasturtiums carry out all the functions necessary to stay alive? To answer this question, you are about to take an imaginary journey. You will travel inside a nasturtium leaf, visiting its tiny cells. You will observe some of the structures found in plant cells. You will also learn some differences between plant and animal cells.

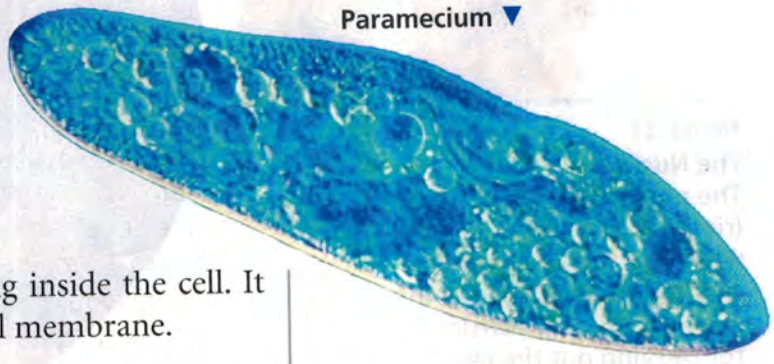
As you will discover on your journey, there are even smaller structures inside a cell. These tiny cell structures, called **organelles,** carry out specific functions within the cell. Just as your stomach, lungs, and heart have different functions in your body, each organelle has a different function within the cell. Now it's time to hop aboard your imaginary ship and sail into a typical plant cell.

Nasturtiums ▶



◀ Onion root cells

Paramecium ▼



Enter the Cell

Your ship doesn't have an easy time getting inside the cell. It has to pass through the cell wall and the cell membrane.

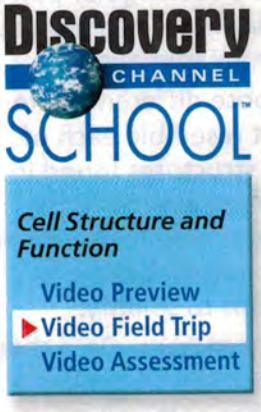
Cell Wall As you travel through the plant cell, refer to Figure 24 in this section. First, you must slip through the cell wall. The **cell wall** is a rigid layer of nonliving material that surrounds the cells of plants and some other organisms. The cells of animals, in contrast, do not have cell walls. **A plant's cell wall helps to protect and support the cell.** The cell wall is made mostly of a strong material called cellulose. Although the cell wall is tough, many materials, including water and oxygen, can pass through easily.

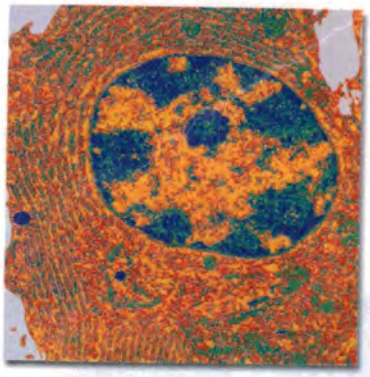
Cell Membrane After you sail through the cell wall, the next barrier you must cross is the **cell membrane.** All cells have cell membranes. In cells with cell walls, the cell membrane is located just inside the cell wall. In other cells, the cell membrane forms the outside boundary that separates the cell from its environment.

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. Fortunately, your ship can slip through, too. Harmful waste products leave the cell through the cell membrane. For a cell to survive, the cell membrane must allow these materials to pass in and out. In addition, the cell membrane prevents harmful materials from entering the cell. In a sense, the cell membrane is like a window screen. The screen allows air to enter and leave a room, but it keeps insects out.

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

FIGURE 20
Cell Wall and Cell Membrane
The onion root cells have both a cell wall and a cell membrane. The single-celled paramecium has only a cell membrane.
Interpreting Photographs *What shape do the cell walls give to the onion root cells?*





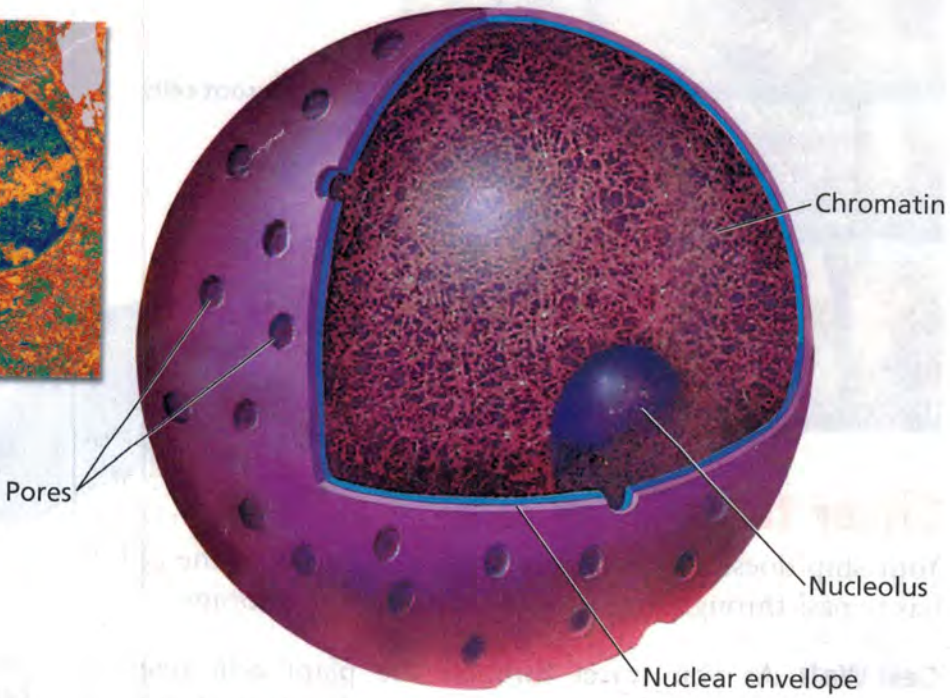


FIGURE 21
The Nucleus
The photo (left) and diagram (right) both show the nucleus, which is the cell's control center. The chromatin in the nucleus contains instructions for carrying out the cell's activities.

Sail On to the Nucleus

As you sail inside the cell, a large, oval structure comes into view. This structure, the nucleus, 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 Envelope Notice in Figure 21 that the nucleus is surrounded by a membrane called the nuclear envelope. Just as a mailing envelope protects the letter inside it, the nuclear envelope protects the nucleus. Materials pass in and out of the nucleus through pores in the nuclear envelope. So aim for that pore just ahead and carefully glide into the nucleus.

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 genetic material, the instructions for directing the cell's functions. For example, the instructions in the chromatin ensure that leaf cells grow and divide to form more leaf cells.

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

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

Lab zone Try This Activity

Gelatin Cell

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.

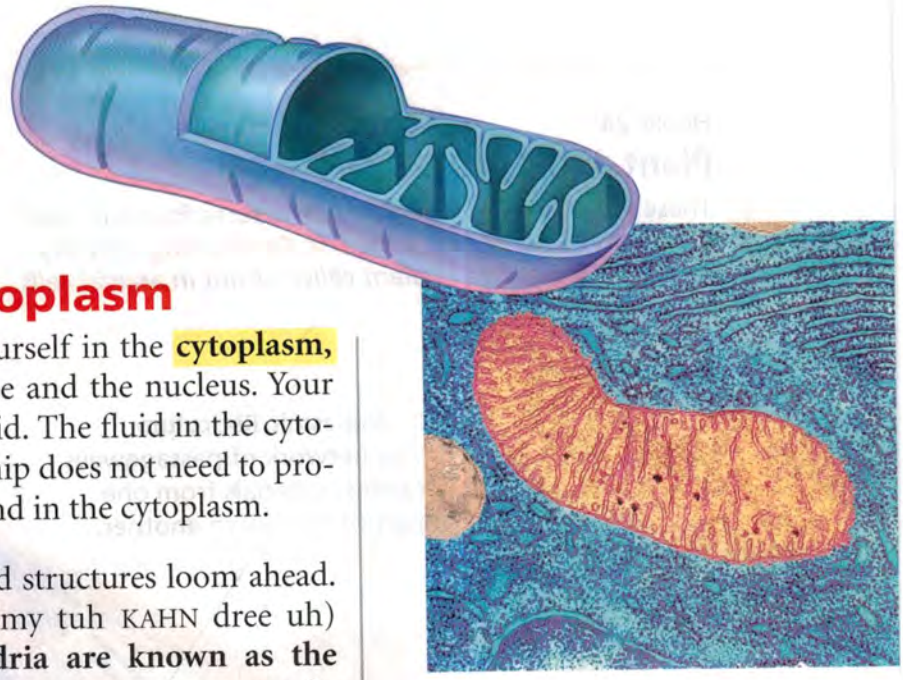


FIGURE 22 Mitochondrion
The mitochondria produce most of the cell's energy. **Inferring** *In what types of cells would you expect to find a lot of mitochondria?*

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.

Mitochondria Suddenly, rod-shaped structures loom ahead. These organelles are **mitochondria** (my tuh KAHN dree uh) (singular *mitochondrion*). **Mitochondria are known as the "powerhouses" of the cell because they convert energy in food molecules to energy the cell can use to carry out its functions.** Figure 22 shows a mitochondrion up close.

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). **The endoplasmic reticulum's passageways carry proteins and other materials from one part of the cell to another.**

Ribosomes Attached to some surfaces of the endoplasmic reticulum are small, grainlike bodies called **ribosomes.** Other ribosomes float in the cytoplasm. **Ribosomes function as factories to produce proteins.** Some newly made proteins are released through the wall of the endoplasmic reticulum. From the interior of the endoplasmic reticulum, the proteins will be transported to the Golgi bodies.

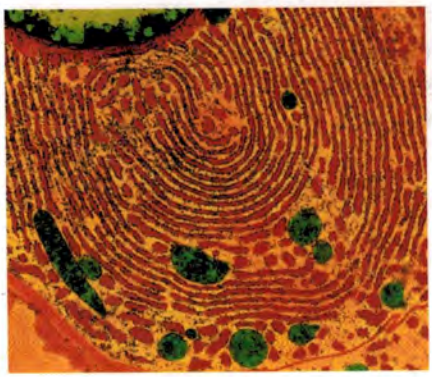


FIGURE 23
Endoplasmic Reticulum
The endoplasmic reticulum is similar to the system of hallways in a building. Proteins and other materials move throughout the cell by way of the endoplasmic reticulum. The spots on this organelle are ribosomes, which produce proteins.

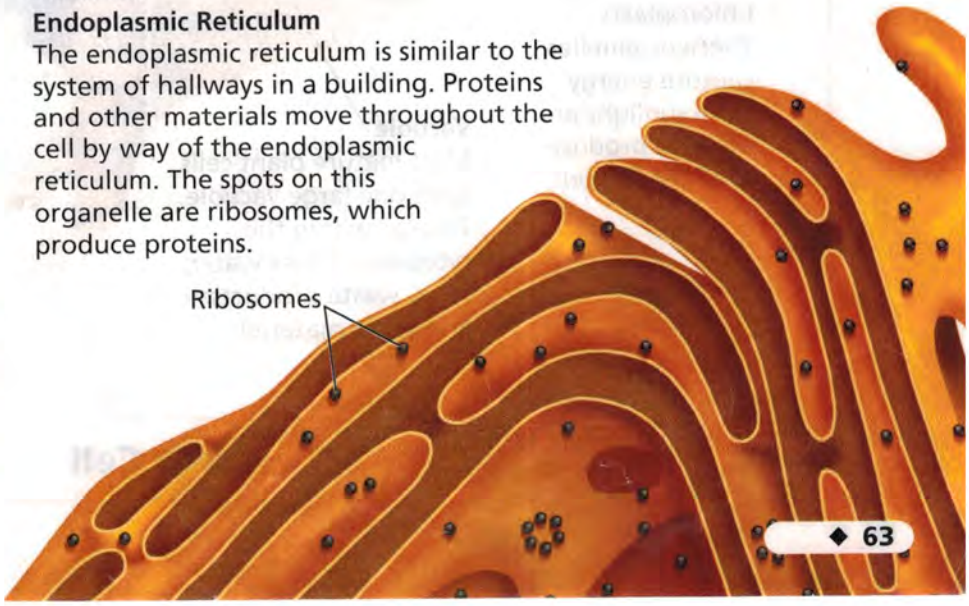
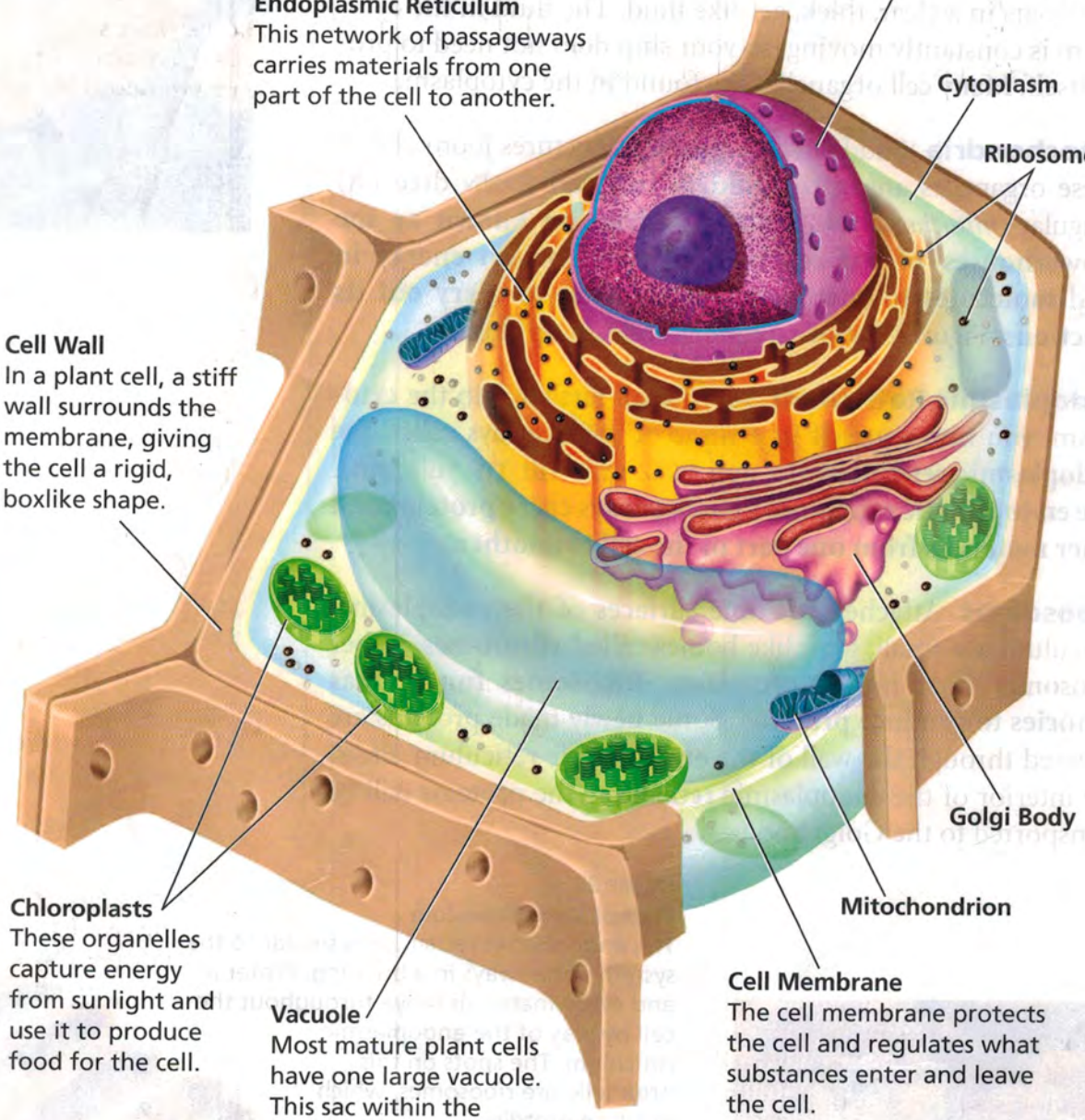


FIGURE 24

Plant and Animal Cells

These illustrations show typical structures found in plant and animal cells. **Comparing and Contrasting** *Identify one structure found in plant cells but not in animal cells.*



Nucleus
The nucleus directs all of the cell's activities, including reproduction.

Endoplasmic Reticulum
This network of passageways carries materials from one part of the cell to another.

Cytoplasm

Ribosomes

Cell Wall
In a plant cell, a stiff wall surrounds the membrane, giving the cell a rigid, boxlike shape.

Golgi Body

Mitochondrion

Chloroplasts
These organelles capture energy from sunlight and use it to produce food for the cell.

Vacuole
Most mature plant cells have one large vacuole. This sac within the cytoplasm stores water, food, waste products, and other materials.

Cell Membrane
The cell membrane protects the cell and regulates what substances enter and leave the cell.

Plant Cell

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active art

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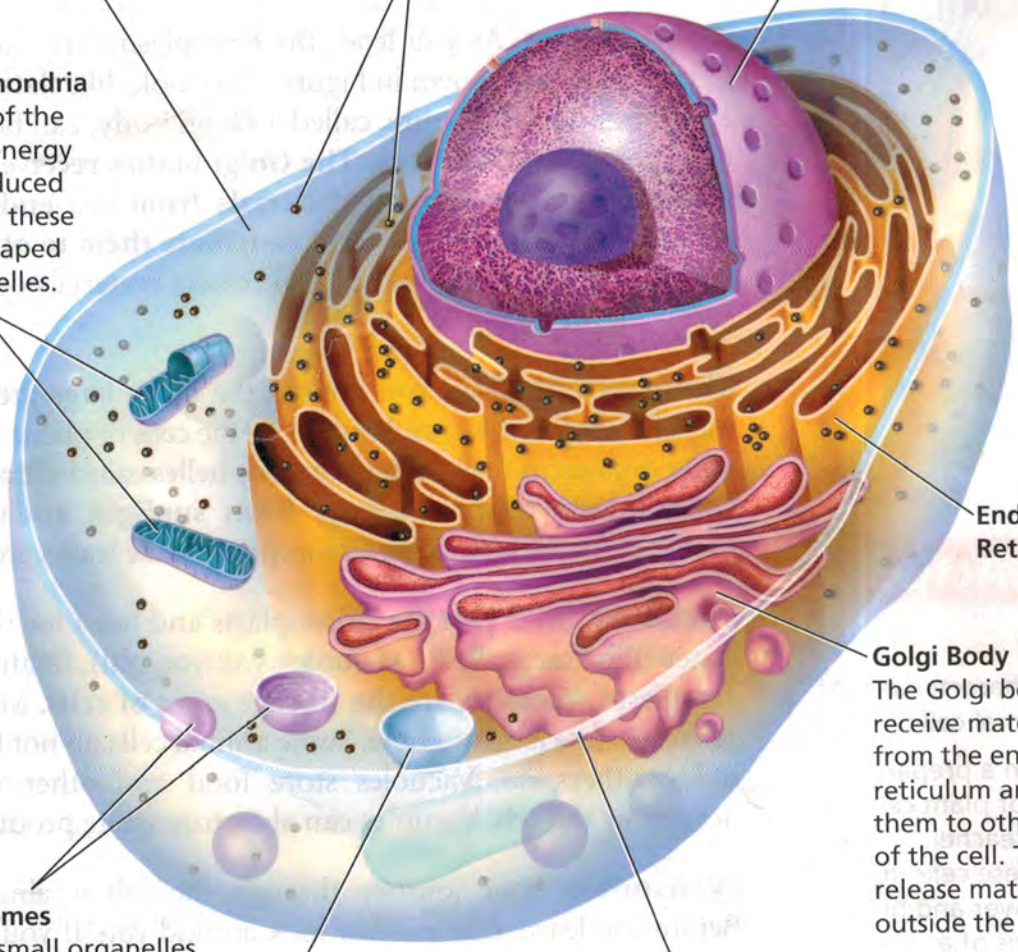

Cytoplasm
The cytoplasm includes a gel-like fluid in which many different organelles are found.

