

3.1

Cell Theory

KEY CONCEPT Cells are the basic unit of life.

▶ MAIN IDEAS

- Early studies led to the development of the cell theory.
- Prokaryotic cells lack a nucleus and most internal structures of eukaryotic cells.

VOCABULARY

cell theory, p. 71

cytoplasm, p. 72

organelle, p. 72

prokaryotic cell, p. 72

eukaryotic cell, p. 72



REVIEW AT
CLASSZONE.COM

Connect You and all other organisms are made of cells. As you saw on the previous page, a cell's structure is closely related to its function. Today we know that cells are the smallest unit of living matter that can carry out all processes required for life. But before the 1600s, people had many other ideas about the basis of life. Like many breakthroughs, the discovery of cells was aided by the development of new technology—in this case, the microscope.

▶ MAIN IDEA

Early studies led to the development of the cell theory.

TAKING NOTES

As you read, make an outline using the headings as topics. Summarize details that further explain those ideas.

I. Main Idea

A. Supporting idea

1. Detail

2. Detail

B. Supporting idea

Almost all cells are too small to see without the aid of a microscope. Although glass lenses had been used to magnify images for hundreds of years, the early lenses were not powerful enough to reveal individual cells. The invention of the compound microscope in the late 1500s was an early step toward this discovery. The Dutch eyeglass maker Zacharias Janssen, who was probably assisted by his father, Hans, usually gets credit for this invention.

A compound microscope contains two or more lenses. Total magnification, the product of the magnifying power of each individual lens, is generally much more powerful with a compound microscope than with a single lens.

Discovery of Cells

In 1665, the English scientist Robert Hooke used the three-lens compound microscope shown in **FIGURE 3.1** to examine thin slices of cork. Cork is the tough outer bark of a species of oak tree. He observed that cork is made of tiny, hollow compartments. The compartments reminded Hooke of small rooms found in a monastery, so he gave them the same name: cells. The plant cells he observed, shown in **FIGURE 3.2** (top), were dead. Hooke was looking only at cell walls and empty space.

Around the same time, Anton van Leeuwenhoek, a Dutch tradesman, was studying new methods for making lenses to examine cloth. As a result of his research, his single-lens microscopes were much more powerful than Hooke's crude compound microscope. In 1674, Leeuwenhoek became one of the first people to describe living cells when he observed numerous single-celled organisms swimming in a drop of pond water. Sketches of his "animalcules" are pictured in **FIGURE 3.2** (bottom).



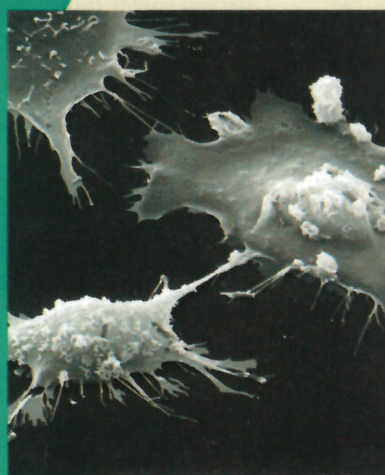
FIGURE 3.1 Hooke first identified cells using this microscope. Its crude lenses severely limited the amount of detail he could see.

colored SEM; magnification 11,000×

Why do these cells look like fried eggs?

Macrophages (large tan cells) take in and digest foreign material, such as invading bacteria (small red cells). They play an important role in your immune system. Many macrophages travel the body, recognize foreign material, engulf it, and break it down using chemicals. They have an adaptable internal skeleton that helps them move and stretch out their “arms” to capture invading particles.

Connecting CONCEPTS



Technology The scanning electron microscope (SEM) uses electrons to create greatly magnified, three-dimensional images of surface structures. Samples must be carefully prepared to withstand the vacuum and to prevent shriveling. This means that any cell or organism you see in an SEM image is dead. In addition, images are generated in black and white (left). The picture above is artificially colored to highlight specific parts.

As people continued to improve the microscope over the next century and a half, it became sturdier, easier to use, and capable of greater magnification. This combination of factors led people to examine even more organisms. They observed a wide variety of cell shapes, and they observed cells dividing. Scientists began to ask important questions: Is all living matter made of cells? Where do cells come from?

Cell Theory

The German scientist Matthias Schleiden also used compound microscopes to study plant tissue. In 1838, he proposed that plants are made of cells. Schleiden discussed the results of his work with another German scientist, Theodor Schwann, who was struck by the structural similarities between plant cells and the animal cells he had been studying. Schwann concluded that all animals are made of cells. Shortly thereafter, in 1839, he published the first statement of the cell theory, concluding that all living things are made of cells and cell products. This theory helped lay the groundwork for all biological research that followed. However, it had to be refined over the years as additional data led to new conclusions. For example, Schwann stated in his publication that cells form spontaneously by free-cell formation. As later scientists studied the process of cell division, they realized that this part of Schwann's idea was wrong. In 1855, Rudolf Virchow, another German scientist, reported that all cells come from preexisting cells. These early contributors are shown in **FIGURE 3.3**.

This accumulated research can be summarized in the cell theory, one of the first unifying concepts developed in biology. The major principles of the **cell theory** are the following:



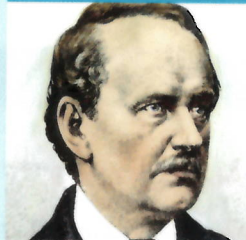
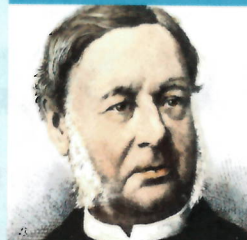

- All organisms are made of cells.
- All existing cells are produced by other living cells.
- The cell is the most basic unit of life.



FIGURE 3.2 Hooke observed the cell walls of dead plant cells (top). In contrast, Leeuwenhoek observed and drew microscopic life, which he called animalcules, in pond water (bottom).

Summarize Explain the three major principles of cell theory in your own words.

FIGURE 3.3 Contributors to Cell Theory

HOOKE	LEEUWENHOEK	SCHLEIDEN	SCHWANN	VIRCHOW
				
1665 Hooke was the first to identify cells, and he named them.	1674 Because he made better lenses, Leeuwenhoek observed cells in greater detail.	1838 Schleiden was the first to note that plants are made of cells.	1839 Schwann concluded that all living things are made of cells.	1855 Virchow proposed that all cells come from other cells.

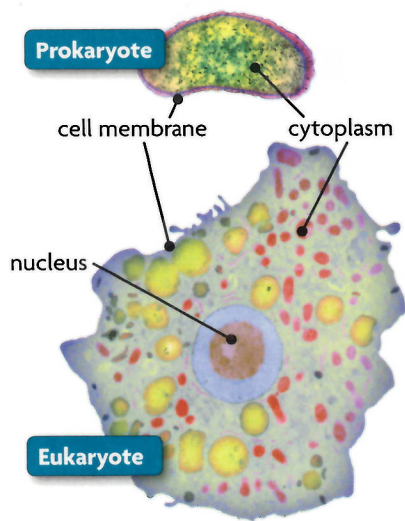


FIGURE 3.4 In prokaryotic cells, such as this bacterium (top), DNA is suspended in the cytoplasm. In eukaryotic cells, such as this protozoan (bottom), the nuclear envelope separates DNA from the cytoplasm. (colored TEMs; magnifications: protozoan 3200×; bacterium 19,000×)

Connecting CONCEPTS

Prokaryotes You will learn more about prokaryotes in Chapter 18, which discusses their requirements to sustain life, their role in the ecosystem, and, their role in human disease.

MAIN IDEA

Prokaryotic cells lack a nucleus and most internal structures of eukaryotic cells.

The variety of cell types found in living things is staggering. Your body alone is made of trillions of cells of many different shapes, sizes, and functions. They include long, thin nerve cells that transmit sensory information, as well as short, blocky skin cells that cover and protect the body. Despite this variety, the cells in your body share many characteristics with one another and with the cells that make up every other organism. In general, cells tend to be microscopic in size and have similar building blocks. They are also enclosed by a membrane that controls the movement of materials into and out of the cell.

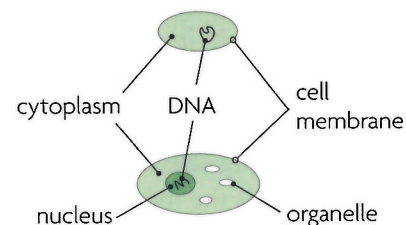
Within the membrane, a cell is filled with cytoplasm. **Cytoplasm** is a jellylike substance that contains dissolved molecular building blocks—such as proteins, nucleic acids, minerals, and ions. In some types of cells, the cytoplasm also contains **organelles**, which are structures specialized to perform distinct processes within a cell. Most organelles are surrounded by a membrane. In many cells, the largest and most visible organelle is the nucleus, which stores genetic information.

As shown in **FIGURE 3.4**, cells can be separated into two broad categories based on their internal structures: prokaryotic cells and eukaryotic cells.

- **Prokaryotic cells** (pro-KAR-ee-AHT-ihk) do not have a nucleus or other membrane-bound organelles. Instead, the cell's DNA is suspended in the cytoplasm. All prokaryotes are microscopic single-celled organisms.
- **Eukaryotic cells** (yoo-KAR-ee-AHT-ihk) have a nucleus and other membrane-bound organelles. The nucleus, the largest organelle, encloses the genetic information. Eukaryotes may be multicellular or single-celled organisms.

VISUAL VOCAB

Prokaryotic cells do not have a nucleus or other membrane-bound organelles.



Eukaryotic cells have a nucleus and other membrane-bound organelles.

Summarize What characteristics are shared by most cells?

3.1 ASSESSMENT



REVIEWING MAIN IDEAS

1. How did improvements in the microscope help scientists form the **cell theory**?
2. How do **prokaryotic** and **eukaryotic cells** differ?

