Chapter 7

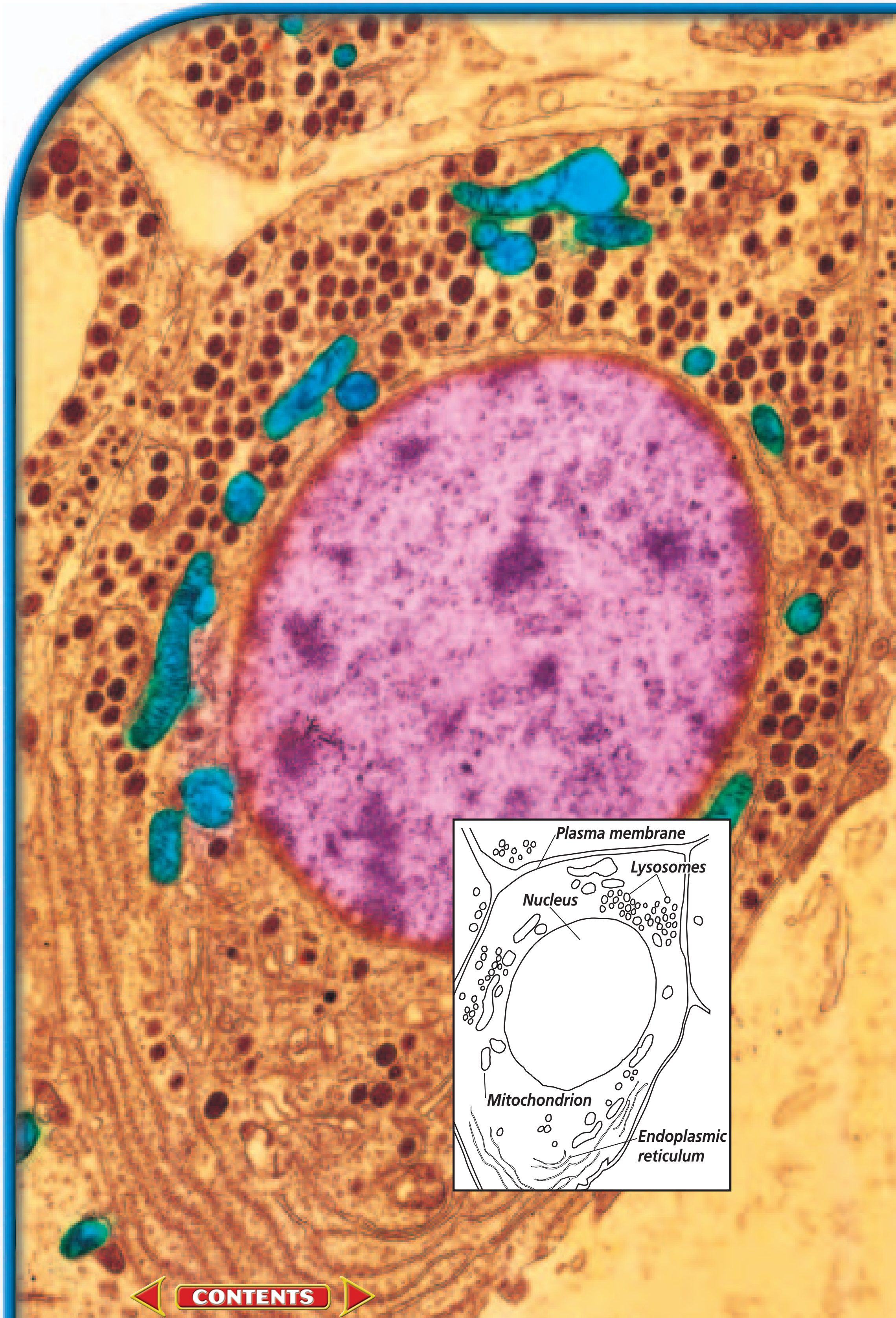
A View of the Cell

What You'll Learn

- You will identify the parts of prokaryotic and eukaryotic cells.
- You will identify the structure and function of the plasma membrane.
- You will relate the structure of cell parts to their functions.

Why It's Important

Cells are the foundation for all life forms. Birth, growth, development, death, and all life functions begin as cellular processes.



Understanding the Photo

You and all other organisms are made of cells. A human cell appears in this color-enhanced photograph. Scientists use color enhancement with assistance from computer software to distinguish various cell parts.

Color-enhanced TEM Magnification: 4700×

Biology Online

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- study the entire chapter online
- access Web Links for more information and activities on cells
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Section 7.1

The Discovery of Cells

SECTION PREVIEW

Objectives

Relate advances in microscope technology to discoveries about cells and cell structure.

Compare the operation of a compound light microscope with that of an electron microscope.

Identify the main ideas of the cell theory.

Review Vocabulary

organization: the orderly structure of cells in an organism (p. 7)

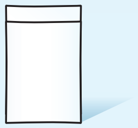
New Vocabulary

cell
compound light microscope
cell theory
electron microscope
organelle
prokaryote
eukaryote
nucleus

FOLDABLES Study Organizer

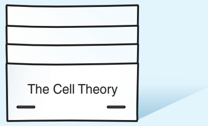
The Cell Theory Make the following Foldable to help you organize the ideas of the cell theory.

STEP 1 **Collect** 2 sheets of paper and layer them about 1.5 cm apart vertically. Keep the edges level.



STEP 2 **Fold** up the bottom edges of the paper to form 4 equal tabs.

STEP 3 **Fold** the papers and crease well to hold the tabs in place. Staple along the fold. **Label** each tab with one of the main ideas of the cell theory.



Summarize After you read Section 7.1, summarize the three main ideas of the cell theory in your own words. Review the theory using the information provided and note its strengths and weaknesses.

The History of the Cell Theory

Before microscopes were invented, people believed that diseases were caused by curses and supernatural spirits. They had no idea that organisms such as bacteria existed. As scientists began using microscopes, they quickly realized they were entering a new world—one of microorganisms (my kroh OR guh nih zumz). Microscopes enabled scientists to view and study **cells,** the basic units of living organisms.

Physical Science Connection

Lenses and the refraction of light Because light waves travel faster in air than in glass, they change direction as they move from air into a glass lens. This bending of light waves is called refraction. Refraction occurs when a wave changes speed as it moves from one material into another.

Light microscopes

The microscope Anton van Leeuwenhoek (LAY vun hook) used in the 1600s is considered a simple light microscope because it contained one lens and used light to view objects. Over the next 200 years, scientists greatly improved microscopes by grinding higher quality lenses and developing the compound light microscope. **Compound light microscopes** use a series of lenses to magnify objects in steps. These microscopes can magnify objects up to about 1500 times. As the observations of organisms viewed under a microscope expanded, scientists began to draw conclusions about the organization of living matter. With the microscope established as a valid scientific tool, scientists had to learn the size relationship of magnified objects to their true size. See what specimens look like at different magnifications on pages 1064–1065 in the *Focus On*.

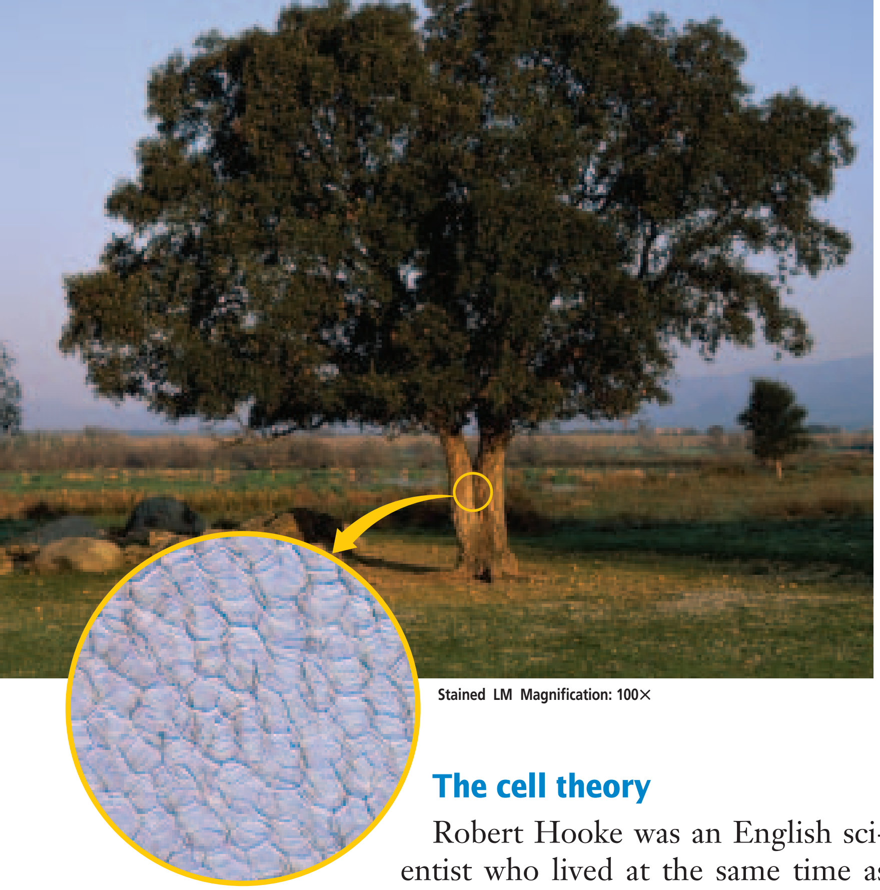


Figure 7.1
Cork cells (above) from the dead bark of an oak tree (top) were observed by Robert Hooke using a crude compound light microscope that magnified structures only 30 times.
Infer ***Why did Hooke name them "cells"?***

The cell theory

Robert Hooke was an English scientist who lived at the same time as van Leeuwenhoek. Hooke used a compound light microscope to study cork, the dead cells of oak bark. In cork, Hooke observed small geometric shapes, like those shown in ***Figure 7.1.*** Hooke gave these box-shaped structures the name *cells* because they reminded him of the small rooms monks lived in at a monastery. Cells are the basic units of all living things.

Several scientists extended Hooke's observations and drew some important conclusions. In the 1830s, the German scientist Matthias Schleiden observed a variety of plants and concluded that all plants are composed of cells. Another German scientist, Theodor Schwann, made similar observations on animals. The observations and conclusions of these scientists are summarized as the cell theory, one of the fundamental ideas of modern biology.

The **cell theory** is made up of three main ideas:

1. *All organisms are composed of one or more cells.* An organism may be a single cell, such as the organisms van Leeuwenhoek saw in water. Others, like the plants and animals with which you are most familiar, are multicellular, or made up of many cells.
2. *The cell is the basic unit of structure and organization of organisms.* Although organisms such as humans, dogs, and trees can become very large and complex, the cell remains the simplest, most basic component of any organism.
3. *All cells come from preexisting cells.* Before the cell theory, no one knew how cells were formed, where they came from, or what determined the type of cell they became. The cell theory states that a cell divides to form two identical cells.

Reading Check **Summarize** the main ideas of the cell theory.

Electron microscopes

The microscopes we have discussed so far use a beam of light and can magnify an object up to about 1500 times its actual size. Although light microscopes continue to be valuable tools, scientists knew that another world, which they could not yet see, existed within a cell. In the 1930s and 1940s, a new type of microscope, the **electron microscope,** was developed. This microscope uses a beam of electrons instead of light to magnify structures up to 500 000 times their actual size, allowing scientists to see structures within a cell. Because the electrons can collide with air particles and scatter, specimens must be examined in a vacuum.

There are two basic types of electron microscopes. Scientists commonly use the scanning electron microscope (SEM) to scan the surfaces of cells to learn their three-dimensional shape. The transmission electron microscope

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(TEM) allows scientists to study the structures contained within a cell.