Ribosomes
These small structures function as factories to produce proteins. Ribosomes may be attached to the endoplasmic reticulum, or they may float in the cytoplasm.

Nucleus
The nucleus directs all of the cell's activities, including reproduction.

Mitochondria
Most of the cell's energy is produced within these rod-shaped organelles.

Endoplasmic Reticulum

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.

Lysosomes
These small organelles contain chemicals that break down food particles and worn-out cell parts.

Vacuole
Some animal cells have vacuoles that store food, water, waste, and other materials.

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.

Animal Cell

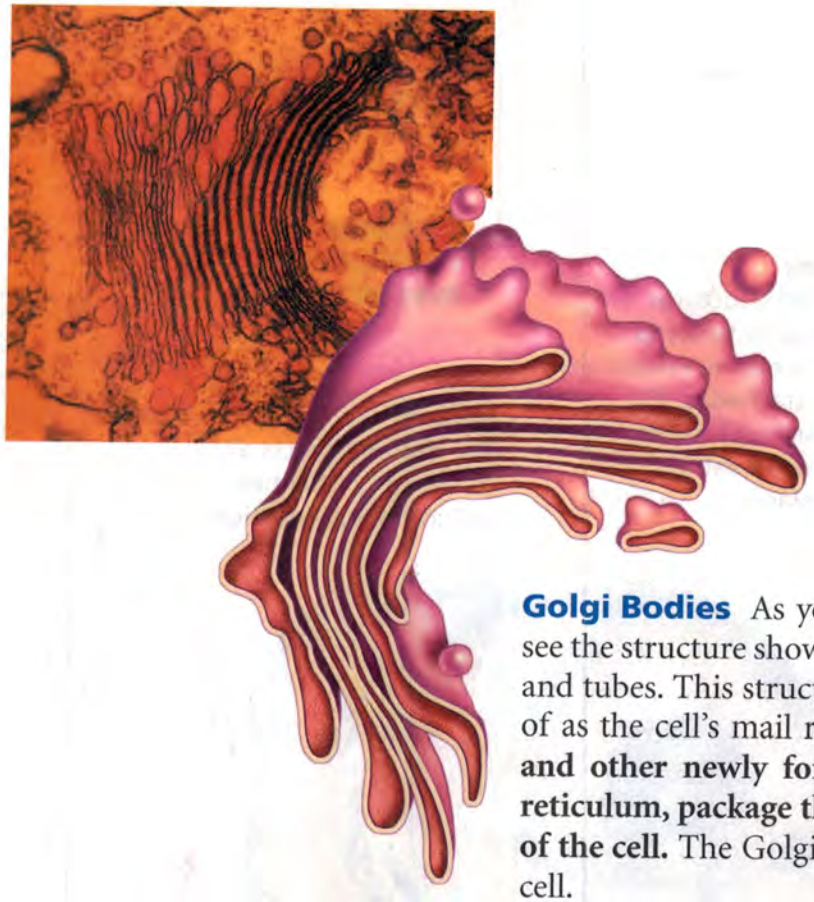

FIGURE 25
A Golgi Body
Golgi bodies are organelles that transport materials.
Applying Concepts *Why can a Golgi body be described as a cell's mail room?*

Golgi Bodies As you leave the endoplasmic reticulum, you see the structure shown in Figure 25. It looks like flattened sacs and tubes. This structure, called a **Golgi body**, can be thought of as the cell's mail room. **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 green organelles called **chloroplasts. Chloroplasts capture energy from sunlight and use it to produce food for the cell.** Chloroplasts make leaves green.

Vacuoles Steer past the chloroplasts and head for that large, water-filled sac, called a **vacuole** (VAK yoo ohl), floating in the cytoplasm. **Vacuoles are the storage areas of cells.** 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.

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** (LY suh sohm). **Lysosomes are small, round structures containing chemicals that break down certain materials in the cell.** Some chemicals 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 lysosomes as the cell's cleanup crew.

Reading Checkpoint **What organelle captures the energy of sunlight and uses it to make food for the cell?**

Lab zone Skills Activity

Observing

Observe the characteristics of plant and animal cells.

1. Obtain a prepared slide of plant cells from your teacher. Examine these cells under the low-power and high-power lenses of a microscope.
2. Draw a picture of what you see.
3. Repeat Steps 1 and 2 with a prepared slide of animal cells.

How are plant and animal cells alike? How are they different?

Specialized Cells

Plants and animals (including yourself) contain many cells. In a many-celled organism, the cells are often quite different from each other and are specialized to perform specific functions. Contrast, for example, the nerve cell and red blood cells in Figure 26. Nerve cells are specialized to transmit information from one part of your body to another, and red blood cells carry oxygen throughout your body.

In many-celled organisms, cells are often organized into tissues, organs, and organ systems. A tissue is a group of similar cells that work together to perform a specific function. For example, your brain is made mostly of nervous tissue, which consists of nerve cells. An organ, such as your brain, is made of different kinds of tissues that function together. In addition to nervous tissue, the brain contains other kinds of tissue that support and protect it. Your brain is part of your nervous system, which is an organ system that directs body activities and processes. An organ system is a group of organs that work together to perform a major function.

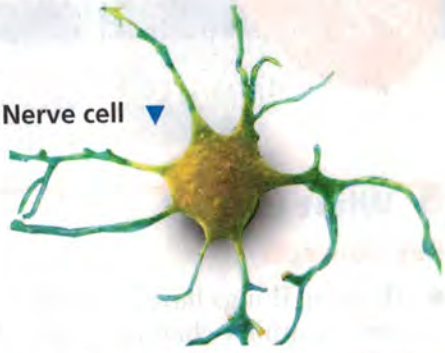

FIGURE 26 Specialized Cells Nerve cells carry information throughout the human body. Red blood cells carry oxygen.

Section 4 Assessment

Target Reading Skill **Previewing Visuals** Refer to your questions and answers about Figure 24 to help you answer the questions below.

Reviewing Key Concepts

1. a. **Comparing and Contrasting** Compare the functions of the cell wall and the cell membrane.
   b. **Inferring** How does cellulose help with one function of the cell wall?
2. a. **Identifying** Identify the functions of ribosomes and Golgi bodies.
   b. **Describing** Describe the characteristics of the endoplasmic reticulum.
   c. **Applying Concepts** How are the functions of ribosomes, Golgi bodies, and the endoplasmic reticulum related to one another?
3. a. **Reviewing** What is a tissue? What is an organ?
   b. **Explaining** What is the relationship among cells, tissues, and organs?
   c. **Inferring** Would a tissue or an organ have more kinds of specialized cells? Explain.

Writing in Science

Writing a Description Write a paragraph describing a typical animal cell. Your paragraph should include all the structures generally found in animal cells and a brief explanation of the functions of those structures.

Chapter 2

Study Guide

The BIG Idea **Structure and Function** Cells are the basic building blocks of all living things. Specialized structures inside cells carry out specific functions, such as obtaining oxygen and food, necessary for life.

1 What Is Life?

Key Concepts

- All living things have a cellular organization, contain similar chemicals, use energy, respond to their surroundings, grow and develop, and reproduce.
- Living things arise from living things through reproduction.
- All living things must satisfy their basic needs for water, food, living space, and stable internal conditions.

Key Terms

• organism • cell • unicellular • multicellular
• stimulus • response • development
• spontaneous generation • autotroph
• heterotroph • homeostasis

2 Classifying Organisms

Key Concepts

- Biologists use classification to organize living things into groups so that the organisms are easier to study.
- The more classification levels that two organisms share, the more characteristics they have in common.
- Organisms are placed into domains and kingdoms based on their cell type, their ability to make food, and the number of cells in their bodies.

Key Terms

classification
taxonomy
binomial nomenclature
genus
species
prokaryote
nucleus
eukaryote

3 Discovering Cells

Key Concepts

- Cells are the basic units of structure and function in living things.
- The cell theory states the following: All living things are composed of cells. Cells are the basic units of structure and function in living things. All cells are produced from other cells.
- The invention of the microscope enabled people to learn about cells. Light microscopes magnify an object by bending light. Electron microscopes use electrons instead of light.

Key Terms

cell microscope cell theory

4 Looking Inside Cells

Key Concepts

- A plant's cell wall protects and supports the cell. The cell membrane controls what substances come into and out of a cell.
- The nucleus directs the cell's activities.
- Mitochondria convert energy in food molecules to energy the cell can use.
- The endoplasmic reticulum carries materials throughout the cell. Ribosomes produce proteins.
- The Golgi bodies receive materials, package them, and distribute them.
- Chloroplasts capture energy from sunlight and use it to produce food for the cell. Vacuoles are the storage areas of cells.
- Lysosomes contain chemicals that break down certain materials in the cell.
- In many-celled organisms, cells are often organized into tissues, organs, and organ systems.

Key Terms

• organelle • cell wall • cell membrane
• cytoplasm • mitochondria
• endoplasmic reticulum • ribosome
• Golgi body • chloroplast • vacuole
• lysosome

Review and Assessment

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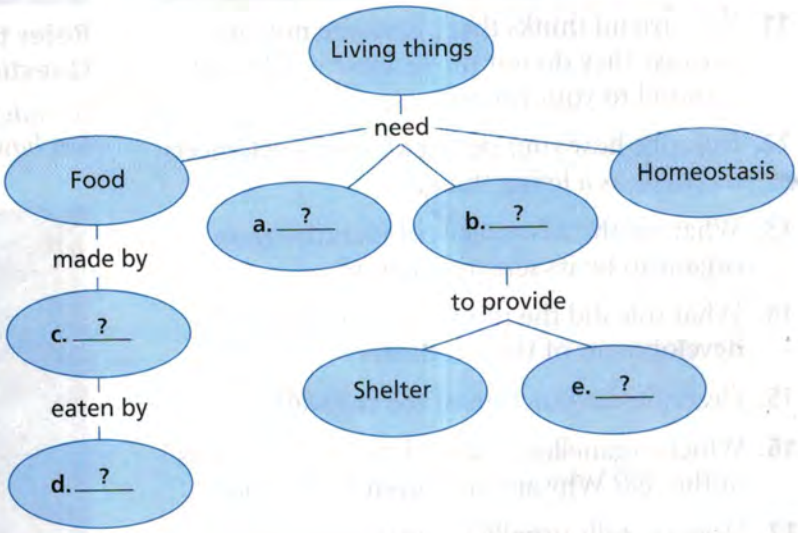
Organizing Information

Concept Mapping 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 Mapping, see the Skills Handbook.)



Reviewing Key Terms

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 scientific study of how living things are classified is called
   a. development.
   b. biology.
   c. taxonomy.
   d. evolution.
3. A genus is divided into
   a. species. **b.** phyla.
   c. families. **d.** classes.
4. The basic units of structure in all living things are
   a. nuclei. **b.** organelles.
   c. tissues. **d.** cells.
5. In plant and animal cells, the control center of the cell is the
   a. chloroplast.
   b. cytoplasm.
   c. nucleus.
   d. Golgi body.

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

6. Bacteria are <u>unicellular</u> organisms.
7. Linnaeus devised a system of naming organisms called <u>binomial nomenclature</u>.
8. The gray wolf, *Canis lupus*, and the red wolf, *Canis rufus*, belong to the same <u>species</u>.
9. Cells were discovered using <u>electron</u> microscopes.
10. <u>Ribosomes</u> produce proteins.

Writing in Science

Dialogue A dialogue is a conversation. Write a dialogue that might have taken place between Schleiden and Schwann. The scientists should discuss their observations and conclusions.

Discovery CHANNEL SCHOOL

Cell Structure and Function
Video Preview
Video Field Trip
▶ Video Assessment

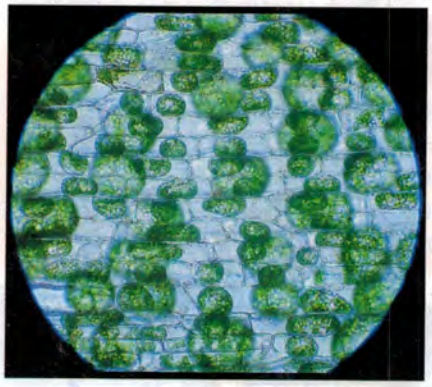
Review and Assessment

Checking Concepts

11. Your friend thinks that plants are not alive because they do not move. How would you respond to your friend?
12. Describe how your pet, or a friend's pet, meets its needs as a living thing.
13. What are the advantages of identifying an organism by its scientific name?
14. What role did the microscope play in the development of the cell theory?
15. Describe the function of the cell wall.
16. Which organelles are called the "powerhouses" of the cell? Why are they given that name?
17. How are cells usually organized in large multicellular organisms?

Thinking Critically

18. **Applying Concepts** How do you know that a robot is not alive?
19. **Inferring** Which two of the following organisms are most closely related: *Entamoeba histolytica, Escherichia coli, Entamoeba coli*? Explain your answer.
20. **Applying Concepts** The photograph below has not been artificially colored. Do the cells in the photo come from a plant or an animal? Explain your answer.



21. **Classifying** If you were trying to classify an unfamiliar organism by looking at its cells, what could the cells tell you?

Applying Skills

Refer to the illustrations below to answer Questions 22–25.

A student designed the experiment pictured below to test how light affects the growth of plants.

22. **Controlling Variables** Is this a controlled experiment? If so, identify the manipulated variable. If not, why not?
23. **Developing Hypotheses** What hypothesis might this experiment be testing?
24. **Predicting** Based on what you know about plants, predict how each plant will change in two weeks.
25. **Designing Experiments** Design a controlled experiment to determine whether the amount of water that a plant receives affects its growth.

Lab zone Chapter Project

Performance Assessment Prepare a display presenting your conclusion about your mystery object. Describe the observations that helped you to reach your conclusion. Compare your ideas with those of other students. If necessary, defend your work.

Standardized Test Prep

Test-Taking Tip

Watching for Qualifiers

You may be asked to answer a question that uses a qualifying word such as *always, never, most,* or *least.* For example, in the sample question below, only one of the answer choices is *always* true. Read the question and think about whether each choice is always true. Then answer the question.

Sample Question

Two organisms that are classified in the same phylum will *always* be classified in the same

A kingdom.
B order.
C family.
D genus.

Answer

The correct answer is **A** because a phylum is part of a kingdom. Any two organisms classified in the same phylum must always share the same kingdom. They may, however, be classified in different levels below the phylum level. Thus, you can eliminate **B, C,** and **D.**

Choose the letter of the best answer.

1. Which of the following statements about cells is *not* true?

A Cells are the building blocks of living things.
B Cells carry out the basic life functions of living things.
C Some organisms are made up of only one cell.
D Most cells can be seen with the naked eye.

2. Organisms that are autotrophs are classified in which of the following domains?

F Bacteria
G Archaea
H Eukarya
J all of the above

Use the table below and your knowledge of science to answer Questions 3–4.

Some Types of Trees

Common Name of Tree	Kingdom	Family	Species
Bird cherry	Plants	Rosaceae	*Prunus avium*
Flowering cherry	Plants	Rosaceae	*Prunus serrula*
Smooth-leaved elm	Plants	Ulmaceae	*Ulmus minor*
Whitebeam	Plants	Rosaceae	*Sorbus aria*

3. In the system of binomial nomenclature, what is the name for the whitebeam tree?

A Rosaceae
B *Sorbus aria*
C *Prunus serrula*
D *Ulmus minor*

4. Which of the following organisms is most different from the other three?

F *Prunus avium*
G *Prunus serrula*
H *Ulmus minor*
J *Sorbus aria*

5. A compound microscope has two lenses. One lens has a magnification of 15 and the other lens has a magnification of 40. What is the total magnification of the microscope?

A 55
B 150
C 25
D 600

Constructed Response

6. Name five characteristics that all living things share. Then describe each characteristic or give an example.

Chapter 3

Cell Processes and Energy

The BIG Idea

Structure and Function

How do cells obtain energy they need to carry out all their functions?

Chapter Preview

Sunlight on these maple leaves powers the process of photosynthesis.

Discovery CHANNEL SCHOOL

Cell Processes and Energy

- ▶ Video Preview
- Video Field Trip
- Video Assessment

Lab zone™

Chapter Project

Shine On!

Every morning at sunrise, tiny living factories start a manufacturing process called photosynthesis. The power they use is sunlight. In this project, you will investigate how light affects one familiar group of photosynthesizers—plants.

Your Goal To determine how different lighting conditions affect the health and growth of plants

To complete the project, you will

- write up a plan to grow plants under different lighting conditions
- care for your plants daily and keep careful records of their health and growth for three weeks
- graph your data and draw conclusions about the effect of light on plant growth
- follow the safety guidelines in Appendix A

Plan It! Brainstorm with classmates to answer these questions: What different light conditions might you test? What plants will you use? How will you measure health and growth? How can you be sure your results are due to the light conditions? Write up your plan and submit it to your teacher.

Chemical Compounds in Cells

Reading Preview

Key Concepts

- What are elements and compounds?
- How is water important to the function of cells?
- What are the main kinds of organic molecules in living things?

Key Terms

- element • compound
- carbohydrate • lipid
- protein • amino acid
- enzyme • nucleic acid
- DNA • RNA

Target Reading Skill

Comparing and Contrasting
As you read, compare and contrast carbohydrates, lipids, and proteins in a table like the one below.

Type of Compound	Elements	Functions
Carbo-hydrate	Carbon, hydrogen, oxygen	
Lipid		
Protein		

Lab zone Discover Activity

What Is a Compound?

1. Your teacher will provide you with containers filled with various substances. All of the substances are chemical compounds.
2. Examine each substance. Read the label on each container to learn what each substance is made of.