CRITICAL THINKING

3. **Analyze** Today, scientists can study human cells grown in petri dishes. Explain how this technique builds on the work of early scientists.
4. **Compare** In what way are cells similar to atoms?

Connecting CONCEPTS

5. **Medicine** Suppose a certain poison kills human cells by blocking pores in the nuclear membrane. Explain why it would or would not kill bacteria.

3.2

Cell Organelles

KEY CONCEPT Eukaryotic cells share many similarities.

▶ MAIN IDEAS

- Cells have an internal structure.
- Several organelles are involved in making and processing proteins.
- Other organelles have various functions.
- Plant cells have cell walls and chloroplasts.

VOCABULARY

cytoskeleton, p. 73

nucleus, p. 75

endoplasmic reticulum, p. 76

ribosome, p. 76

Golgi apparatus, p. 76

vesicle, p. 77

mitochondrion, p. 77

vacuole, p. 77

lysosome, p. 78

centriole, p. 78

cell wall, p. 79

chloroplast, p. 79



REVIEW AT
CLASSZONE.COM

Connect Your body is highly organized. It contains organs that are specialized to perform particular tasks. For example, your skin receives sensory information and helps prevent infection. Your intestines digest food, your kidneys filter wastes, and your bones protect and support other organs. On a much smaller scale, your cells have a similar division of labor. They contain specialized structures that work together to respond to stimuli and efficiently carry out other necessary processes.

▶ MAIN IDEA

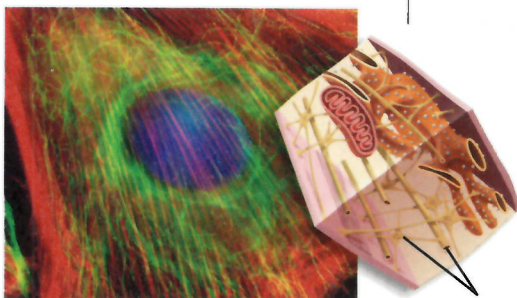
Cells have an internal structure.

Like your body, eukaryotic cells are highly organized structures. They are surrounded by a protective membrane that receives messages from other cells. They contain membrane-bound organelles that perform specific cellular processes, divide certain molecules into compartments, and help regulate the timing of key events. But the cell is not a random jumble of suspended organelles and molecules. Rather, certain organelles and molecules are anchored to specific sites, which vary by cell type. If the membrane was removed from a cell, the contents wouldn't collapse and ooze out in a big puddle. How does a cell maintain this framework?

Each eukaryotic cell has a **cytoskeleton**, which is a network of proteins that is constantly changing to meet the needs of a cell. It is made of small protein subunits that form long threads, or fibers, that crisscross the entire cell, as shown in **FIGURE 3.5**. Three main types of fibers make up the cytoskeleton and allow it to serve a wide range of functions.

- Microtubules are long hollow tubes. They give the cell its shape and act as “tracks” for the movement of organelles. When cells divide, microtubules form fibers that pull half of the DNA into each new cell.
- Intermediate filaments, which are somewhat smaller than microtubules, give a cell its strength.
- Microfilaments, the smallest of the three, are tiny threads that enable cells to move and divide. They play an important role in muscle cells, where they help the muscle contract and relax.

FIGURE 3.5 The cytoskeleton supports and shapes the cell. The cytoskeleton includes microtubules (green) and microfilaments (red). (epifluorescence microscopy; magnification 750×)



components of
the cytoskeleton

FIGURE 3.6 Cell Structure

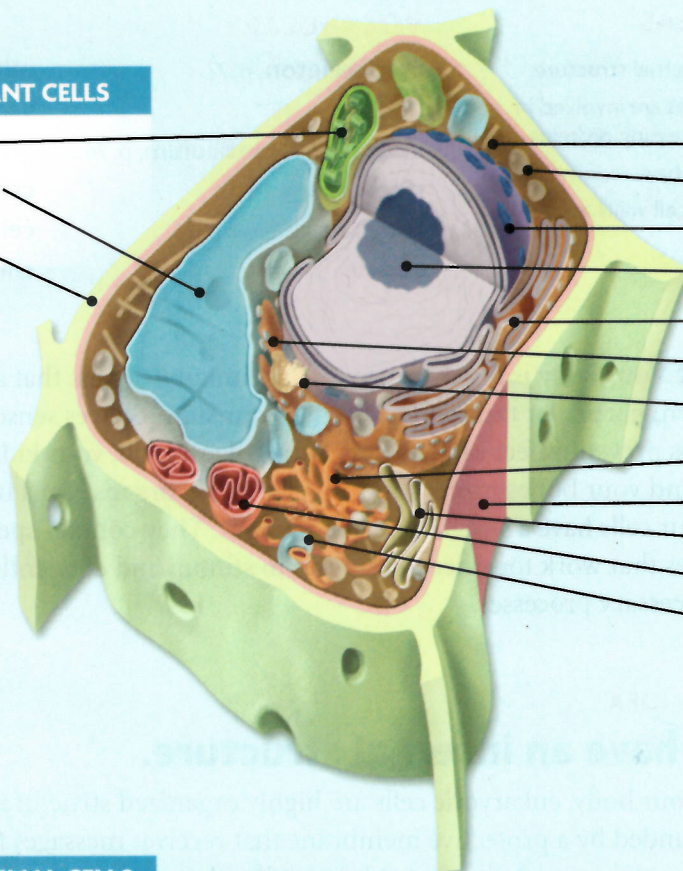


Eukaryotic cells have highly organized structures, including membrane-bound organelles. Plant and animal cells share many of the same types of organelles, but both also have organelles that are unique to their needs.

PLANT CELL

FOUND IN PLANT CELLS

chloroplast
central vacuole
cell wall



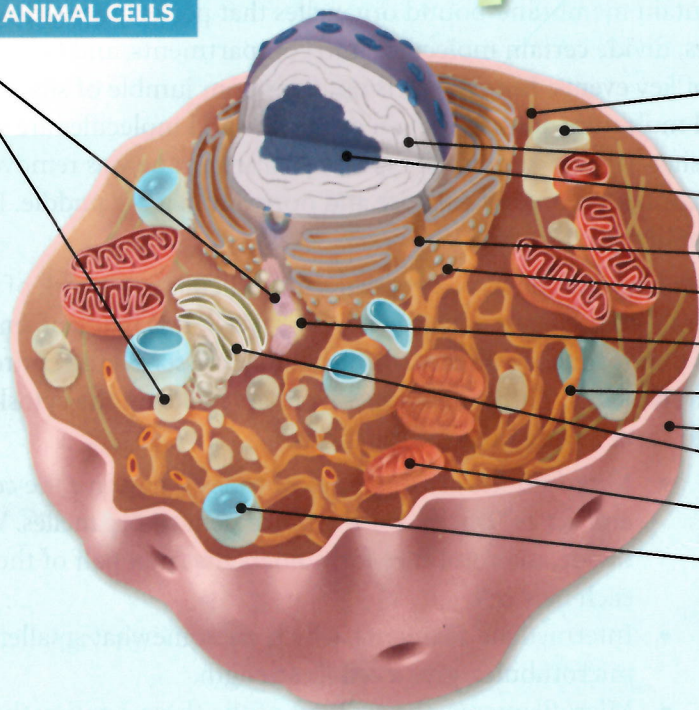
FOUND IN BOTH

cytoskeleton
vesicle
nucleus
nucleolus
endoplasmic reticulum (rough)
ribosome
centrosome
endoplasmic reticulum (smooth)
cell membrane
Golgi apparatus
mitochondrion
vacuole

ANIMAL CELL

FOUND IN ANIMAL CELLS

centriole
lysosome



cytoskeleton
vesicle
nucleus
nucleolus
endoplasmic reticulum (rough)
ribosome
centrosome
endoplasmic reticulum (smooth)
cell membrane
Golgi apparatus
mitochondrion
vacuole

CRITICAL VIEWING

What differences do you observe between animal and plant cells?

Cytoplasm, which you read about in Section 3.1, is itself an important contributor to cell structure. In eukaryotes, it fills the space between the nucleus and the cell membrane. The fluid portion, excluding the organelles, is called cytosol and consists mostly of water. The makeup of cytoplasm shows that water is necessary for maintaining cell structure. This is only one of many reasons that water is an essential component for life, however. Many chemical reactions occur in the cytoplasm, where water acts as an important solvent.

The remainder of this chapter highlights the structure and function of the organelles found in eukaryotic cells. As **FIGURE 3.6** shows, plant and animal cells use many of the same types of organelles to carry out basic functions. Both cell types also have organelles that are unique to their needs.

Infer What problems might a cell experience if it had no cytoskeleton?

▶ MAIN IDEA

Several organelles are involved in making and processing proteins.

Much of the cell is devoted to making proteins. Proteins are made of 20 types of amino acids that have unique characteristics of size, polarity, and acidity. They can form very long or very short protein chains that fold into different shapes. And multiple protein chains can interact with each other. This almost limitless variety of shapes and interactions makes proteins very powerful. Proteins carry out many critical functions, so they need to be made correctly.

Nucleus

The **nucleus** (NOO-klee-uhs) is the storehouse for most of the genetic information, or DNA (deoxyribonucleic acid), in your cells. DNA contains genes that are instructions for making proteins. There are two major demands on the nucleus: (1) DNA must be carefully protected, and (2) DNA must be available for use at the proper times. Molecules that would damage DNA need to be kept out of the nucleus. But many proteins are involved in turning genes on and off, and they need to access the DNA at certain times. The special structure of the nucleus helps it meet both demands.

The nucleus is composed of the cell's DNA enclosed in a double membrane called the nuclear envelope. Each membrane in the nuclear envelope is similar to the membrane surrounding the entire cell. As **FIGURE 3.7** shows, the nuclear envelope is pierced with holes called pores that allow large molecules to pass between the nucleus and cytoplasm.