New types of microscopes and new techniques are continually being designed. For example, the scanning tunneling microscope (STM) uses the flow of electrons to create computer images of atoms on the surface of a molecule. New techniques using the light microscope have increased the information scientists can gain with this basic tool. Most of these new techniques seek to add contrast to structures within the cells, such as adding dyes that stain some parts of a cell, but not others. Try *MiniLab 7.1* to practice the basic technique of measuring objects under a microscope.

Two Basic Cell Types

With the development of better microscopes, scientists observed that all cells contain small, specialized structures called **organelles.** Many, but not all, organelles are surrounded by membranes. Each organelle has a specific function in the cell.

Cells can be divided into two broad groups: those that contain membrane-bound organelles and those that do not. Cells that do not contain any membrane-bound organelles are called prokaryotic (pro kar ee AW tik) cells. Most unicellular organisms, such as bacteria, do not have membrane-bound organelles and are therefore called **prokaryotes.**

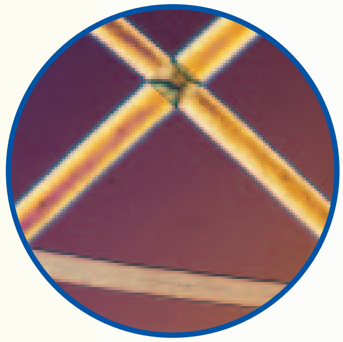
Cells of the other type, those containing membrane-bound organelles, are called eukaryotic (yew kar ee AW tik) cells. Most of the multicellular organisms we know are made up of eukaryotic cells and are therefore called **eukaryotes.** It is important to note, however, that some eukaryotes, such as amoebas, or some algae and yeast, are unicellular organisms.

MiniLab 7.1

Measure in SI

Measuring Objects Under a Microscope Knowing the diameter of the circle of light you see when looking through a microscope allows you to measure the size of objects being viewed. For most microscopes, the diameter of the circle of light is 1.5 mm, or 1500 μm (micrometers), under low power and 0.375 mm, or 375 μm, under high power.

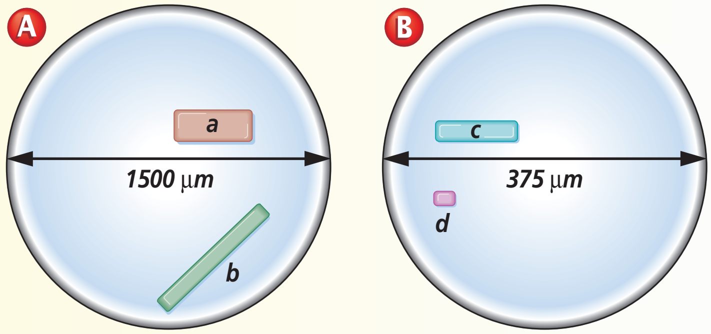
Stained LM Magnification: 75×



Human hair

Procedure

1. Look at diagram A that shows an object viewed under low power. Knowing the circle diameter to be 1500 μm, the estimated length of object (a) is 400 μm. What is the estimated length of object (b)?
2. Look at diagram B that shows an object viewed under high power. Knowing the circle diameter to be 375 μm, the estimated length of object (c) is 100 μm. What is the estimated length of object (d)?
3. With help from your teacher, prepare a wet mount of a strand of your hair. **CAUTION:** ***Use caution when handling microscopes and glass slides.*** Measure the diameter of your hair strand while viewing it under low and then high power.

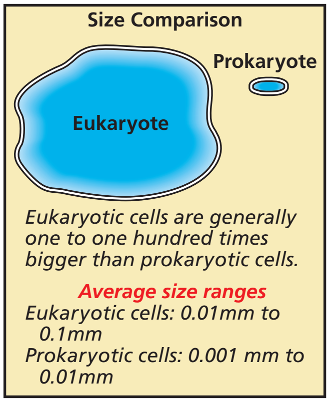


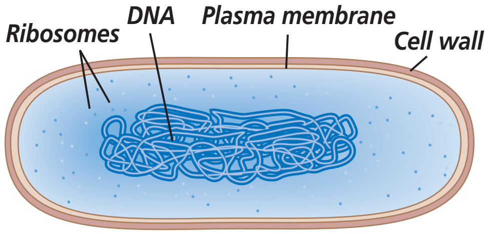
Analysis

1. **Observe and Infer** An object can be magnified 100, 200, or 1000 times when viewed under a microscope. Does the object's actual size change with each magnification? Explain.
2. **Estimate** Do your observations of the diameter of your hair strand under low and high power support the answer to question 1? If not, offer a possible explanation why.

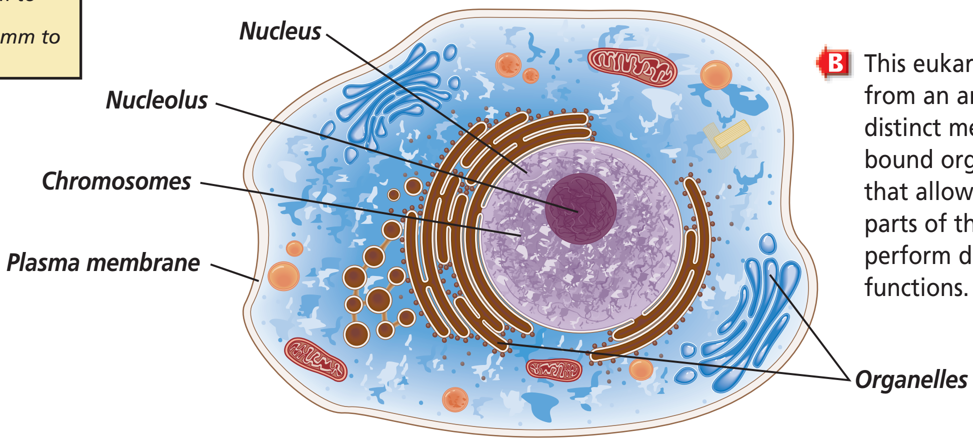
George Musil/Visuals Unlimited

Figure 7.2
Some parts of prokaryotic and eukaryotic cells are shown here.





A A prokaryotic cell does not have internal organelles surrounded by a membrane. Most of a prokaryote's metabolism takes place in the cytoplasm.



B This eukaryotic cell from an animal has distinct membrane-bound organelles that allow different parts of the cell to perform different functions.

Compare the prokaryotic and eukaryotic cells in ***Figure*** **7.2.** Separation of cell functions into distinct compartments—the organelles—benefits the eukaryotic cell. One benefit is that chemical reactions that would normally not occur in the same area of the cell can now be carried out at the same time.

Robert Brown, a Scottish scientist, observed that eukaryotic cells contain a prominent structure, which Rudolf Virchow later concluded was the structure responsible for cell division. We now know this structure as the **nucleus,** the central membrane-bound organelle that manages or controls cellular functions.

Section Assessment

Understanding Main Ideas

1. Describe the history of microscopes, and evaluate their impact in the study of cells.
2. How does the cell theory describe the levels of organization of living organisms?
3. Compare the sources of the beam in light microscopes and electron microscopes.
4. Describe the differences between a prokaryotic and a eukaryotic cell, and identify their parts.
5. Explain the difference between a scanning electron microscope and a transmission electron microscope and their uses.

Thinking Critically

6. Suppose you discovered a new type of plant. Applying the cell theory, what can you say for certain about this organism?

Skill Review

7. **Care and Use of a Microscope** Most compound light microscopes have four objective lenses with magnifications of 4×, 10×, 40×, and 100×. What magnifications are available if the eyepiece magnifies 15 times? For more help, refer to *Care and Use of a Microscope* in the **Skill Handbook.**

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Section 7.2

The Plasma Membrane

SECTION PREVIEW

Objectives

Describe how a cell's plasma membrane functions.

Relate the function of the plasma membrane to the fluid mosaic model.

Review Vocabulary

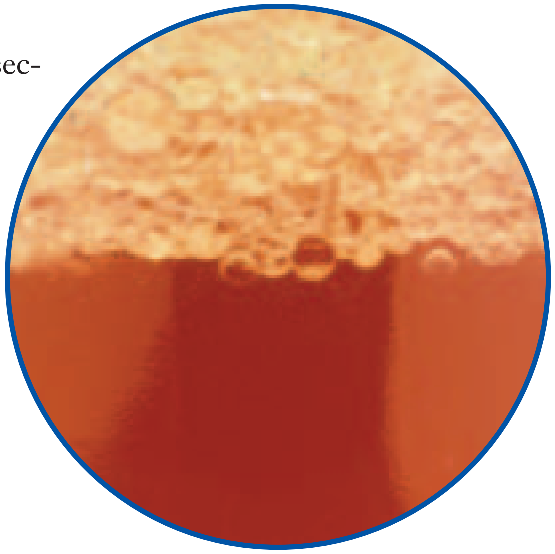
ion: an atom or group of atoms with a positive or negative electrical charge (p. 147)

New Vocabulary

plasma membrane
selective permeability
phospholipid
fluid mosaic model
transport protein

Controlling the Flow

Using Prior Knowledge In this section, you will learn about the plasma membrane which surrounds the cell and serves as a gateway through which materials enter and exit the cell. The plasma membrane is composed of two layers of lipids. You have read that lipids are organic compounds that are insoluble in water, which is why the oil and vinegar in this salad dressing form two separate layers that do not dissolve in each other.



Infer *Considering that a cell's environment is extremely watery, why might lipids be important to the composition of the plasma membrane?*

Maintaining a Balance

You are comfortable in your house largely because the thermostat maintains the temperature within a limited range regardless of what's happening outside. Similarly, all living cells must maintain a balance regardless of internal and external conditions. Survival depends on the cell's ability to maintain the proper conditions within itself.

Why cells must control materials

Your cells need nutrients such as glucose, amino acids, and lipids to function. It is the job of the **plasma membrane,** the flexible boundary between the cell and its environment, to allow a steady supply of these nutrients to come into the cell no matter what the external conditions are. However, too much of any of these nutrients or other substances, especially ions, can be harmful to the cell. If levels become too high, the excess is removed through the plasma membrane. Waste and other products also leave the cell through the plasma membrane. Recall that this process of maintaining balance in the cell's environment is called homeostasis.

How does the plasma membrane maintain homeostasis? One mechanism is **selective permeability,** a process in which a membrane allows some molecules to pass through while keeping others out. In your home, a screen in a window can perform selective permeability in a similar way. When you open the window, the screen lets fresh air in and keeps most insects out.

Word Origin

permeable from the Latin words *per,* meaning "through," and *meare,* meaning "to glide"; Materials move easily (glide) through permeable membranes.

Kristen Brochmann/Fundamental Photographs

Problem-Solving Lab 7.1

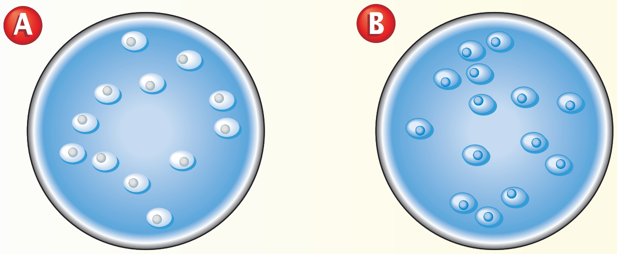
Recognize Cause and Effect

Is the plasma membrane a selective barrier? Yeast cells are living organisms and are surrounded by a plasma membrane. Below are the results of an experiment which shows that living yeast plasma membranes can limit what enters the cell.

Solve the Problem

Diagram A shows yeast cells in a solution of blue stain. Note their color as well as the color of the surrounding stain.

Diagram B also shows yeast cells in a solution of blue stain. These cells, however, were boiled for 10 minutes before being placed in the stain. Again, note the color of the yeast cells as well as the color of the surrounding stain.