Think It Over
Forming Operational Definitions Write a definition of what you think a chemical compound is.

Watch out—you are surrounded by particles that you can't see! Air is made up of millions of tiny particles. They bump into your skin, hide in the folds of your clothes, and whoosh into your nose every time you take a breath. In fact, you and the world around you, including the cells in your body, are composed of tiny particles. Some of these particles are elements, and others are compounds.

Elements and Compounds

You may not realize it, but air is a mixture of gases. These gases include both elements and compounds. Three gases in the air are oxygen, nitrogen, and carbon dioxide.

Elements Oxygen and nitrogen are examples of **elements.** **An element is any substance that cannot be broken down into simpler substances.** The smallest unit of an element is called an atom. An element is made up of only one kind of atom. The elements found in living things include carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur.

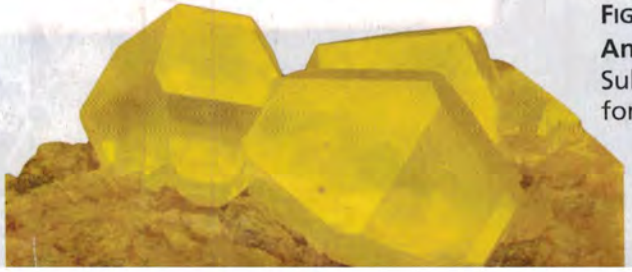


FIGURE 1
An Element
Sulfur is an element. In its pure form, it sometimes forms crystals.

Compounds Carbon dioxide is a **compound** made up of the elements carbon and oxygen. **When two or more elements combine chemically, they form a compound.** Most elements in living things occur in the form of compounds. The smallest unit of any compound is called a molecule. A molecule of carbon dioxide consists of one carbon atom and two oxygen atoms.

The Compound Called Water Like carbon dioxide, water is a compound. Each water molecule is made up of two hydrogen atoms and one oxygen atom. Water makes up about two thirds of your body. Water plays many important roles in cells. Water dissolves chemicals that cells need. **Most chemical reactions within cells could not take place without water.** Water also helps cells keep their size and shape. In fact, a cell without water would be like a balloon without air. In addition, because water changes temperature so slowly, it helps keep the temperature of cells from changing rapidly.

Organic and Inorganic Compounds Many compounds in living things contain the element carbon. Most compounds that contain carbon are called organic compounds. Compounds that don't contain carbon are called inorganic compounds. Water and sodium chloride, or table salt, are familiar examples of inorganic compounds.

Reading Checkpoint **How are inorganic compounds different from organic compounds?**

Go Online
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For: Links on proteins
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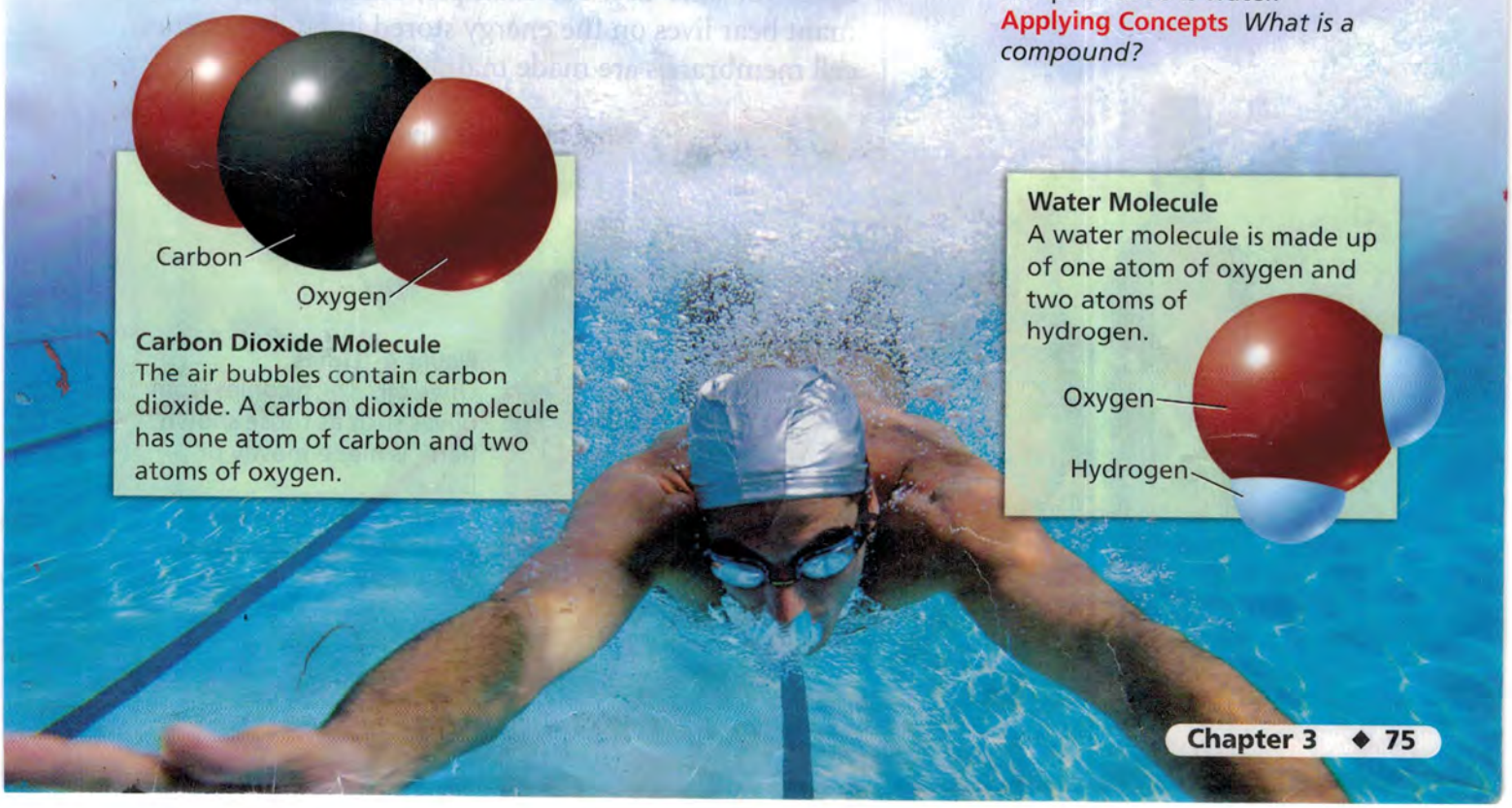
Web Code: scn-0313

FIGURE 2
Molecules and Compounds
Carbon dioxide, which is found in the gas bubbles, is a chemical compound. So is water.
Applying Concepts *What is a compound?*



Carbon Dioxide Molecule
The air bubbles contain carbon dioxide. A carbon dioxide molecule has one atom of carbon and two atoms of oxygen.

Water Molecule
A water molecule is made up of one atom of oxygen and two atoms of hydrogen.

FIGURE 3 Starch
These potatoes contain a large amount of starch. Starch is a carbohydrate. The blue grains in the close-up are starch granules in a potato. The grains have been colored blue to make them easier to see.

Carbohydrates

Carbohydrates, lipids, proteins, and nucleic acids are important groups of organic compounds in living things. A **carbohydrate** is an energy-rich organic compound made of the elements carbon, hydrogen, and oxygen. Sugars and starches are carbohydrates.

Sugars are produced during the food-making process that takes place in plants. Foods such as fruits and some vegetables have a high sugar content. Sugar molecules can combine, forming large molecules called starches, or complex carbohydrates. Plant cells store excess energy in molecules of starch. Many foods that come from plants contain starch. These foods include potatoes, pasta, rice, and bread. When you eat those foods, your body breaks down the starch into glucose, a sugar that your cells can use to produce energy.

Carbohydrates are important components of some cell parts. For example, the cellulose found in the cell walls of plants is a type of carbohydrate. Carbohydrates are also found in cell membranes.

Lipids

Fats, oils, and waxes are all lipids. Like carbohydrates, **lipids** are energy-rich organic compounds made of carbon, hydrogen, and oxygen. Lipids contain even more energy than carbohydrates. Cells store energy in lipids for later use. For example, during winter, a dormant bear lives on the energy stored in fat. In addition, cell membranes are made mainly of lipids.

Reading Checkpoint **What are three kinds of lipids?**

FIGURE 4 Lipids
Olive oil, which comes from olives such as those shown here, is made mostly of lipids.
Making Generalizations *What elements are lipids composed of?*

Proteins

What do a bird's feathers, a spider's web, and your fingernails have in common? All of these substances are made mainly of proteins. **Proteins** are large organic molecules made of carbon, hydrogen, oxygen, nitrogen, and, in some cases, sulfur. Foods that are high in protein include meat, eggs, fish, nuts, and beans.

Structure of Proteins Protein molecules are made up of smaller molecules called **amino acids.** Although there are only 20 common amino acids, cells can combine them in different ways to form thousands of different proteins. The kinds of amino acids and the order in which they link together determine the type of protein that forms. You can think of the 20 amino acids as being like the 26 letters of the alphabet. Those 26 letters can form thousands of words. The letters you use and their order determine the words you form. Even a change in one letter, for example, from *rice* to *mice,* creates a new word. Similarly, a change in the type or order of amino acids can result in a different protein.

Functions of Proteins Much of the structure of cells is made up of proteins. Proteins form parts of cell membranes. Proteins also make up many of the organelles within the cell.

The proteins known as enzymes perform important functions in the chemical reactions that take place in cells. An **enzyme** is a type of protein that speeds up a chemical reaction in a living thing. Without enzymes, many chemical reactions that are necessary for life would either take too long or not occur at all. For example, enzymes in your saliva speed up the digestion of food by breaking down starches into sugars in your mouth.

Reading Checkpoint **What is the role of enzymes in cells?**

Lab zone Try This Activity

What's That Taste?

Use this activity to discover one role that enzymes play in your body.

1. Put an unsalted soda cracker in your mouth. Chew it, but do not swallow. Note what the cracker tastes like.
2. Continue to chew the cracker for a few minutes, mixing it well with your saliva. Note how the taste of the cracker changes.

Inferring Soda crackers are made up mainly of starch, with little sugar. How can you account for the change in taste after you chewed the cracker for a few minutes?

FIGURE 5
Feathers Made of Protein
The feathers of this peacock are made mainly of protein.
Applying Concepts *What smaller molecules make up protein molecules?*

Nucleic Acids

Nucleic acids are very long organic molecules made of carbon, oxygen, hydrogen, nitrogen, and phosphorus. Nucleic acids contain the instructions that cells need to carry out all the functions of life.

There are two kinds of nucleic acids. Deoxyribonucleic acid (dee ahk see ry boh noo KLEE ik), or **DNA,** is the genetic material that carries information about an organism and is passed from parent to offspring. The information in DNA also directs all of the cell's functions. Most of the DNA in a cell is found in the chromatin in the nucleus. Ribonucleic acid (ry boh noo KLEE ik), or **RNA,** plays an important role in the production of proteins. RNA is found in the cytoplasm as well as in the nucleus.

Reading Checkpoint **What are the two kinds of nucleic acids? What are their functions?**

FIGURE 6 DNA in the Nucleus
A cell's nucleus (colored purple) contains most of the cell's DNA in its chromatin (colored red and yellow).

Section 1 Assessment

Target Reading Skill

Comparing and Contrasting Use the information in your table to help you answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What is an element?
   b. **Comparing and Contrasting** How is a compound different from an element?
   c. **Classifying** A molecule of ammonia consists of one atom of nitrogen and three atoms of hydrogen. Is ammonia an element or a compound? Explain.
2. a. **Reviewing** What three important functions does water perform in cells?
   b. **Relating Cause and Effect** Suppose a cell is seriously deprived of water. How might this lack of water affect the cell's enzymes? Explain.
3. a. **Reviewing** What are four types of organic molecules found in living things?
   b. **Classifying** Which of the four types of organic molecules contain the element nitrogen?
   c. **Inferring** An organic compound contains only the elements carbon, hydrogen, and oxygen. Could this compound be a carbohydrate? Could it be a protein? Explain.

Lab zone At-Home Activity

Compounds in Food With family members, look at the "Nutrition Facts" labels on a variety of food products. Identify foods that contain large amounts of the following organic compounds: carbohydrates, proteins, and fats. Discuss with your family what elements make up each of these compounds and what roles they play in cells and in your body.

Lab zone Consumer Lab

Which Foods Are Fat-Free?

Problem

Some people want to limit their intake of fats, or lipids. How can you determine whether information about fats on a food label is accurate?

Skills Focus

interpreting data, inferring

Materials

- permanent marker
- 5 cotton swabs
- 5 different snack dips in their containers, including nutrition labels
- 5 fat-testing strips with color key
- watch or clock
- 5 small squares of paper towel

Procedure

1. Copy the data table on a sheet of paper. Record the brand names of the five snack dips in the table. **CAUTION:** *Do not taste the dips at any time.*
2. Examine the nutrition label on the container of each dip. Record the percentage of the Daily Value (% DV) of fat that the dip contains.
3. Look at other information on the container to see whether the dip is labeled "fat-free." Record this information in the table.
4. Obtain five fat-testing strips. Label each strip with the name of one of the dips.
5. Use a cotton swab to smear a bit of one dip onto the test square of the corresponding testing strip. After 30 seconds, gently wipe the dip from the strip with a paper towel.
6. To determine whether the sample contains fat, compare the test square with the color key. Record your observation in the table.
7. Repeat Steps 5–6 for each of the sample dips.

Analyze and Conclude

1. **Observing** According to the information on the containers, which dips had 0% fat? Which dips were labeled "fat-free"?
2. **Interpreting Data** Did the result shown on the test square always agree with the information on the dip's container?
3. **Inferring** Based on your results, what can you conclude about the accuracy of labels indicating that foods are fat-free?
4. **Communicating** Write a report for consumers that summarizes your results. Summarize the processes you used.

Design an Experiment

Protein test strips indicate *how much* protein is present in a food sample. Design an experiment to rank five food samples in the order of least protein to most protein. *Obtain your teacher's permission before carrying out your investigation.*

Data Table

Name of Dip	Percent Fat (% Daily Value)	Labeled Fat-Free?	Result of Test

Section 2

The Cell in Its Environment

Reading Preview

Key Concepts

- How do most small molecules cross the cell membrane?
- Why is osmosis important to cells?
- What is the difference between passive transport and active transport?

Key Terms

- selectively permeable
- diffusion • osmosis
- passive transport
- active transport

Target Reading Skill

Building Vocabulary

A definition states the meaning of a word or phrase. After you read the section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a definition of each Key Term in your own words.

Lab zone **Discover Activity**

How Do Molecules Move?

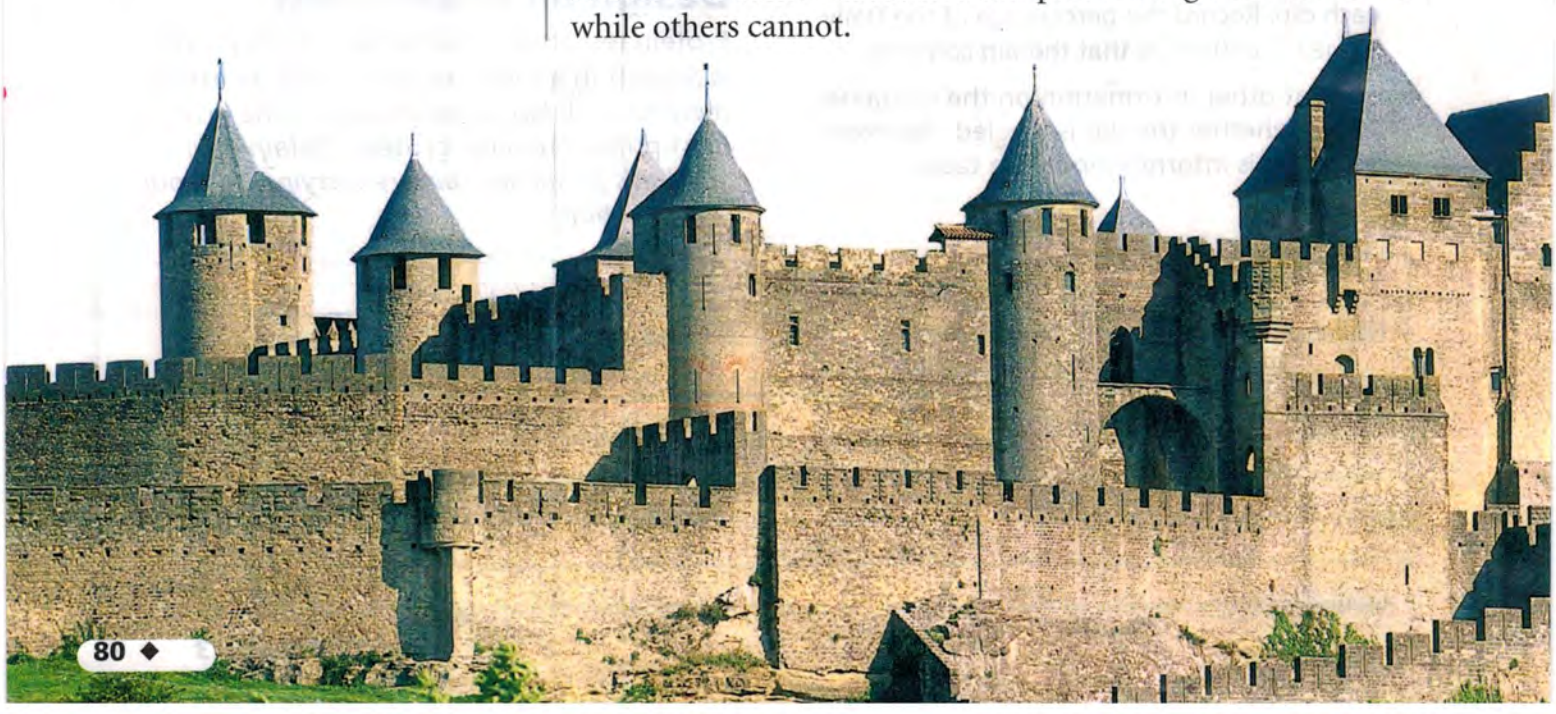
1. Stand with your classmates in locations that are evenly spaced throughout the classroom.
2. Your teacher will spray an air freshener into the room. When you first smell the air freshener, raise your hand.
3. Note how long it takes for other students to smell the scent.

Think It Over

Developing Hypotheses How was each student's distance from the teacher related to when he or she smelled the air freshener? Develop a hypothesis about why this pattern occurred.

As darkness fell, the knight urged his horse toward the castle. The weary knight longed for the safety of the castle, with its thick walls of stone and strong metal gates. The castle's gatekeeper opened the gates and slowly lowered the drawbridge. The horse clopped across the bridge, and the knight sighed with relief. Home at last!