The nucleus also contains the nucleolus. The nucleolus is a dense region where tiny organelles essential for making proteins are assembled. These organelles, called ribosomes, are a combination of proteins and RNA molecules. They are discussed on the next page, and a more complete description of their structure and function is given in Chapter 8.

TAKING NOTES

Make a chart to correlate each organelle with its function.

Organelle	Function
Nucleus	stores DNA
Ribosome	

Connecting CONCEPTS

Biochemistry Recall from **Chapter 2** that certain amino acids within a protein molecule may form hydrogen bonds with other amino acids. These bonds cause the protein to form a specific shape.

FIGURE 3.7 The nucleus stores and protects DNA. (colored SEM; magnification 90,000×)

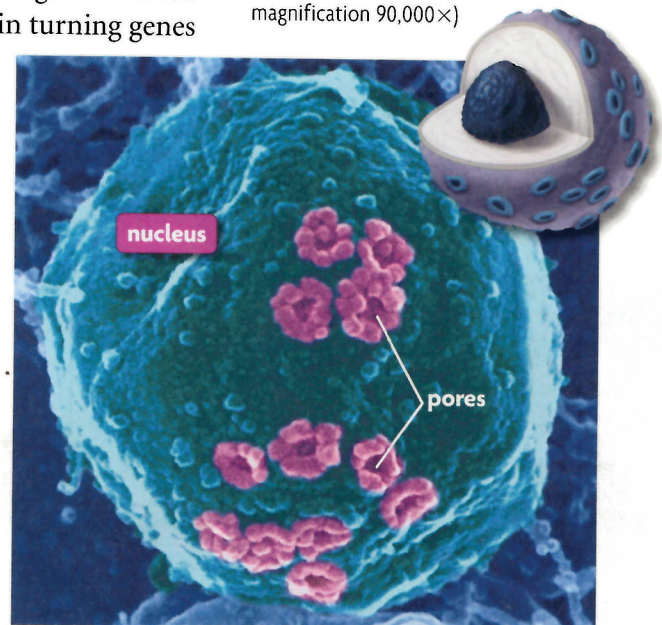


FIGURE 3.8 The endoplasmic reticulum aids in the production of proteins and lipids. (colored TEM; magnification about 20,000×)

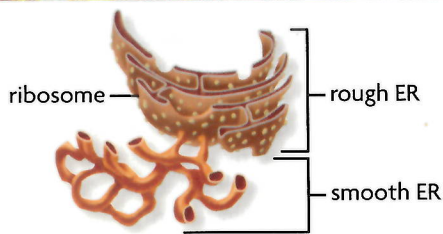
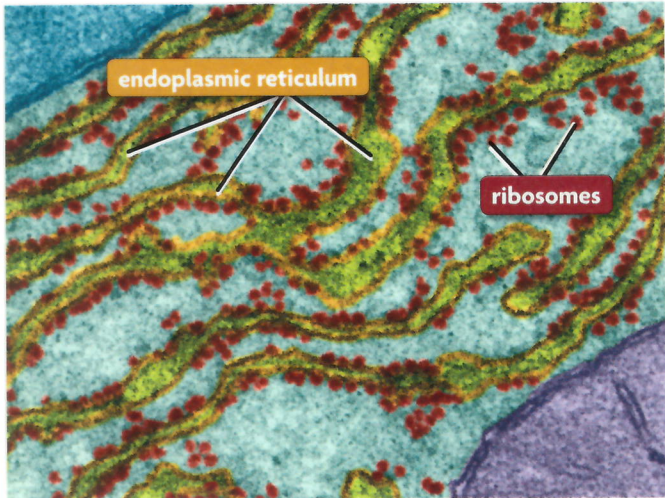
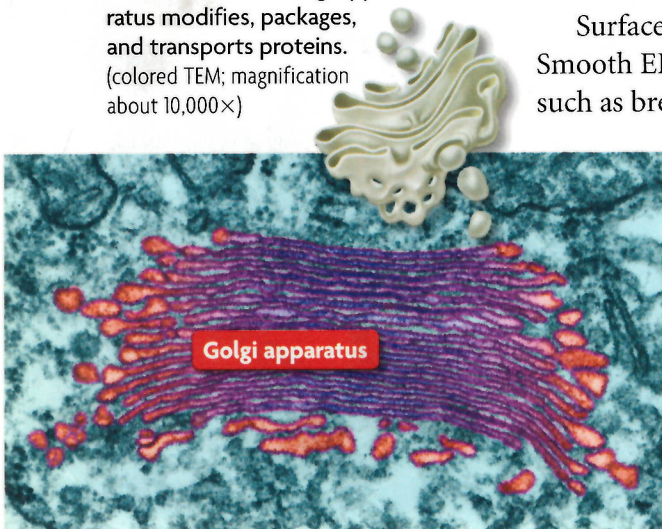


FIGURE 3.9 The Golgi apparatus modifies, packages, and transports proteins. (colored TEM; magnification about 10,000×)



Endoplasmic Reticulum and Ribosomes

A large part of the cytoplasm of most eukaryotic cells is filled by the endoplasmic reticulum, shown in **FIGURE 3.8**. The **endoplasmic reticulum** (EHN-duh-PLAZ-mihk rih-TIHK-yuh-luhm), or the ER, is an interconnected network of thin folded membranes. The composition is very similar to that of the cell membrane and nuclear membranes. The ER membranes form a maze of enclosed spaces. The interior of this maze is called the lumen. Numerous processes, including the production of proteins and lipids, occur both on the surface of the ER and inside the lumen. The ER must be large enough to accommodate all these processes. How does it fit inside a cell?

The ER membrane has many creases and folds. If you have ever gone camping, you probably slept in a sleeping bag that covered you from head to foot. The next morning, you stuffed it back into a tiny little sack. How does the entire sleeping bag fit inside such a small sack? The surface area of the sleeping bag does not change, but the folds allow it to take up less space. Likewise, the ER's many folds enable it to fit within the cell.

In some regions, the ER is studded with **ribosomes** (RY-buh-SOHMZ), tiny organelles that link amino acids together to form proteins. Ribosomes are both the site of protein synthesis and active participants in the process. Ribosomes are themselves made of proteins and RNA. After assembly in the nucleolus, ribosomes pass through the nuclear pores into the cytoplasm, where most protein synthesis occurs.

Surfaces of the ER that are covered with ribosomes are called rough ER because they look bumpy when viewed with an electron microscope. As a protein is being made on these ribosomes, it enters the lumen. Inside the lumen, the protein may be modified by having sugar chains added to it, which can help the protein fold or give it stability.

Not all ribosomes are bound to the ER; some are suspended in the cytoplasm. In general, proteins made on the ER are either incorporated into the cell membrane or secreted. In contrast, proteins made on suspended ribosomes are typically used in chemical reactions occurring within the cytoplasm.

Surfaces of the ER that do not contain ribosomes are called smooth ER. Smooth ER makes lipids and performs a variety of other specialized functions, such as breaking down drugs and alcohol.

Golgi Apparatus

From the ER, proteins generally move to the Golgi apparatus, shown in **FIGURE 3.9**. The **Golgi apparatus** (GOHL-jee) consists of closely layered stacks of membrane-enclosed spaces that process, sort, and deliver proteins. Its membranes contain enzymes that make additional changes to proteins. The Golgi apparatus also packages proteins. Some of the packaged proteins are stored within the Golgi apparatus for later use. Some are transported to other organelles within the cell. Still others are carried to the membrane and secreted outside the cell.

Vesicles

Cells need to separate reactants for various chemical reactions until it is time for them to be used. **Vesicles** (VEHS-ih-kuhlz), shown in **FIGURE 3.10**, are a general name used to describe small membrane-bound sacs that divide some materials from the rest of the cytoplasm and transport these materials from place to place within the cell. Vesicles are generally short-lived and are formed and recycled as needed.

After a protein has been made, part of the ER pinches off to form a vesicle surrounding the protein. Protected by the vesicle, the protein can be safely transported to the Golgi apparatus. There, any necessary modifications are made, and the protein is packaged inside a new vesicle for storage, transport, or secretion.

Compare and Contrast How are the nucleus and a vesicle similar and different in structure and function?

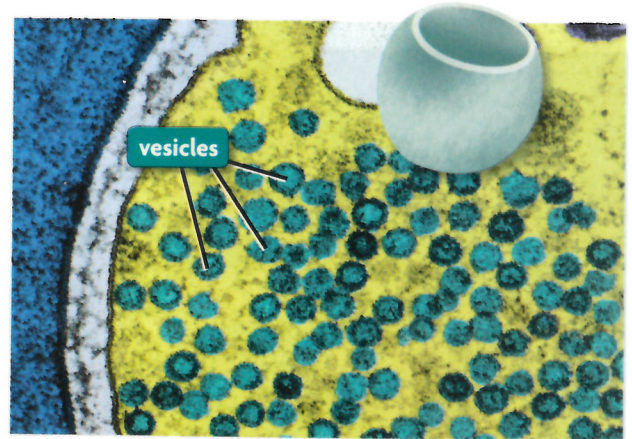


FIGURE 3.10 Vesicles isolate and transport specific molecules. (colored SEM; magnification 20,000×)

▶ MAIN IDEA

Other organelles have various functions.

Mitochondria

Mitochondria (MY-tuh-KAHN-dree-uh) supply energy to the cell. Mitochondria (singular, *mitochondrion*) are bean shaped and have two membranes, as shown in **FIGURE 3.11**. The inner membrane has many folds that greatly increase its surface area. Within these inner folds and compartments, a series of chemical reactions takes place that converts molecules from the food you eat into usable energy. You will learn more about this process in Chapter 4.

Unlike most organelles, mitochondria have their own ribosomes and DNA. This fact suggests that mitochondria were originally free-living prokaryotes that were taken in by larger cells. The relationship must have helped both organisms to survive.