Thinking Critically

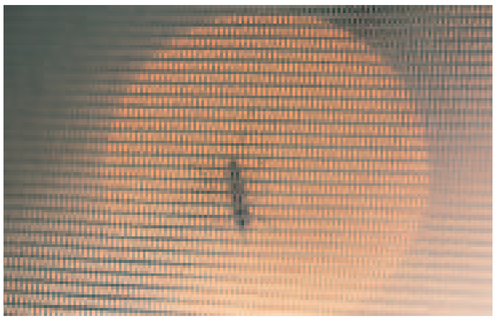
1. **Explain** How does boiling affect the yeast cells?
2. **Hypothesize** Why is the color of the cells different under different conditions? Be sure that your hypothesis takes the role of the plasma membrane into consideration.
3. **Infer** Are plasma membranes selective barriers? Explain.

Some molecules, such as water, freely enter the cell through the plasma membrane, as shown in ***Figure* 7.3**. Other particles, such as sodium and calcium ions, must be allowed into the cell only at certain times, in certain amounts, and through certain channels. The plasma membrane must be selective in allowing these ions to enter. Use the *Problem-Solving Lab* here to analyze the plasma membrane of a yeast cell.

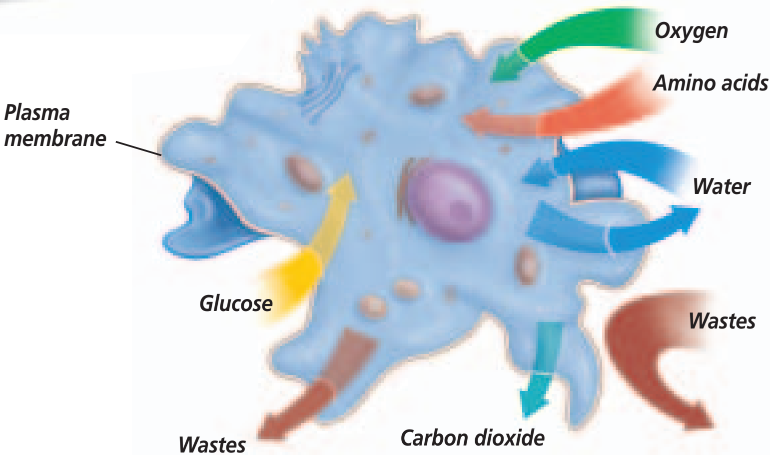
Structure of the Plasma Membrane

Now that you understand the basic function of the plasma membrane, you can study its structure. Recall from Chapter 6 that lipids are large molecules that are composed of glycerol and three fatty acids. If a phosphate group replaces a fatty acid, a phospholipid is formed. Thus, a **phospholipid** (fahs foh LIH pid) has a glycerol backbone, two fatty acid chains, and a phosphate group. The plasma membrane is composed of a phospholipid bilayer, which has two layers of phospholipids back-to-back.

Figure 7.3
The selectively permeable plasma membrane controls substances entering and leaving a cell.



A A window screen is selectively permeable because it allows air but not most insects to pass through it.



B The plasma membrane is also selectively permeable. Substances, such as glucose, must enter and stay in a cell. Other substances must leave a cell, and some substances must be prevented from entering a cell.

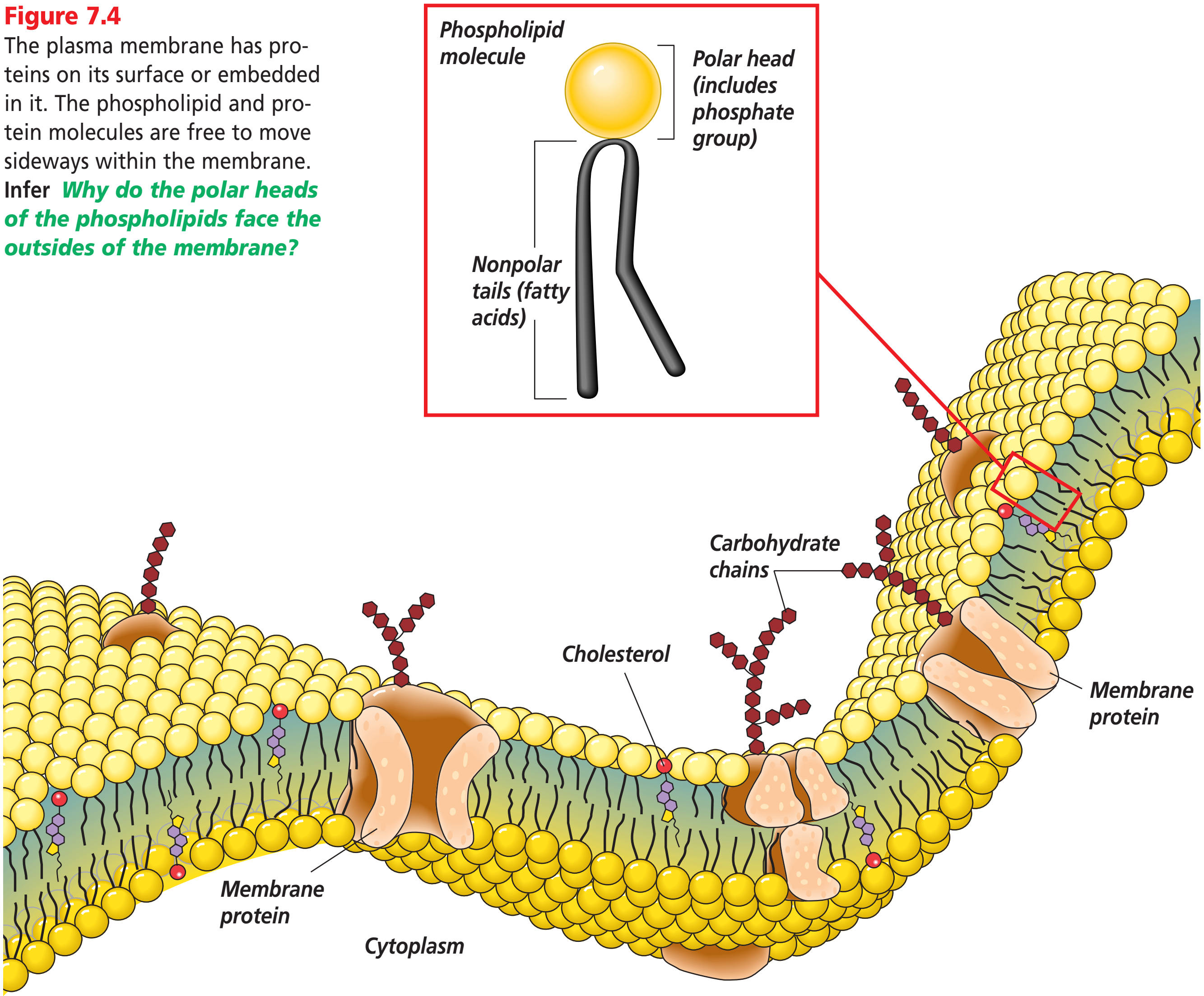


Figure 7.4
The plasma membrane has proteins on its surface or embedded in it. The phospholipid and protein molecules are free to move sideways within the membrane.
Infer ***Why do the polar heads of the phospholipids face the outsides of the membrane?***

The phospholipid bilayer

The phosphate group is critical for the formation and function of the plasma membrane. The two fatty acid tails of the phospholipids are nonpolar, whereas the head of the phospholipid molecule containing the phosphate group is polar.

Water is a key component of living organisms, both inside and outside the cell. The polar phosphate group allows the cell membrane to interact with its watery environment because, as you recall, water is also polar. The fatty acid tails, on the other hand, avoid water. The two layers of phospholipid molecules make a sandwich with the fatty acid tails forming the interior of the membrane and the phospholipid heads facing the watery environments found inside and outside the cell. *Figure 7.4* illustrates phospholipids and their place within the structure of the plasma membrane. When many phospholipid molecules come together in this manner, a barrier is created that is water-soluble at its outer surfaces and water-insoluble in the middle. Water-soluble molecules will not easily move through the membrane because they are stopped by this water-insoluble layer.

Reading Check **Describe** the structure of the phospholipid bilayer.

Physical Science Connection

Solubility and the nature of solute and solvent
Solvents made of polar molecules usually dissolve polar and ionic solutes. Solvents made of nonpolar molecules, such as oil or fat, usually dissolve nonpolar solutes.

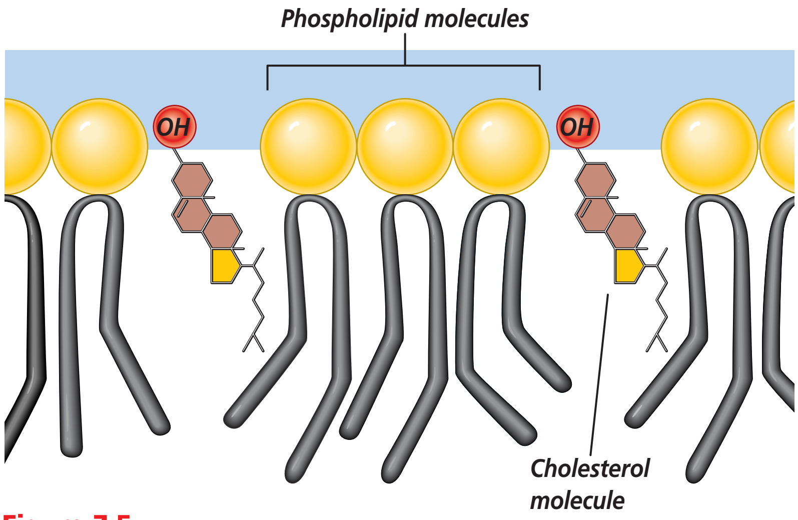


Figure 7.5
Eukaryotic plasma membranes can contain large amounts of cholesterol—as many as one molecule for every phospholipid molecule.

The model of the plasma membrane is called the **fluid mosaic model.** It is fluid because the phospholipids move within the membrane just as water molecules move with the currents in a lake. At the same time, proteins in the membrane also move among the phospholipids like boats with their decks above water and hulls below water. These proteins create a "mosaic," or pattern, on the membrane surface.

Other components of the plasma membrane

Cholesterol, shown in ***Figure*** *7.5*, is also found in the plasma membrane where it helps to stabilize the phospholipids by preventing their fatty acid tails from sticking together. Cholesterol is a common topic in health issues today because high levels are associated with reduced blood flow in blood vessels. Yet, for all the emphasis on cholesterol-free foods, it is important to recognize that cholesterol plays a critical role in the stability of the plasma membrane and is therefore a necessary part of your diet.

You've learned that proteins are found within the lipid membrane. Proteins that span the entire membrane help form the selectively permeable membrane that regulates which molecules enter and which molecules leave a cell. These proteins are called transport proteins. **Transport proteins** move needed substances or waste materials through the plasma membrane. Other proteins and carbohydrates that stick out from the cell surface help cells to identify chemical signals and each other. As you will discover later, these characteristics are important in protecting your cells from infection. Proteins at the inner surface of a plasma membrane play an important role in attaching the plasma membrane to the cell's internal support structure, giving the cell its flexibility.

Reading Check **Explain** how a water-soluble substance can pass through the plasma membrane.

Section Assessment

Understanding Main Ideas

1. Describe the plasma membrane, and explain why it is called a bilayer structure.
2. Describe the structure of a phospholipid. Use the terms *polar* and *nonpolar* in your answer.
3. What are the specialized parts of the phospholipid bilayer, and how do their structures relate to the structure of the plasma membrane?
4. Why is the structure of the plasma membrane referred to as a fluid mosaic?

Thinking Critically

5. Suggest what might happen if cells grow and reproduce in an environment where no cholesterol is available.

Skill Review

6. **Get the Big Picture** Plasma membranes allow certain materials to pass through them. Investigate how this property contributes to homeostasis. For more help, refer to *Get the Big Picture* in the **Skill Handbook.**

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Section 7.3

Eukaryotic Cell Structure

SECTION PREVIEW

Objectives

Identify the structure and function of the parts of a typical eukaryotic cell.

Explain the advantages of highly folded membranes in cells.

Compare and contrast the structures of plant and animal cells.