Like ancient castles, cells have structures that protect their contents from the world outside. All cells are surrounded by a cell membrane that separates the cell from the outside environment. The cell membrane is **selectively permeable,** which means that some substances can pass through the membrane while others cannot.



Cells, like castles, must let things enter and leave. Cells must let in needed materials, such as oxygen and food molecules. In contrast, waste materials must move out of cells. Oxygen, food molecules, and waste products all must pass through the cell membrane.

Diffusion

Substances that can move into and out of a cell do so by one of three methods: diffusion, osmosis, or active transport. **Diffusion is the main method by which small molecules move across the cell membrane.** **Diffusion** (dih FYOO zhun) is the process by which molecules move from an area of higher concentration to an area of lower concentration. The concentration of a substance is the amount of the substance in a given volume. For example, suppose you dissolve 1 gram of sugar in 1 liter of water. The concentration of the sugar solution is 1 gram per liter.

If you did the Discover activity, you observed diffusion in action. The area where the air freshener was sprayed had many molecules of freshener. The molecules gradually moved from this area of higher concentration to the other parts of the classroom, where there were fewer molecules of freshener—and thus a lower concentration.

What Causes Diffusion? Molecules are always moving. As they move, the molecules bump into one another. The more molecules there are in an area, the more collisions there will be. Collisions cause molecules to push away from one another. Over time, the molecules of a substance will continue to spread out. Eventually, they will be spread evenly throughout the area.

Math Skills

Ratios

The concentration of a solution can be expressed as a ratio. A ratio compares two numbers. It tells you how much you have of one item in comparison to another. For example, suppose you dissolve 5 g of sugar in 1 L of water. You can express the concentration of the solution in ratio form as 5 g : 1 L, or 5 g/L.

Practice Problem Suppose you dissolve 7 g of salt in 1 L of water. Express the concentration of the solution as a ratio.

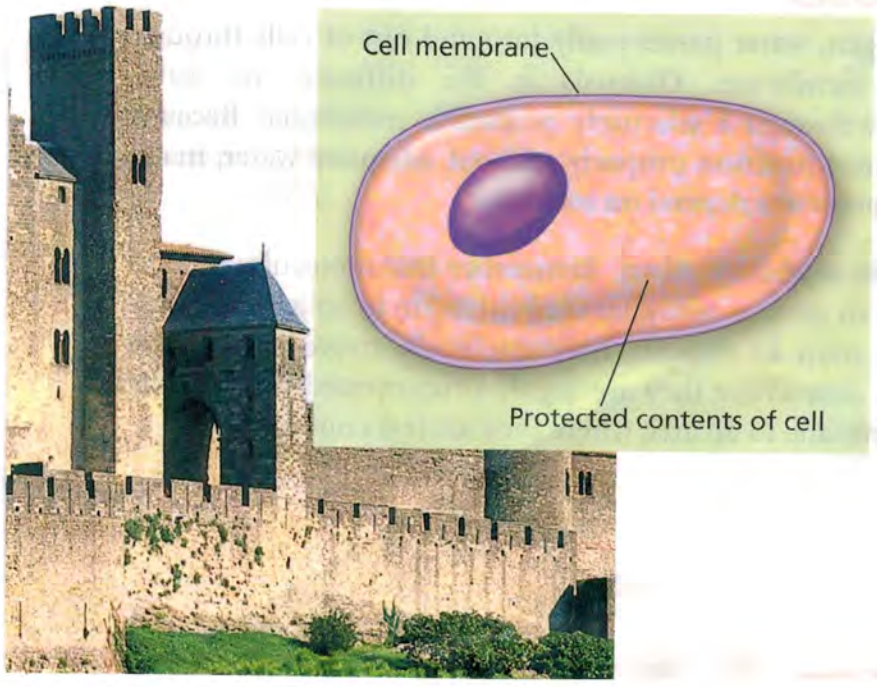
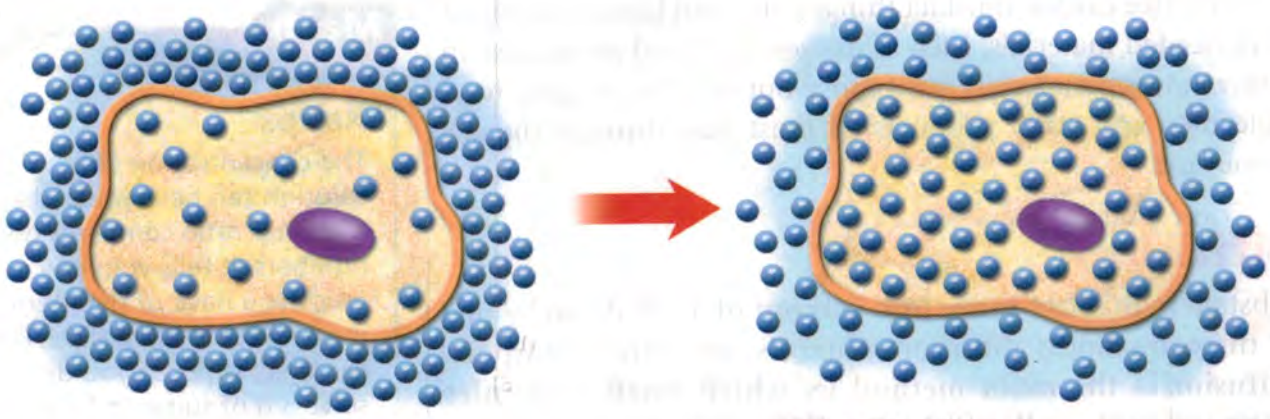


FIGURE 7
A Selective Barrier
The walls of a castle protected the inhabitants within, and the castle gatekeeper allowed only certain people to pass through. Similarly, the cell membrane protects the contents of the cell and helps control the materials that enter and leave.



Before Diffusion
There is a higher concentration of oxygen molecules outside the cell than inside the cell.

After Diffusion
The concentration of oxygen molecules is the same outside and inside the cell.

FIGURE 8
Diffusion in Action

Molecules move by diffusion from an area of higher concentration to an area of lower concentration.
Predicting *What would happen if the concentration of oxygen molecules outside the cell was lower than inside the cell?*

Diffusion of Oxygen Have you ever used a microscope to observe one-celled organisms in pond water? These organisms obtain the oxygen they need to survive from the water around them. Luckily for them, there are many more molecules of oxygen in the water outside the cell than there are inside the cell. In other words, there is a higher concentration of oxygen molecules in the water than inside the cell. Remember that the cell membrane is permeable to oxygen molecules. The oxygen molecules diffuse from the area of higher concentration—the pond water—through the cell membrane to the area of lower concentration—the inside of the cell.

Reading Checkpoint **By what process do small molecules move into cells?**

Osmosis

Like oxygen, water passes easily into and out of cells through the cell membrane. **Osmosis** is the diffusion of water molecules through a selectively permeable membrane. **Because cells cannot function properly without adequate water, many cellular processes depend on osmosis.**

Osmosis and Diffusion Remember that molecules tend to move from an area of higher concentration to an area of lower concentration. In osmosis, water molecules move by diffusion from an area where they are highly concentrated through the cell membrane to an area where they are less concentrated.

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Effects of Osmosis Osmosis can have important consequences for a cell. Look at Figure 9 to see the effect of osmosis on cells. In Figure 9A, a red blood cell is bathed in a solution in which the concentration of water is the same as it is inside the cell. This is the normal shape of a red blood cell.

Contrast this shape to the cell in Figure 9B. The red blood cell is floating in water that contains a large amount of salt. The concentration of water molecules outside the cell is lower than the concentration of water molecules inside the cell. This difference in concentration occurs because the salt takes up space in the salt water. Therefore, there are fewer water molecules in the salt water outside the cell compared to the water inside the cell. As a result, water moves out of the cell by osmosis. When water moves out, cells shrink.

In Figure 9C, the red blood cell is floating in water that contains a very small amount of salt. The water inside the cell contains more salt than the solution outside the cell. Thus, the concentration of water outside the cell is greater than it is inside the cell. The water moves into the cell, causing it to swell.

Reading Checkpoint **How is osmosis related to diffusion?**

Lab zone Try This Activity

Diffusion in Action

Here's how you can observe the effects of diffusion.

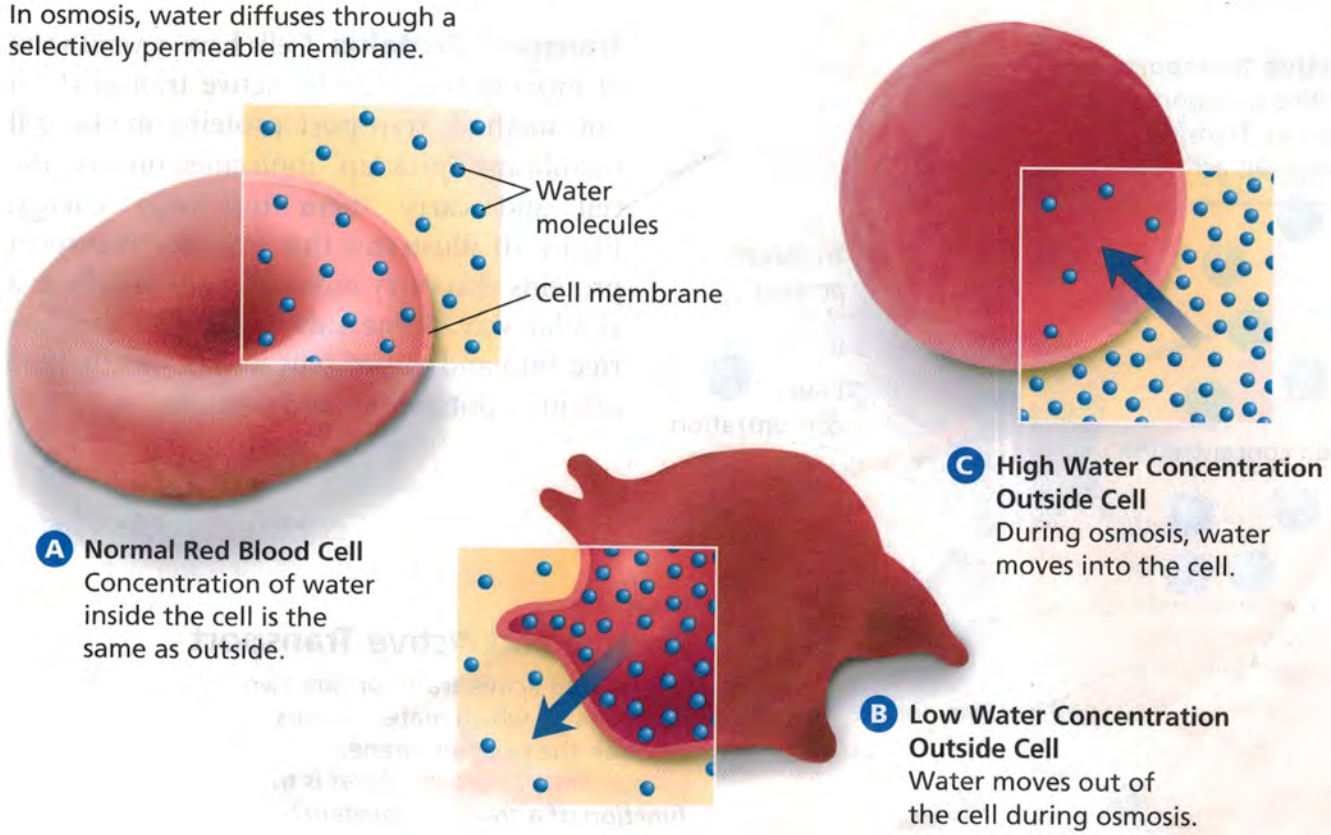
1. Fill a small, clear plastic cup with cold water. Place the cup on the table and allow it to sit until there is no movement in the water.
2. Use a plastic dropper to add one large drop of food coloring to the water.
3. Observe the water every minute. Note any changes that take place. Continue to observe until you can no longer see any changes.

Inferring What role did diffusion play in the changes you observed?

FIGURE 9

Effects of Osmosis on Cells

In osmosis, water diffuses through a selectively permeable membrane.



A Normal Red Blood Cell
Concentration of water inside the cell is the same as outside.

B Low Water Concentration Outside Cell
Water moves out of the cell during osmosis.

C High Water Concentration Outside Cell
During osmosis, water moves into the cell.

Active Transport

If you have ever ridden a bicycle down a long hill, you know that it doesn't take any of your energy to go fast. But you do have to use some of your energy to pedal back up the hill. For a cell, moving materials through the cell membrane by diffusion and osmosis is like cycling downhill. These processes do not require the cell to use its own energy. The movement of dissolved materials through a cell membrane without using cellular energy is called **passive transport.**

What if a cell needs to take in a substance that is present in a higher concentration inside the cell than outside? The cell would have to move the molecules in the opposite direction than they naturally move by diffusion. Cells can do this, but they have to use energy—just as you would use energy to pedal back up the hill. **Active transport** is the movement of materials through a cell membrane using cellular energy. **Active transport requires the cell to use its own energy, while passive transport does not.**

Transport Proteins Cells have several ways of moving materials by active transport. In one method, transport proteins in the cell membrane "pick up" molecules outside the cell and carry them in, using energy. Figure 10 illustrates this process. Transport proteins also carry molecules out of cells in a similar way. Some substances that are carried into and out of cells in this way include calcium, potassium, and sodium.

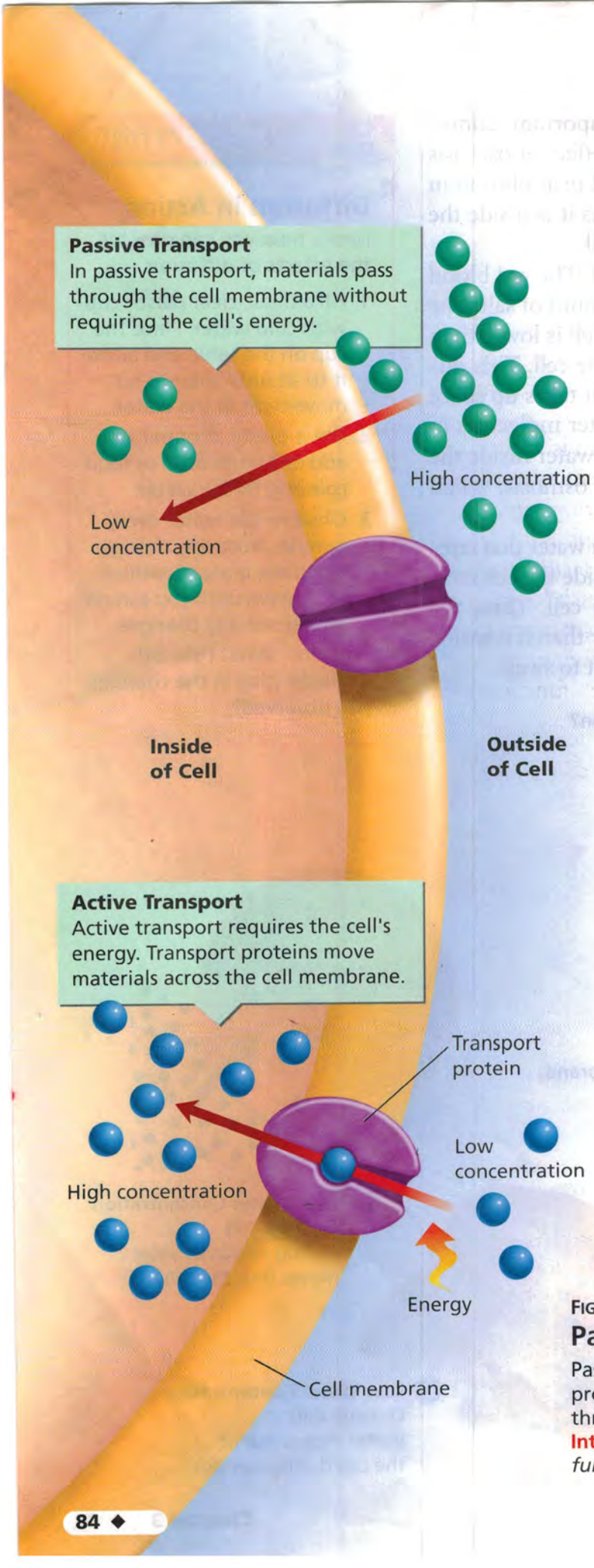


FIGURE 10
Passive and Active Transport
Passive and active transport are two processes by which materials pass through the cell membrane.
Interpreting Diagrams *What is the function of a transport protein?*

Transport by Engulfing Figure 11 shows another method of active transport. First, the cell membrane surrounds and engulfs, or encloses, a particle. Once the particle is engulfed, the cell membrane wraps around the particle and forms a vacuole within the cell. The cell must use energy in this process.

FIGURE 11
Amoeba Engulfing Food
This single-celled amoeba is surrounding a smaller organism. The amoeba will engulf the organism and use it for food. Engulfing is a form of active transport.

Why Cells Are Small As you know, most cells are so small that you cannot see them without a microscope. Have you ever wondered why cells are so small? One reason is related to how materials move into and out of cells.

As a cell's size increases, more of its cytoplasm is located farther from the cell membrane. Once a molecule enters a cell, it is carried to its destination by a stream of moving cytoplasm, somewhat like the way currents in the ocean move a raft. But in a very large cell, the streams of cytoplasm must travel farther to bring materials to all parts of the cell. It would take much longer for a molecule to reach the center of a very large cell than it would in a small cell. Likewise, it would take a long time for wastes to be removed. If a cell grew too large, it could not function well enough to survive.

Reading Checkpoint **What prevents cells from growing very large?**

Section 2 Assessment

Target Reading Skill **Building Vocabulary** Use your definitions to help answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What is diffusion?
   b. **Relating Cause and Effect** Use diffusion to explain what happens when you drop a sugar cube into a mug of hot tea.
2. a. **Defining** What is osmosis?
   b. **Describing** Describe how water molecules move through the cell membrane during osmosis.
   c. **Applying Concepts** A selectively permeable membrane separates solutions A and B. The concentration of water molecules in Solution B is higher than that in Solution A. Describe how the water molecules will move.
3. a. **Comparing and Contrasting** How is active transport different from passive transport?
   b. **Reviewing** What are transport proteins?
   c. **Explaining** Explain why transport proteins require energy to function in active transport.

Math Practice

A scientist dissolves 60 g of sugar in 3 L of water.

4. **Calculating a Concentration** Calculate the concentration of the solution in grams per liter.
5. **Ratios** Express the concentration as a ratio.

Section 3

Photosynthesis

Reading Preview

Key Concepts

- How does the sun supply living things with the energy they need?
- What happens during the process of photosynthesis?

Key Terms

- photosynthesis
- autotroph
- heterotroph
- pigment
- chlorophyll
- stomata

Target Reading Skill

Sequencing A sequence is the order in which the steps in a process occur. As you read, create a flowchart that shows the steps in photosynthesis. Put each step in a separate box in the flowchart in the order in which it occurs.