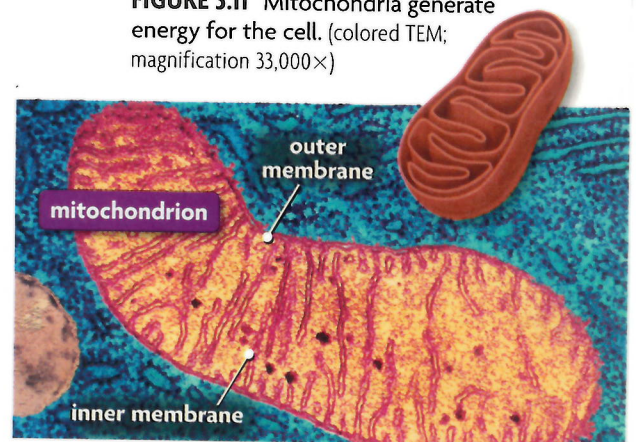


FIGURE 3.11 Mitochondria generate energy for the cell. (colored TEM; magnification 33,000×)

Vacuole

A **vacuole** (VAK-yoo-OHL) is a fluid-filled sac used for the storage of materials needed by a cell. These materials may include water, food molecules, inorganic ions, and enzymes. Most animal cells contain many small vacuoles. The central vacuole, shown in **FIGURE 3.12**, is a structure unique to plant cells. It is a single large vacuole that usually takes up most of the space inside a plant cell. It is filled with a watery fluid that strengthens the cell and helps to support the entire plant. When a plant wilts, its leaves shrivel because there is not enough water in each cell's central vacuole to support the leaf's normal structure. The central vacuole may also contain other substances, including toxins that would harm predators, waste products that would harm the cell itself, and pigments that give color to cells—such as those in the petals of a flower.

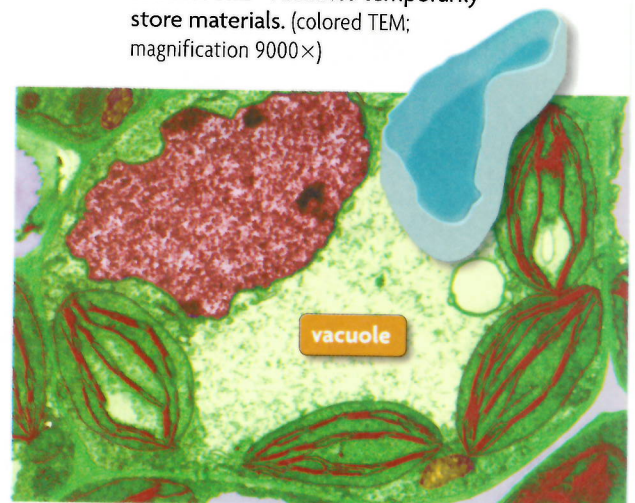


FIGURE 3.12 Vacuoles temporarily store materials. (colored TEM; magnification 9000×)

FIGURE 3.13 Lysosomes digest and recycle foreign materials or worn-out parts. (colored TEM; magnification 21,000 \times)

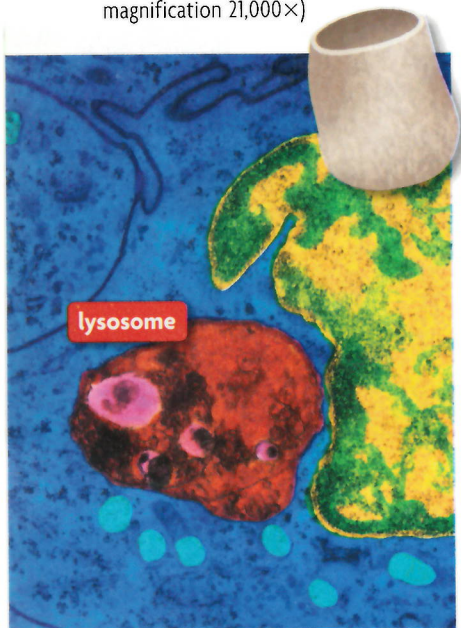
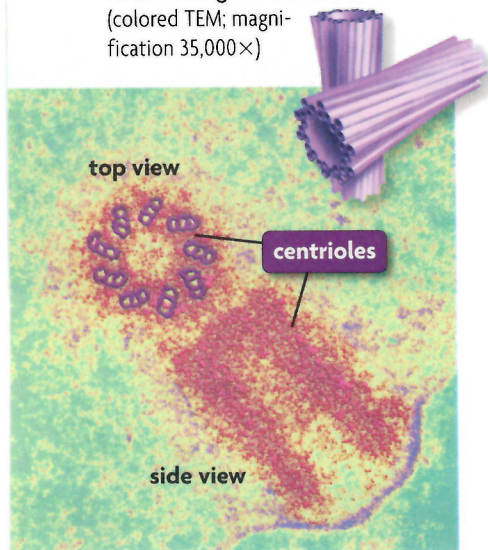


FIGURE 3.14 Centrioles divide DNA during cell division. (colored TEM; magnification 35,000 \times)



Lysosomes

Lysosomes (LY-suh-SOHMZ), shown in **FIGURE 3.13**, are membrane-bound organelles that contain enzymes. They defend a cell from invading bacteria and viruses. They also break down damaged or worn-out cell parts. Lysosomes tend to be numerous in animal cells. Their presence in plant cells is still questioned by some scientists, but others assert that plant cells do have lysosomes, though fewer than are found in animal cells.

Recall that all enzymes are proteins. Initially, lysosomal enzymes are made in the rough ER in an inactive form. Vesicles pinch off from the ER membrane, carry the enzymes, and then fuse with the Golgi apparatus. There, the enzymes are activated and packaged as lysosomes that pinch off from the Golgi membrane. The lysosomes can then engulf and digest targeted molecules. When a molecule is broken down, the products pass through the lysosomal membrane and into the cytoplasm, where they are used again.

Lysosomes provide an example of the importance of membrane-bound structures in the eukaryotic cell. Because lysosomal enzymes can destroy cell components, they must be surrounded by a membrane that prevents them from destroying necessary structures. However, the cell also uses other methods to protect itself from these destructive enzymes. For example, the enzymes do not work as well in the cytoplasm as they do inside the lysosome.

Centrosome and Centrioles

The centrosome is a small region of cytoplasm that produces microtubules. In animal cells, it contains two small structures called centrioles. **Centrioles** (SEHN-tree-OHLZ) are cylinder-shaped organelles made of short microtubules arranged in a circle. The two centrioles are perpendicular to each other, as shown in **FIGURE 3.14**. Before an animal cell divides, the centrosome, including the centrioles, doubles and the two new centrosomes move to opposite ends of the cell. Microtubules grow from each centrosome, forming spindle fibers. These fibers attach to the DNA and appear to help divide it between the two cells.

Centrioles were once thought to play a critical role in animal cell division. However, experiments have shown that animal cells can divide even if the centrioles are removed, which makes their role more questionable. In addition, although centrioles are found in some algae, they are not found in plants.

Centrioles also organize microtubules to form cilia and flagella. Cilia look like little hairs; flagella look like a whip or a tail. Their motion forces liquids past a cell. For single cells, this movement results in swimming. For cells anchored in tissue, this motion sweeps liquid across the cell surface.

Compare In what ways are lysosomes, vesicles, and the central vacuole similar?

MAIN IDEA

Plant cells have cell walls and chloroplasts.

Plant cells have two features not shared by animal cells: cell walls and chloroplasts. Cell walls are structures that provide rigid support. Chloroplasts are organelles that help a plant convert solar energy to chemical energy.

Cell Walls

In plants, algae, fungi, and most bacteria, the cell membrane is surrounded by a **strong cell wall**, which is a rigid layer that gives protection, support, and shape to the cell. The cell walls of multiple cells, as shown in **FIGURE 3.15**, can adhere to each other to help support an entire organism. For instance, much of the wood in a tree trunk consists of dead cells whose cell walls continue to support the entire tree.

Cell wall composition varies and is related to the different needs of each type of organism. In plants and algae, the cell wall is made of cellulose, a polysaccharide. Because molecules cannot easily diffuse across cellulose, the cell walls of plants and algae have openings, or channels. Water and other molecules small enough to fit through the channels can freely pass through the cell wall. In fungi, cell walls are made of chitin, and in bacteria, they are made of peptidoglycan. The unique characteristics and functions of these materials will be discussed in Chapters 18 and 19.

Chloroplasts

Chloroplasts (KLAWR-uh-PLASTS) are organelles that carry out photosynthesis, a series of complex chemical reactions that convert solar energy into energy-rich molecules the cell can use. Photosynthesis will be discussed more fully in Chapter 4. Like mitochondria, chloroplasts are highly compartmentalized. They have both an outer membrane and an inner membrane. They also have stacks of disc-shaped sacs within the inner membrane, shown in **FIGURE 3.16**. These sacs, called thylakoids, contain chlorophyll, a light-absorbing molecule that gives plants their green color and plays a key role in photosynthesis. Like mitochondria, chloroplasts also have their own ribosomes and DNA. Scientists have hypothesized that they, too, were originally free-living prokaryotes that were taken in by larger cells.

Both chloroplasts and mitochondria are present in plant cells, where they work together to capture and convert energy. Chloroplasts are found in the cells of certain other organisms as well, including green algae.

Analyze Would it be accurate to say that a chloroplast makes energy for a plant cell? Explain your answer.

