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

MICHIGAN STANDARDS

B2.4g Explain that some structures in the modern eukaryotic cell developed from early prokaryotes, such as mitochondria, and in plants, chloroplasts.
B2.5g Compare and contrast plant and animal cells.

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×)

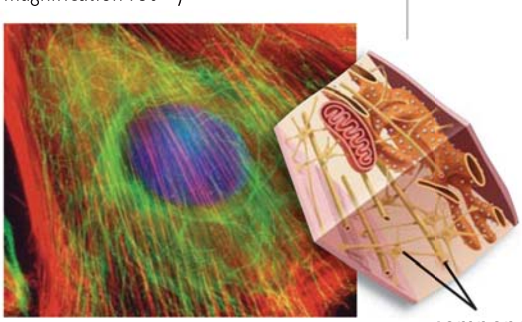
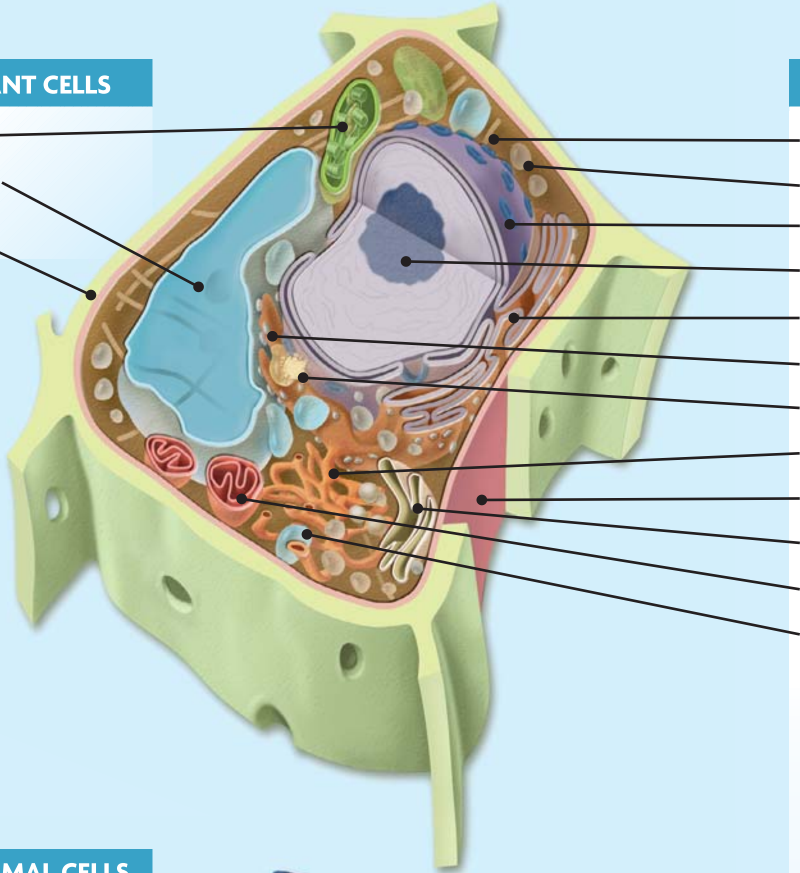


FIGURE 3.6 Cell Structure

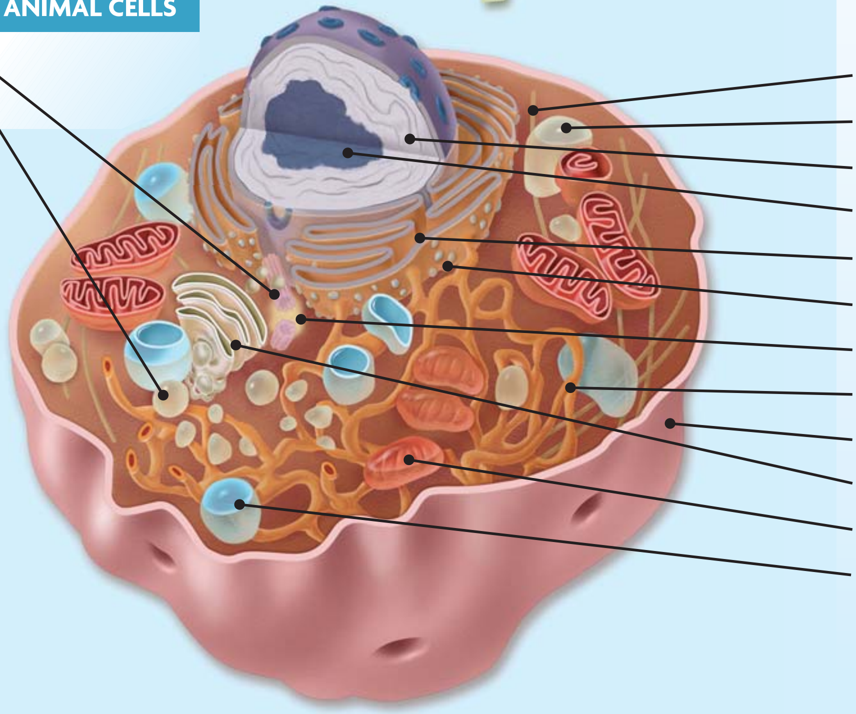
Animated BIOLOGY Explore cell organelles at ClassZone.com.

