Chapter 7

Cell Structure

Preview

Why It Matters

All living things are made of cells. Scientists study how cells work to understand life.

Magnified, the single-celled protist *Lembadion bullinum* looks like a pretty seashell.

Section 1

Introduction to Cells

Key Ideas	Key Terms		Why It Matters
❯ How were cells discovered? ❯ What defines cell shape and size? ❯ What enables eukaryotes to perform more specialized functions than prokaryotes do?	cell membrane cytoplasm ribosome	prokaryote eukaryote nucleus organelle	Cells are the basic unit of life. By studying cells, biologists can better understand life's processes.

All life-forms on our planet are made up of cells. The bacteria that live in our gut and the cells that make up our body are built from the same chemical machinery. This machinery allows living things to obtain and use energy, to respond to their environment, and to reproduce. In all organisms, cells have the same basic structure.

The Discovery of Cells

How do living things differ from nonliving things? The discovery of cells was an important step toward answering this question. Most cells are too small to see with the naked eye. As **Figure 1** shows, microscopes have become an important tool for studying biology. ❯ **Microscope observations of organisms led to the discovery of the basic characteristics common to all living things.**

In 1665, Robert Hooke, an English scientist, used a crude microscope to look at a thin slice of cork. His microscope could magnify objects to only 30 times their normal size. Hooke saw many "little boxes" in the cork. They reminded him of the small rooms in which monks lived, so he called them *cells*. Hooke later discovered cells in the stems and roots of plants. Ten years later, Anton van Leeuwenhoek, a Dutch scientist, used a more powerful microscope that could magnify objects 300-fold. He discovered many living creatures in pond water. He named them *animalcules,* or "tiny animals." Today, we know that they were not animals. They were single-celled organisms.

❯ **Reading Check** *How powerful was Hooke's microscope? (See the Appendix for answers to Reading Checks.)*

Figure 1 A student looks through a light microscope. Euglena (inset) are single-celled organisms that are commonly found in pond water.

Cell Theory It took more than 150 years for scientists to fully appreciate the discoveries of Hooke and Leeuwenhoek. By the 1830s, microscopes were powerful enough to resolve structures only 1 µm apart. In 1838, Matthias Schleiden, a German botanist, concluded that cells make up every part of a plant. A year later, Theodor Schwann, a German zoologist, discovered that animals are also made up of cells. In 1858, Rudolph Virchow, a German physician, proposed that cells come only from the division of existing cells. The observations of Schleiden, Schwann, and Virchow form the *cell theory:*

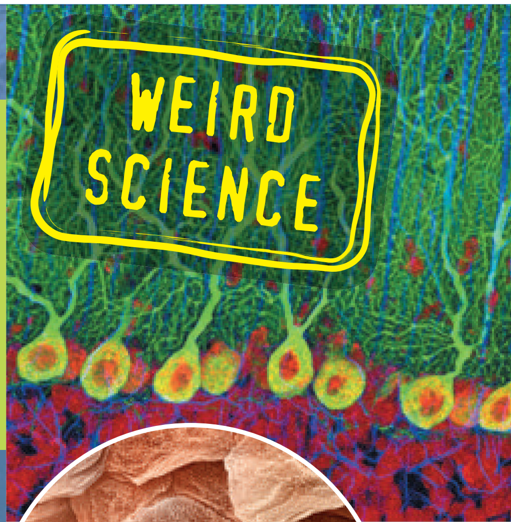
- All living things are made up of one or more cells.
- Cells are the basic units of structure and function in organisms.
- All cells arise from existing cells.

The cell theory has withstood the rigorous examination of cells by scientists equipped with today's high-powered microscopes. As new tools and techniques are invented, scientists will learn more about the characteristics of cells.

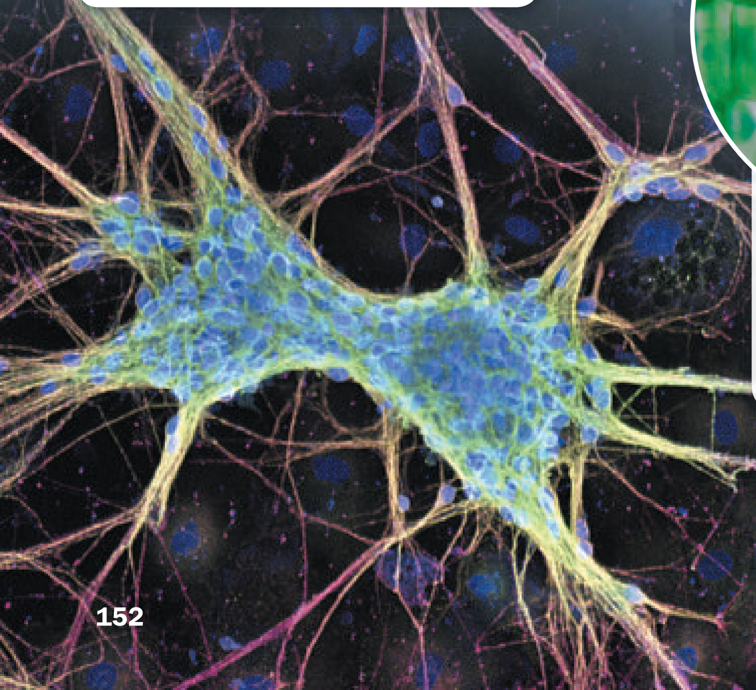
Why It Matters

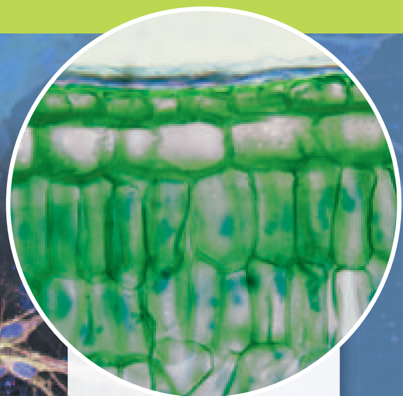
Cell Shape

Cells of living things are modified for different functions. Even single types of cells, such as nerve cells, might have different shapes in the body. The nerve cells to the right have many branches and allow the body to time muscle contractions for precise movement.

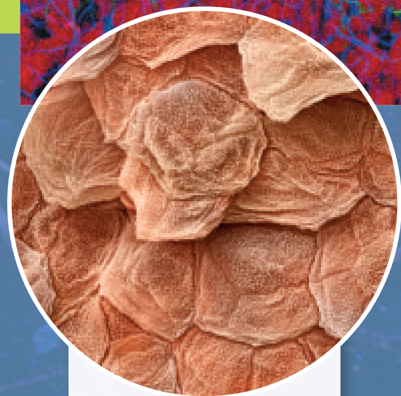


In the nerve cells below, the cell body is the large blue structure. The threadlike projections enable these cells to send and receive messages over great distances in the body.





Plant cells Water in these rectangular cells pushes against their cell wall, giving a leaf its firm structure.



Skin Cells Broad, flat cells cover the body surface like the shingles of a roof.

Quick Project Find out what single cell is considered the largest in the world.

Math Skills Ratio of Surface Area and Volume

A ratio compares two numbers by dividing one number by the other number. A ratio can be expressed in three ways:

x to y $\qquad \frac{x}{y} \qquad x : y$

You can improve your understanding of a cell's surface area–to-volume ratio by practicing with cubes of various sizes. What is the surface area–to-volume ratio of a cube that has a side length (l) of 4 mm?