Review Vocabulary

enzyme: a protein that speeds up the rate of a chemical reaction (p. 161)

New Vocabulary

cell wall
chromatin
nucleolus
ribosome
cytoplasm
endoplasmic reticulum
Golgi apparatus
vacuole
lysosome
chloroplast
plastid
chlorophyll
mitochondria
cytoskeleton
microtubule
microfilament
cilia
flagella

Working Together for a Common Goal

Using an Analogy When you work on a group project, each person has his or her own skills and talents that add a particular value to the group's work. In the same way, each component of a eukaryotic cell has a specific job, and all of the parts of the cell work together to help the cell survive.

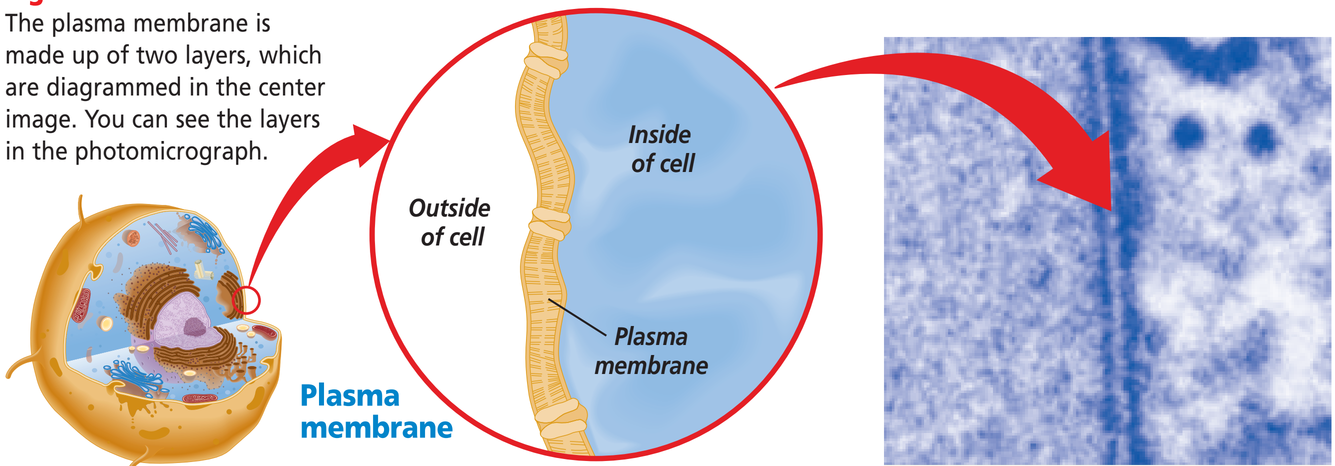
Organize Information *As you read the section, make a list of the cell parts. Next to each one, identify something from everyday life that functions in the same way. Then, explain what they both do.*

Cell structures, like this team of students, work together.

Cellular Boundaries

When a group works together, someone on the team decides what resources are necessary for the project and provides these resources. In the cell, the plasma membrane, shown in ***Figure*** **7.6**, performs this task by acting as a selectively permeable membrane. The fluid mosaic model describes the plasma membrane as a flexible boundary of a cell. However, plant cells, fungi, bacteria, and some protists have an additional boundary, the cell wall. The **cell wall** is a fairly rigid structure located outside the plasma membrane that provides additional support and protection.

Figure 7.6
The plasma membrane is made up of two layers, which are diagrammed in the center image. You can see the layers in the photomicrograph.



Problem-Solving Lab 7.2

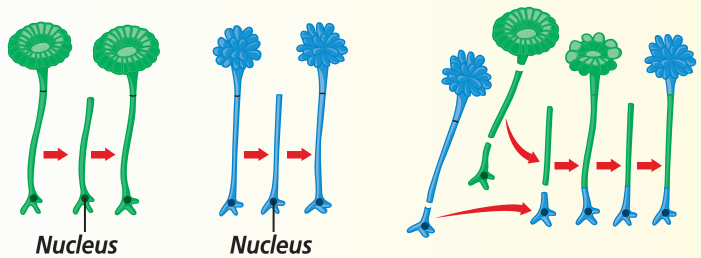
Interpret the Data

What organelle directs cell activity? *Acetabularia,* a type of marine alga, grows as single, large cells 2 to 5 cm in height. The nuclei of these cells are in the "feet." Different species of these algae have different kinds of caps, some petal-like and others that look like umbrellas. If a cap is removed, it quickly grows back. If both cap and foot are removed from the cell of one species and a foot from another species is attached, a new cap will grow. This new cap will have a structure with characteristics of both species. If this new cap is removed, the cap that grows back will be like the cell that donated the nucleus.

The scientist who discovered these properties was Joachim Hämmerling. He wondered why the first cap that grew had characteristics of both species, yet the second cap was clearly like that of the cell that donated the nucleus.

Solve the Problem

Look at the diagram below and identify how the final cell develops.



Thinking Critically

Interpret Data Why is the final cap like that of the cell from which the nucleus was taken?

The cell wall

The cell wall forms an inflexible barrier that protects the cell and gives it support. ***Figure*** 7.7 shows a plant cell wall composed of a carbohydrate called cellulose. The cellulose forms a thick, tough mesh of fibers. This fibrous cell wall is very porous and allows molecules to enter. Unlike the plasma membrane, it does not select which molecules can enter into the cell.

The Nucleus and Cell Control

Just as every team needs a leader to direct activity, so the cell needs a leader to give directions. The nucleus is the leader of the eukaryotic cell because it contains the directions to make proteins. Every part of the cell depends on proteins, so by containing the blueprint to make proteins, the nucleus controls the activity of the organelles. Read the *Problem-Solving Lab* on this page and consider how the *Acetabularia* (a suh tab yew LAIR ee uh) nucleus controls the cell.

The master set of directions for making proteins is contained in **chromatin,** which are strands of the genetic material, DNA. When a cell

Color-enhanced TEM Magnification: 48 000×

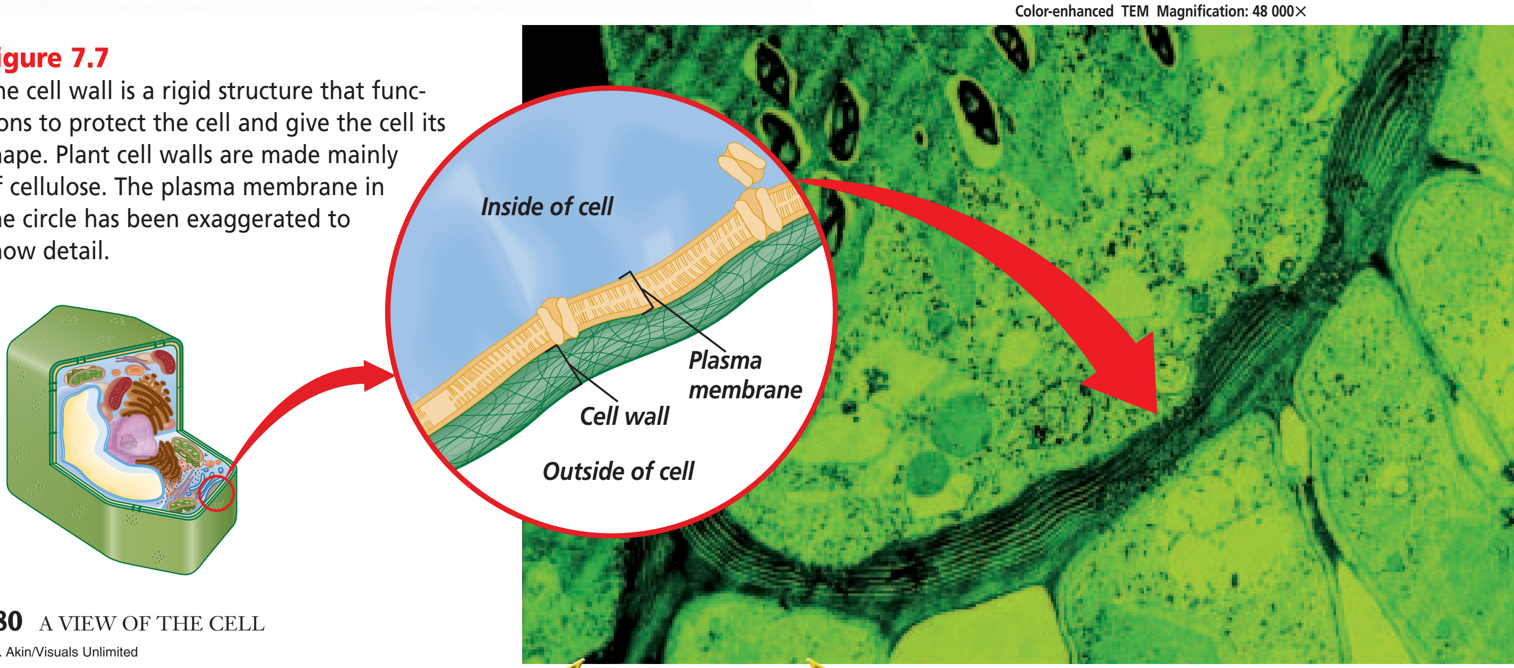


Figure 7.7
The cell wall is a rigid structure that functions to protect the cell and give the cell its shape. Plant cell walls are made mainly of cellulose. The plasma membrane in the circle has been exaggerated to show detail.

divides, the chromatin condenses to form chromosomes. Within the nucleus is a prominent organelle called the **nucleolus,** which makes ribosomes. **Ribosomes** are the sites where the cell produces proteins according to the directions of DNA. Unlike other organelles, ribosomes are not bound by a membrane. They are simple structures made of RNA and protein. Look at the onion cells as described in the *MiniLab* on the next page and try to identify the nucleus.

For proteins to be made, ribosomes must leave the nucleus and enter the cytoplasm, and the blueprints contained in DNA must be translated into RNA and sent to the cytoplasm. **Cytoplasm** is the clear, gelatinous fluid inside a cell. Ribosomes and translated RNA are transported to the cytoplasm through the nuclear envelope—a structure that separates the nucleus from the cytoplasm, as shown in ***Figure*** *7.8.* The nuclear envelope is a double membrane made up of two phospholipid bilayers containing small nuclear pores for substances to pass through. Ribosomes and translated RNA pass into the cytoplasm through these pores in the nuclear envelope.

Assembly, Transport, and Storage

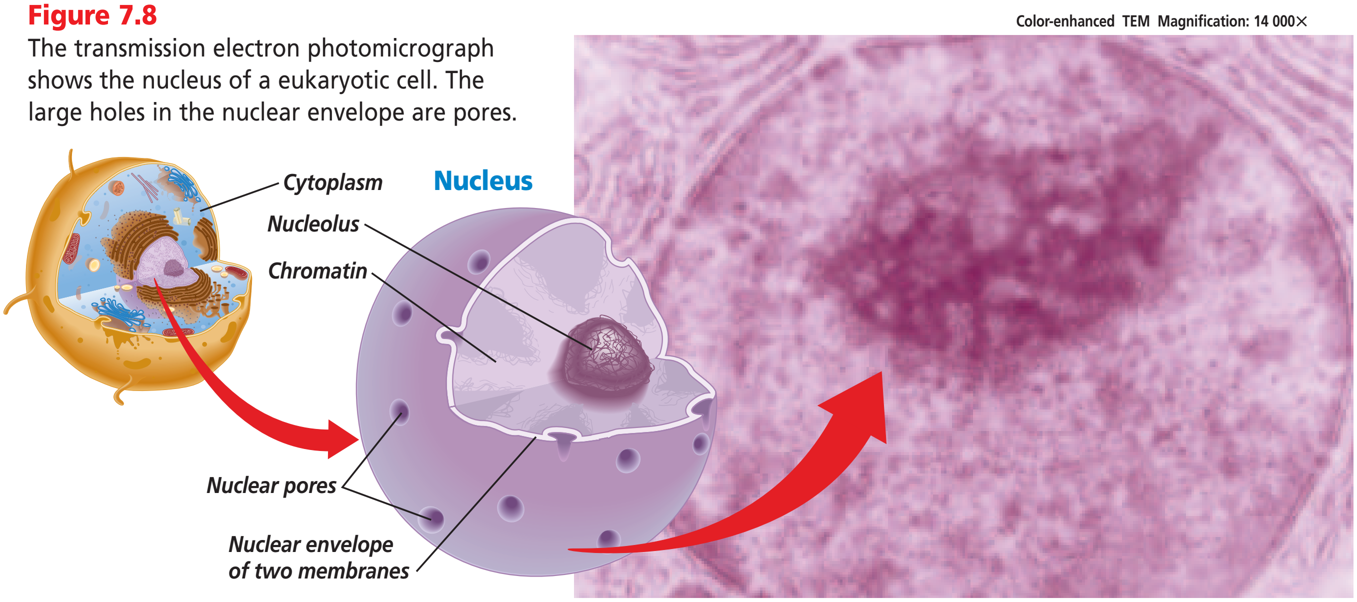
You have begun to follow the trail of protein production as directed by the cell manager—the nucleus. But what happens to the copy of the blueprints for proteins once it passes from the nucleus into the cytoplasm?