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



ANIMAL CELL



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?

TAKING NOTES

Make a chart to correlate each organelle with its function.

Organelle	*Function*
Nucleus	*stores DNA*
Ribosome	

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.

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.

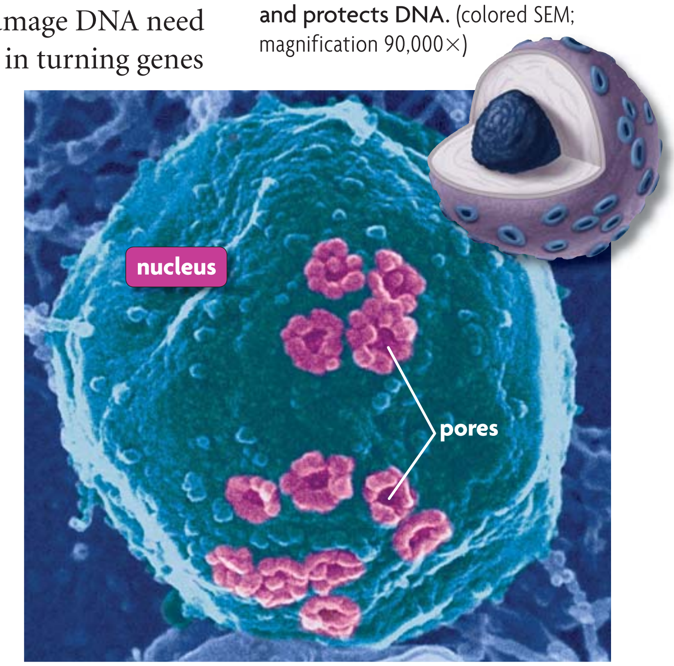
Nucleus

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.

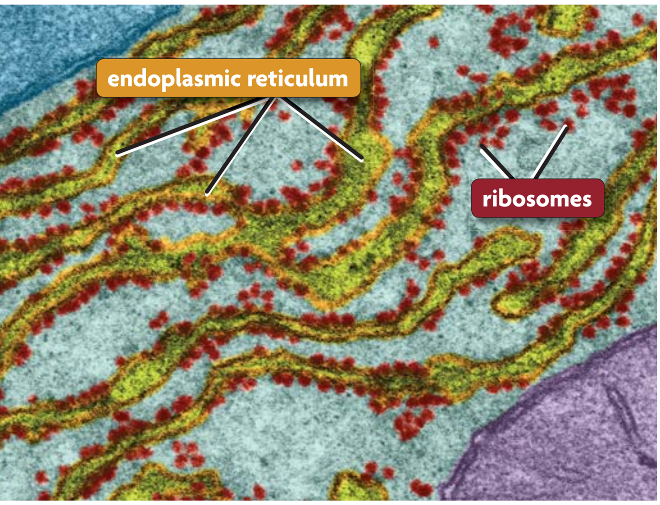
FIGURE 3.7 The nucleus stores and protects DNA. (colored SEM; magnification 90,000×)

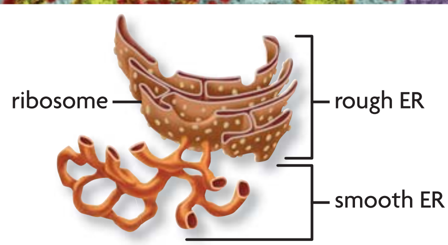


Endoplasmic Reticulum and Ribosomes

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?