1 Find the surface area of the cube. A cube has six square faces. The surface area of one face is $l \times l$, or l^2.

- *total surface area of cube* $= 6 \times l^2$
- *total surface area of cube* $= 6 \times (4\text{ mm})^2 = 96\text{ mm}^2$

2 Find the volume of the cube.

- *volume of cube* $= l^3$
- *volume of cube* $= (4\text{ mm})^3 = 64\text{ mm}^3$

Surface Area and Volume

Side length	Surface area	Volume	Surface area–to-volume
1 mm	6 mm^2	1 mm^3	6:1
2 mm	24 mm^2	8 mm^3	3:1
4 mm	96 mm^2	64 mm^3	3:2

3 Divide the total surface area by volume:

- *surface area–to-volume ratio* $= \frac{\textit{total surface area}}{\textit{volume}}$

Reduce both numbers by their greatest common factor:

- *surface area–to-volume ratio* $= \frac{(96 \div 32)}{(64 \div 32)} = \frac{3}{2}$

Looking at Cells

Cells vary greatly in size and in shape. **A cell's shape reflects the cell's function.** Cells may be branched, flat, round, or rectangular. Some cells have irregular shapes, while other cells constantly change shapes. These differences enable different cells to perform highly specific functions in the body. There are at least 200 types of cells. The human body is made up of about 100 trillion cells, most of which range from 5 to 20 µm in diameter. Why are cells so small?

Cell Size All substances that enter or leave a cell must pass through the surface of the cell. As a cell gets larger, it takes up more nutrients and releases more wastes. These substances must move farther to reach their destination in a larger cell. **Cell size is limited by a cell's surface area–to-volume ratio.**

Scientists can estimate a cell's ability to exchange materials by calculating the cell's surface area–to-volume ratio. Cells with greater surface area–to-volume ratios can exchange substances more efficiently. When cells that are the same shape as one another are compared, the smaller cells have greater surface area–to-volume ratios than larger cells do.

Cell Shape Larger cells often have shapes that increase the surface area available for exchange. A cell may grow large in one or two dimensions but remain small in others. For example, some skin cells are broad and flat. Some nerve cells are highly extended and can be more than 10,000 times as long as they are thick. In both of these types of cells, the surface area–to-volume ratio is larger than it would be if the cells were spheres.

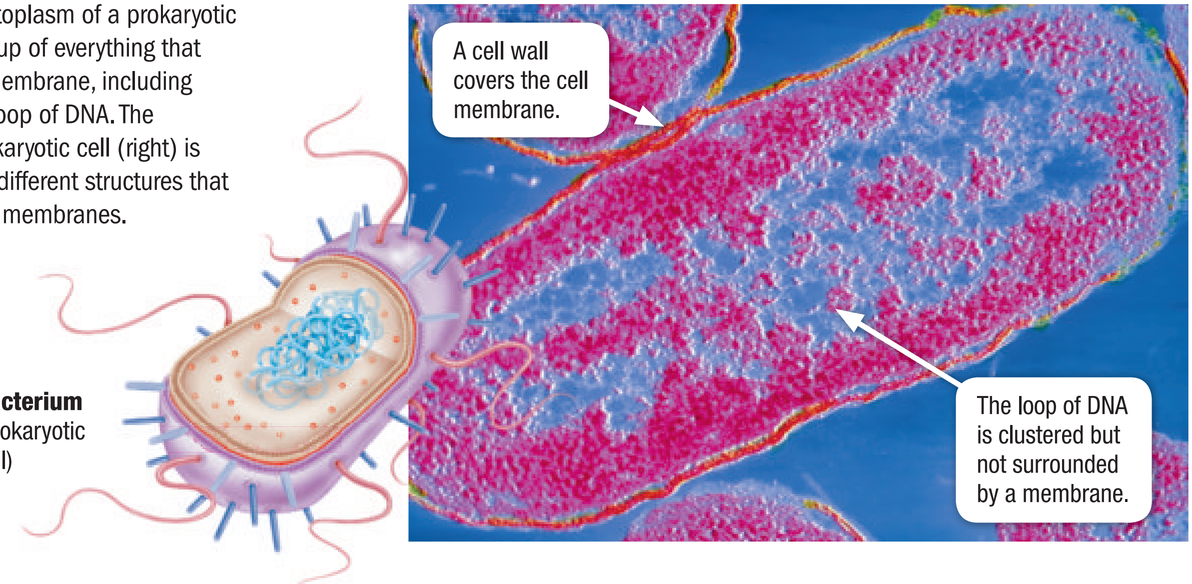
Reading Check *How does a cell's size affect the cell's function?*

ACADEMIC VOCABULARY

dimension a measurement in a particular direction

Features of Prokaryotic and Eukaryotic Cells

Figure 2 The cytoplasm of a prokaryotic cell (left) is made up of everything that is inside the cell membrane, including ribosomes and a loop of DNA. The cytoplasm of a eukaryotic cell (right) is made up of many different structures that are surrounded by membranes.



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Topic: Cell Features
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cell membrane a phospholipid layer that covers a cell's surface and acts as a barrier between the inside of a cell and the cell's environment

cytoplasm (SIET oh PLAZ uhm) the region of the cell within the membrane

ribosome (RIE buh SOHM) a cell organelle where protein synthesis occurs

prokaryote a single-celled organism that does not have a nucleus or membrane-bound organelles

eukaryote an organism made up of cells that have a nucleus and membrane-bound organelles

nucleus in a eukaryotic cell, a membrane-bound organelle that contains the cell's DNA

organelle one of the small bodies that are found in the cytoplasm of a cell and that are specialized to perform a specific function

Cell Features

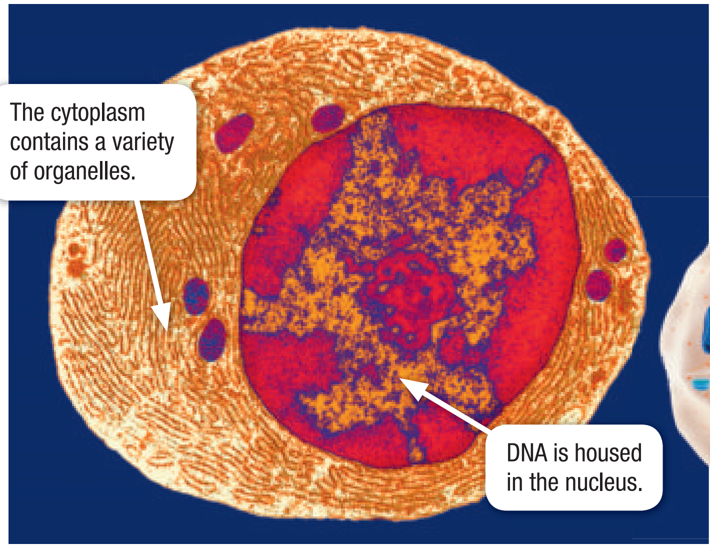
All cells—from bacteria to those in a berry, bug, or bunny—share common structural features. All cells have a cell membrane, cytoplasm, ribosomes, and DNA. The **cell membrane** is the cell's outer boundary. It acts as a barrier between the outside environment and the inside of the cell. The *cytosol,* the fluid inside the cell, is full of dissolved particles. The **cytoplasm** includes this fluid and almost all of the structures that are suspended in the fluid. Many ribosomes are found in the cytoplasm. A **ribosome** is a cellular structure on which proteins are made. All cells also have DNA, the genetic material. DNA provides instructions for making proteins, regulates cellular activities, and enables cells to reproduce.

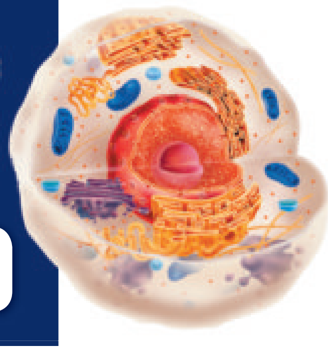
Features of Prokaryotic Cells The bacterium shown in **Figure 2** is an example of a **prokaryote,** an organism that is a single prokaryotic cell. A prokaryotic cell is quite simple in its organization. The genetic material is a single loop of DNA, which looks like a tangled string and usually lies near the center of the cell. Ribosomes and enzymes share the cytoplasm with the DNA.

Prokaryotic cells have a cell wall that surrounds the cell membrane and that provides structure and support. Some prokaryotic cell walls are surrounded by a *capsule,* a structure that enables prokaryotes to cling to surfaces, including teeth, skin, and food.

Scientists think that the first prokaryotes may have lived 2.5 billion years ago or more. For millions of years, prokaryotes were the only organisms on Earth. They were very simple and small (1 to 2 µm in diameter). Like their ancestors, modern prokaryotes are also very small (1 to 15 µm), and they live in a wide range of habitats. Prokaryotes make up a very large and diverse group of cells.