FIGURE 3.15 Cell walls shape and support individual cells and entire organisms. (LM; magnification 3000 \times)

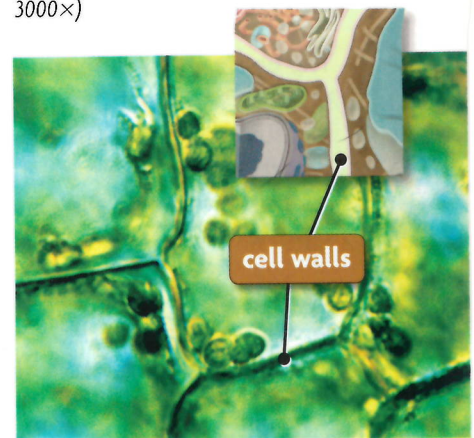
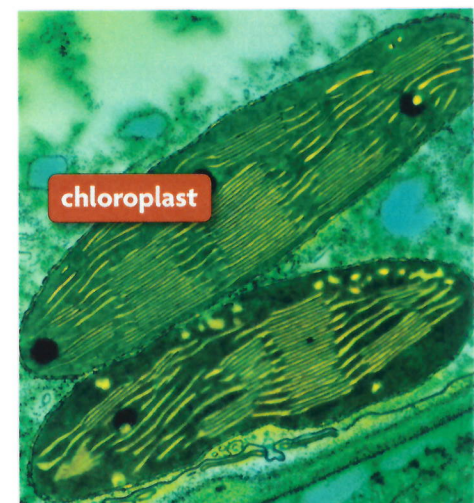


FIGURE 3.16 Chloroplasts convert solar energy into chemical energy through photosynthesis. (colored TEM; magnification 21,000 \times)



3.2 ASSESSMENT

 **ONLINE QUIZ**
ClassZone.com

REVIEWING MAIN IDEAS

1. What are the functions of the **cytoskeleton**?
2. Describe the structure of the **nucleus**.
3. Explain the structure and function of the **mitochondrion**.
4. What function does the **cell wall** perform in a plant?

CRITICAL THINKING

5. **Compare** What similarities do mitochondria and **chloroplasts** share?
6. **Compare** Describe how the **endoplasmic reticulum**, mitochondrion, and **Golgi apparatus** are structurally similar.

Connecting CONCEPTS

7. **Health** Medicine, alcohol, and many drugs are detoxified in liver cells. Why do you think the liver cells of some people who abuse alcohol and drugs have an increased amount of smooth ER?

Operational Definitions

The **operational definition** of a dependent variable is a description of what is to be observed and measured in an experiment, and what that measurement represents. It is important for scientists to include in their reports the operational definition of the dependent variable so that different scientists repeating the experiment will collect and record data in exactly the same way.

EXAMPLE

Students wanted to determine if the rate of photosynthesis was greater in summer or fall. They collected leaves from many trees in both summer and fall and counted the number of chloroplasts with chlorophyll.

Chloroplasts are organelles that can have a variety of pigments. Only chloroplasts that contain chlorophyll, a type of pigment, can carry out photosynthesis. The rate of photosynthesis increases as the number of chloroplasts with chlorophyll increases. Students wanted to determine if the rate of photosynthesis was greater in summer or fall. They collected leaves from many trees in both summer and fall and counted the number of chloroplasts with chlorophyll.

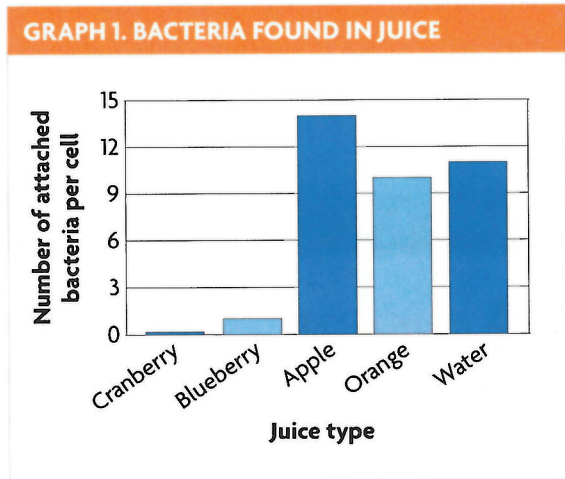
In this experiment, the number of chloroplasts with chlorophyll is what is being measured. The operational definition is the number of chloroplasts with chlorophyll in the leaf. This number represents the rate at which a plant can carry out photosynthesis.



TABLE 1. CHLOROPLASTS WITH CHLOROPHYLL		
Tree	Leaf Chloroplasts with Chlorophyll (no./cell)	
	Summer	Fall
Birch	192	44
Linden	182	32
Maple	183	28
Weeping willow	177	35

FORM AN OPERATIONAL DEFINITION

Some studies suggest that drinking cranberry juice may help prevent the development of urinary tract infections caused by bacterial cells, which are prokaryotes. Researchers hypothesize that a chemical in cranberry juice may stop the bacteria from attaching to cells in the wall of the urinary bladder. Researchers grew the eukaryotic bladder cells in culture and exposed them to a solution containing bacteria. The cells were then treated with a solution of different juices or water to determine if the juices interfered with bacterial attachment. The results are shown in the graph.



- Apply** What is the operational definition of the dependent variable in this experiment?
- Conclude** Which juices may be effective in preventing urinary tract infections?

3.3

Cell Membrane

KEY CONCEPT The cell membrane is a barrier that separates a cell from the external environment.

▶ MAIN IDEAS

- Cell membranes are composed of two phospholipid layers.
- Chemical signals are transmitted across the cell membrane.

VOCABULARY

cell membrane, p. 81

phospholipid, p. 81

fluid mosaic model, p. 82

selective permeability, p. 83

receptor, p. 84



REVIEW AT
CLASSZONE.COM

Connect Think about how the products you buy are packaged—a pint of berries, perhaps, or a tube of toothpaste. The berries are probably in a plastic container that has holes to allow air circulation. The toothpaste is in a tube strong enough to be squeezed without ripping. Both containers protect their contents, but they do so in different ways. Like these products, the cell needs protection, but it must also be able to respond to its surroundings. It is constantly taking in and getting rid of various molecules. The structure of the cell membrane allows it to perform all those functions.

▶ MAIN IDEA

Cell membranes are composed of two phospholipid layers.

The **cell membrane**, or the plasma membrane, forms a boundary between a cell and the outside environment and controls the passage of materials into and out of a cell. The cell membrane consists of a double layer of phospholipids interspersed with a variety of other molecules. A **phospholipid** (FAHS-foh-LIHP-ihd) is a molecule composed of three basic parts:

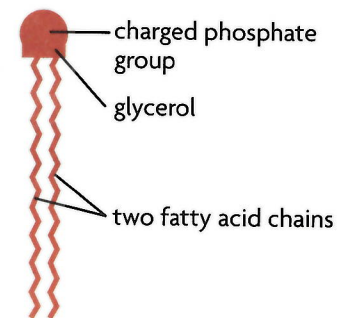
- a charged phosphate group
- glycerol
- two fatty acid chains

Together, the glycerol and the phosphate groups form the “head” of a phospholipid; the fatty acids form the “tail.” Because the head bears a charge, it is polar. Recall that water molecules are also polar. Therefore, the polar head of the phospholipid forms hydrogen bonds with water molecules. In contrast, the fatty acid tails are nonpolar and cannot form hydrogen bonds with water. As a result, the nonpolar tails are attracted to each other and repelled by water.

Because the membrane touches the cytoplasm inside the cell and the watery fluid outside the cell, the properties of polar heads and nonpolar tails cause the phospholipids to arrange themselves in layers, like a sandwich.

VISUAL VOCAB

A **phospholipid** is composed of three basic parts:



Connecting CONCEPTS

Biochemistry Recall from Chapter 2 that a hydrogen bond is a weak chemical bond that forms between a slightly positive hydrogen atom and a negatively charged region of another molecule.

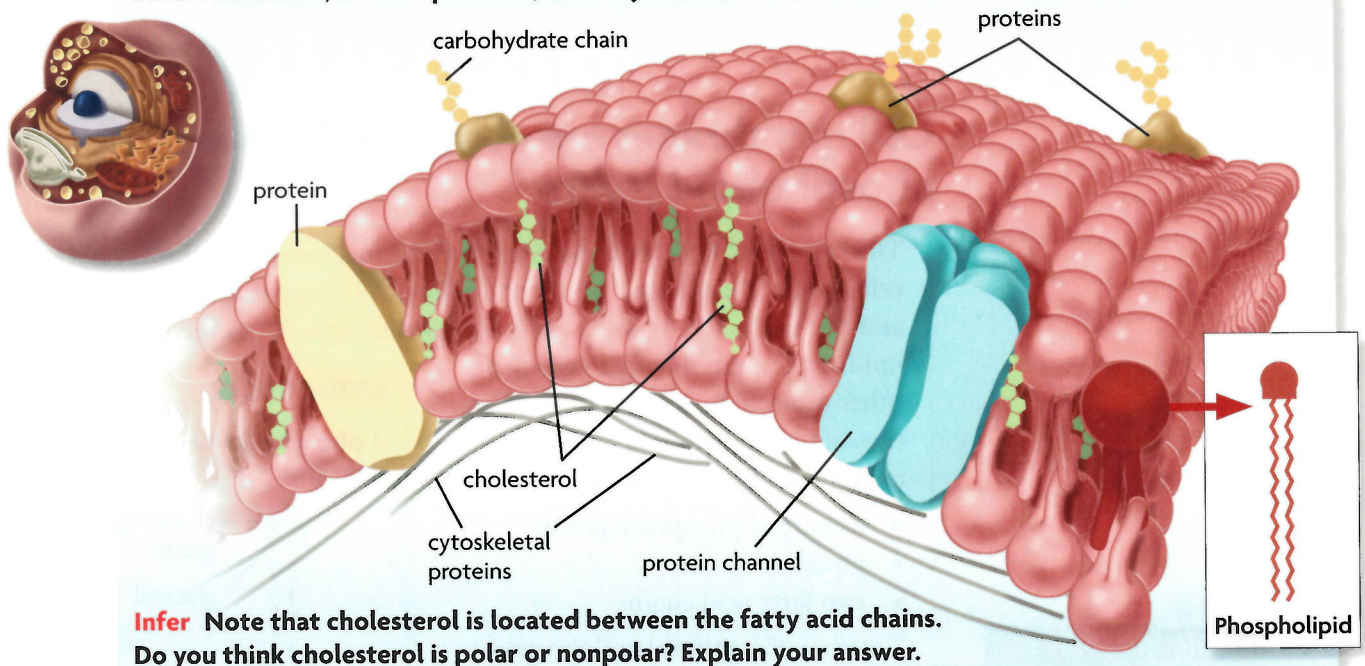
The polar heads are like the bread. They form the outer surfaces of the membrane, where they interact with the watery environment both outside and inside a cell. The nonpolar tails are like the filling. They are sandwiched between the layers of polar heads, where they are protected from the watery environment.