Organelles for assembly and transport of proteins

The cytoplasm suspends the cell's organelles. One particular organelle in a eukaryotic cell, the **endoplasmic reticulum** (ER), is the site of cellular chemical reactions. Shown in ***Figure*** *7.9,* the ER is arranged in a series of highly folded membranes in the cytoplasm. Its folds are like the folds of an accordion. If you spread the accordion out, it would take up tremendous space. By pleating and folding, the accordion fits into a compact unit. Similarly, a large amount of folded ER is available to do work in a small space.

Ribosomes in the cytoplasm are attached to the surface of the endoplasmic reticulum, called rough endoplasmic reticulum, where they carry out the function of protein synthesis.

Figure 7.8
The transmission electron photomicrograph shows the nucleus of a eukaryotic cell. The large holes in the nuclear envelope are pores.



Don W. Fawcett/Visuals Unlimited

MiniLab 7.2

Experiment

Cell Organelles Adding stains to cellular material helps you distinguish cell organelles.

Procedure

CAUTION: ***Iodine stain is hazardous. Handle it with care. Be sure to wash hands with soap or detergent before and after this lab.***

1. Prepare a water wet mount of onion skin. Do this by using your fingernail to peel off the inside of a layer of onion bulb. The layer must be almost transparent. Use the following diagram as a guide.

2. Make sure that the onion layer is laying flat on the glass slide and is not folded.
3. Observe the onion cells under low- and high-power magnification. Identify as many organelles as possible.
4. Repeat steps 1 through 3, only this time use an iodine stain instead of water.

Analysis

1. **Observe and Infer** What organelles were easily seen in the unstained onion cells? In cells stained with iodine?
2. **Experiment** How are stains useful for viewing cells?

The ribosome's job is to make proteins. Each protein made in the rough ER has a particular function; it may become a protein that forms a part of the plasma membrane, a protein that is released from the cell, or a protein transported to other organelles. Ribosomes can also be found floating freely in the cytoplasm. They make proteins that perform tasks within the cytoplasm itself.

Areas of the ER that are not studded with ribosomes are known as smooth endoplasmic reticulum. The smooth ER is involved in numerous biochemical activities, including the production and storage of lipids.

After proteins are made, they are transferred to another organelle called the **Golgi** (GAWL jee) **apparatus.** The Golgi apparatus, as shown in ***Figure* 7.10,** is a flattened stack of tubular membranes that modifies the proteins. The Golgi apparatus sorts proteins into packages and packs them into membrane-bound structures, called vesicles, to be sent to the appropriate destination, like mail being sorted at the post office.

Reading Check **Compare and contrast** the two types of ER.

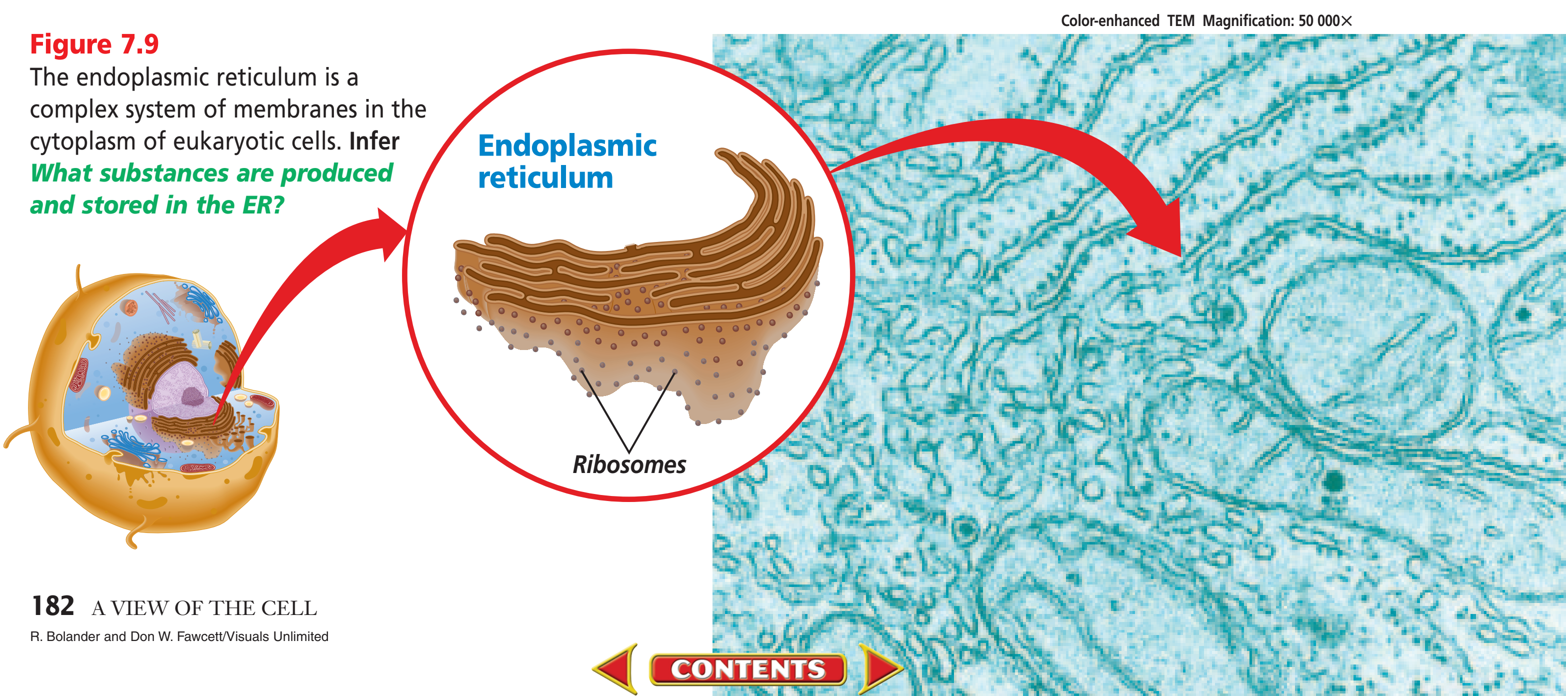
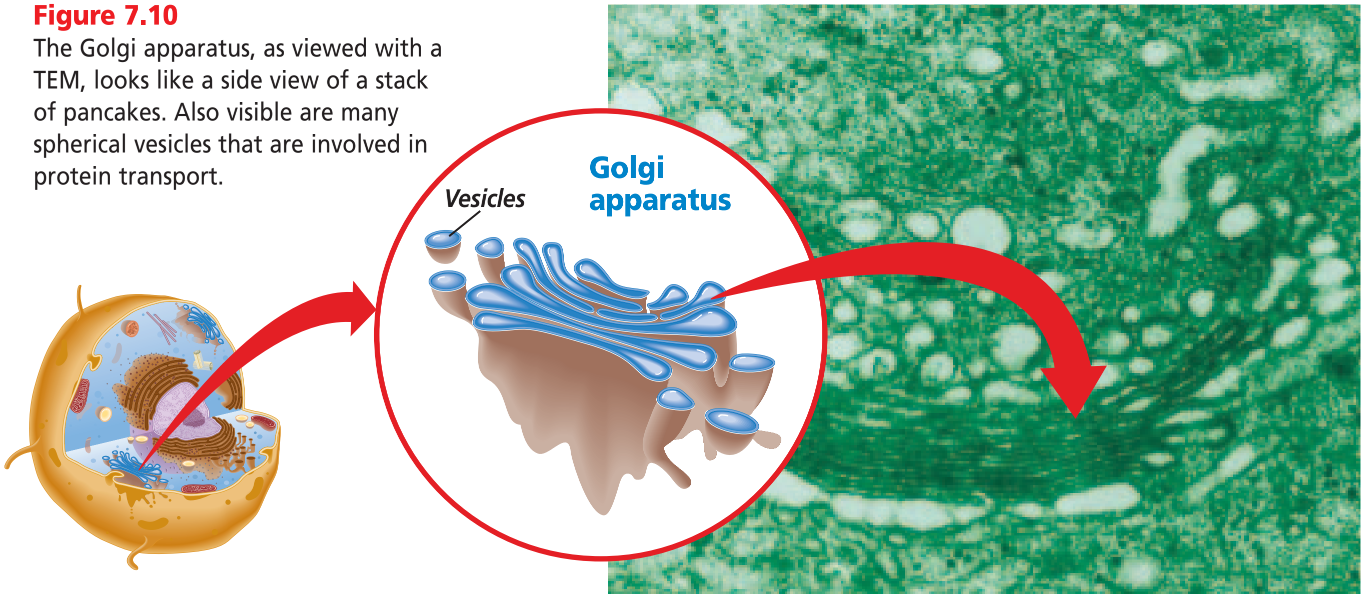


Figure 7.9
The endoplasmic reticulum is a complex system of membranes in the cytoplasm of eukaryotic cells. **Infer** ***What substances are produced and stored in the ER?***

Figure 7.10
The Golgi apparatus, as viewed with a TEM, looks like a side view of a stack of pancakes. Also visible are many spherical vesicles that are involved in protein transport.