Reading Check *What is a ribosome?*





Animal cell
(Eukaryotic cell)

Features of Eukaryotic Cells A **eukaryote** is an organism that is made up of one or more eukaryotic cells. Some eukaryotes live as single cells. Others are multicellular organisms. In fact, all multicellular organisms are made up of eukaryotic cells. **Because of their complex organization, eukaryotic cells can carry out more specialized functions than prokaryotic cells can.**

Primitive eukaryotic cells first appeared about 1.5 billion years ago. As shown in the animal cell in **Figure 2,** a eukaryotic cell contains compartments that are separated by membranes. The cell's DNA is housed in an internal compartment called the **nucleus.**

In addition to having a membrane, cytoplasm, ribosomes, and a nucleus, all eukaryotic cells have membrane-bound organelles. An **organelle** is a structure that carries out specific activities inside the cell. The animal cell in **Figure 2** shows many of the organelles found in eukaryotic cells. Each organelle performs distinct functions. Many organelles are surrounded by a membrane. Some of the membranes are connected by channels that help move substances within the cell.

READING TOOLBOX

Word Parts The root *kary* means "kernel," which describes the nucleus. *Eu-* means "true," so a eukaryotic cell has a true nucleus. If *pro-* means "before," what does prokaryotic mean?

Section 1 Review

KEY IDEAS

1. **List** the three parts of the cell theory.
2. **Describe** the importance of a cell's surface area–to-volume ratio.
3. **Compare** the structure of a eukaryotic cell with that of a prokaryotic cell.

CRITICAL THINKING

4. **Explaining Relationships** The development of the cell theory is directly related to advances in microscope technology. Why are these two developments related?
5. **Applying Information** Every multicellular organism is made up of eukaryotic cells. Why can't a multicellular organism be made up of prokaryotic cells?

METHODS OF SCIENCE

6. **Extraterrestrial Cells** You are a scientist with NASA. Some samples of extraterrestrial material containing living things have arrived on your spaceship. Your first job is to determine if the samples contain prokaryotic or eukaryotic cells. How will you proceed?

Section 2

Inside the Eukaryotic Cell

Key Ideas	Key Terms	Why It Matters
What does the cytoskeleton do? How does DNA direct activity in the cytoplasm? What organelles participate in protein production? What is the role of vesicles in cells? How do cells get energy?	vesicle endoplasmic reticulum Golgi apparatus vacuole chloroplast mitochondrion	You must know how cells are constructed to understand how a normal body functions and what goes wrong when you get sick.

The cytoplasm of a eukaryotic cell is packed with all sorts of structures and molecules. Molecules can be concentrated in certain parts of the cell because of the membranes that divide the cytoplasm into compartments. This organization enables each organelle to perform highly sophisticated and specialized functions.

The Framework of the Cell

The *cytoskeleton* is a web of protein fibers, shown in **Figure 3,** found in eukaryotic cells. The cytoskeleton supports the cell in much the same way that bones support your body. **The cytoskeleton helps the cell move, keep its shape, and organize its parts.** There are three kinds of cytoskeleton fibers.

Microfilaments are long, thin fibers that are made of the protein actin. Some are attached to the cell membrane. They contract to pull the membrane in some places and expand to push it out in others. *Microtubules* are thick, hollow fibers that are made of the protein tubulin. Information molecules move through these tubes to various parts of the cell. *Intermediate fibers* are moderately thick and mainly anchor organelles and enzymes to certain parts of the cell.

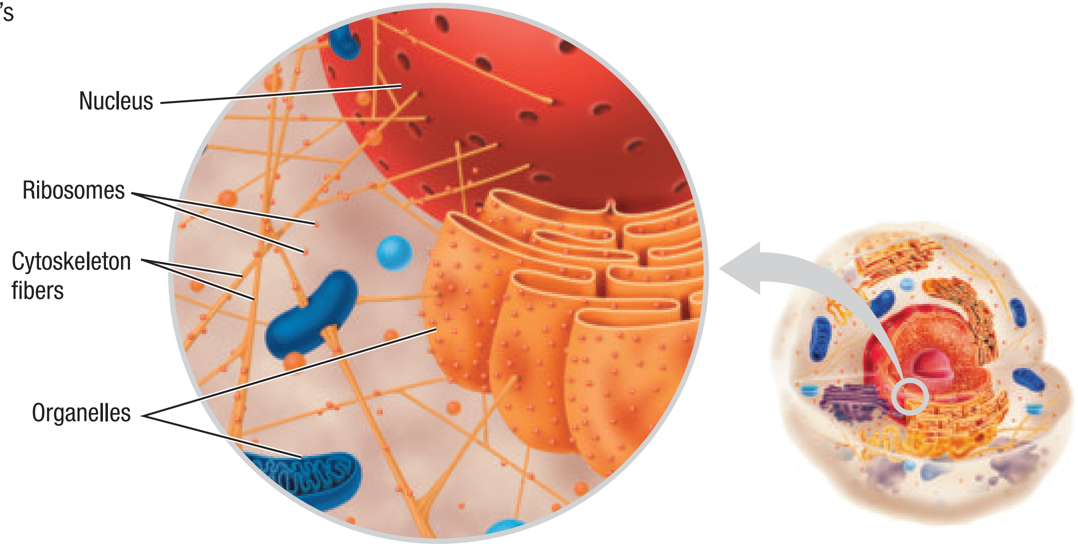


Figure 3 The cytoskeleton's network of protein fibers anchors cell organelles and other components of the cytoplasm. **What are the three types of cytoskeleton fibers?**

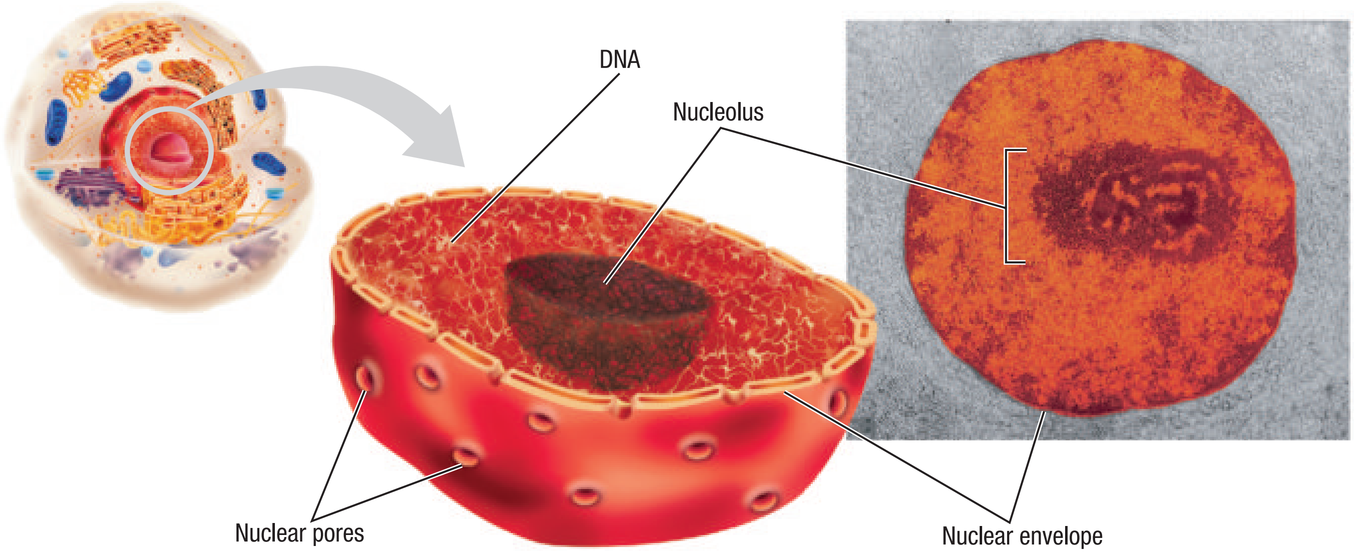


Figure 4 The nucleus stores the cell's DNA. The nuclear envelope is a double membrane that surrounds the nucleus of a cell. Ribosomes are made in the nucleolus. **How do molecules move from the nucleus to the cytoplasm?**