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





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.

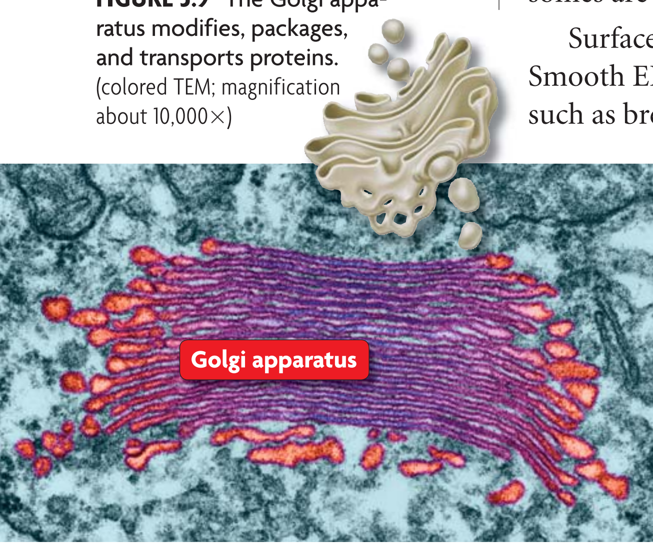
In some regions, the ER is studded with **ribosomes** (RY-buh-SOHMZ), tiny organelles that link amino acids together to form proteins. Ribosomes are both the site of protein synthesis and active participants in the process. Ribosomes are themselves made of proteins and RNA. After assembly in the nucleolus,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

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



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.

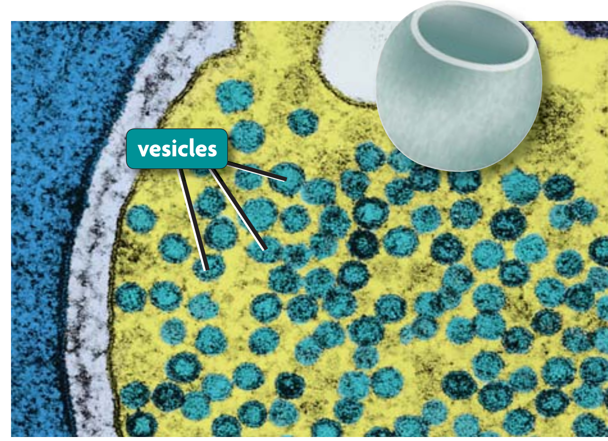
Vesicles

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

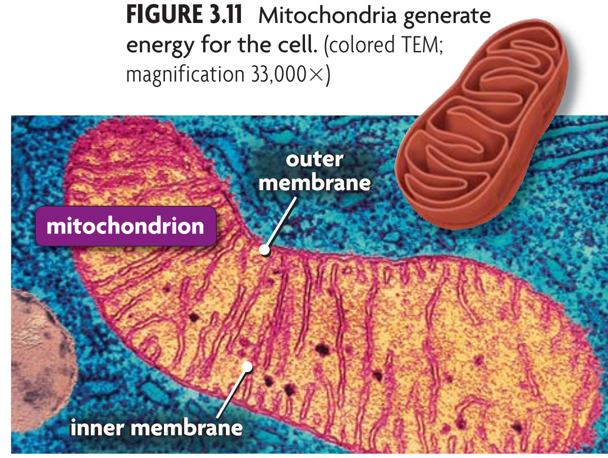
Other organelles have various functions.

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×)

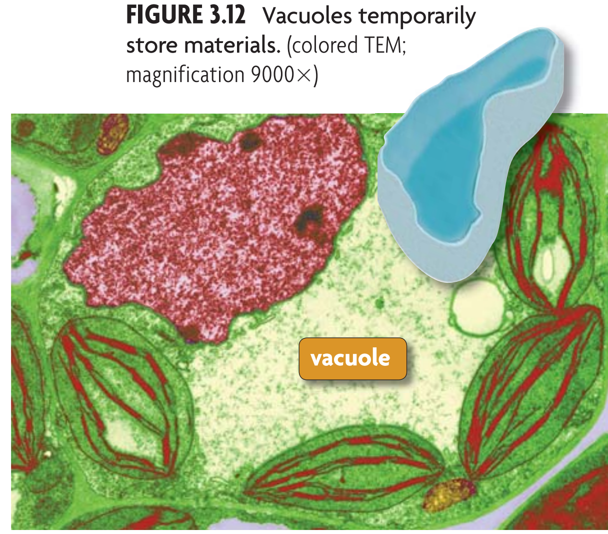


FIGURE 3.13 Lysosomes digest and recycle foreign materials or worn-out parts. (colored TEM; magnification 21,000×)