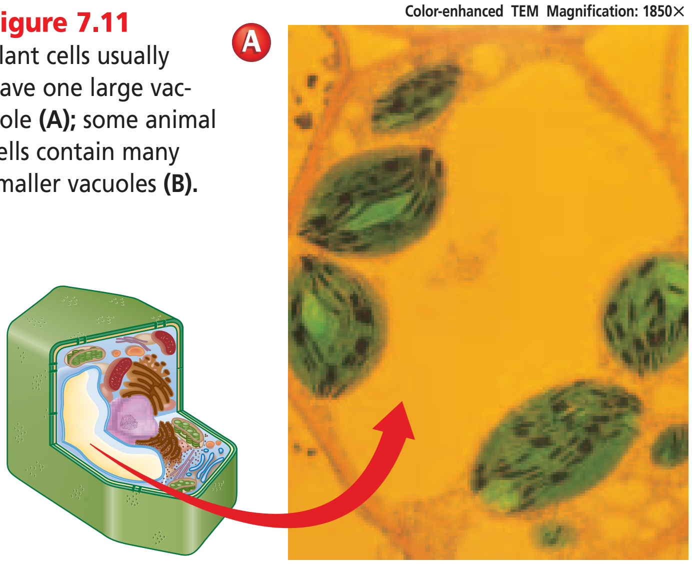
Vacuoles and storage

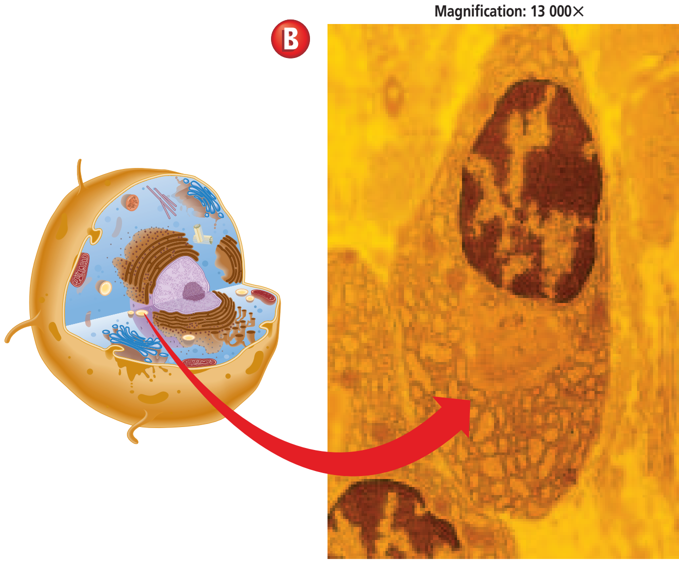
Now let's look at some of the other members of the cell team important for the cell's functioning. Cells have membrane-bound compartments, called **vacuoles,** for temporary storage of materials. A vacuole, like that in ***Figure 7.11A,*** is a sac used to store food, enzymes, and other materials needed by a cell. Some vacuoles store waste products. Animal cells usually do not contain vacuoles. If they do, the vacuoles are much smaller, as shown in ***Figure 7.11B.***

Lysosomes and recycling

Did anyone ever ask you to take out the trash? Is that action part of a team effort? In a cell, it is. **Lysosomes** are organelles that contain digestive enzymes. They digest excess or worn out organelles, food particles, and engulfed viruses or bacteria. The membrane surrounding a lysosome prevents the digestive enzymes inside from destroying the cell. Lysosomes can fuse with vacuoles and dispense their enzymes into the vacuole, digesting its contents.

Figure 7.11
Plant cells usually have one large vacuole **(A);** some animal cells contain many smaller vacuoles **(B).**





> **Word Origin**
>
> **chloroplast** from the Greek words *chloros,* meaning "green," and *platos,* meaning "formed object"; Chloroplasts capture light energy and produce food for plant cells. Plants are green because they contain the green pigment chlorophyll.

For example, when an amoeba engulfs food and encloses it in a vacuole, a lysosome fuses with the vacuole and releases its enzymes, which digest the food. Sometimes, lysosomes digest the cells that contain them. When a tadpole develops into a frog, lysosomes within the cells of the tadpole's tail cause its digestion. The molecules released are used to build different cells, perhaps in the legs of the adult frog.

Energy Transformers

After learning about cell parts and what they do, it's easy to imagine that each of these cell team members requires a lot of energy. Protein production, modification, transportation, digestion—all require energy. Two other organelles, chloroplasts and mitochondria, provide that energy.

Chloroplasts and energy

When you walk through a field or pick a vegetable from the garden, you may not think of the plants as energy generators. In fact, that is exactly what you see. Located in the cells of green plants and some protists, chloroplasts are the heart of the generator. **Chloroplasts** are cell organelles that capture light energy and convert it to chemical energy.

A chloroplast, like a nucleus, has a double membrane. The diagram and TEM photomicrograph of a chloroplast in ***Figure 7.12*** shows an outer membrane and a folded inner membrane system. It is within these inner thylakoid membranes that the energy from sunlight is trapped. These inner membranes are arranged in stacks of membranous sacs called grana, which resemble stacks of coins. The fluid that surrounds the stacks of grana is called stroma.

The chloroplast belongs to a group of plant organelles called **plastids,** which are used for storage. Some plastids store starches or lipids, whereas others contain pigments, molecules that give color. Plastids are named according to their color or the pigment they contain. Chloroplasts contain the green pigment chlorophyll. **Chlorophyll** traps light energy and gives leaves and stems their green color.

Reading Check **Describe** the internal structure of a chloroplast.

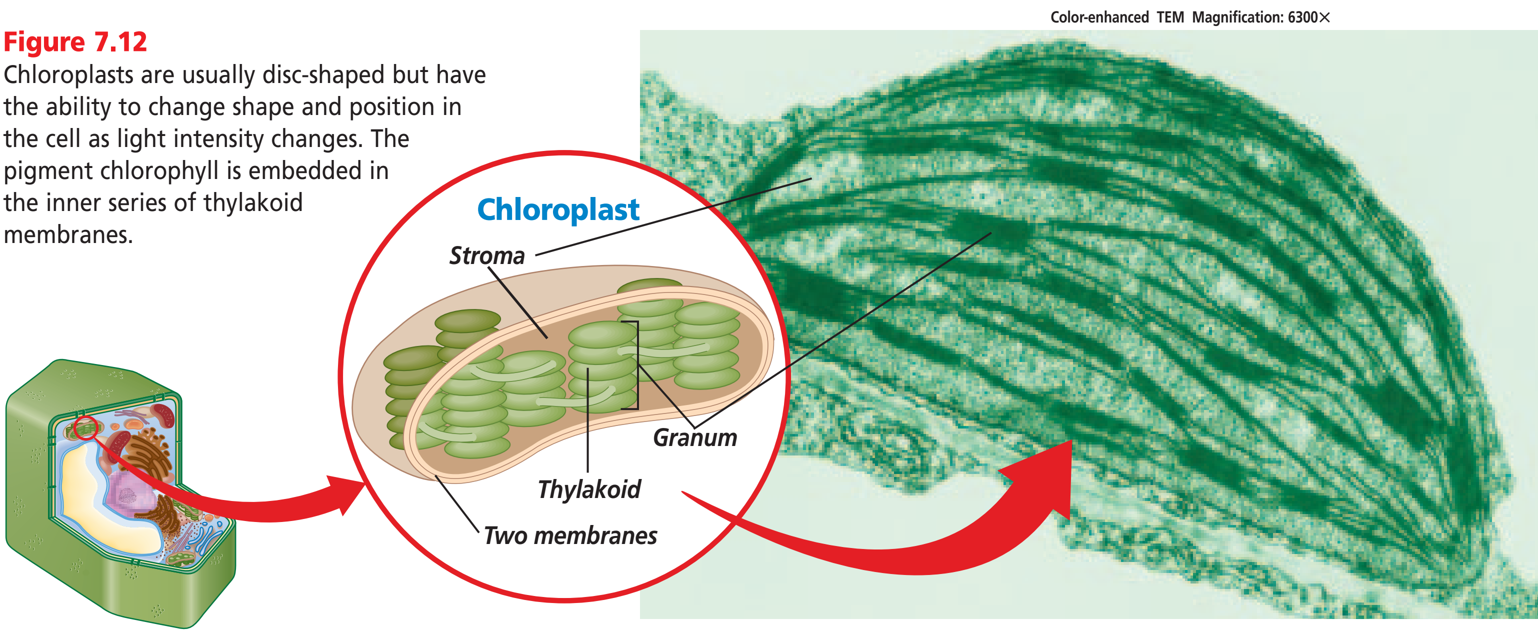


Figure 7.12
Chloroplasts are usually disc-shaped but have the ability to change shape and position in the cell as light intensity changes. The pigment chlorophyll is embedded in the inner series of thylakoid membranes.

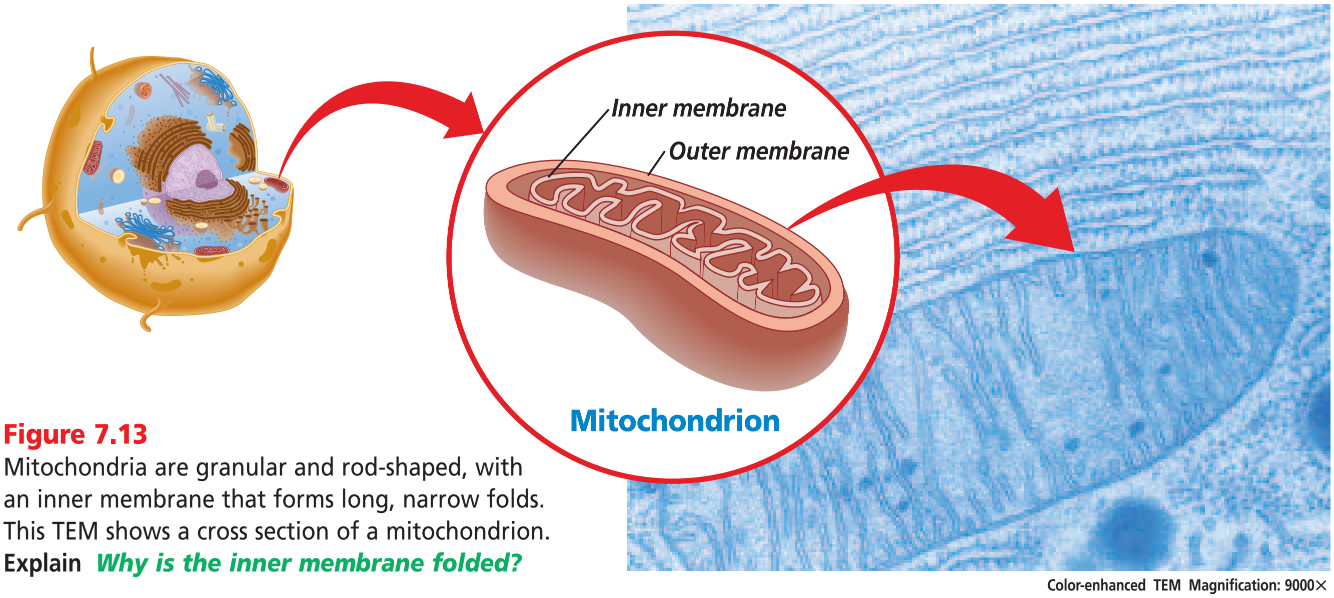


Figure 7.13
Mitochondria are granular and rod-shaped, with an inner membrane that forms long, narrow folds. This TEM shows a cross section of a mitochondrion.
Explain ***Why is the inner membrane folded?***

Mitochondria and energy

The chemical energy generated by chloroplasts is stored in the bonds of sugar molecules until they are broken down by mitochondria, shown in ***Figure 7.13.*** **Mitochondria** are membrane-bound organelles in plant and animal cells that transform energy for the cell. This energy is then stored in the bonds of other molecules that cell organelles can access easily and quickly when energy is needed.

A mitochondrion has an outer membrane and a highly folded inner membrane. As with the endoplasmic reticulum and chloroplasts, the folds of the inner membrane provide a large surface area that fits in a small space. Energy-storing molecules are produced on the inner folds. Mitochondria occur in varying numbers depending on the function of the cell. For example, liver cells may have up to 2000 mitochondria.

Although the process by which energy is transformed and used in the cells is a technical concept that you will learn in a later chapter, the *Connection to Literature* at the end of this chapter explains how cellular processes can also be inspiring.

Organelles for Support and Locomotion

Scientists once thought that cell organelles just floated in a sea of cytoplasm. More recently, cell biologists have discovered that cells have a support structure called the **cytoskeleton** within the cytoplasm.

The cytoskeleton

The cytoskeleton forms a framework for the cell, like the skeleton that forms the framework for your body. However, unlike your bones, the cytoskeleton is a constantly changing structure. It can be dismantled in one place and reassembled somewhere else in the cell, changing the cell's shape.

The cytoskeleton is a network of tiny rods and filaments. **Microtubules** are thin, hollow cylinders made of protein. **Microfilaments** are smaller, solid protein fibers. Together, they act as a sort of scaffold to maintain the shape of the cell in the same way that poles maintain the shape of a tent. They also anchor and support many organelles and provide a sort of highway system through which materials move within the cell.

Word Origin

cytoskeleton from the Latin word *cyte,* meaning "cell"; The cytoskeleton provides support and structure for the cell.