Directing Cellular Activity

Almost all cellular activity depends on the proteins that the cell makes. The instructions for making proteins are stored in the DNA. In a eukaryotic cell, the DNA is packed into the nucleus. This location separates the DNA from the activity in the cytoplasm and helps protect the information from getting lost or destroyed. **DNA instructions are copied as RNA messages, which leave the nucleus. In the cytoplasm, ribosomes use the RNA messages to assemble proteins.**

Academic Vocabulary

assemble to fit together parts or pieces; to build

Nucleus As **Figure 4** shows, the nucleus is surrounded by a double membrane called the *nuclear envelope*. The nuclear envelope has many nuclear pores. Nuclear pores are small channels that allow certain molecules to move into and out of the nucleus. Even though the inside of the nucleus appears to be quite jumbled, the DNA is very organized. Within the nucleus is a prominent structure called the *nucleolus*. The nucleolus is the region where ribosome parts are made. These "preassembled" parts of ribosomes pass through the nuclear pores into the cytoplasm. Outside the nucleus, the parts are assembled to form a complete ribosome.

Ribosomes Each ribosome is made of RNA and many proteins. Some ribosomes in a eukaryotic cell are suspended in the cytosol, as they are in prokaryotic cells. These "free" ribosomes make proteins that remain inside the cell, such as proteins that build new organelles or enzymes to speed chemical reactions. Other ribosomes are attached to the membrane of another organelle. These "bound" ribosomes make proteins that are exported from the cell. Some of these proteins are important in cell communication. Bound ribosomes also make proteins that must be kept separate from the rest of the cytoplasm. Ribosomes can switch between being bound or free depending on the kind of protein that the cell needs to make.

Reading Check *What kind of protein do "free" ribosomes make?*

vesicle a small cavity or sac that contains materials in a eukaryotic cell

endoplasmic reticulum (EN doh PLAZ mik ri TIK yuh luhm) a system of membranes that is found in a cell's cytoplasm and that assists in the production, processing, and transport of proteins and in the production of lipids

Golgi apparatus (GOHL jee) a cell organelle that helps make and package materials to be transported out of the cell

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Topic: Proteins
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READING TOOLBOX

Process Chart Make a process chart that shows how the cell digests food particles.

Protein Processing

The proteins produced by cells have many uses. The proteins that are sent outside the cell must be kept separate from the rest of the cytoplasm. To achieve this separation, the cell packages the proteins in vesicles. A **vesicle** is a small, often spherical-shaped sac that is formed by a membrane.

In a eukaryotic cell, two structures are mainly responsible for modifying, packaging, and transporting proteins for use outside the cell. **The endoplasmic reticulum and the Golgi apparatus are organelles that prepare proteins for extracellular export.**

Endoplasmic Reticulum The **endoplasmic reticulum** (ER) is a system of internal membranes that moves proteins and other substances through the cell. The membrane of the ER is connected to the outer membrane of the nuclear envelope.

Rough ER Ribosomes are attached to some parts of the surface of the ER. This *rough ER* has a bumpy appearance when viewed with an electron microscope, as shown in **Figure 5.** 1 As proteins are made, they cross the ER membrane, entering the ER. Then, the ER membrane pinches off to form a vesicle around the proteins.

Smooth ER The rest of the ER, called *smooth ER,* has no attached ribosomes. Thus it appears smooth when viewed with an electron microscope. Enzymes of the smooth ER performs various functions, such as making lipids and breaking down toxic substances.

Golgi Apparatus The **Golgi apparatus** is a set of flattened, membrane-bound sacs. Cell products enter one side of the Golgi apparatus, which modifies, sorts, and packages them for distribution.

Repackaging Vesicles that contain newly made proteins move through the cytoplasm from the ER to the Golgi apparatus. 2 The vesicle membrane fuses with the Golgi membrane. Inside the Golgi apparatus, enzymes modify the proteins as they move through the organelle. On the other side, the finished proteins are enclosed in new vesicles that bud from the surface of the Golgi apparatus.

Exporting Many of these vesicles then migrate to the cell membrane. 3 As the vesicle membrane fuses with the cell membrane, the completed proteins are released to the outside the cell.

Storage and Maintenance

Vesicles have many functions in the cell. Some transport materials within the cell. Others have important storage roles. **Vesicles help maintain homeostasis by storing and releasing various substances as the cell needs them.**

Lysosome A lysosome is a vesicle that contains specific enzymes that break down large molecules. These enzymes can digest food particles to provide nutrients for the cell. They also help recycle materials in the cell by digesting old, damaged, or unused organelles. Lysosomes work by fusing with other vesicles. Lysosomes, made by the Golgi apparatus, prevent the enzymes from destroying the cell.

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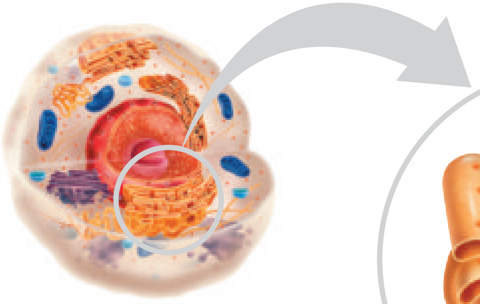
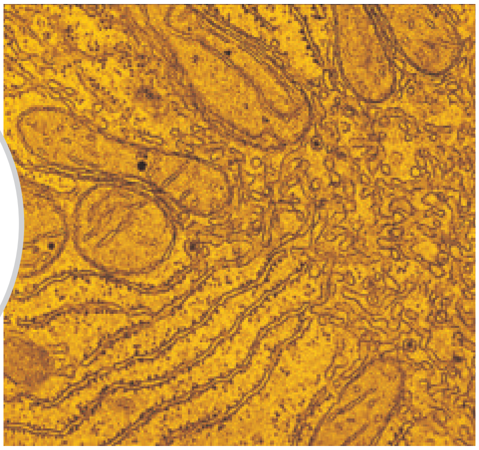
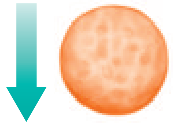
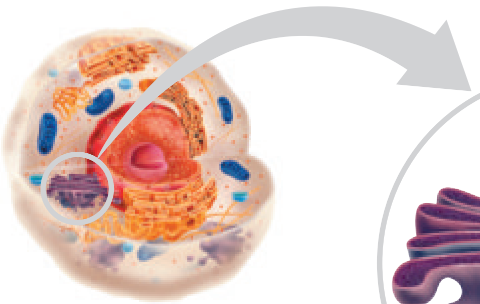
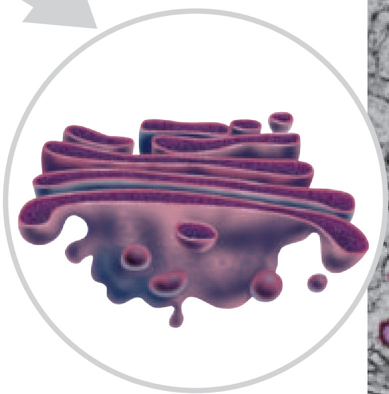
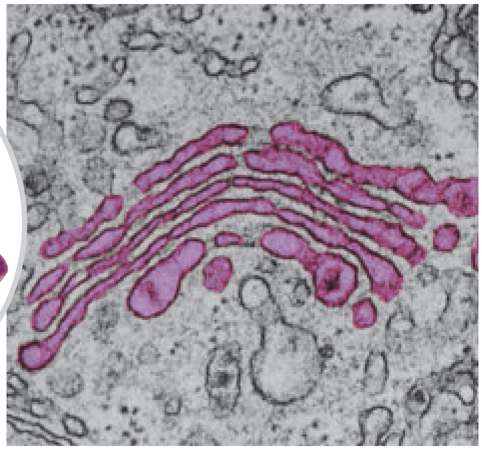
Making and Exporting Proteins

Figure 5 The cell manufactures many proteins. Some proteins are used outside the cell that makes them. Many organelles play a role in producing, processing, and packaging these proteins.