Steps in Photosynthesis

Sunlight strikes leaf.

↓

Chlorophyll captures light energy.

↓

Lab zone Discover Activity

Where Does the Energy Come From?

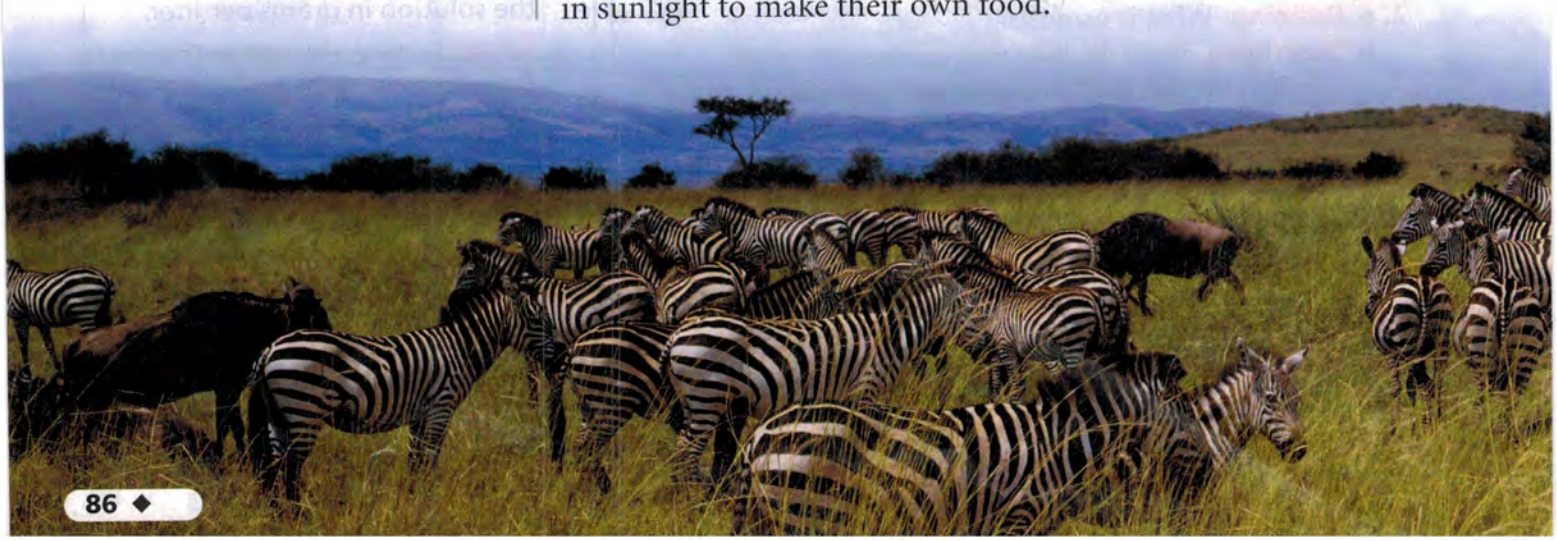
1. Obtain a solar-powered calculator that does not use batteries. Place the calculator in direct light.
2. Cover the solar cells with your finger. Note how your action affects the number display.
3. Uncover the solar cells. What happens to the number display?
4. Now cover all but one of the solar cells. How does that affect the number display?

Think It Over

Inferring From your observations, what can you infer about the energy that powers the calculator?

On a plain in Africa, dozens of zebras peacefully eat the grass. But watch out—the zebras' grazing will soon be harshly interrupted. A group of lions is about to attack the herd. The lions will kill one of the zebras and eat it.

Both the zebras and the lions use the food they eat to obtain energy. Every living thing needs energy. All cells need energy to carry out their functions, such as making proteins and transporting substances into and out of the cell. The zebra's meat supplies the lion's cells with the energy they need, just as the grass provides the zebra's cells with energy. But plants and certain other organisms, such as algae and some bacteria, obtain their energy in a different way. These organisms use the energy in sunlight to make their own food.



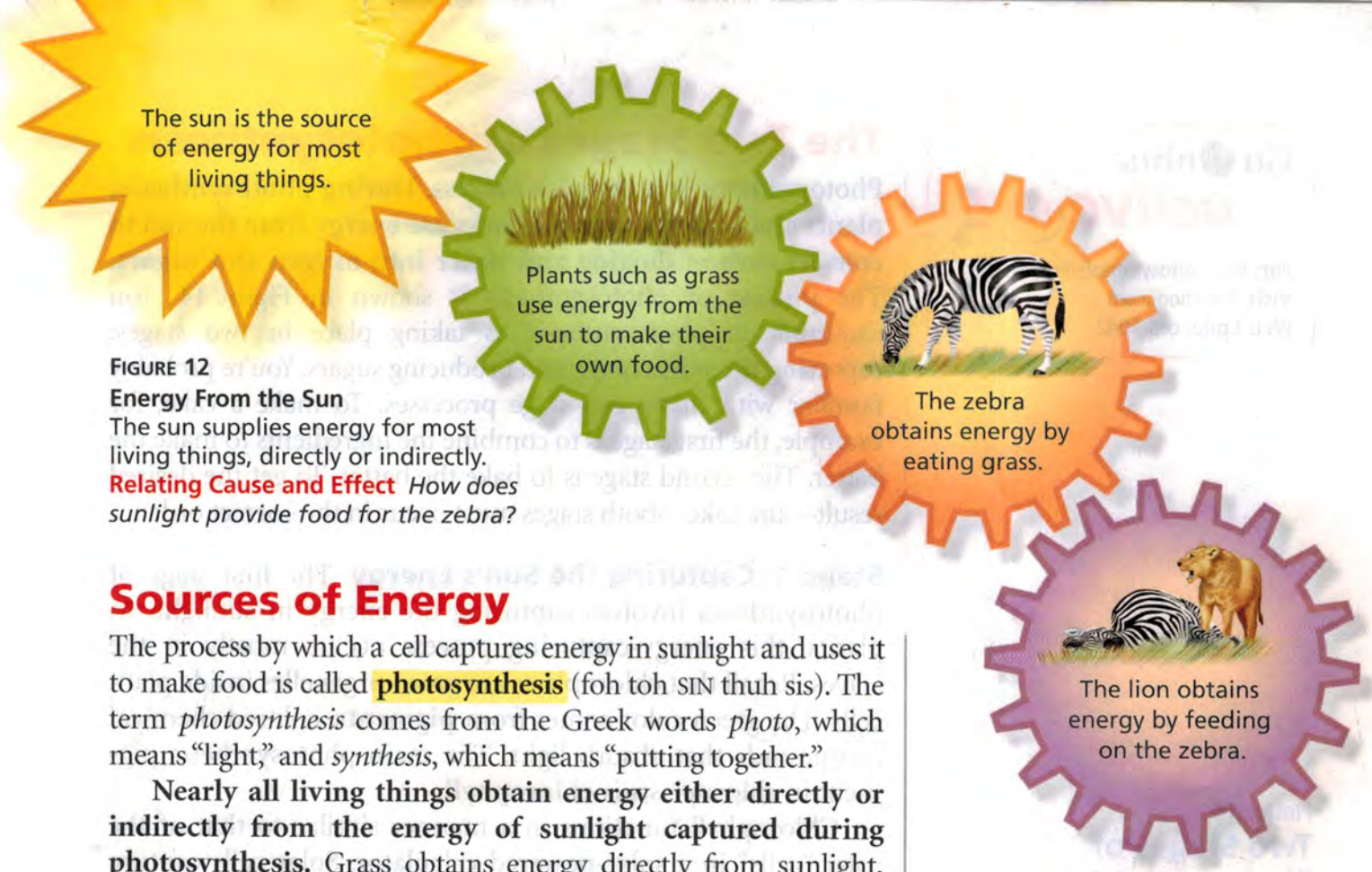


FIGURE 12
Energy From the Sun
The sun supplies energy for most living things, directly or indirectly.
Relating Cause and Effect *How does sunlight provide food for the zebra?*

Sources of Energy

The process by which a cell captures energy in sunlight and uses it to make food is called **photosynthesis** (foh toh SIN thuh sis). The term *photosynthesis* comes from the Greek words *photo*, which means "light," and *synthesis*, which means "putting together."

Nearly all living things obtain energy either directly or indirectly from the energy of sunlight captured during photosynthesis. Grass obtains energy directly from sunlight, because it makes its own food during photosynthesis. When the zebra eats the grass, it gets energy that has been stored in the grass. Similarly, the lion obtains energy stored in the zebra. The zebra and lion both obtain the sun's energy indirectly, from the energy that the grass obtained through photosynthesis.

Plants manufacture their own food through the process of photosynthesis. An organism that makes its own food is called an **autotroph** (AWT oh trahf). An organism that cannot make its own food, including animals such as the zebra and the lion, is called a **heterotroph** (HET ur oh trahf). Many heterotrophs obtain food by eating other organisms. Some heterotrophs, such as fungi, absorb their food from other organisms.

Reading Checkpoint **What are autotrophs?**

FIGURE 13
Autotrophs and Heterotrophs
Grass, which makes its own food during photosynthesis, is an autotroph. Zebras and lions are heterotrophs, because they cannot make their own food.

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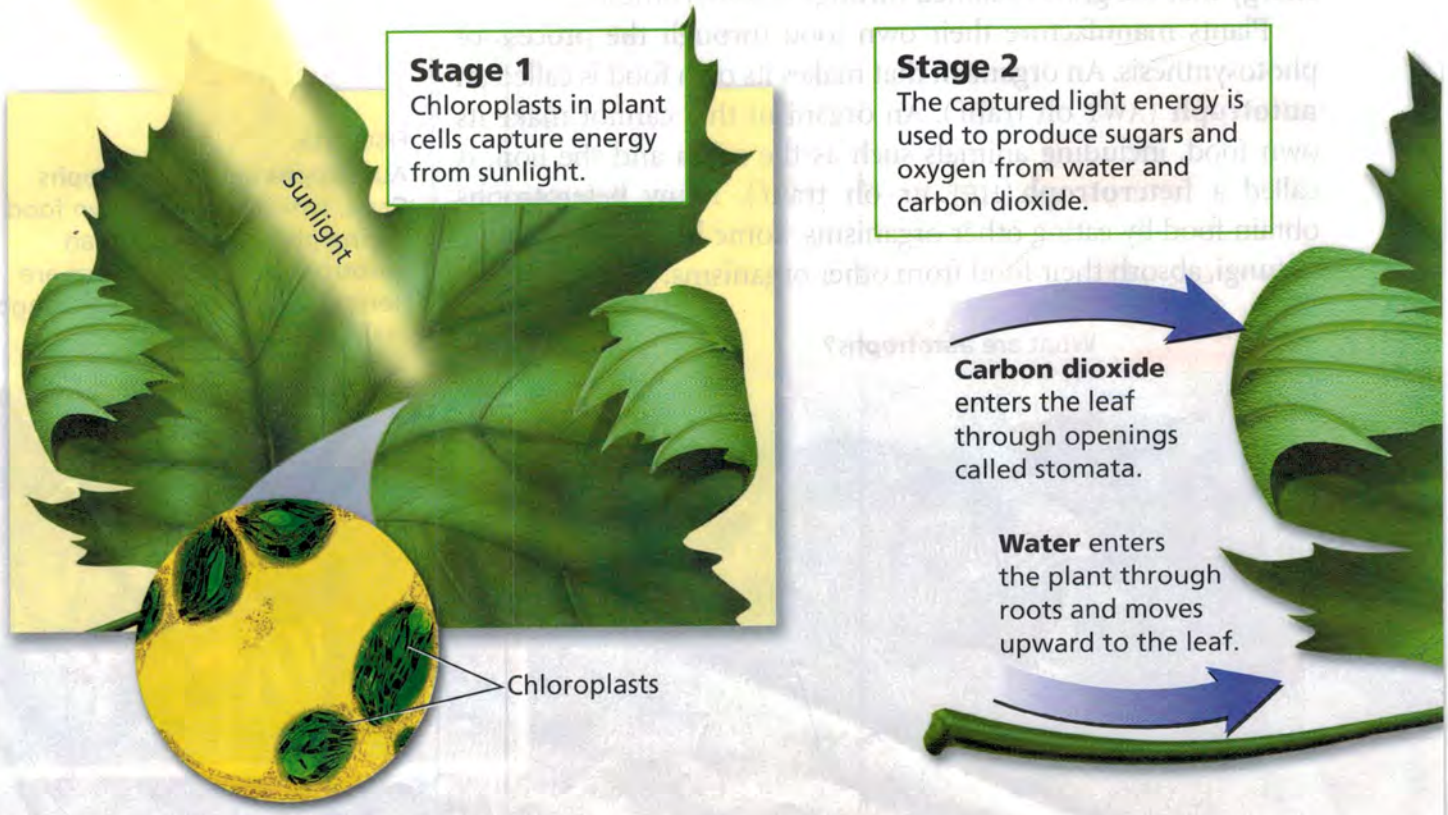
The Two Stages of Photosynthesis

Photosynthesis is a complex process. **During photosynthesis, plants and some other organisms use energy from the sun to convert carbon dioxide and water into oxygen and sugars.** The process of photosynthesis is shown in Figure 14. You can think of photosynthesis as taking place in two stages: capturing the sun's energy and producing sugars. You're probably familiar with many two-stage processes. To make a cake, for example, the first stage is to combine the ingredients to make the batter. The second stage is to bake the batter. To get the desired result—the cake—both stages must occur in the correct order.

Stage 1: Capturing the Sun's Energy The first stage of photosynthesis involves capturing the energy in sunlight. In plants, this energy-capturing process occurs mostly in the leaves. Recall that chloroplasts are green organelles inside plant cells. The green color comes from **pigments,** colored chemical compounds that absorb light. The main photosynthetic pigment in chloroplasts is **chlorophyll.**

Chlorophyll functions in a manner similar to that of the solar "cells" in a solar-powered calculator. Solar cells capture the energy in light and use it to power the calculator. Similarly, chlorophyll captures light energy and uses it to power the second stage of photosynthesis.

FIGURE 14
Two Stages of Photosynthesis
Photosynthesis has two stages, as shown in the diagram.
Interpreting Diagrams *Which stage requires light?*



Stage 2: Using Energy to Make Food In the next stage of photosynthesis, the cell uses the captured energy to produce sugars. The cell needs two raw materials for this stage: water (H_2O) and carbon dioxide (CO_2). In plants, the roots absorb water from the soil. The water then moves up through the plant's stem to the leaves. Carbon dioxide is one of the gases in the air. Carbon dioxide enters the plant through small openings on the undersides of the leaves called **stomata** (STOH muh tuh) (singular *stoma*). Once in the leaves, the water and carbon dioxide move into the chloroplasts.

Inside the chloroplasts, the water and carbon dioxide undergo a complex series of chemical reactions. The reactions are powered by the energy captured in the first stage. These reactions produce chemicals as products. One product is a sugar that has six carbon atoms. Six-carbon sugars have the chemical formula $C_6H_{12}O_6$. Recall that sugars are a type of carbohydrate. Cells can use the energy in the sugar to carry out important cell functions.

The other product of photosynthesis is oxygen (O_2), which exits the leaf through the stomata. In fact, almost all the oxygen in Earth's atmosphere was produced by living things through the process of photosynthesis.

Reading Checkpoint **What makes plants green?**

Lab zone Try This Activity

Looking at Pigments

You can observe the pigments in a leaf.

1. Cut a strip 5 cm by 20 cm out of a paper coffee filter.
2. Place a leaf on top of the paper strip, about 2 cm from the bottom.
3. Roll the edge of a dime over a section of the leaf, leaving a narrow band of color on the paper strip.
4. Pour rubbing alcohol into a plastic cup to a depth of 1 cm. Stand the paper strip in the cup so the color band is about 1 cm above the alcohol. Hook the other end of the strip over the top of the cup.
5. After 10 minutes, remove the paper strip and let it dry. Observe the strip.
6. Wash your hands.

Inferring What does the paper strip's appearance reveal about leaf pigments?

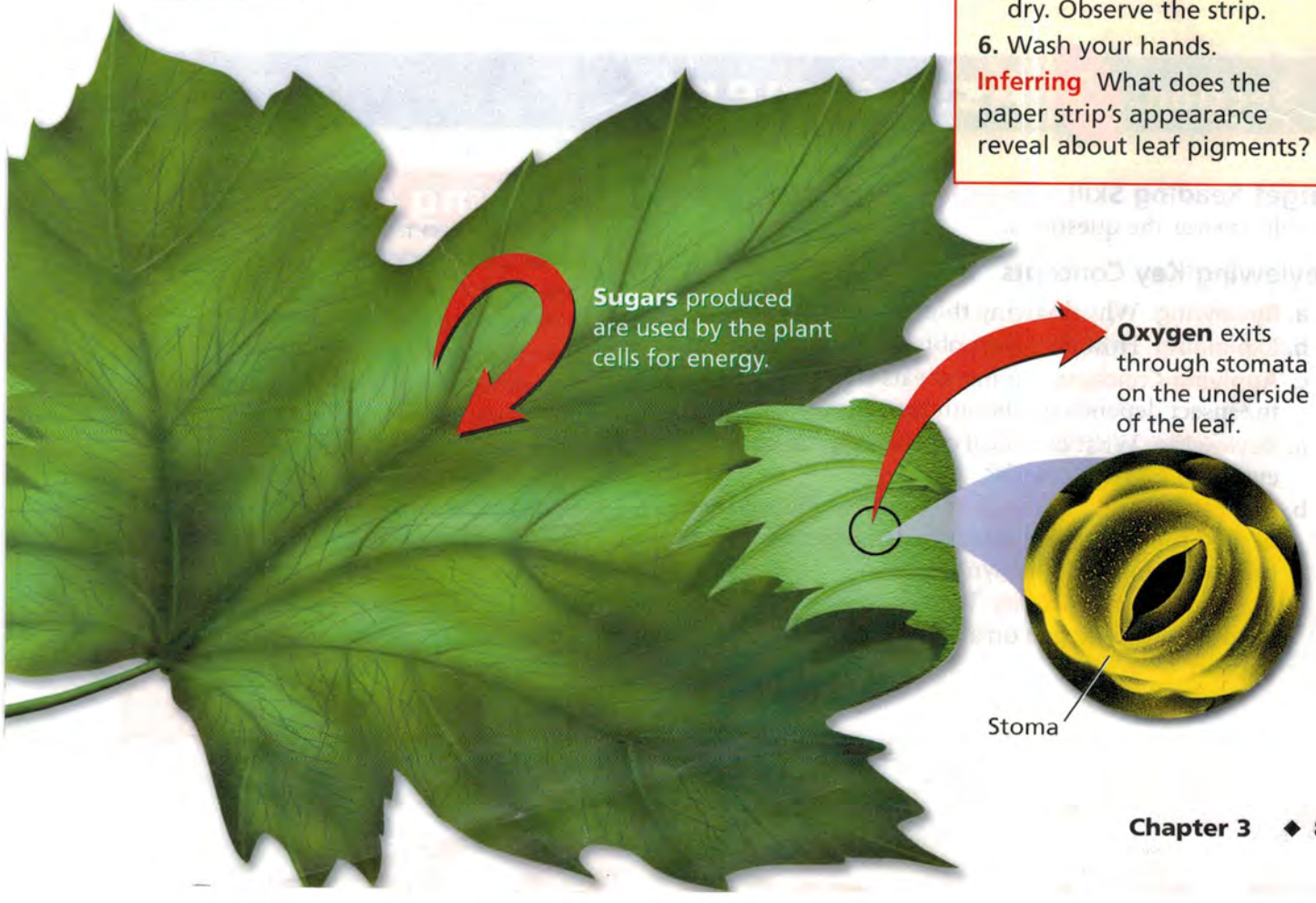


FIGURE 15 Stored Energy When you eat a carrot, you obtain energy stored during photosynthesis.