Physical Science Connection

Conservation of energy Energy can exist in different forms, such as thermal, electrical, chemical, and light energy. However, even though energy can change from one form to another, energy cannot be created or destroyed—it is always conserved.

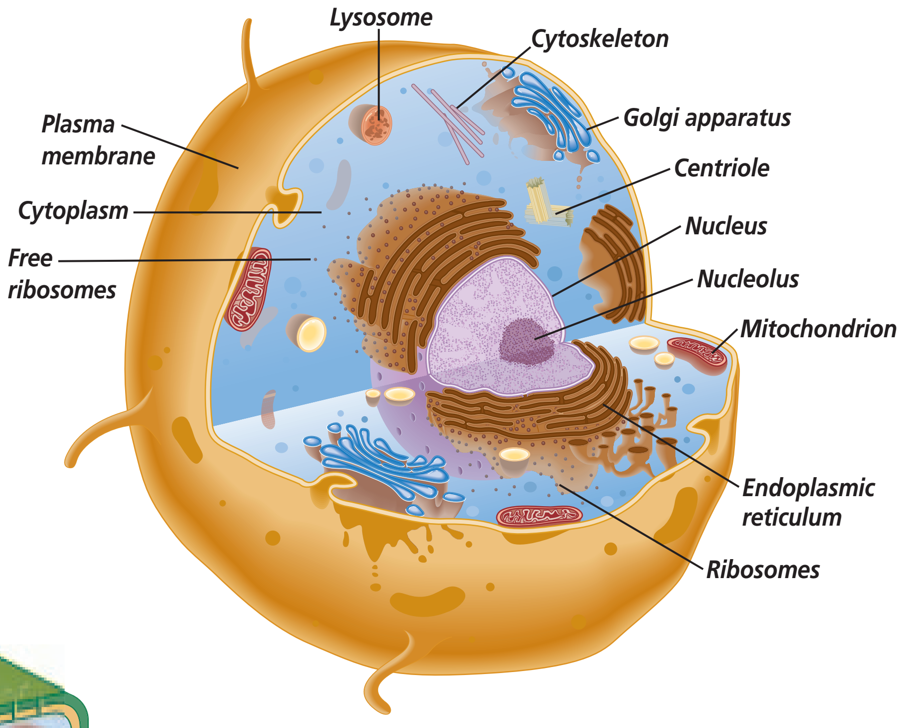
INSIDE STORY

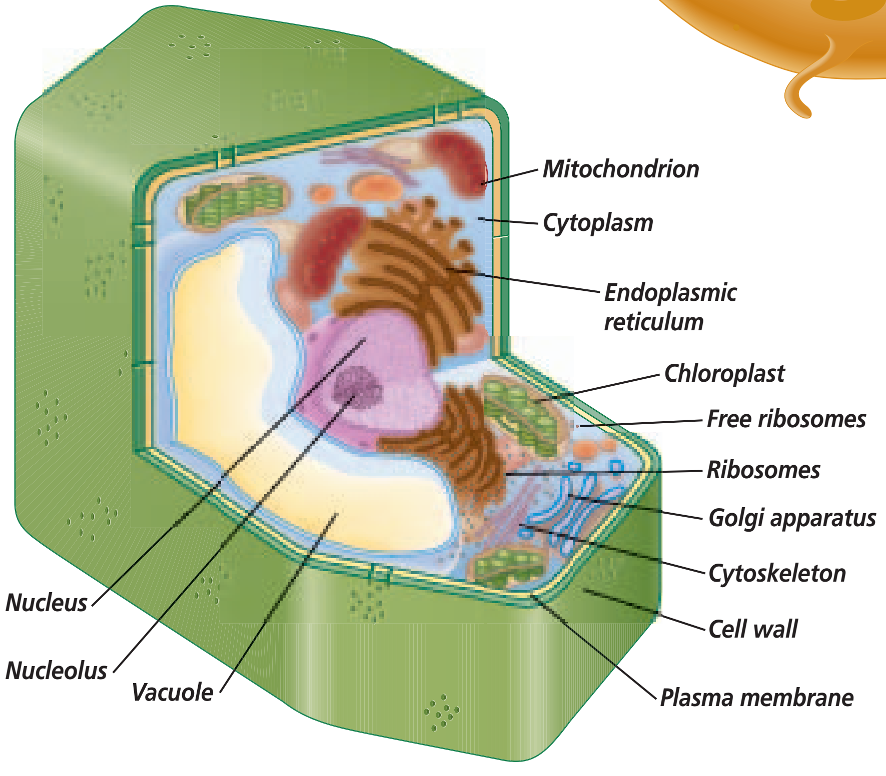
Comparing Animal and Plant Cells

Figure 7.14

You can easily recognize that a person does not look like a flower and a moose does not resemble a tree. But at the cellular level under a microscope, the cells that make up all of the different animals and plants of the world are very much alike. **Critical Thinking** ***Why are animal and plant cells similar?***

Animal Cells A
Notice that animal cells have centrioles, whereas plant cells do not. Animal cells typically have small lysosomes.





B Plant Cells Plant cells are characterized by a cell wall and chloroplasts. Plant cells usually have one large vacuole.

Table 7.1 Comparison of Prokaryotic and Eukaryotic Cells

Cell Part	Function	Prokaryotic Cell	Eukaryotic Cell
Plasma membrane	Maintains homeostasis	Present	Present
Cell wall	Supports and protects cell	Present	Present in plants
Ribosome	Makes proteins	Present	Present
Chloroplast	Produces food	Absent	Present in plants
Cytoskeleton	Provides internal structure	Absent	Present
Endoplasmic reticulum	Chemical reactions	Absent	Present
Golgi apparatus	Sorts and transports	Absent	Present
Lysosome	Digests material	Absent	Present in some
Mitochondrion	Transforms energy	Absent	Present
Nucleus	Cell control center	Absent	Present
Vacuole	Storage	Absent	Present

Centrioles

Centrioles are organelles found in the cells of animals and most protists. They occur in pairs and are made up of microtubules. Centrioles play an important role in cell division.

Cilia and flagella

Some cell surfaces have cilia and flagella, which are organelles made of microtubules that aid the cell in locomotion or feeding. Cilia and flagella can be distinguished by their structure and by the nature of their action. **Cilia** are short, numerous projections that look like hairs. Their motion is similar to that of oars in a rowboat. **Flagella** are longer projections that move with a whiplike motion. A cell usually has only one or two flagella. In unicellular organisms, cilia and flagella are the major means of locomotion.

Remember that prokaryotic cells lack the membrane-bound organelles that are found in eukaryotic cells. ***Table 7.1*** shows a side-by-side comparison of eukaryotic and prokaryotic cells, their cell parts, and what those parts do. ***Figure 7.14*** summarizes the structure of eukaryotic plant and animal cells.

Section Assessment

Understanding Main Ideas

1. How are highly folded membranes an advantage for the functions of cellular parts? Name an organelle that has highly folded membranes.
2. If a cell synthesizes large quantities of protein molecules, which organelles might be numerous in that cell?
3. A cell's digestive enzymes are enclosed in a membrane-bound organelle. How can these molecules function in the cell?
4. Compare and contrast the functions of a cell wall to the functions of a plasma membrane.
5. Compare the number of vacuoles in plant cells and animal cells.

Thinking Critically

6. Compare mitochondria and chloroplasts. Why are they referred to as energy transformers?

Skill Review

7. **Student Presentation Builder** Create a class presentation that follows a protein molecule from its formation to its final destination, using the *Student Presentation Builder.*

INVESTIGATE

BioLab

Observing and Comparing Different Cell Types

Before You Begin

Are all cells alike in appearance, shape, and size? Do all cells have some of the same organelles present within their cell boundaries? One way to answer these questions is to observe a variety of cells using a light microscope. In this lab, you will make observations of a bacterial cell *(Bacillus subtilis)*, frog blood cells, and a plant cell (from *Elodea*).

PREPARATION

Problem

Are all cells alike in appearance and size?

Objectives

In this BioLab, you will:

- **Observe, diagram,** and **measure** cells and their organelles.
- **Infer** whether cells are prokaryotic or eukaryotic and whether they are from unicellular organisms or multicellular organisms.
- **List** the traits of plant and animal cells.

Materials

microscope, dropper, glass slide
coverslip, forceps, *Elodea* leaf
prepared slides of *Bacillus subtilis* and frog blood

Safety Precautions

CAUTION: ***Use care when handling slides. Dispose of any broken glass in a container provided by your teacher. Always wear goggles in the lab.***

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

PROCEDURE

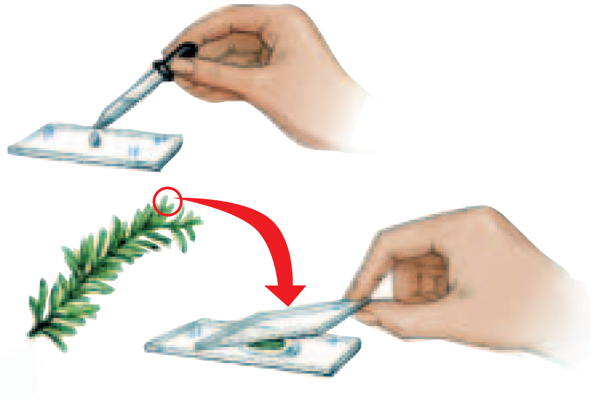
1. Copy the data table.
2. Examine a prepared slide of *Bacillus subtilis* using both low- and high-power magnification. (Note: This slide has been stained. Bacterial cells have no natural color.)

Data Table

	Bacillus subtilis	*Elodea*	Frog Blood
Organelles observed			
Prokaryote or eukaryote			
From a multicellular or unicellular organism			
Diagram (with size in micrometers, µm)			

CONTENTS

3. Identify and record the names of any observed organelles. Infer whether these cells are prokaryotic or eukaryotic. Infer whether these cells are from a unicellular or multicellular organism. Record your findings in the table.
4. Diagram one cell as seen under high-power magnification.
5. While using high power, determine the length and width in micrometers of this cell. Refer to *Thinking Critically* in the **Skill Handbook** for help with determining magnification. Record your measurements on the diagram.



6. Prepare a wet mount of a single leaf from *Elodea* using the diagram as a guide.
7. Observe the *Elodea* cells under low- and high-power magnification.
8. Repeat steps 3 through 5 for *Elodea.*
9. Examine a prepared slide of frog blood. (Note: This slide has been stained. Its natural color is pink.)
10. Observe cells under low- and high-power magnification.
11. Repeat steps 3 through 5 for frog blood cells.
12. **CLEANUP AND DISPOSAL** Clean all equipment as instructed by your teacher, and return everything to its proper place for reuse. Wash your hands thoroughly.

Leopard frog

ANALYZE AND CONCLUDE

1. **Observe and Infer** Which cells were prokaryotic and which were eukaryotic? How were you able to tell?
2. **Predict** Which cell was from a plant and which was from an animal? Explain your answer.
3. **Measure** Are prokaryotic or eukaryotic cells larger? Give specific measurements to support your answer.
4. **Define Operationally** Compare the structure and function of the plant and animal cells you saw.
5. **ERROR ANALYSIS** Suppose you estimate that eight *Elodea* cells will fit across the high-power field of view of your microscope. You calculate that the diameter of an *Elodea* cell is approximately 50 mm. Is this a reasonable value? If not, what was the error in your analysis?

Apply Your Skill

Lab Techniques Prepare a wet mount of very thin slices of bamboo (saxophone reed). Observe under low and high power. What structures are you looking at? Explain the absence of all other organelles from this material.