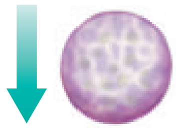
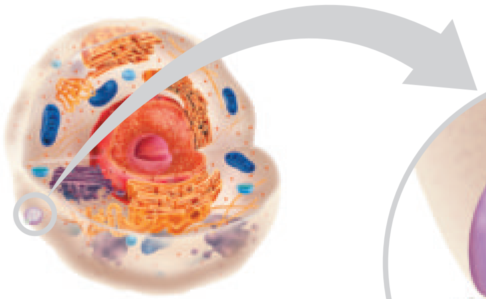
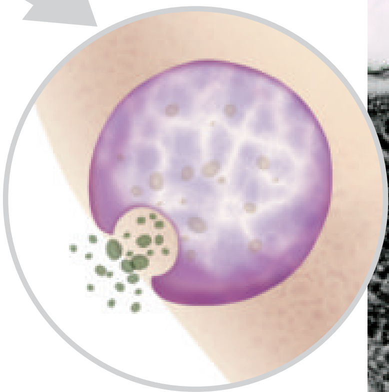
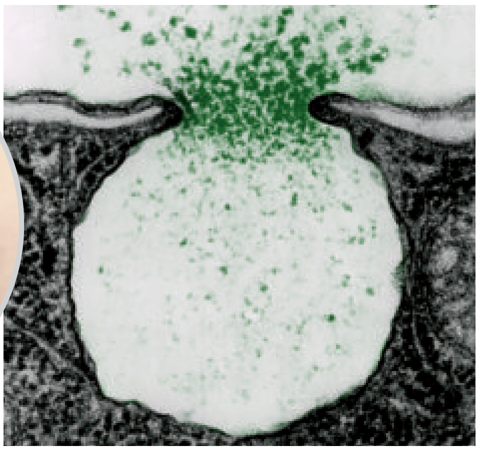




1 Endoplasmic Reticulum Proteins are made by ribosomes on the rough ER, which packages the proteins into vesicles. The vesicles transport the newly made proteins from the rough ER to the Golgi apparatus.

2 Golgi Apparatus The vesicle enters one side of the Golgi apparatus. As the proteins move through the folds, they are changed and repackaged into new vesicles. These new vesicles then move to the cell membrane.

3 Cell Membrane The vesicles move to the cell membrane and release their contents (modified proteins) outside the cell. The vesicle membrane becomes part of the cell membrane.

Hands-On QuickLab

10 min

Cell Parts Model

No space is wasted inside a cell. Packed into the cell are all parts essential to its survival.

Procedure

1. Fill a **sealable plastic sandwich bag** halfway with **tap water.** Add several drops of **blue food dye.** Before you seal the bag, push out any remaining air.
2. Roll this water-filled bag into a cylindrical shape. Use two long strips of **tape** to secure this shape.
3. Fill **two smaller jewelry bags** with water. Before sealing the bags, add several drops of **green food dye** to each bag.
4. Place the large rolled bag and the two smaller jewelry bags into a second **large plastic bag.**
5. Fill this outer bag two-thirds full with water. Push out any remaining air, and seal the bag.

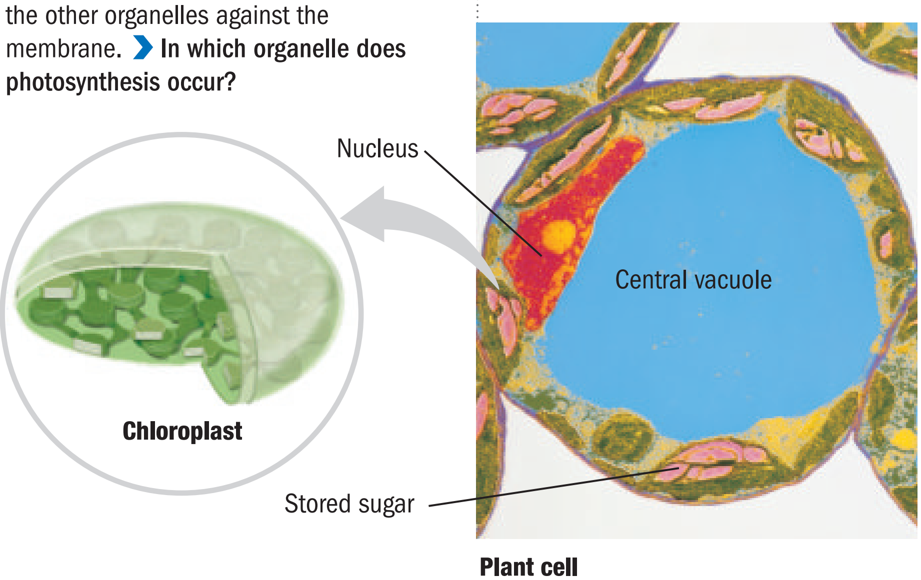
Analysis

1. **State** what each plastic bag in this model represented.
2. **Describe** how the "central vacuole" affects the contents of your cell model.
3. CRITICAL THINKING **Predicting Outcomes** Explain how removing water from the model's central bag might affect the tension and shape of the outer plastic bag.

Central Vacuole Many plant cells contain a large, membrane-bound compartment called the central **vacuole.** This large vacuole stores water, ions, nutrients, and wastes. It can also store toxins or pigments. When water fills the central vacuole, as shown in **Figure 6,** it makes the cell rigid, allowing the plant to stand upright. When the vacuole loses water, the cell shrinks, and the plant wilts.

Other Vacuoles Some protists have contractile vacuoles, which pump excess water out of the cell. This process controls the concentration of salts and other molecules and helps the cell maintain homeostasis. Another type of vacuole forms when the cell membrane surrounds food particles outside the cell and pinches off to form a vesicle inside the cell. When the food vacuole later fuses with a lysosome, the enzymes that digest the stored food are released.

Figure 6 A plant cell may have a large central vacuole and several chloroplasts. When filled, the central vacuole pushes the other organelles against the membrane. **In which organelle does photosynthesis occur?**



Energy Production

Cells need a constant source of energy. **The energy for cellular functions is produced by chemical reactions that occur in the mitochondria and chloroplasts.** Nearly all eukaryotic cells contain mitochondria. Chloroplasts are found in plants and some plant-like protists, such as seaweed, but not in animal cells. In both organelles, chemical reactions produce adenosine triphosphate (ATP), the form of energy that fuels almost all cell processes.