The Photosynthesis Equation The events of photosynthesis can be summed up by the following chemical equation:

$$\underset{\text{carbon dioxide}}{6\ CO_2} + \underset{\text{water}}{6\ H_2O} \xrightarrow{\text{light energy}} \underset{\text{a sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6\ O_2}$$

Notice that the raw materials—six molecules of carbon dioxide and six molecules of water—are on the left side of the equation. The products—one molecule of a sugar and six molecules of oxygen—are on the right side of the equation. An arrow, which you can read as "yields," connects the raw materials to the products. Light energy, which is necessary for the chemical reaction to occur, is written above the arrow.

What happens to the sugar produced in photosynthesis? Plant cells use some of the sugar for food. The cells break down the sugar molecules to release the energy they contain. This energy can then be used to carry out the plant's functions. Some sugar molecules are converted into other compounds, such as cellulose. Other sugar molecules may be stored in the plant's cells for later use. When you eat food from plants, such as potatoes or carrots, you are eating the plant's stored energy.

Reading Checkpoint **In the photosynthesis equation, what does the arrow mean?**

Section 3 Assessment

Target Reading Skill **Sequencing** Use your definitions to help answer the questions.

Reviewing Key Concepts

1. a. **Reviewing** Why do living things need energy?
   b. **Explaining** How do plants obtain energy?
   c. **Applying Concepts** An insect eats a leaf. Explain how the insect depends on the sun for energy.
2. a. **Reviewing** What chemical equation sums up the events of photosynthesis?
   b. **Comparing and Contrasting** What are the substances needed for photosynthesis? What substances are produced during photosynthesis?
   c. **Making Generalizations** Would you expect a plant to produce more oxygen on a cloudy day or a sunny day? Explain.

Writing in Science

Job Qualifications When people apply for jobs, they often must complete a job application form in which they describe their qualifications for a job. Suppose that you are a leaf, and that you are applying for a job in a photosynthesis factory. Write a paragraph in which you summarize your qualifications for the job of photosynthesis. Your paragraph should include the following words: *chloroplasts, chlorophyll, light, energy, water, carbon dioxide,* and *stomata*.

Section 4

Respiration

Reading Preview

Key Concepts

- What events occur during respiration?
- What is fermentation?

Key Terms

- respiration
- fermentation

Target Reading Skill

Using Prior Knowledge Your prior knowledge is what you already know before you read about a topic. Before you read, write a definition of respiration in a graphic organizer like the one below. As you read, revise your definition based on what you learn.

What You Know
1. Definition of respiration:

What You Learned
1.

Lab zone **Discover Activity**

What Is a Product of Respiration?

1. Put on your goggles. Fill two test tubes half full of warm water. Add 5 mL of sugar to one of the test tubes. Put the tubes in a test-tube rack.
2. Add 0.5 mL of dried yeast (a single-celled organism) to each tube. Stir the contents of each tube with a straw. Place a stopper snugly in the top of each tube.
3. Observe the two test tubes over the next 10 to 15 minutes.

Think It Over

Observing How can you account for any changes you observed?

You've been hiking all morning, and you are hungry. You get out the sandwich you packed and begin munching. Why does your body need food?

What Is Respiration?

Food supplies your body with glucose, an energy-rich sugar. **Respiration** is the process by which cells obtain energy from glucose. **During respiration, cells break down simple food molecules such as sugar and release the energy they contain.**

Storing and Releasing Energy Energy stored in cells is something like money in a savings account. During photosynthesis, plants capture energy from sunlight and "save" it in the form of carbohydrates, including sugars and starches. Similarly, when you eat, you add to your body's energy savings account. When cells need energy, they "withdraw" it by breaking down the carbohydrates in the process of respiration.

Breathing and Respiration The term *respiration* has two meanings. You have probably used it to mean "breathing," that is, moving air in and out of your lungs. To avoid confusion, the respiration process that takes place inside cells is sometimes called cellular respiration. Breathing brings oxygen, which is usually necessary for cellular respiration, into your lungs.

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The Two Stages of Respiration Like photosynthesis, respiration is a two-stage process. The first stage takes place in the cytoplasm of the organism's cells. There, molecules of glucose are broken down into smaller molecules. Oxygen is not involved, and only a small amount of energy is released.

The second stage of respiration takes place in the mitochondria. There, the small molecules are broken down into even smaller molecules. These chemical reactions require oxygen, and they release a great deal of energy. This is why the mitochondria are sometimes called the "powerhouses" of the cell.

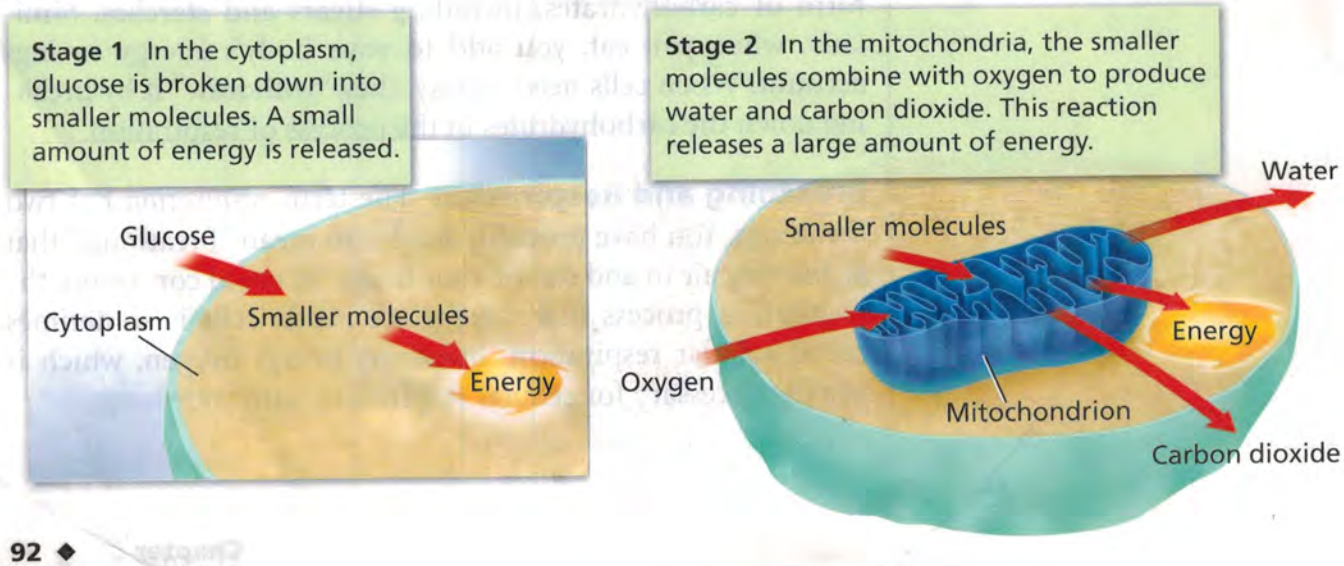
Trace the steps in the breakdown of glucose in Figure 16. Note that energy is released in both stages. Two other products of respiration are carbon dioxide and water. These products diffuse out of the cell. In most animals, the carbon dioxide and some water leave the body during exhalation, or breathing out. Thus, when you breathe in, you take in oxygen—a raw material for respiration. When you breathe out, you release carbon dioxide and water—products of respiration.

The Respiration Equation Although respiration occurs in a series of complex steps, the overall process can be summarized in the following equation:

$$\underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6\,O_2} \longrightarrow \underset{\text{carbon dioxide}}{6\,CO_2} + \underset{\text{water}}{6\,H_2O} + \text{energy}$$

Notice that the raw materials for respiration are sugar and oxygen. Plants and other organisms that undergo photosynthesis make their own sugar. The glucose in the cells of animals and other organisms comes from the food they consume. The oxygen used in respiration comes from the air or water surrounding the organism.

FIGURE 16
Two Stages of Respiration
Respiration, like photosynthesis, takes place in two stages.
Interpreting Diagrams *In which stage is oxygen used?*



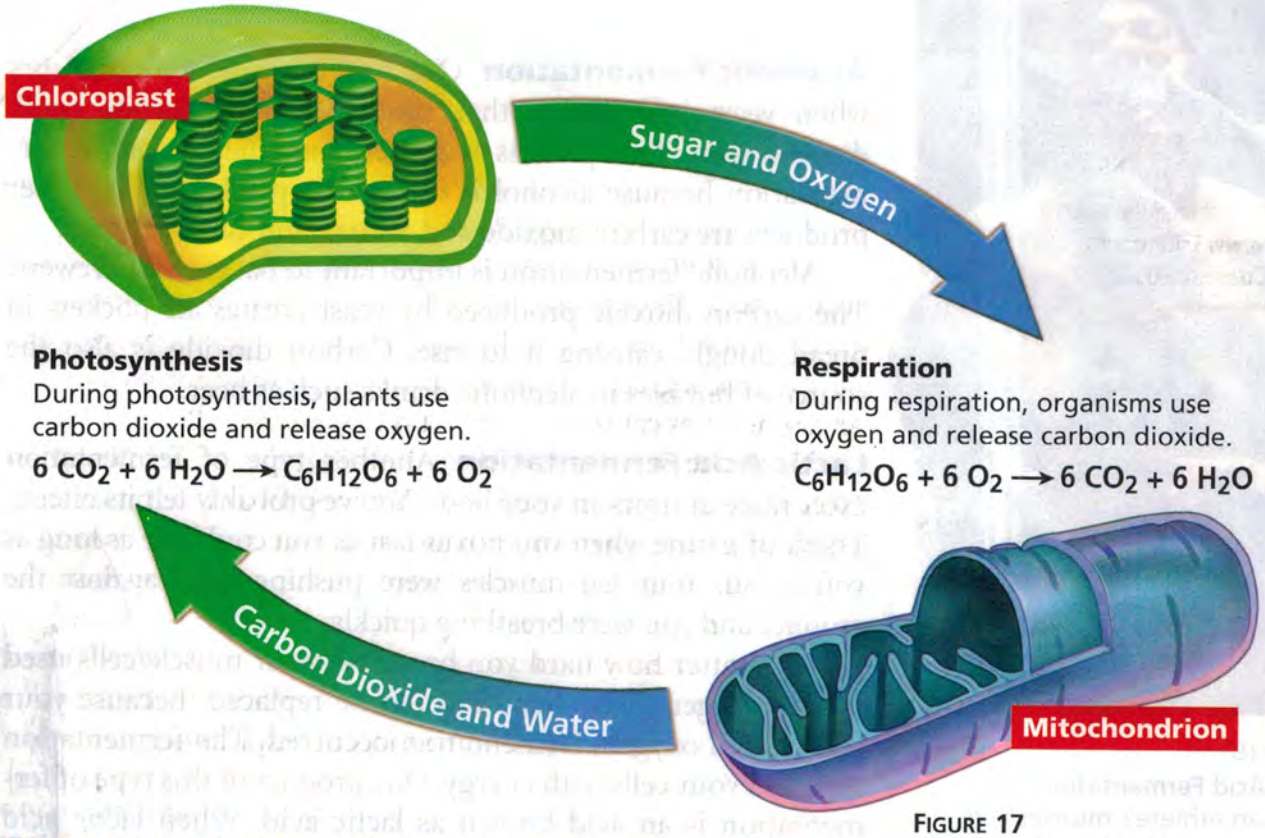


FIGURE 17
Photosynthesis and Respiration
You can think of photosynthesis and respiration as opposite processes.
Comparing and Contrasting
Which process uses oxygen? Which uses carbon dioxide?

Comparing Photosynthesis and Respiration Can you notice anything familiar about the equation for respiration? You are quite right if you said it is the opposite of the equation for photosynthesis. This is an important point. During photosynthesis, carbon dioxide and water are used to produce sugars and oxygen. During respiration, the sugar glucose and oxygen are used to produce carbon dioxide and water. Photosynthesis and respiration can be thought of as opposite processes.

Together, these two processes form a cycle that keeps the levels of oxygen and carbon dioxide fairly constant in Earth's atmosphere. As you can see in Figure 17, living things use both gases over and over again.

Reading Checkpoint **Which process—photosynthesis or respiration—produces water?**

Fermentation

Some cells are able to obtain energy from food without using oxygen. For example, some single-celled organisms live where there is no oxygen, such as deep in the ocean or in the mud of lakes or swamps. These organisms obtain their energy through **fermentation,** an energy-releasing process that does not require oxygen. **Fermentation provides energy for cells without using oxygen.** The amount of energy released from each sugar molecule during fermentation, however, is much lower than the amount released during respiration.

FIGURE 18
Lactic Acid Fermentation
When an athlete's muscles run out of oxygen, lactic acid fermentation supplies the cells with energy.

Alcoholic Fermentation One type of fermentation occurs when yeast and some other single-celled organisms break down sugars. This process is sometimes called alcoholic fermentation because alcohol is one of the products. The other products are carbon dioxide and a small amount of energy.

Alcoholic fermentation is important to bakers and brewers. The carbon dioxide produced by yeast creates air pockets in bread dough, causing it to rise. Carbon dioxide is also the source of bubbles in alcoholic drinks such as beer.

Lactic Acid Fermentation Another type of fermentation takes place at times in your body. You've probably felt its effects. Think of a time when you ran as fast as you could for as long as you could. Your leg muscles were pushing hard against the ground, and you were breathing quickly.

No matter how hard you breathed, your muscle cells used up the oxygen faster than it could be replaced. Because your cells lacked oxygen, fermentation occurred. The fermentation supplied your cells with energy. One product of this type of fermentation is an acid known as lactic acid. When lactic acid builds up, you feel a painful sensation in your muscles. Your muscles feel weak and sore.

Section 4 Assessment

Target Reading Skill

Using Prior Knowledge Review your graphic organizer about respiration. List two things that you learned about respiration.

Reviewing Key Concepts

1. a. **Reviewing** What happens during respiration?
   b. **Reviewing** What is the equation for respiration?
   c. **Comparing and Contrasting** Compare the equations for respiration and photosynthesis.
   d. **Relating Cause and Effect** Explain why cellular respiration adds carbon dioxide to the atmosphere, but photosynthesis does not.
2. a. **Identifying** What is the process in which cells obtain energy without using oxygen?
   b. **Inferring** How would athletes be affected if this process could not take place?
   c. **Predicting** Is this process more likely to occur during a short run or a long walk? Explain your answer.

Lab zone At-Home Activity

Make Bread With an adult family member, follow a recipe in a cookbook to make a loaf of bread using yeast. Explain to your family what causes the dough to rise. After you bake the bread, observe a slice and look for evidence that fermentation occurred.

Section 5

Cell Division

Reading Preview

Key Concepts

- What events take place during the three stages of the cell cycle?
- How does the structure of DNA help account for the way in which DNA copies itself?

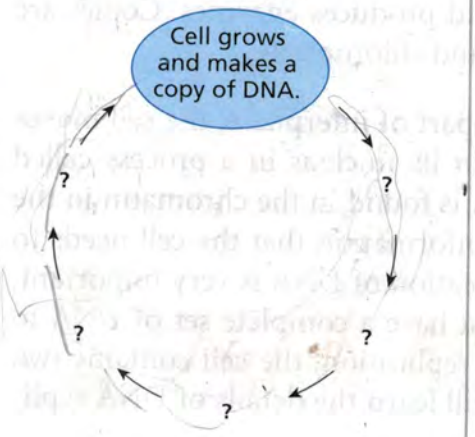
Key Terms

- cell cycle
- interphase
- replication
- mitosis
- chromosome
- cytokinesis

Target Reading Skill

Sequencing As you read, make a cycle diagram that shows the events in the cell cycle, including the phases of mitosis. Write each event in a separate circle.

The Cell Cycle



Lab zone Discover Activity

What Are the Yeast Cells Doing?

1. Use a plastic dropper to transfer some yeast cells from a yeast culture to a microscope slide. Your teacher has prepared the slide by drying methylene blue stain onto it. Add a coverslip and place the slide under a microscope.
2. Examine the cells on the slide. Use low power first and then high power. Look for what appear to be two cells attached to each other. One cell may be larger than the other. Draw what you see.

Think It Over

Developing Hypotheses What process do you think the "double cells" are undergoing? Develop a hypothesis that might explain what you see.

In the early autumn, many local fairs run pumpkin contests. Proud growers enter their largest pumpkins, hoping to win a prize. The pumpkin below has a mass greater than 600 kilograms! This giant pumpkin began as a small flower. How did the pumpkin grow so big?

A pumpkin grows in size by increasing both the size and the number of its cells. A single cell grows and then divides, forming two cells. Then two cells grow and divide, forming four, and so on. This process of cell growth and division does not occur only in pumpkins, though. In fact, many cells in your body are dividing as you read this page.

Prize-winning pumpkin ▲

Discovery CHANNEL SCHOOL

Cell Processes and Energy

Video Preview
▶ Video Field Trip
Video Assessment

Stage 1: Interphase

How do little pigs get to be big pigs? Their cells grow and divide, over and over. The regular sequence of growth and division that cells undergo is known as the **cell cycle.** During the cell cycle, a cell grows, prepares for division, and divides into two new cells, which are called "daughter cells." Each of the daughter cells then begins the cell cycle again. You can see details of the cell cycle in Figure 21. Notice that the cell cycle is divided into three main stages: interphase, mitosis, and cytokinesis.

The first stage of the cell cycle is called **interphase.** Interphase is the period before cell division. **During interphase, the cell grows, makes a copy of its DNA, and prepares to divide into two cells.**

Growing During the first part of interphase, the cell grows to its full size and produces structures it needs. For example, the cell makes new ribosomes and produces enzymes. Copies are made of both mitochondria and chloroplasts.