FIGURE 3.17 shows other molecules embedded within the phospholipid layers. They give the membrane properties and characteristics it would not otherwise have. These molecules serve diverse functions. Here are a few examples:

- Cholesterol molecules strengthen the cell membrane.
- Some proteins extend through one or both phospholipid layers and help materials cross the membrane. Other proteins are key components of the cytoskeleton. Different cell types have different membrane proteins.
- Carbohydrates attached to membrane proteins serve as identification tags, enabling cells to distinguish one type of cell from another.

FIGURE 3.17 Cell Membrane

The cell membrane is made of two phospholipid layers embedded with other molecules, such as proteins, carbohydrates, and cholesterol.



Infer Note that cholesterol is located between the fatty acid chains. Do you think cholesterol is polar or nonpolar? Explain your answer.

Fluid Mosaic Model

Scientists have developed the **fluid mosaic model**, which describes the arrangement of the molecules that make up a cell membrane. This model of cell membrane structure takes its name from two characteristics. First, the cell membrane is flexible, not rigid. The phospholipids in each layer can move from side to side and slide past each other. As a result, the membrane behaves like a fluid, similar to a film of oil on the surface of water. However, proteins embedded in the membrane do not flip vertically. If one part of a protein is outside the membrane, it will stay outside the membrane. Second, the variety of molecules studding the membrane is similar to the arrangement of colorful tiles with different textures and patterns that make up a dynamic mosaic.

Modeling the Cell Membrane

The cell membrane regulates what moves into and out of the cell.

PROBLEM How does the cell membrane regulate what moves into and out of the cells?

PROCEDURE

1. Bundle the swabs as shown.
2. Make a receptor from one pipe cleaner. It should extend through the bunch of swabs and have a region that would bind to a signal molecule. Use the other pipe cleaner to make a carbohydrate chain. Insert the chain into the “membrane” of the bunch of swabs.
3. Cut the drinking straw in half and insert both halves into the bunch of swabs.

ANALYZE AND CONCLUDE

1. **Explain** How do the swabs represent the polar and nonpolar characteristics of the cell membrane?
2. **Apply** In this model, the swabs and proteins can be moved around. Explain whether this is an accurate representation of actual cell membranes.

MATERIALS

- 50 cotton swabs
- 1 thick medium-sized rubber band
- 2 pipe cleaners, each a different color
- 1 drinking straw
- scissors



Selective Permeability

The cell membrane has the property of **selective permeability**, which means it allows some, but not all, materials to cross. Selective permeability is illustrated in **FIGURE 3.18**. The terms *semipermeable* and *selectively permeable* also refer to this property. As an example, outdoor clothing is often made of semipermeable fabric. The material is waterproof yet breathable. Molecules of water vapor from sweat are small enough to exit the fabric, but water droplets are too large to enter.

Selective permeability enables a cell to maintain homeostasis in spite of unpredictable, changing conditions outside the cell. Because a cell needs to maintain certain conditions to carry out its functions, it must control the import and export of certain molecules and ions. Thus, even if ion concentrations change drastically outside a cell, these ions won't necessarily interfere with vital chemical reactions inside a cell.

Molecules cross the membrane in several ways. Some of these methods require the cell to expend energy; others do not. How a particular molecule crosses the membrane depends on the molecule's size, polarity, and concentration inside versus outside the cell. In general, small nonpolar molecules easily pass through the cell membrane, small polar molecules are transported via proteins, and large molecules are moved in vesicles.

Connect Describe a semipermeable membrane with which you are already familiar.

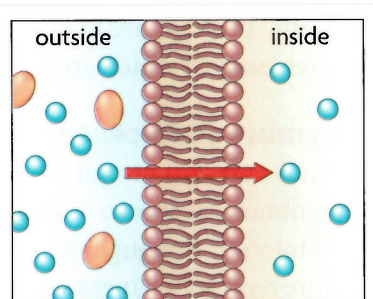


FIGURE 3.18 A selectively permeable membrane allows some, but not all, molecules to cross.

Connecting CONCEPTS

Homeostasis Recall from **Chapter 1** that homeostasis must be maintained in all organisms because vital chemical reactions can take place only within a limited range of conditions.

MAIN IDEA

Chemical signals are transmitted across the cell membrane.

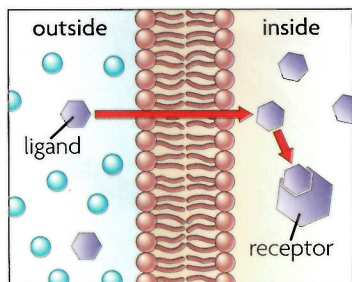


FIGURE 3.19 Intracellular receptors are located inside the cell. They are bound by molecules that can cross the membrane.

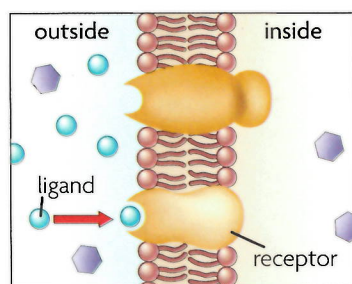


FIGURE 3.20 Membrane receptors bind to molecules that cannot enter the cell. When bound, the receptor transmits the signal inside the cell by changing shape.

Recall that cell membranes may secrete molecules and may contain identifying molecules, such as carbohydrates. All these molecules can act as signals to communicate with other cells. How are these signals recognized?

A **receptor** is a protein that detects a signal molecule and performs an action in response. It recognizes and binds to only certain molecules, which ensures that the right cell gets the right signal at the right time. The molecule a receptor binds to is called a ligand. When a receptor and a ligand bind, they change shape. This change is critical because it affects how a receptor interacts with other molecules. Two major types of receptors are present in your cells.

Intracellular Receptor

A molecule may cross the cell membrane and bind to an intracellular receptor, as shown in **FIGURE 3.19**. *Intracellular* means “within, or inside, a cell.” Molecules that cross the membrane are generally nonpolar and may be relatively small. Many hormones fit within this category. For example, aldosterone can cross most cell membranes. However, it produces an effect only in cells that have the right type of receptor, such as kidney cells. When aldosterone enters a kidney cell, it binds to an intracellular receptor. The receptor-ligand complex enters the nucleus, interacts with the DNA, and turns on certain genes. As a result, specific proteins are made that help the kidneys absorb sodium ions and retain water, both of which are important for maintaining normal blood pressure.

Membrane Receptor

A molecule that cannot cross the membrane may bind to a receptor in the cell membrane, as shown in **FIGURE 3.20**. The receptor then sends the message to the cell interior. Although the receptor binds to a signal molecule outside the cell, the entire receptor changes shape—even the part inside the cell. As a result, it causes molecules inside the cell to respond. These molecules, in turn, start a complicated chain of events inside the cell that tells the cell what to do. For instance, band 3 protein is a membrane receptor in red blood cells. When activated, it triggers processes that carry carbon dioxide from body tissues to the lungs.

Contrast How do intracellular receptors differ from membrane receptors?

3.3 ASSESSMENT



REVIEWING MAIN IDEAS

1. Why do **phospholipids** form a double layer?
2. Explain how membrane **receptors** transmit messages across the **cell membrane**.

CRITICAL THINKING

3. **Compare** Describe the similarities between enzymes and receptors.
4. **Infer** If proteins were rigid, why would they make poor receptors?

Connecting CONCEPTS

5. **Human Biology** Insulin helps cells take up sugar from the blood. Explain the effect on blood sugar levels if insulin receptors stopped working.

3.4

Diffusion and Osmosis

KEY CONCEPT Materials move across membranes because of concentration differences.

MAIN IDEAS

- Diffusion and osmosis are types of passive transport.
- Some molecules diffuse through transport proteins.

VOCABULARY

passive transport, p. 85

diffusion, p. 85

concentration gradient, p. 85

osmosis, p. 86

isotonic, p. 86

hypertonic, p. 86

hypotonic, p. 87

facilitated diffusion, p. 87



REVIEW AT
CLASSZONE.COM

Connect If you have ever been stuck in traffic behind a truck full of pigs, you know that “unpleasant” fails to fully describe the situation. That is because molecules travel from the pigs to receptors in your nose, which your brain interprets as a really bad odor. Or perhaps you have tie-dyed a T-shirt and have seen dye molecules spread throughout the pot of water, turning it neon green or electric blue. Why does that happen? Why don't the molecules stay in one place?

MAIN IDEA

Diffusion and osmosis are types of passive transport.

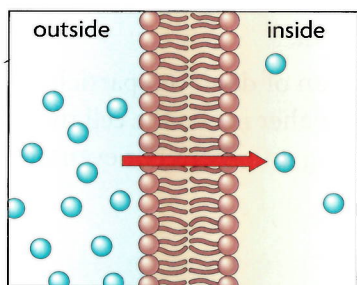


FIGURE 3.21 Passive transport is the movement of molecules across the membrane from areas of higher concentration to areas of lower concentration. It does not require energy input from the cell.

Cells almost continually import and export substances. If they had to expend energy to move every molecule, cells would require an enormous amount of energy to stay alive. Fortunately, some molecules enter and exit a cell without requiring the cell to work. As **FIGURE 3.21** shows, **passive transport** is the movement of molecules across a cell membrane without energy input from the cell. It may also be described as the diffusion of molecules across a membrane.