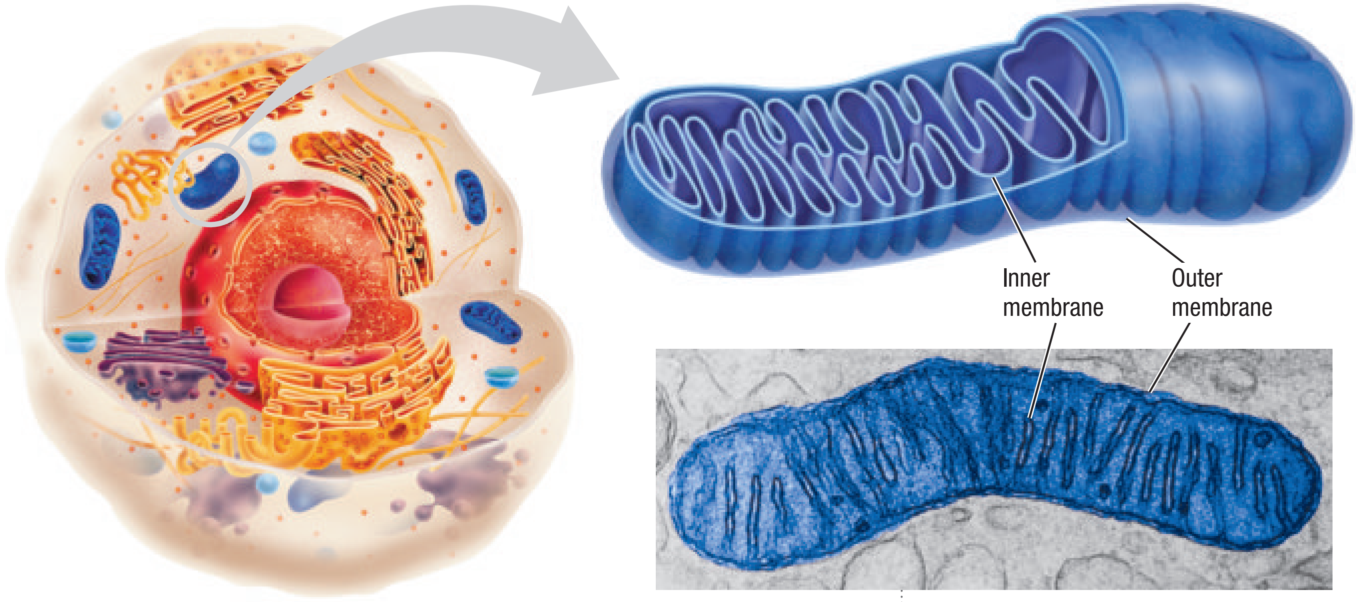


Figure 7 A mitochondrion uses the energy in organic molecules to make ATP for the cell. The mitochondrion has two membranes. **Where in the mitochondrion is ATP produced?**

Chloroplasts A **chloroplast** is an organelle that uses light energy to make sugar from carbon dioxide and water. As **Figure 6** shows, plant cells may have several chloroplasts. Each chloroplast is surrounded by a pair of membranes. Inside the inner membrane are many stacks of flattened sacs. The ATP-producing chemical reactions take place on the membranes of these sacs.

Mitochondria A **mitochondrion** is an organelle that uses energy from organic compounds to make ATP. Although some ATP is made in the cytosol, most of a cell's ATP is made inside mitochondria. Cells that have a high energy requirement, such as muscle cells, may contain hundreds or thousands of mitochondria. As **Figure 7** shows, a mitochondrion has a smooth outer membrane. It also has a greatly folded inner membrane, which divides the organelle into two compartments. Many ATP-producing enzymes are located on the inner membrane.

Reading Check *In what kinds of cells are mitochondria found?*

vacuole (VAK yoo OHL) a fluid-filled vesicle found in the cytoplasm of plant cells or protozoans

chloroplast an organelle found in plant and algae cells where photosynthesis occurs

mitochondrion (MIET oh KAHN dree uhn) in eukaryotic cells, the cell organelle that is surrounded by two membranes and that is the site of cellular respiration

Section 2 Review

KEY IDEAS

1. **Compare** the functions of the three types of cytoskeletal fibers.
2. **Describe** the nucleus.
3. **Trace** a protein's path through the cell, from assembly to export.
4. **Contrast** vesicles and vacuoles.
5. **Compare** the role of mitochondria and chloroplasts.

CRITICAL THINKING

6. **Constructing Explanations** Is it accurate to say that organelles are floating freely in the cytosol? Why or why not?
7. **Real World** Research Tay-Sachs disease, and explain what goes wrong in diseased cells.

ALTERNATIVE ASSESSMENT

8. **Analogy** Compare the organelles of a eukaryotic cell to the parts of a city. For example, the lysosome could be a recycling center.

Section
3 From Cell to Organism

Key Ideas	Key Terms	Why It Matters
What makes cells and organisms different? How are cells organized in a complex multicellular organism? What makes an organism truly multicellular?	flagellum tissue organ organ system colonial organism	Diverse organisms have unique cells and cellular organization.

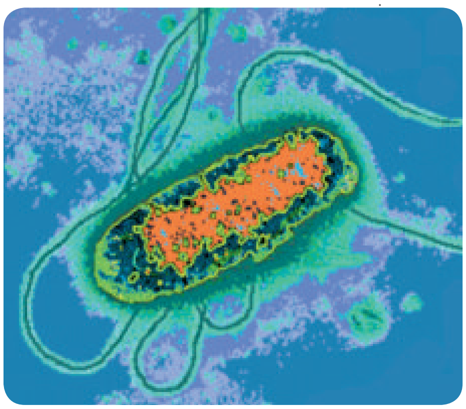
More than 50 million types of organisms live on Earth. Each organism is made up of different types of cells. Differences in cells enable organisms to adapt to their natural environments.

Diversity in Cells

Prokaryotes are always unicellular and limited in size. Eukaryotes are often larger and can be either unicellular or multicellular. Prokaryotic cells lack a nucleus and membrane-bound organelles, which are found in eukaryotic cells. Within both types, cells can have a variety of shapes and structures. Recall that a cell's shape reflects its function. **The different organelles and features of cells enable organisms to function in unique ways in different environments.**

Diversity in Prokaryotes Prokaryotes can vary in shape, the way that they obtain and use energy, the makeup of their cell walls, and their ability to move. Many prokaryotes have **flagella**—long, threadlike structures that rotate to quickly move an organism through its environment. Many prokaryotes have pili. Pili are short, thick outgrowths that allow prokaryotes to attach to surfaces or to other cells. These features are shown in **Figure 8.**

flagellum a long, hairlike structure that grows out of a cell and enables the cell to move



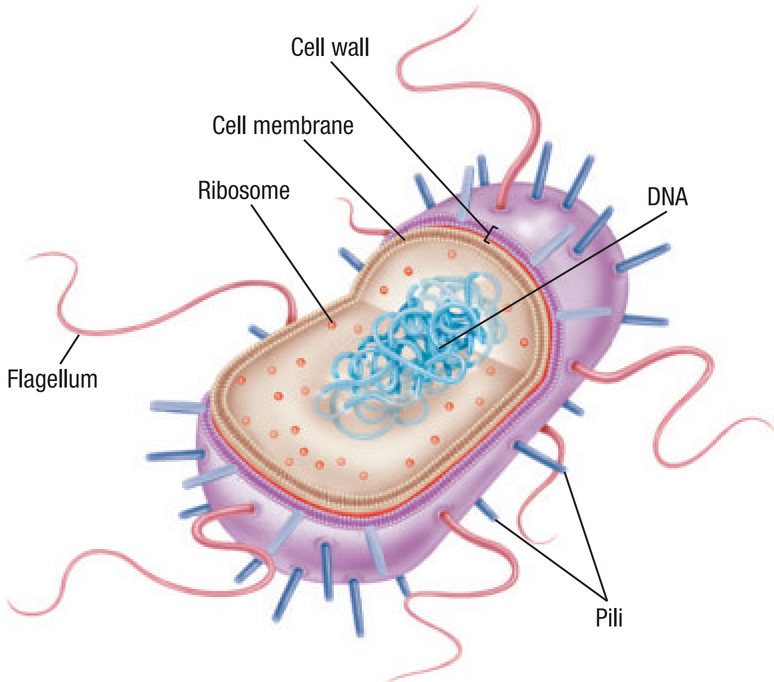


Figure 8 The bacterium *Escherichia coli* is a rod-shaped prokaryote that has both pili and flagella. **What do flagella enable prokaryotic cells to do?**

Diversity in Eukaryotic Cells Animal and plant cells are two types of eukaryotic cells, as **Figure 9** shows. Both have many of the same organelles, but plant cells also have chloroplasts, a large central vacuole, and a cell wall that surrounds the cell membrane.