Copying DNA In the next part of interphase, the cell makes an exact copy of the DNA in its nucleus in a process called **replication.** Recall that DNA is found in the chromatin in the nucleus. DNA holds all the information that the cell needs to carry out its functions. Replication of DNA is very important, since each daughter cell must have a complete set of DNA to survive. At the end of DNA replication, the cell contains two identical sets of DNA. You will learn the details of DNA replication later in this section.

Preparing for Division Once the DNA has replicated, preparation for cell division begins. The cell produces structures that it will use to divide into two new cells. At the end of interphase, the cell is ready to divide.

Reading Checkpoint **What is replication?**

Lab zone **Try This Activity**

Modeling Mitosis

Refer to Figure 21 as you carry out this activity.

1. Construct a model of a cell that has four chromosomes. Use a piece of construction paper to represent the cell. Use different-colored pipe cleaners to represent the chromosomes. Make sure that the chromosomes look like double rods.
2. Position the chromosomes in the cell where they would be during prophase.
3. Repeat Step 2 for metaphase, anaphase, and telophase.

Making Models How did the model help you understand the events of mitosis?

FIGURE 19
Bigger Pig, More Cells
The mother pig has more cells in her body than her small piglets.

Stage 2: Mitosis

Once interphase is complete, the second stage of the cell cycle begins. **Mitosis** (my TOH sis) is the stage during which the cell's nucleus divides into two new nuclei. **During mitosis, one copy of the DNA is distributed into each of the two daughter cells.**

Scientists divide mitosis into four parts, or phases: prophase, metaphase, anaphase, and telophase. During prophase, the threadlike chromatin in the nucleus condenses to form double-rod structures called **chromosomes.** Each chromosome has two rods because the cell's DNA has replicated, and each rod in a chromosome is an exact copy of the other. Each identical rod in a chromosome is called a chromatid. Notice in Figure 20 that the two chromatids are held together by a structure called a centromere.

As the cell progresses through metaphase, anaphase, and telophase, the chromatids separate from each other and move to opposite ends of the cell. Then two nuclei form around the new chromosomes at the two ends of the cell.

FIGURE 20
Chromosomes
During mitosis, the chromatin condenses to form chromosomes. Each chromosome consists of two identical strands, or chromatids.
Applying Concepts *During which phase of mitosis do the chromosomes form?*

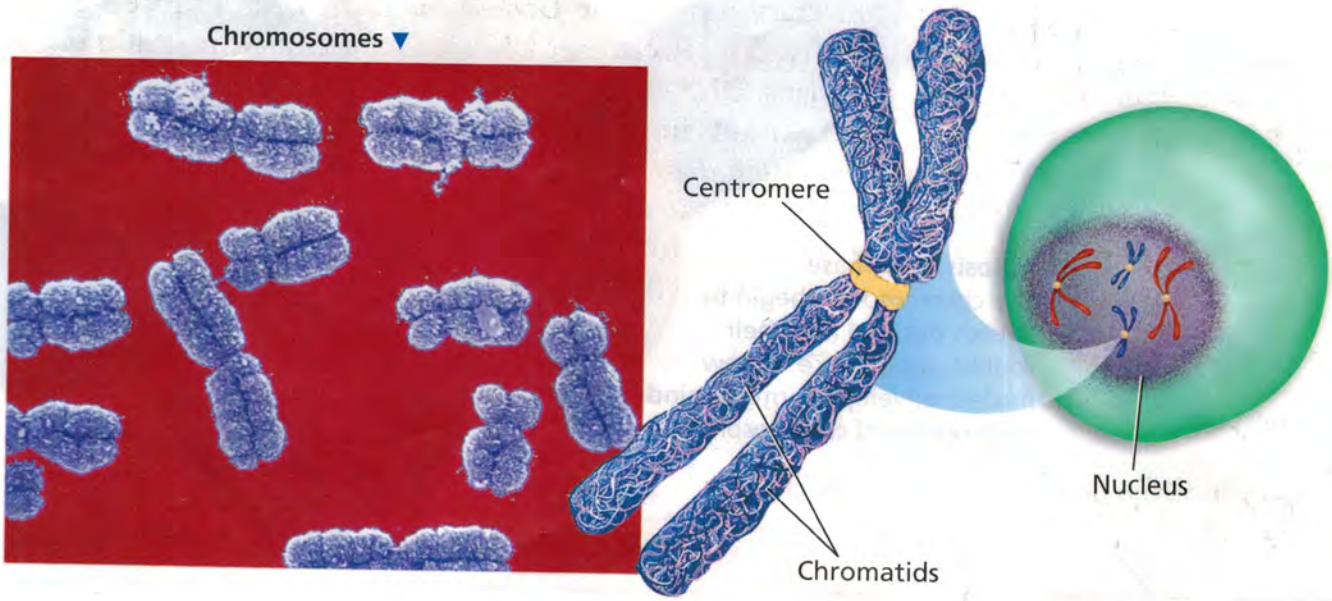
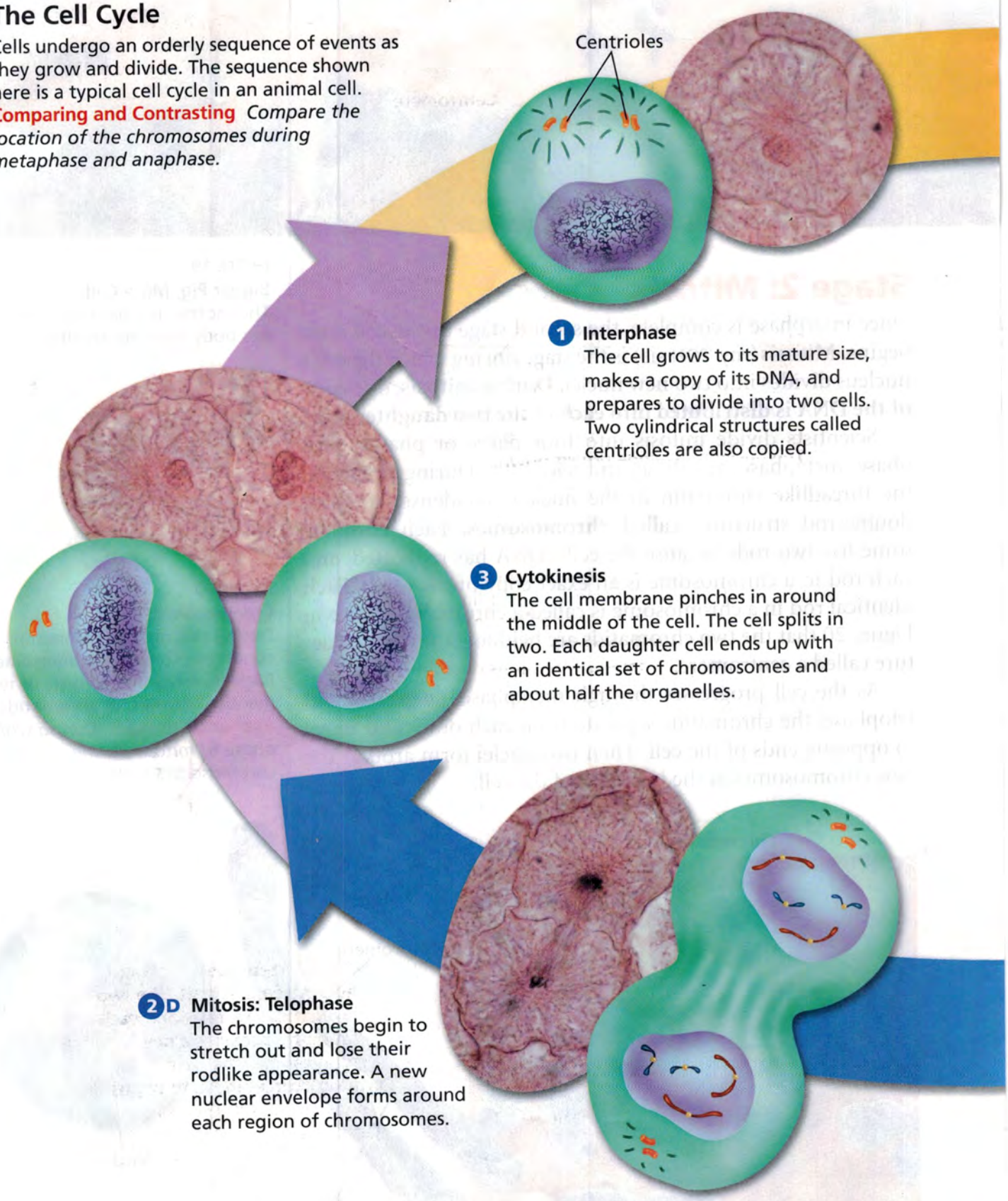


FIGURE 21

The Cell Cycle

Cells undergo an orderly sequence of events as they grow and divide. The sequence shown here is a typical cell cycle in an animal cell.
Comparing and Contrasting *Compare the location of the chromosomes during metaphase and anaphase.*



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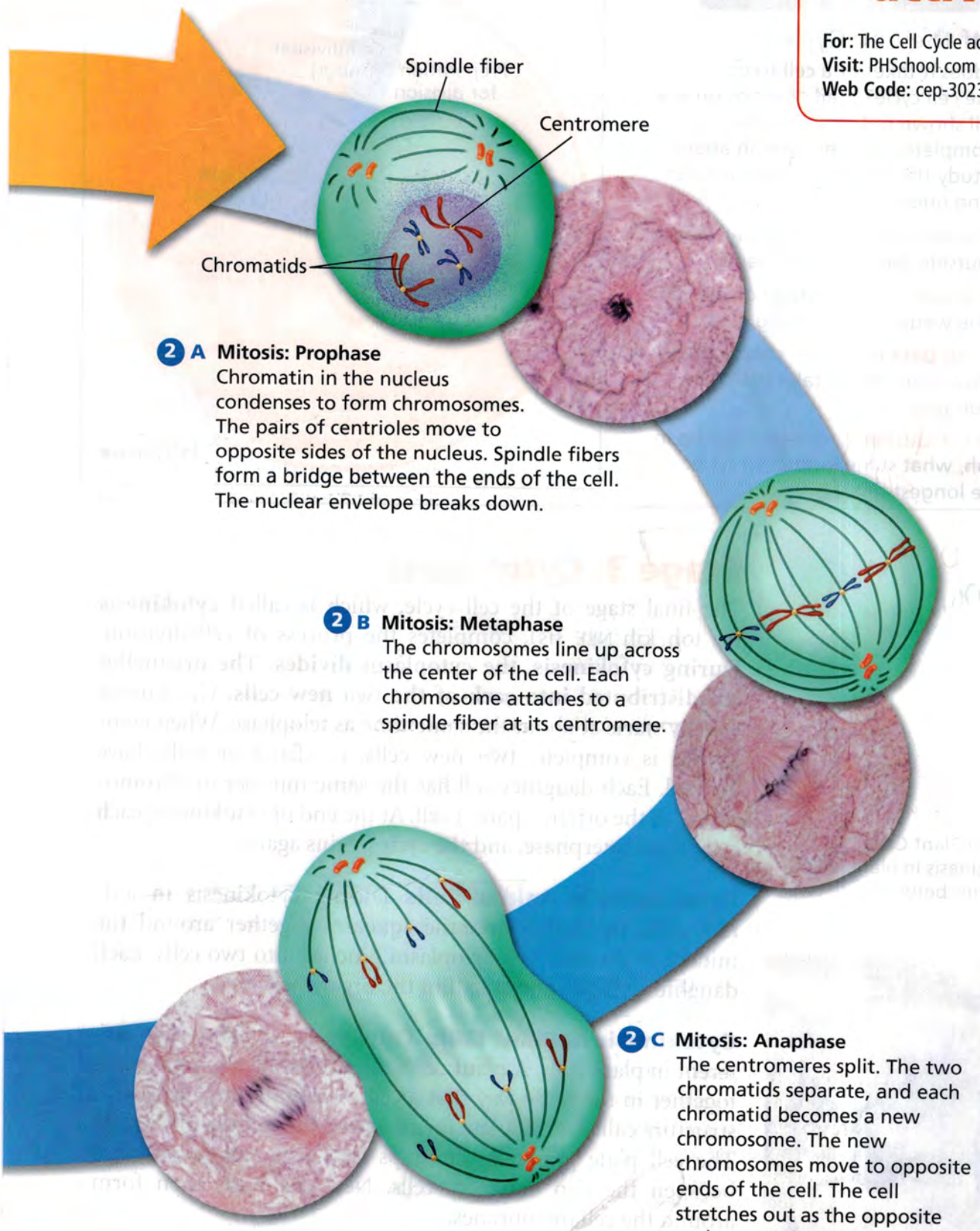


2 A Mitosis: Prophase
Chromatin in the nucleus condenses to form chromosomes. The pairs of centrioles move to opposite sides of the nucleus. Spindle fibers form a bridge between the ends of the cell. The nuclear envelope breaks down.

2 B Mitosis: Metaphase
The chromosomes line up across the center of the cell. Each chromosome attaches to a spindle fiber at its centromere.

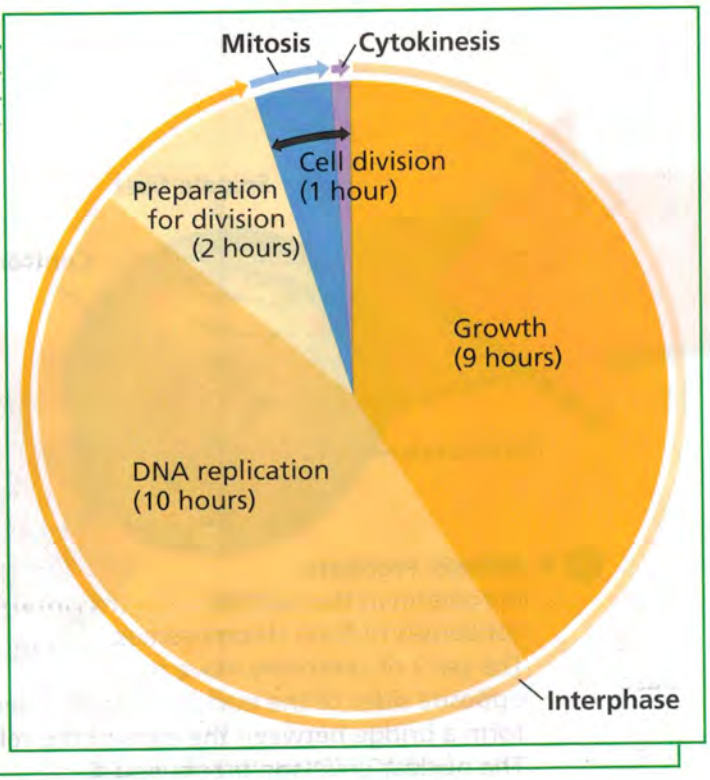
2 C Mitosis: Anaphase
The centromeres split. The two chromatids separate, and each chromatid becomes a new chromosome. The new chromosomes move to opposite ends of the cell. The cell stretches out as the opposite ends are pushed apart.

Math Analyzing Data

Length of the Cell Cycle

How long does it take for a cell to go through one cell cycle? It all depends on the cell. The cell shown in the graph, for example, completes one cell cycle in about 22 hours. Study the graph and then answer the following questions.

1. **Reading Graphs** What do the three curved arrows outside the circle represent?
2. **Reading Graphs** In what stage of the cell cycle is the wedge representing growth?
3. **Interpreting Data** In the cell shown in the graph, how long does it take DNA replication to occur?
4. **Drawing Conclusions** In the cell shown in the graph, what stage in the cell cycle takes the longest time?



Stage 3: Cytokinesis

The final stage of the cell cycle, which is called **cytokinesis** (sy toh kih NEE sis), completes the process of cell division. **During cytokinesis, the cytoplasm divides. The organelles are distributed into each of the two new cells.** Cytokinesis usually starts at about the same time as telophase. When cytokinesis is complete, two new cells, or daughter cells, have formed. Each daughter cell has the same number of chromosomes as the original parent cell. At the end of cytokinesis, each cell enters interphase, and the cycle begins again.

Cytokinesis in Animal Cells During cytokinesis in animal cells, the cell membrane squeezes together around the middle of the cell. The cytoplasm pinches into two cells. Each daughter cell gets about half of the organelles.

Cytokinesis in Plant Cells Cytokinesis is somewhat different in plant cells. A plant cell's rigid cell wall cannot squeeze together in the same way that a cell membrane can. Instead, a structure called a cell plate forms across the middle of the cell. The cell plate gradually develops into new cell membranes between the two daughter cells. New cell walls then form around the cell membranes.

Reading Checkpoint During what phase of mitosis does cytokinesis begin?

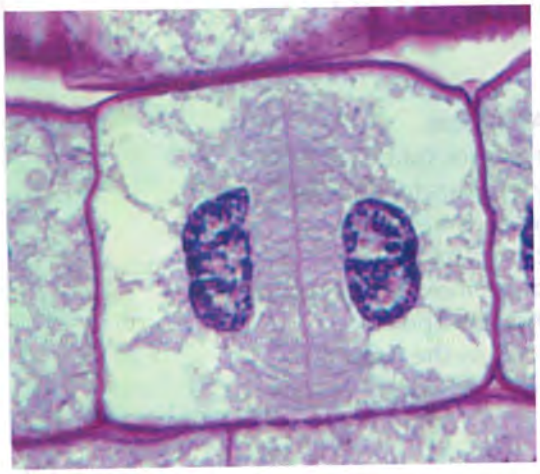


FIGURE 22
Cytokinesis in Plant Cells
During cytokinesis in plant cells, a cell plate forms between the two new nuclei.

Structure and Replication of DNA

DNA replication ensures that each daughter cell will have the genetic information it needs to carry out its activities. Before scientists could understand how DNA replicates, they had to know its structure. In 1952, Rosalind Franklin used an X-ray method to photograph DNA molecules. Her photographs helped James Watson and Francis Crick figure out the structure of DNA in 1953.

The Structure of DNA Notice in Figure 23 that a DNA molecule looks like a twisted ladder, or spiral staircase. The two sides of the DNA ladder are made up of molecules of a sugar called deoxyribose, alternating with molecules known as phosphates.

Each rung is made up of a pair of molecules called nitrogen bases. Nitrogen bases are molecules that contain the element nitrogen and other elements. DNA has four kinds of nitrogen bases: adenine (AD uh neen), thymine (THY meen), guanine (GWAH neen), and cytosine (SY tuh seen). The capital letters A, T, G, and C are used to represent the four bases.

The bases on one side of the ladder pair with the bases on the other side. Adenine (A) only pairs with thymine (T), while guanine (G) only pairs with cytosine (C). This pairing pattern is the key to understanding how DNA replication occurs.