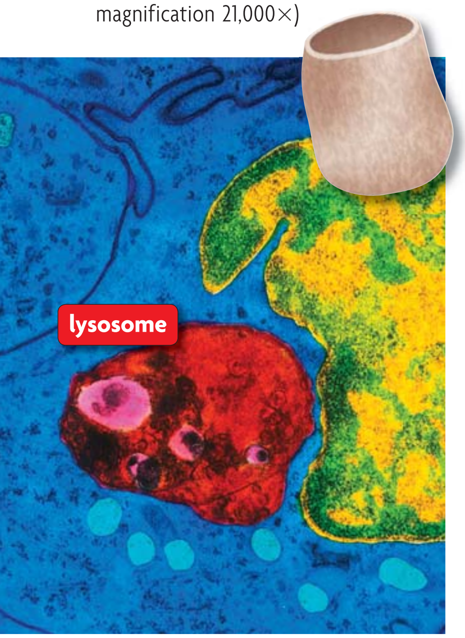
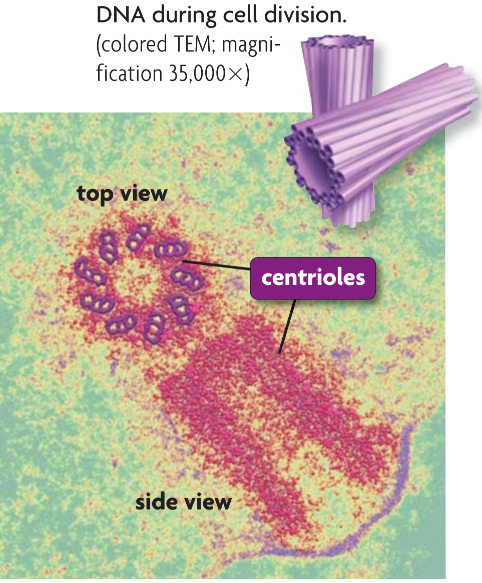


FIGURE 3.14 Centrioles divide DNA during cell division. (colored TEM; magnification 35,000×)



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.

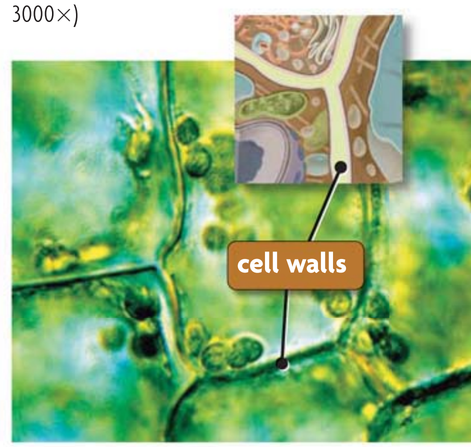
Plant cells have two features not shared by animal cells: cell walls and chloroplasts. Cell walls are structures that provide rigid support. Chloroplasts are organelles that help a plant convert solar energy to chemical energy.

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.

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

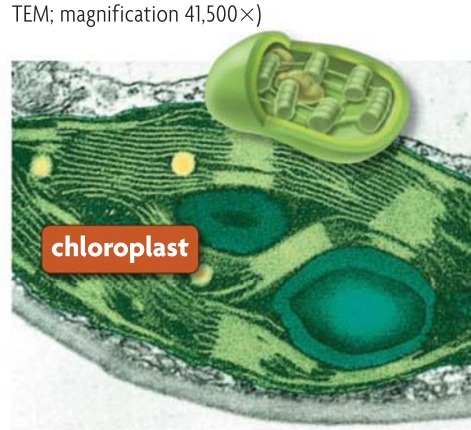


Chloroplasts

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.

FIGURE 3.16 Chloroplasts convert solar energy into chemical energy through photosynthesis. (colored TEM; magnification 41,500×)



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

3.2 ASSESSMENT

ONLINE QUIZ
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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?