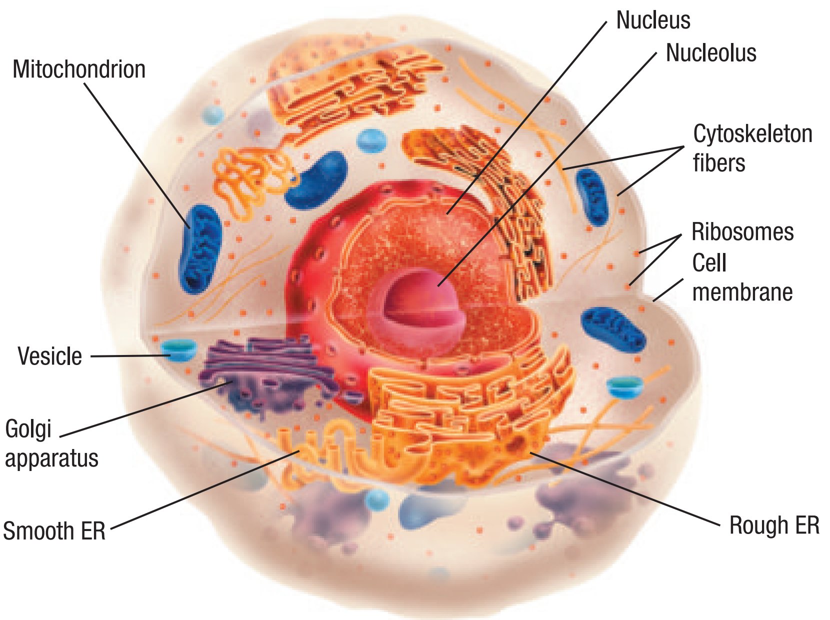
Like prokaryotic cells, eukaryotic cells vary in structure according to their function. Also, some organelles are more prominent in some cell types. By varying in their internal makeup, cells can become specialized for certain functions. For example, muscle cells, which use large amounts of energy, have many mitochondria.

› **Reading Check** *What are flagella?*

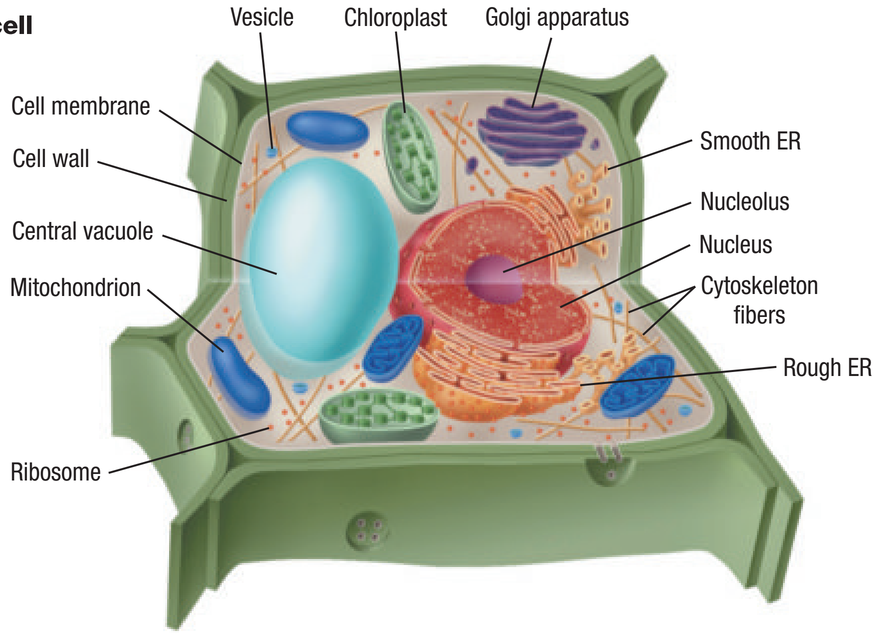
Eukaryotic Cells

Figure 9 Most eukaryotic cells contain all of the organelles shown here. Depending on their function, cells may have different shapes and different amounts of certain organelles. › **What are three features that plant cells have, but animal cells lack?**

Animal cell



Plant cell



Levels of Organization

Multicellular organisms, such as plants and animals, are made up of thousands, millions, or even trillions of highly specialized cells. These cells cooperate to perform a specific task. They assemble together to form structures called tissues and organs. **Plants and animals have many highly specialized cells that are arranged into tissues, organs, and organ systems.** The relationships between tissues, organs, and organ systems are shown in **Figure 10.**

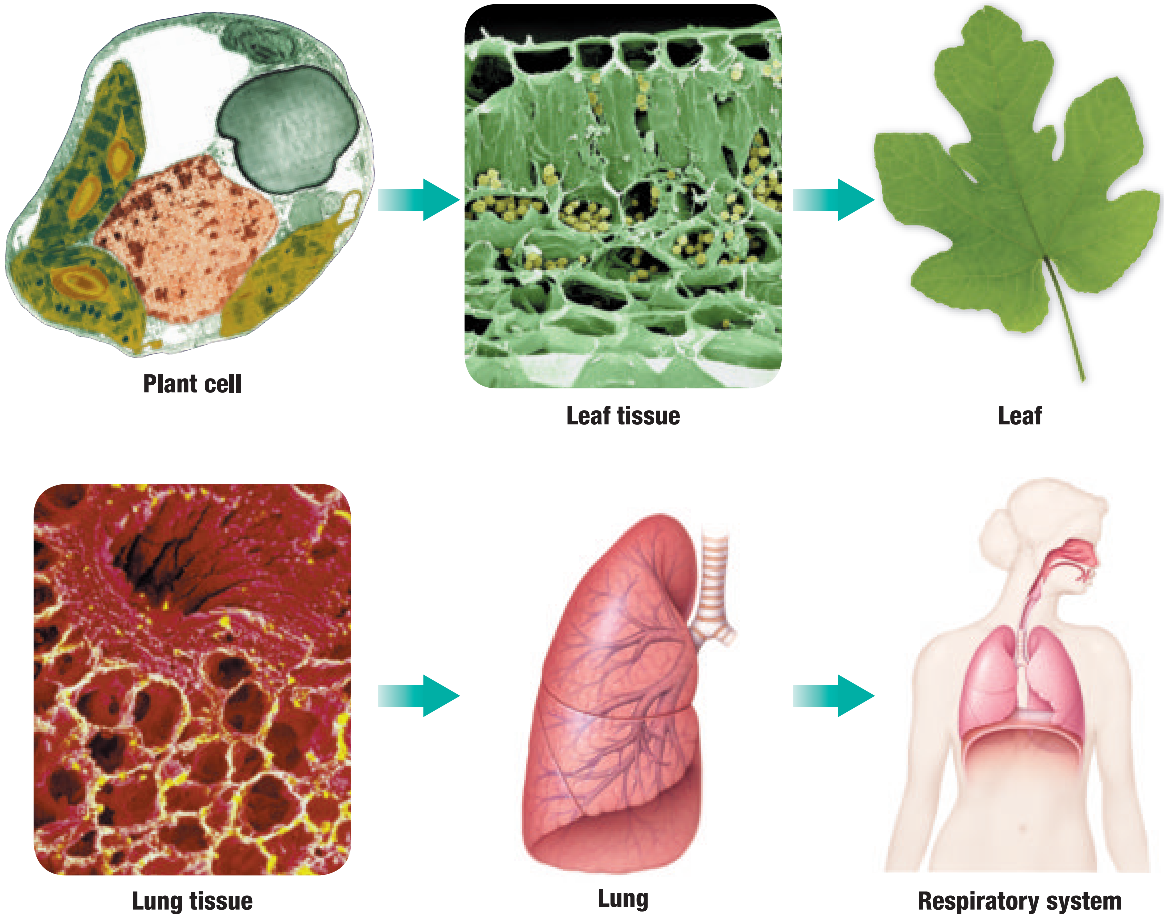
READING TOOLBOX

Similes Write a simile comparing each level of organization to a part of your textbook. (Hint: Cells are like letters.)

Tissues A **tissue** is a distinct group of cells that have similar structures and functions. For example, muscle tissue is a group of many cells that have bundles of cytoskeletal structures. When the bundles contract at the same time, they help animals move. In plants, vascular tissue is made of hollowed cells that are stacked up to make tiny straws. These structures help carry fluids and nutrients to various parts of the plant.

Organs Different tissues may be arranged into an **organ,** which is a specialized structure that has a specific function. In animals, the heart is an organ made of muscle, nerve, and other tissues. These tissues work together to pump blood. In plants, a leaf is an organ. A leaf is made of vascular tissue and other types of plant tissues that work together to trap sunlight and produce sugar.

Figure 10 Cells group together to make tissues, which assemble into organs. A leaf is an example of an organ in plants. A lung is an example of an organ in animals.
What level of organization is the respiratory system?