Diffusion

Diffusion is the movement of molecules in a fluid or gas from a region of higher concentration to a region of lower concentration. It results from the natural motion of particles, which causes molecules to collide and scatter. Concentration is the number of molecules of a substance in a given volume, and it can vary from one region to another. A **concentration gradient** is the difference in the concentration of a substance from one location to another. Molecules diffuse down their concentration gradient—that is, from a region of higher concentration to a region of lower concentration.

In the tie-dye example, dye molecules are initially at a high concentration in the area where they are added to the water. Random movements of the dye and water molecules cause them to bump into each other and mix. Thus, the dye molecules move from an area of higher concentration to an area of lower concentration. Eventually, they are evenly spread throughout the solution. This means the molecules have reached a dynamic equilibrium. The concentration of dye molecules is the same throughout the solution (equilibrium), but the molecules continue to move (dynamic).

Connecting CONCEPTS

Human Biology As you will learn in **Chapter 30**, diffusion plays a key role in gas exchange in the lungs and other body tissues.



FIGURE 3.22 Diffusion results from the natural motion of particles.

In cells, diffusion plays an important role in moving substances across the membrane. Small lipids and other nonpolar molecules, such as carbon dioxide and oxygen, easily diffuse across the membrane. For example, most of your cells continually consume oxygen, which means that the oxygen concentration is almost always higher outside a cell than it is inside a cell. As a result, oxygen generally diffuses into a cell, without the cell's expending any energy.

Osmosis

Water molecules, of course, also diffuse. They move across a semipermeable membrane from an area of higher water concentration to an area of lower water concentration. This process is called **osmosis**. It is important to recognize that the higher the concentration of dissolved particles in a solution, the lower the concentration of water molecules in the same solution. So if you put 1 teaspoon of salt in a cup of water and 10 teaspoons of salt in a different cup of water, the first cup would have the higher water concentration.

A solution may be described as isotonic, hypertonic, or hypotonic relative to another solution. Note that these terms are comparisons; they require a point of reference, as shown in **FIGURE 3.23**. For example, you may be taller than your coach or taller than you were two years ago, but you are never just taller. Likewise, a solution may be described as isotonic only in comparison with another solution. To describe it as isotonic by itself would be meaningless.

- 1 A solution is **isotonic** to a cell if it has the same concentration of dissolved particles as the cell. Water molecules move into and out of the cell at an equal rate, so the cell's size remains constant.
- 2 A **hypertonic** solution has a higher concentration of dissolved particles than a cell. This means water concentration is higher inside the cell than outside. Thus, water flows out of the cell, causing it to shrivel or even die.

FIGURE 3.23 Effects of Osmosis

Osmosis is the diffusion of water across a semipermeable membrane from an area of higher water concentration to an area of lower water concentration.

1 ISOTONIC SOLUTION	2 HYPERTONIC SOLUTION	3 HYPOTONIC SOLUTION
<p>isotonic</p> <p>isotonic</p>	<p>hypertonic</p> <p>hypotonic</p>	<p>hypotonic</p> <p>hypertonic</p>
<p>A solution is isotonic to a cell if it has the same concentration of solutes as the cell. Equal amounts of water enter and exit the cell, so its size stays constant.</p>	<p>A hypertonic solution has more solutes than a cell. Overall, more water exits a cell in hypertonic solution, causing the cell to shrivel or even die.</p>	<p>A hypotonic solution has fewer solutes than a cell. Overall, more water enters a cell in hypotonic solution, causing the cell to expand or even burst.</p>

Apply How would adding salt to the isotonic solution above affect the cell?

colored SEMs; magnification 4500×

- 3** A **hypotonic** solution has a lower concentration of dissolved particles than a cell. This means water molecules are more concentrated outside the cell than inside. Water diffuses into the cell. If too much water enters a cell, the cell membrane could potentially expand until it bursts.

Some animals and single-celled organisms can survive in hypotonic environments. Their cells have adaptations for removing excess water. In plants, the rigid cell wall prevents the membrane from expanding too much. Remember from Section 3.2 that pressure exerted on the cell wall by fluid inside the central vacuole provides structural support for each cell and for the plant as a whole.

Apply What will happen to a houseplant if you water it with salt water (a hypertonic solution)?

▶ MAIN IDEA

Some molecules diffuse through transport proteins.

Some molecules cannot easily diffuse across a membrane. They may cross more easily through transport proteins—openings formed by proteins that pierce the cell membrane. **Facilitated diffusion** is the diffusion of molecules across a membrane through transport proteins. The word *facilitate* means “to make easier.” Transport proteins make it easier for molecules to enter or exit a cell. But the process is still a form of passive transport. The molecules move down a concentration gradient, requiring no energy expenditure by the cell.

There are many types of transport proteins. Most types allow only certain ions or molecules to pass. As **FIGURE 3.24** shows, some transport proteins are simple channels, or tunnels, through which particles such as ions can pass. Others act more like enzymes. When bound, the protein changes shape, allowing the molecule to travel the rest of the way into the cell.

Summarize Explain why transport proteins are needed in the cell membrane.

VOCABULARY

The words *isotonic*, *hypertonic*, and *hypotonic* share the root word *tonic*, which means “pressure.” Their prefixes give them different comparative meanings.

iso- = equal, same

hyper- = over, above

hypo- = under, below

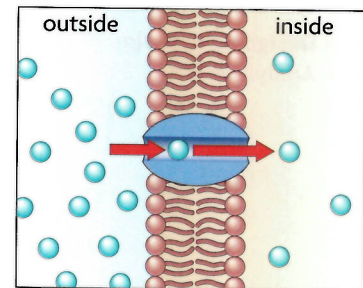


FIGURE 3.24 Facilitated diffusion enables molecules that cannot directly cross the phospholipid bilayer to diffuse through transport proteins in the membrane.

3.4 ASSESSMENT



REVIEWING **▶** MAIN IDEAS

1. Explain what a **concentration gradient** is and what it means for a molecule to diffuse down its concentration gradient.
2. Explain why **facilitated diffusion** does not require energy from a cell.

CRITICAL THINKING

3. **Apply** A cell is bathed in fluid. However, you notice that water is flowing out of the cell. In what kind of solution is this cell immersed: **isotonic**, **hypotonic**, or **hypertonic**?
4. **Compare** How are receptors and transport proteins similar?

Connecting CONCEPTS

5. **Health** When a person becomes dehydrated due to the loss of fluids and solutes, saline solution (water and salts) is infused into the bloodstream by medical personnel. Why is saline solution used instead of pure water?

MATERIALS

- 2 vinegar-soaked chicken eggs
- water
- balance
- 2 disposable plastic cups
- distilled water
- 5% NaCl solution
- 20% NaCl solution
- 50% glucose solution
- 10 cm masking tape
- marker
- 500-mL beaker
- 20 cm piece of plastic wrap
- 2 rubber bands

**PROCESS SKILL**

- Designing Experiments
- Analyzing Data

Diffusion Across a Membrane

In this investigation, you will determine whether different solutions are hypotonic, isotonic, or hypertonic relative to the inside of a chicken egg. Your teacher has already soaked the eggs in vinegar, which removes calcium from the shell. This allows the egg to act as a single cell encased in a selectively permeable membrane.

PROBLEM Are the tested solutions hypotonic, isotonic, or hypertonic to the egg?

PROCEDURE

1. Choose two solutions you want to test in your experiment to determine whether they are hypotonic, isotonic, or hypertonic relative to the chicken egg. Select from distilled water, 5% NaCl, 20% NaCl, and 50% glucose solutions.
2. Identify the variables you will measure and the constants you will maintain during the investigation. Examples of constants include the amount of solution used for each egg.
3. Design a data table, such as the example shown below, to organize your results.
4. Thoroughly rinse each egg and find its mass. Place each egg in a separate plastic cup.
5. Cover each egg with one of the solutions you are testing. Label the cups with the solution names.
6. Cover each cup with plastic wrap, securing it with a rubber band. Soak the eggs overnight.
7. The next day, find the mass of each egg and note any changes in appearance.

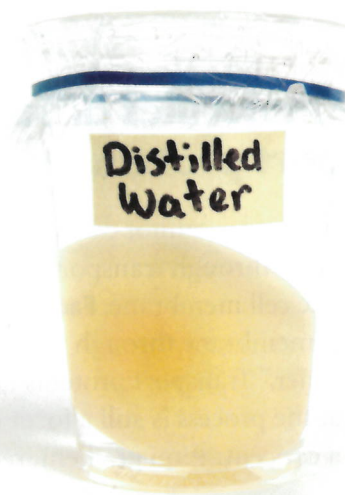


TABLE 1. CHANGES IN EGG MASS

	Name of Solution 1	Name of Solution 2
Initial mass of egg (g)		
Mass of egg after soaking in solution (g)		

ANALYZE AND CONCLUDE

1. **Apply** What is the operational definition of the dependent variable in this lab?
2. **Analyze** How did you conclude whether the solutions you tested were hypotonic, isotonic, or hypertonic?
3. **Identify** What were the independent and dependent variables in your experiment? What was held constant?
4. **Calculate** Calculate the change in the mass of the eggs. Explain how this may relate to your findings.
5. **Predict** What effect would eating too much salt have on the human body?
6. **Experimental Design** List possible reasons for any inconsistent results you may have observed.

3.5

Active Transport, Endocytosis, and Exocytosis

KEY CONCEPT Cells use energy to transport materials that cannot diffuse across a membrane.

▶ MAIN IDEAS

- Proteins can transport materials against a concentration gradient.
- Endocytosis and exocytosis transport materials across the membrane in vesicles.

VOCABULARY

active transport, p. 89

endocytosis, p. 90

phagocytosis, p. 90

exocytosis, p. 91



REVIEW AT
CLASSZONE.COM

Connect You have seen that a cell membrane controls the passive transport of materials into and out of a cell. However, a cell needs many substances that cannot simply diffuse across the membrane. The cell has several ways to take in or get rid of these materials. These processes, such as active transport, endocytosis, and exocytosis, all need energy from the cell.