Web Links To find out more about microscopy and cell types, visit bdol.glencoe.com/microscopy

connection to literature

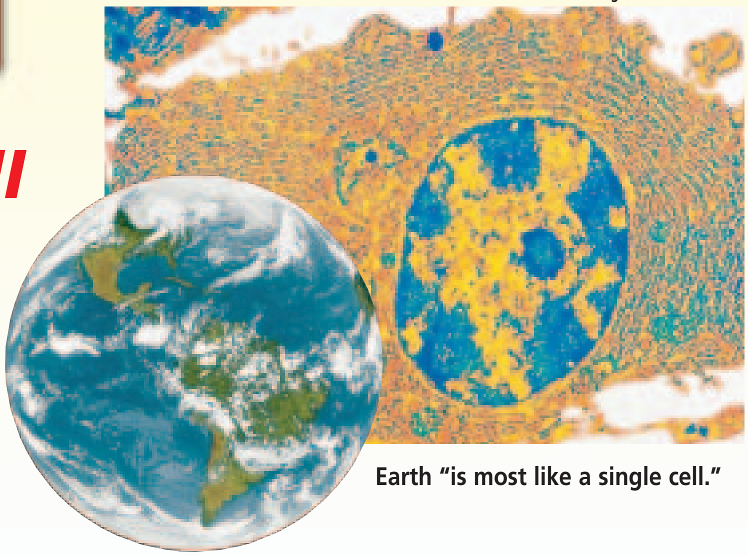
The Lives of a Cell

by Lewis Thomas

“I have been trying to think of the earth as a kind of organism, but it is no go. I cannot think of it this way. It is too big, too complex, with too many working parts lacking visible connections. . . . I wondered about this. If not like an organism, what is it like, what is it most like? Then, satisfactorily for that moment, it came to me: it is most like a single cell.”

—Lewis Thomas

Color-enhanced TEM Magnification: 10 000×



Earth “is most like a single cell.”

You may think of yourself as a body made up of parts. Arms, legs, skin, stomach, eyes, brain, heart, lungs. In actual fact, you are a community of living structures that work together for growth and survival.

Your body is made up of eukaryotic cells containing organelles that work together for each cell’s survival. Organelles such as the Golgi apparatus and vesicles may work closely together. Other organelles, such as the mitochondria that serve as the cell’s power plants, may perform a unique function within the cell.

On a much more complex level, an organism is similar to a cell in that many parts work together for the good of the whole. Groups of cells work together as tissues. Several tissues form an organ, and many organs form an organ system. For example, in an organ system such as the digestive system, cells and tissues form an organ such as the stomach, but several related organs—including the intestines, the pancreas, and the liver—are needed to completely digest and absorb the food you eat. In a similar manner, the organisms within a community are all connected to and dependent upon each other. You could extend this view to the entire Earth, which consists of a collection of interconnected ecosystems.

Words are like organelles Now that you have formed an image in your mind of a cell and its working parts, imagine a paragraph composed of words. Just as a cell contains a group of organelles working together, the words in a paragraph interact to convey thoughts and ideas. Despite all his technical knowledge, Dr. Thomas —a physician and medical researcher—writes simply and engagingly about everything from the tiny universe inside a single cell to the possibility of visitors from a distant planet.

Medicine, a young science Dr. Thomas grew up with the practice of medicine. As a boy, he accompanied his father, a family physician, on house calls to patients. Years later, Lewis Thomas described those days in his autobiography, *The Youngest Science*. The title reflects his belief that the practice of medicine is “still very early on” and that some basic problems of disease are just now yielding to exploration.

Writing About Biology

Critique Evaluate Dr. Thomas’s comparison of Earth to a cell. How do you think Earth is like a cell? How would you disagree with this model?

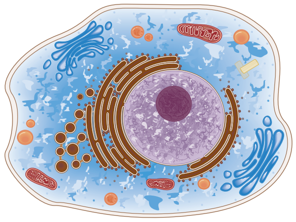
To find out more about the works of Dr. Lewis Thomas, visit bdol.glencoe.com/literature

Chapter 7 Assessment

Study Guide

Section 7.1

The Discovery of Cells



Key Concepts

- Microscopes enabled biologists to see cells and develop the cell theory.
- The cell theory states that the cell is the basic unit of organization, all organisms are made up of one or more cells, and all cells come from preexisting cells.
- Using electron microscopes, scientists can study cell structure in detail.
- Cells are classified as prokaryotic or eukaryotic based on whether or not they have membrane-bound organelles.

Vocabulary

cell (p. 171)
cell theory (p. 172)
compound light microscope (p. 171)
electron microscope (p. 172)
eukaryote (p. 173)
nucleus (p. 174)
organelle (p. 173)
prokaryote (p. 173)

Section 7.2

The Plasma Membrane

Key Concepts

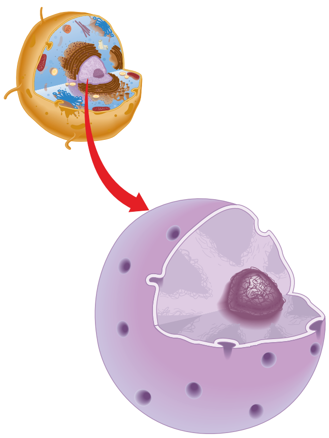
- Through selective permeability, the plasma membrane controls what enters and leaves a cell.
- The fluid mosaic model describes the plasma membrane as a phospholipid bilayer with embedded proteins.

Vocabulary

fluid mosaic model (p. 178)
phospholipid (p. 176)
plasma membrane (p. 175)
selective permeability (p. 175)
transport proteins (p. 178)

Section 7.3

Eukaryotic Cell Structure



Key Concepts

- Eukaryotic cells have a nucleus and other organelles and are enclosed by a plasma membrane. Some cells have a cell wall that provides support and protection.
- Cells make proteins on ribosomes that are often attached to the highly folded endoplasmic reticulum. Cells store materials in the Golgi apparatus and vacuoles.
- Mitochondria break down sugar molecules to release energy. Chloroplasts convert light energy into chemical energy.
- The cytoskeleton helps maintain cell shape and is involved in the movement of organelles and materials.

Vocabulary

cell wall (p. 179)
chlorophyll (p. 184)
chloroplast (p. 184)
chromatin (p. 180)
cilia (p. 187)
cytoplasm (p. 181)
cytoskeleton (p. 185)
endoplasmic reticulum (p. 181)
flagella (p. 187)
Golgi apparatus (p. 182)
lysosome (p. 183)
microfilament (p. 185)
microtubule (p. 185)
mitochondria (p. 185)
nucleolus (p. 181)
plastid (p. 184)
ribosome (p. 181)
vacuole (p. 183)

FOLDABLES Study Organizer — To help you review the cell theory, use the Organizational Study Fold on page 171.

bdol.glencoe.com/vocabulary_puzzlemaker

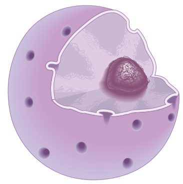
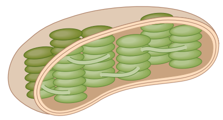
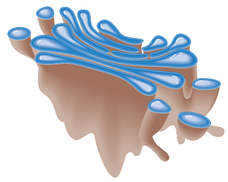
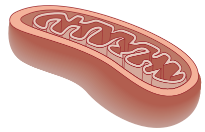
Chapter 7 Assessment

Vocabulary Review

Review the Chapter 7 vocabulary words listed in the Study Guide on page 191. Match the words with the definitions below.

1. organelle that is the boundary between the cell and its environment
2. membrane-bound organelles that transform energy in all eukaryotic cells
3. highly organized structures within cells
4. organelles that are the sites of protein synthesis
5. basic unit of organization of both unicellular and multicellular organisms

Understanding Key Concepts

6. In what type of cell would you find a chloroplast?
   A. prokaryote **C.** plant
   B. animal **D.** fungus
7. In which of the following pairs are the terms NOT related?
   A. nucleus—DNA
   B. chloroplasts—chlorophyll
   C. flagella—chromatin
   D. cell wall—cellulose
8. Magnifications greater than 10 000× can be obtained when using ________.
   A. light microscopes
   B. metric rulers
   C. hand lenses
   D. electron microscopes
9. A bacterium is classified as a prokaryote because it ________.
   A. has cilia
   B. has no membrane-bound nucleus
   C. is a single cell
   D. has no DNA
10. What is the difference between a prokaryote and a eukaryote?
    A. the need for nutrients
    B. plasma membranes
    C. membrane-bound organelles
    D. cell walls
11. Which of these structures captures the sun's energy when synthesizing carbohydrates?
    A. 
    C. 
    B. 
    D. 
12. Which of the following structures is NOT found in both plant and animal cells?
    A. chloroplast **C.** ribosomes
    B. cytoskeleton **D.** mitochondria
13. Which biomolecule is NOT stored in plastids?
    A. a lipid **C.** an amino acid
    B. a pigment **D.** a starch

Constructed Response

14. **Open Ended** Suggest a reason why packets of proteins collected by the Golgi apparatus might merge with lysosomes.
15. **Open Ended** How does the structure of the plasma membrane allow materials to move across it in both directions?
16. **Open Ended** Can live specimens be examined with an electron microscope? Explain.

Thinking Critically

17. **Writing in Biology** Predict whether you would expect muscle cells or fat cells to contain more mitochondria and explain why.
18. **REAL WORLD BIOCHALLENGE** Organelles, cells, and organisms have a wide range of sizes. Visit **bdol.glencoe.com** to find out about these size comparisons. Can any cell be seen with the naked eye? Make a visual display, such as a poster or model, that shows the range of sizes. Present this information to your class.

bdol.glencoe.com/chapter_test

Chapter 7 Assessment

19. Infer In plants, cells that transport water against the force of gravity are found to contain many more mitochondria than do some other plant cells. What is the reason for this?

20. Writing About Biology Describe the contributions of the early cell scientists. Evaluate the impact of their research on scientific thought.

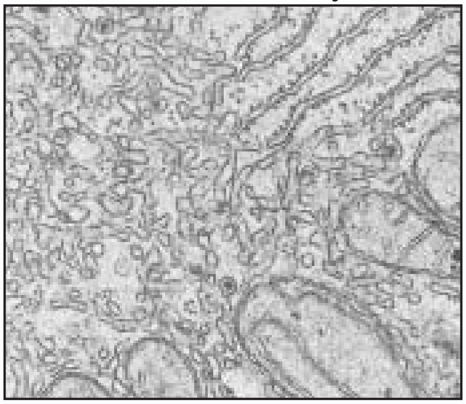
Standardized Test Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the photo to answer questions 21–23.

TEM Magnification: 50 000×

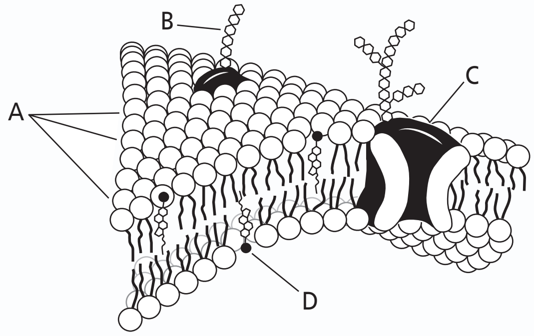


21. The small dots are composed of ________.
A. DNA and lipids
B. DNA and proteins
C. RNA and lipids
D. RNA and proteins

22. The small dots are made in the ________.
A. nucleolus
B. endoplasmic reticulum
C. Golgi apparatus
D. lysosome

23. The function of the small dots is to ________.
A. synthesize lipids
B. transport materials throughout the cell
C. synthesize proteins
D. harness energy for the cell

Use the diagram to answer questions 24–27.



24. Which component stabilizes the phospholipids?
A. A **C.** C
B. B **D.** D

25. Which component helps polar molecules and ions to enter the cell?
A. A **C.** C
B. B **D.** D

26. Which component helps cells identify each other?
A. A **C.** C
B. B **D.** D

27. Which component prevents the cell's watery environment from entering the cell?
A. A **C.** C
B. B **D.** D

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

28. Open Ended Identify and describe a cellular process that maintains homeostasis within a cell.

29. Open Ended Explain the differences between van Leeuwenhoek's microscope and a modern compound light microscope.

bdol.glencoe.com/standardized_test