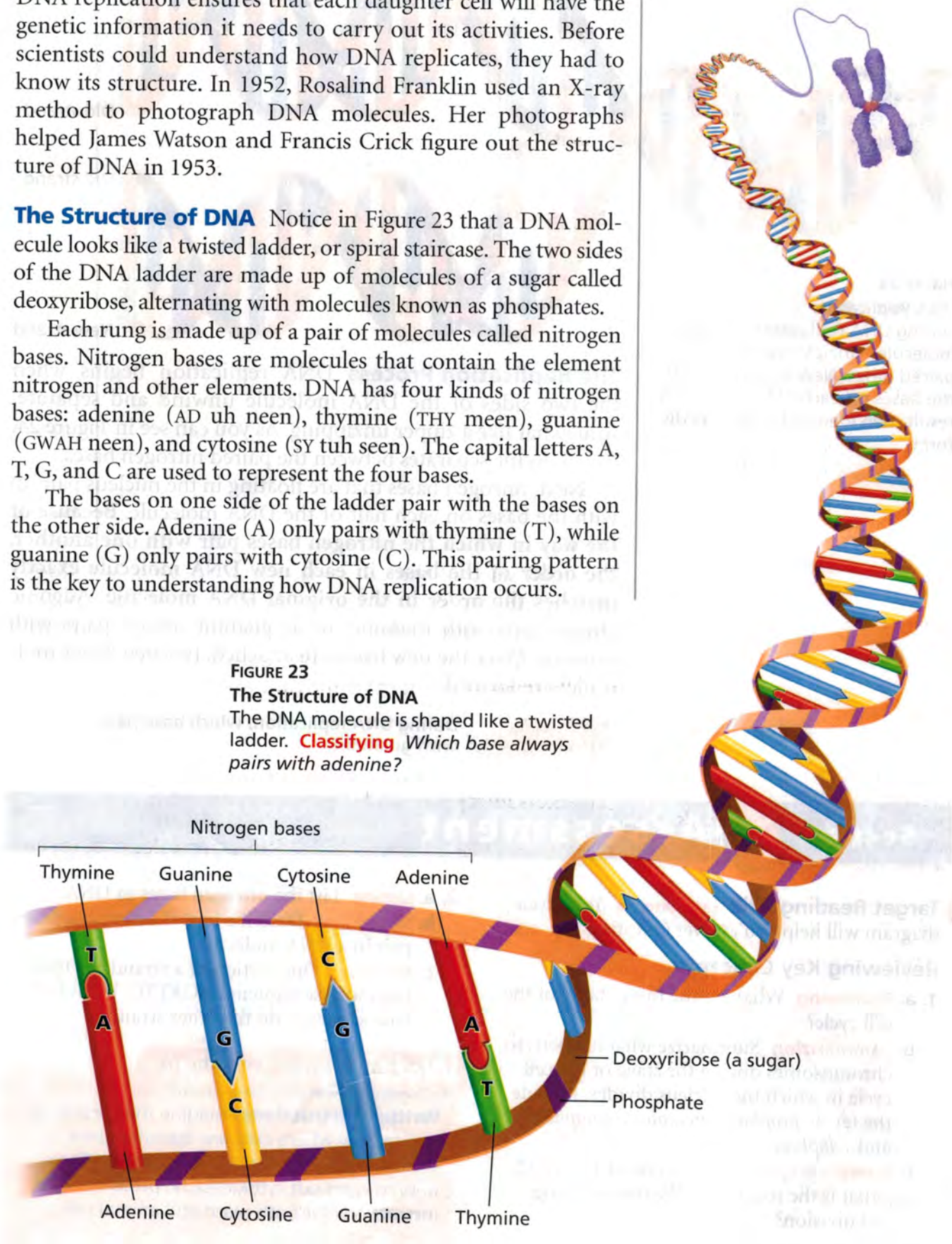


FIGURE 23
The Structure of DNA
The DNA molecule is shaped like a twisted ladder. **Classifying** *Which base always pairs with adenine?*

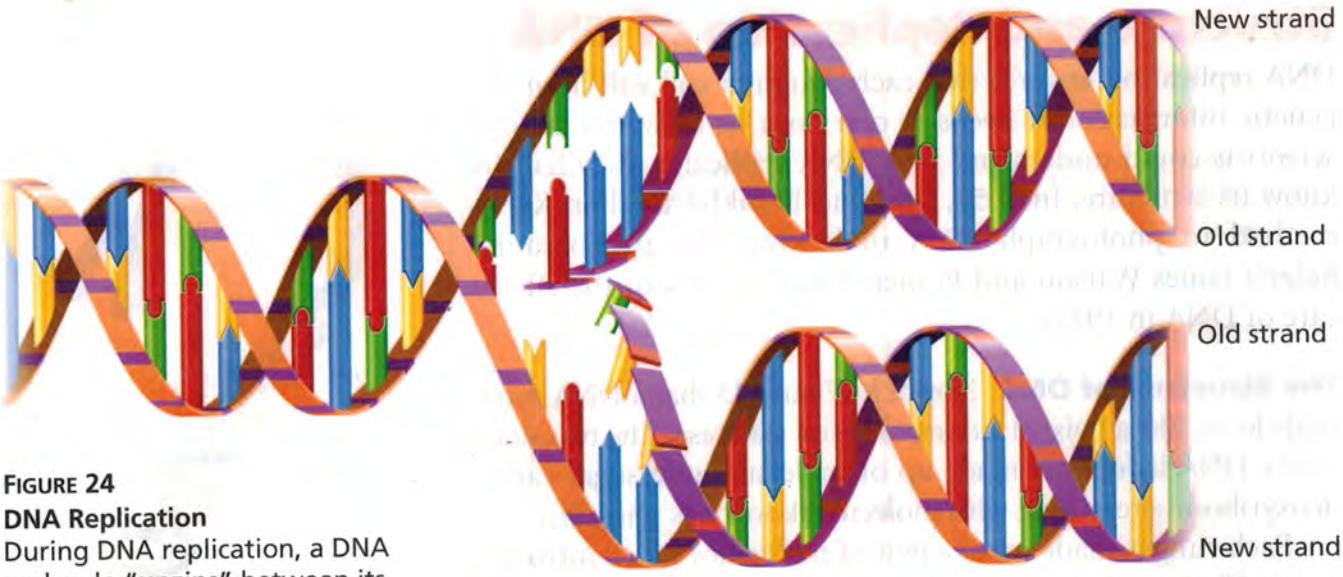


FIGURE 24
DNA Replication
During DNA replication, a DNA molecule "unzips" between its paired bases. New bases pair with the bases on each old strand. As a result, two identical DNA strands form.

The Replication Process DNA replication begins when the two sides of the DNA molecule unwind and separate, somewhat like a zipper unzipping. As you can see in Figure 24, the molecule separates between the paired nitrogen bases.

Next, nitrogen bases that are floating in the nucleus pair up with the bases on each half of the DNA molecule. **Because of the way in which the nitrogen bases pair with one another, the order of the bases in each new DNA molecule exactly matches the order in the original DNA molecule.** Adenine always pairs with thymine, while guanine always pairs with cytosine. Once the new bases are attached, two new DNA molecules are formed.

Reading Checkpoint **During DNA replication, which base pairs with guanine?**

Section 5 Assessment

Target Reading Skill **Sequencing** Your cycle diagram will help you answer Question 1.

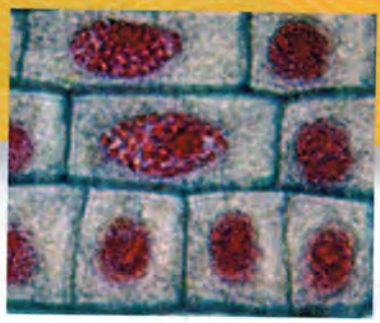
Reviewing Key Concepts

1. a. **Reviewing** What are the three stages of the cell cycle?
   b. **Summarizing** Summarize what happens to chromosomes during the stage of the cell cycle in which the nucleus divides. Include the terms *prophase, metaphase, anaphase,* and *telophase.*
   c. **Interpreting Diagrams** Look at Figure 22. What is the role of spindle fibers during cell division?
2. a. **Listing** List the nitrogen bases in DNA.
   b. **Describing** Describe how the nitrogen bases pair in a DNA molecule.
   c. **Inferring** One section of a strand of DNA has the base sequence AGATTC. What is the base sequence on the other strand?

Writing in Science

Writing Instructions Imagine that you work in a factory where cells are manufactured. Write instructions for newly forming cells on how to carry out cytokinesis. Provide instructions for both plant and animal cells.

Lab zone **Skills Lab**



Multiplying by Dividing

Problem

How long do the stages of the cell cycle take?

Skills Focus

observing, calculating

Materials

- microscope
- colored pencils
- calculator (optional)
- prepared slides of onion root tip cells undergoing cell division

Procedure

1. Place the slide on the stage of a microscope. Use low power to locate a cell in interphase. Then switch to high power, and make a labeled drawing of the cell. **CAUTION:** *Slides and coverslips break easily. Do not allow the objective to touch the slide. If the slide breaks, notify your teacher. Do not touch broken glass.*
2. Repeat Step 1 to find cells in prophase, metaphase, anaphase, and telophase. Then copy the data table into your notebook.
3. Return to low power. Find an area of the slide with many cells undergoing cell division. Switch to the magnification that lets you see about 50 cells at once (for example, 100 ×).
4. Examine the cells row by row, and count the cells that are in interphase. Record that number in the data table under *First Sample*.
5. Examine the cells row by row four more times to count the cells in prophase, metaphase, anaphase, and telophase. Record the results.
6. Move to a new area on the slide. Repeat Steps 3–5 and record your counts in the column labeled *Second Sample*.
7. Fill in the column labeled *Total Number* by adding the numbers across each row in your data table.
8. Add the totals for the five stages to find the total number of cells counted.

Analyze and Conclude

1. **Observing** Which stage of the cell cycle did you observe most often?
2. **Calculating** The cell cycle for onion root tips takes about 720 minutes (12 hours). Use your data and the formula below to find the number of minutes each stage takes.

$$\text{Time for each stage} = \frac{\text{Number of cells at each stage}}{\text{Total number of cells counted}} \times 720 \text{ min}$$

3. **Communicating** Use the data to compare the amount of time spent in mitosis with the total time for the whole cell cycle. Write your answer in the form of a paragraph.

More to Explore

Examine prepared slides of animal cells undergoing cell division. Use drawings and descriptions to compare plant and animal mitosis.

Data Table

Stage of Cell Cycle	First Sample	Second Sample	Total Number
Interphase			
Mitosis:			
Prophase			
Metaphase			
Anaphase			
Telophase			
Total number of cells counted			

Chapter 3 Study Guide

The BIG Idea **Structure and Function** Cells obtain energy through the processes of photosynthesis and respiration, which are carried out by chloroplasts and mitochondria.

1 Chemical Compounds in Cells

Key Concepts

- An element is any substance that cannot be broken down into simpler substances. When two or more elements combine chemically, they form a compound.
- Most chemical reactions in cells could not take place without water.
- Carbohydrates, lipids, proteins, and nucleic acids are important groups of organic compounds in living things.

Key Terms

• element • compound • carbohydrate
• lipid • protein • amino acid • enzyme
• nucleic acid • DNA • RNA

2 The Cell in Its Environment

Key Concepts

- Diffusion is the main method by which small molecules move across cell membranes. Osmosis is important because cells cannot function properly without adequate water.
- Active transport requires the cell to use its own energy, while passive transport does not.

Key Terms

• selectively permeable • diffusion • osmosis
• passive transport • active transport

3 Photosynthesis

Key Concepts

- Nearly all living things obtain energy either directly or indirectly from the energy of sunlight captured during photosynthesis.
- During photosynthesis, plants and some other organisms use energy from the sun to convert carbon dioxide and water into oxygen and sugars. The equation for photosynthesis is

$$6\,CO_2 + 6\,H_2O \longrightarrow C_6H_{12}O_6 + 6\,O_2.$$

Key Terms

• photosynthesis • autotroph • heterotroph
• pigment • chlorophyll • stomata

4 Respiration

Key Concepts

- During respiration, cells break down simple food molecules such as sugar and release their stored energy. The respiration equation is

$$C_6H_{12}O_6 + 6\,O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{energy}.$$

- Fermentation provides energy for cells without using oxygen.

Key Terms

• respiration • fermentation

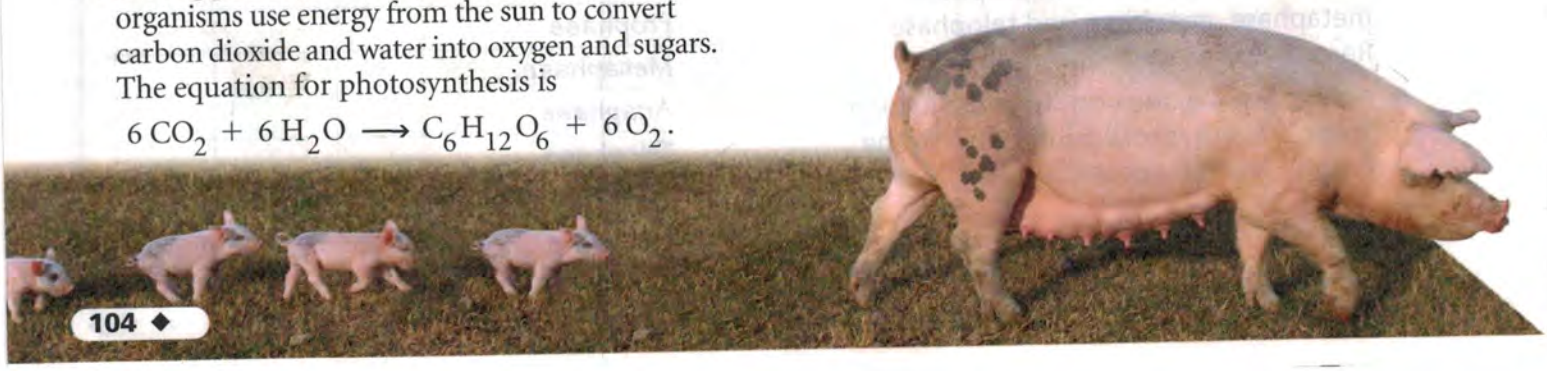
5 Cell Division

Key Concepts

- During interphase, the cell grows, makes a copy of its DNA, and prepares to divide into two cells. During mitosis, one copy of the DNA is distributed into each of the two daughter cells. During cytokinesis, the cytoplasm divides. The organelles are distributed into the new cells.
- Because of the way in which the nitrogen bases pair with one another, the order of the bases in each new DNA molecule exactly matches the order in the original DNA molecule.

Key Terms

• cell cycle • interphase • replication
• mitosis • chromosome • cytokinesis



Review and Assessment

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Organizing Information

Comparing and Contrasting
Copy the compare and contrast table about photosynthesis and respiration. Complete the table to compare these processes. (For more information on compare and contrast tables, see the Skills Handbook.)

Comparing Photosynthesis and Respiration

Feature	Photosynthesis	Respiration
Raw materials	Water and carbon dioxide	a. ?
Products	b. ?	c. ?
Is energy released?	d. ?	Yes

Reviewing Key Terms

Choose the letter of the best answer.

1. Starch is an example of a
   a. nucleic acid.
   b. protein.
   c. lipid.
   d. carbohydrate.
2. The process by which water moves across a cell membrane is called
   a. osmosis.
   b. active transport.
   c. enzyme.
   d. carbohydrate.
3. The organelle in which photosynthesis takes place is the
   a. mitochondrion.
   b. chloroplast.
   c. chlorophyll.
   d. nucleus.
4. What process produces carbon dioxide?
   a. photosynthesis
   b. replication
   c. mutation
   d. respiration
5. What happens during cytokinesis?
   a. A spindle forms.
   b. Chloroplasts release energy.
   c. The cytoplasm divides.
   d. Chromosomes divide.

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

6. Both DNA and RNA are <u>proteins</u>.
7. The cell membrane is <u>selectively permeable</u>.
8. During <u>respiration</u>, most energy is released in the mitochondria.
9. An energy-releasing process that does not require oxygen is <u>replication</u>.
10. The stage of the cell cycle when DNA replication occurs is called <u>telophase</u>.

Writing in Science

Brochure Cancer is a disease in which the cell cycle is disrupted. Suppose you are a volunteer who works with cancer patients. Write a brochure that could be given to cancer patients and their families. The brochure should explain the cell cycle.

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Cell Processes and Energy
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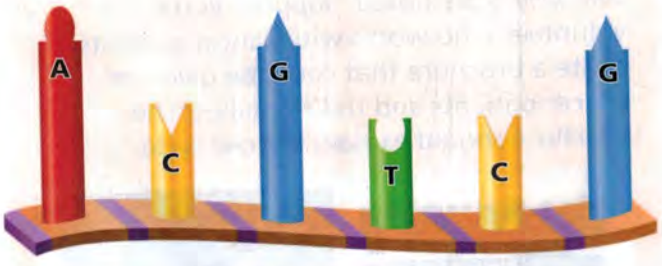
Review and Assessment

Checking Concepts

11. Explain the difference between elements and compounds.
12. How are enzymes important to living things?
13. Briefly explain what happens to energy from the sun during photosynthesis.
14. What are the raw materials needed for photosynthesis? What are the products?
15. Why do organisms need to carry out the process of respiration?
16. Describe what happens during interphase.
17. How do the events in the cell cycle ensure that the genetic information in the daughter cells will be identical to that of the parent cell?

Thinking Critically

18. **Predicting** Suppose a volcano threw so much ash into the air that it blocked most of the sunlight that usually strikes Earth. How might this affect the ability of animals to obtain the energy they need to live?
19. **Comparing and Contrasting** Explain the relationship between the processes of breathing and cellular respiration.
20. **Relating Cause and Effect** Do plant cells need to carry out respiration? Explain.
21. **Inferring** The diagram below shows part of one strand of a DNA molecule. What would the bases on the other strand be?



22. **Comparing and Contrasting** Explain how active transport is different from osmosis.

Applying Skills

Use the table below to answer Questions 23–26.

Percentages of Nitrogen Bases in the DNA of Various Organisms

Nitrogen Base	Human	Wheat	*E. coli* Bacterium
Adenine	30%	27%	24%
Guanine	20%	23%	26%
Thymine	30%	27%	24%
Cytosine	20%	23%	26%

23. **Graphing** For each organism, draw a bar graph to show the percentages of each nitrogen base in its DNA.
24. **Interpreting Data** What is the relationship between the amounts of adenine and thymine in the DNA of each organism? What is the relationship between the amounts of guanine and cytosine?
25. **Inferring** Based on your answer to Question 24, what can you infer about the structure of DNA in these three organisms?
26. **Applying Concepts** Suppose cytosine made up 28% of the nitrogen bases in an organism. What percentage of the organism's nitrogen bases should be thymine? Explain.

Lab zone Chapter Project

Performance Assessment Bring in your plants, recorded observations, and graphs to share with the class. Be prepared to describe your experimental plan and explain your results. How well did you follow your experimental plan? What did you learn about photosynthesis and light from the experiment you performed?