▶ MAIN IDEA

Proteins can transport materials against a concentration gradient.

You just learned that some transport proteins let materials diffuse into and out of a cell down a concentration gradient. Many other transport proteins, often called pumps, move materials against a concentration gradient. **Active transport** drives molecules across a membrane from a region of lower concentration to a region of higher concentration.

This process, shown in **FIGURE 3.25**, uses transport proteins powered by chemical energy. Cells use active transport to get needed molecules regardless of the concentration gradient and to maintain homeostasis.

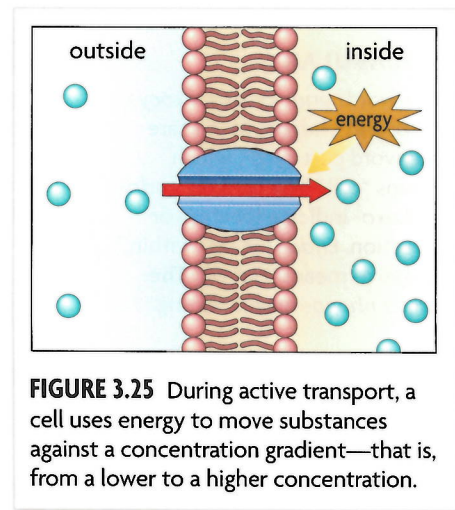


FIGURE 3.25 During active transport, a cell uses energy to move substances against a concentration gradient—that is, from a lower to a higher concentration.

Connecting CONCEPTS

Human Biology As you will learn in **Chapter 32**, active transport is a necessary part of nutrient absorption.

Before we discuss active transport proteins, let's look at transport proteins in general. All transport proteins span the membrane, and most change shape when they bind to a target molecule or molecules. Some transport proteins bind to only one type of molecule. Others bind to two different types. Some proteins that bind to two types of molecules move both types in the same direction. Others move the molecules in opposite directions.



FIGURE 3.26 Just as a cell uses energy in the process of active transport, this boy uses energy to pump air against a concentration gradient.

The key feature of active transport proteins is that they can use chemical energy to move a substance against its concentration gradient. Most use energy from a molecule called ATP, either directly or indirectly. For example, nerve cells, or neurons, need to have a higher concentration of potassium ions and a lower concentration of sodium ions than the fluid outside the cell. The sodium-potassium pump uses energy directly from the breakdown of ATP. It pumps three sodium ions out of the cell for every two potassium ions it pumps in. The proton pump, another transport protein, uses energy from the breakdown of ATP to move hydrogen ions (or protons) out of the cell. This action forms a concentration gradient of hydrogen ions (H^+), which makes the fluid outside the cell more positively charged than the fluid inside. In fact, this gradient is a form of stored energy that is used to power other active transport proteins. In plant cells, this gradient causes yet another protein to transport sucrose into the cell—an example of indirect active transport.

Synthesize In what ways are active transport proteins similar to enzymes?

MAIN IDEA

Endocytosis and exocytosis transport materials across the membrane in vesicles.

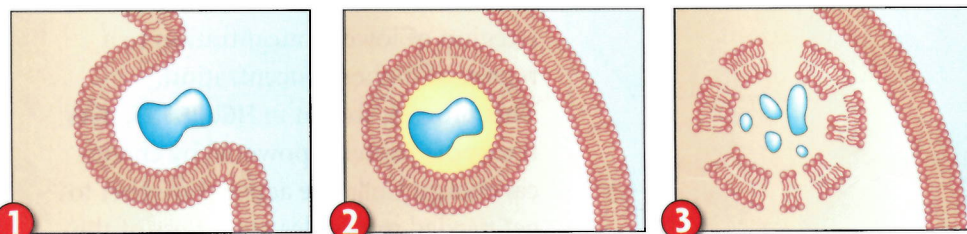
A cell may also use energy to move a large substance or a large amount of a substance in vesicles. Transport in vesicles lets substances enter or exit a cell without crossing through the membrane.

Endocytosis

Endocytosis (EN-doh-sy-TOH-sihs) is the process of taking liquids or fairly large molecules into a cell by engulfing them in a membrane. In this process, the cell membrane makes a pocket around a substance. The pocket breaks off inside the cell and forms a vesicle, which then fuses with a lysosome or a similar type of vesicle. Lysosomal enzymes break down the vesicle membrane and its contents (if necessary), which are then released into the cell.

VOCABULARY

The words *endocytosis*, *exocytosis*, and *phagocytosis* share the word part *cyto-*, which means “cell.” The prefixes *endo-* and *exo-* indicate location or direction. *Endo-* means “within,” and *exo-* means “out of.” The prefix *phago-* means “eating.”



1 During endocytosis, the cell membrane folds inward and fuses together, surrounding the substance in a pocket.

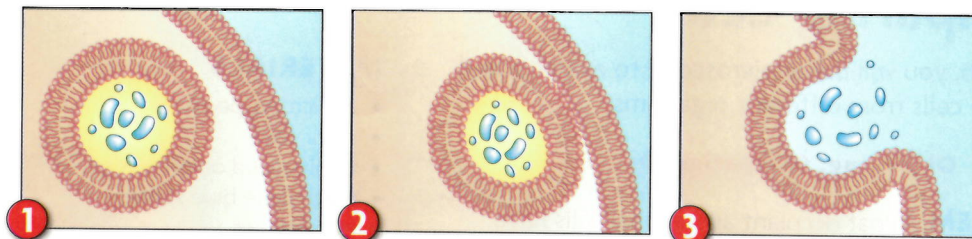
2 The pocket pinches off inside the cell, forming a vesicle.

3 The vesicle fuses with a lysosome or a similar vesicle, where enzymes break down the membrane and its contents.

Phagocytosis (FAG-uh-sy-TOH-sihs) is a type of endocytosis in which the cell membrane engulfs large particles. The word literally means “cell eating.” Phagocytosis plays a key role in your immune system. Some white blood cells called macrophages help your body fight infection. They find foreign materials, such as bacteria, and engulf and destroy them.

Exocytosis

Exocytosis (EHK-soh-sy-TOH-sihs), the opposite of endocytosis, is the release of substances out of a cell by the fusion of a vesicle with the membrane. During this process, a vesicle forms around materials to be sent out of the cell. The vesicle then moves toward the cell's surface, where it fuses with the membrane and lets go of its contents.



1 The cell forms a vesicle around material that needs to be removed or secreted.

2 The vesicle is transported to the cell membrane.

3 The vesicle membrane fuses with the cell membrane and releases the contents.

Exocytosis happens all the time in your body. In fact, you couldn't think or move a muscle without it. When you want to move your big toe, for example, your brain sends a message that travels through a series of nerve cells to reach your toe. This message, or nerve impulse, travels along each nerve cell as an electrical signal, but it must be converted to a chemical signal to cross the tiny gap that separates one nerve cell from the next. These chemicals are stored in vesicles within the nerve cells. When a nerve impulse reaches the end of a cell, it causes the vesicles to fuse with the cell membrane and release the chemicals outside the cell. There they attach to the next nerve cell, which triggers a new electrical impulse in that cell.

Hypothesize What might happen if vesicles in your neurons were suddenly unable to fuse with the cell membrane?

Connecting CONCEPTS

Endocrine System As you will learn in Chapter 29, thyroid hormones play an important role in controlling your growth and development. These hormones are released into the blood by exocytosis.



For more information about active transport, go to scilinks.org.
Keycode: MLB003

3.5 ASSESSMENT



REVIEWING MAIN IDEAS

1. How do transport proteins that are pumps differ from those that are channels?
2. How do **endocytosis** and **exocytosis** differ from diffusion?

THINKING CRITICALLY

3. **Apply** Small lipid molecules are in high concentration outside a cell. They slowly cross the membrane into the cell. What term describes this action? Does it require energy?
4. **Apply** Ions are in low concentration outside a cell. They move rapidly into the cell via protein molecules. What term describes this action? Does it require energy?

Connecting CONCEPTS

5. **Diffusion** Suppose molecules were unable to diffuse into and out of cells. How might life be different if cells had to use **active transport** to move every substance? Explain your reasoning.

Use these inquiry-based labs and online activities to deepen your understanding of cell structure.

INVESTIGATION

Comparing Cells

In this lab, you will use a microscope to examine and compare cells from different organisms.

SKILLS Observing, Comparing, Drawing

PROBLEM What do plant and animal cells have in common?

PROCEDURE

1. Refer to page R8 if you need to review instructions on using a microscope and making a wet mount.
2. Construct a table to organize your observations and drawings.
3. Peel a thin slice of onion and place it on the slide.
4. Carefully add a drop of methylene blue to the onion. Avoid getting the stain on your clothes. Place one side of a cover slip against the methylene blue, and gently lower it, being careful not to trap air bubbles.
5. Examine the onion under the microscope at low and high power, and draw what you see. Large structures such as the nucleus, cell membrane, and cell wall should be visible. Label as many cell structures as you can.
6. Repeat steps 2 through 4 for the celery and the elodea.
7. Examine prepared slides of human cheek cells under the microscope at low and high power. Draw what you see, and label as many structures as you can.

ANALYZE AND CONCLUDE

1. **Compare** What characteristics do all of the cells have in common? List as many as you can.
2. **Contrast** Identify the unique characteristics of each cell type.
3. **Connect** What type of cells did you examine, eukaryotic or prokaryotic? Explain your answer.
4. **Infer** Why do you think it was necessary to add methylene blue to the slides?

MATERIALS

- 3 microscope slides
- razor tool
- thinly sliced onion pieces
- methylene blue stain
- eyedropper
- 3 plastic cover slips
- microscope
- thinly sliced celery stalk
- elodea leaf
- prepared slides of human cheek cells