Hands-On

QuickLab

10 min

Colonies on the Move

Volvox is a green colonial alga. A single colony may contain over 500 cells and is visible to the unaided eye.

Procedure

1. With the unaided eye, examine a **container of Volvox colonies.** What do you see?
2. Use a **dropper** to transfer some of the colonies to a **well slide.**
3. Examine the colonies using a **light microscope.**

Analysis

1. **Draw** the shape and structure of Volvox.
2. **Describe** the motion of a Volvox colony.
3. CRITICAL THINKING **Inferring Relationships** From your observations, do you think that the movements of the colony members are coordinated? Explain.

Organ System Various organs that carry out a major body function make up an **organ system.** One example of an organ system is the circulatory system, which is made up of the heart, the blood vessels, and blood. In plants, the shoot system consists of stems, leaves, and the vascular tissue that connects them.

Body Types

Sometimes, the entire body of an organism is made up of a single cell. This cell must carry out all of the organism's activities, including growing, using energy, responding to the environment, and reproducing. More than half of the biomass on Earth is composed of unicellular organisms.

While single cells cannot grow larger than a certain size, multicellular organisms can be large. **A multicellular organism is composed of many individual, permanently associated cells that coordinate their activities.** Distinct types of cells have specialized functions that help the organism survive. Individual cells cannot survive alone and are dependent on the other cells of the organism.

Cell Groups Some unicellular organisms can thrive independently, but others live in groups. Cells that live as a connected group but depend on each other for survival are considered **colonial organisms.** For example, the cell walls of some bacteria adhere to one another after dividing. These formations are not considered multicellular, because the cells can survive when separated.

Another type of cell grouping occurs in certain types of slime molds. These organisms spend most of their lives as single-celled amoebas. When starved, the individual cells form a large mass, which produces spores.

tissue a group of similar cells that perform a common function

organ a collection of tissues that carry out a specialized function of the body

organ system a group of organs that work together to perform body functions

colonial organism a collection of genetically identical cells that are permanently associated but in which little or no integration of cell activities occurs

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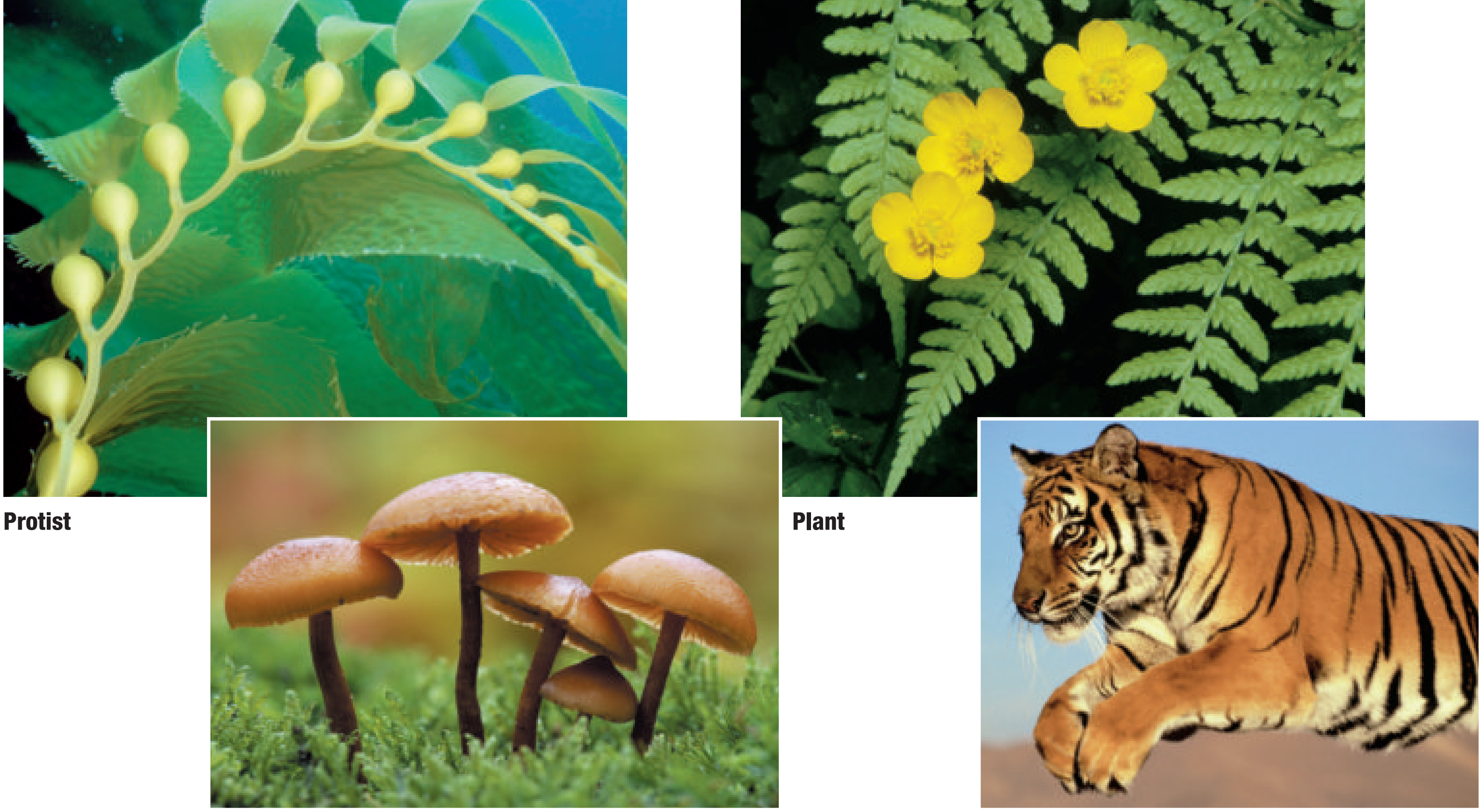

Protist

Plant

Fungus

Animal

Figure 11 The giant kelp is a multicellular protist. Mushrooms are multicellular fungi. All plants and animals are multicellular organisms. **› Can prokaryotes be multicellular?**

Multicellularity True multicellularity occurs only in eukaryotes, such as the organisms shown in **Figure 11.** Some protists, most fungi, and all plants and animals have a multicellular body. The cells of a multicellular body perform highly specific functions. Some cells protect the organism from predators or disease. Others may help with movement, reproduction, or feeding.

Most multicellular organisms begin as a single cell. For example, as a chicken develops from an egg, new cells form by cell division. These cells then grow and undergo differentiation, the process by which cells develop specialized forms and functions. The specialized cells are arranged into tissues, organs, and organ systems, making up the entire organism.

› Reading Check *What is differentiation?*

Section 3 Review

› KEY IDEAS

1. **Relate** the structure of a cell to the cell's function.
2. **Describe** the four levels of organization that make up an organism.
3. **Explain** what makes a group of cells a truly multicellular organism.

CRITICAL THINKING

4. **Comparing** Describe how the circulatory system in animals is similar to the vascular system in plants.
5. **Making Inferences** How would the formation of bacterial colonies be affected if bacterial cells did not contain pili?

WRITING FOR SCIENCE

6. **Cell Group Therapy** Write a short play set in a therapy group that contains cells belonging to a unicellular colony and cells belonging to a multicellular organism. Have the cells discuss issues such as communication and individuality.

Chapter 7 Summary

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SUPER SUMMARY
Keyword: HX8CSFS

Key Ideas	Key Terms

1 Introduction to Cells

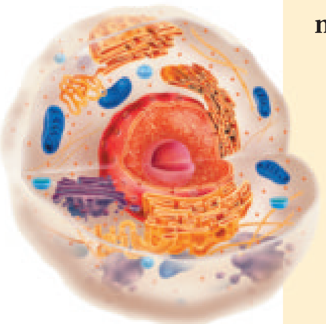
- Microscope observations of organisms led to the discovery of the basic characteristics common to all living things.
- A cell's shape reflects the cell's function. Cell size is limited by a cell's surface area–to-volume ratio.
- Because of their complex organization, eukaryotic cells can carry out more specialized functions than prokaryotic cells can.

Key Terms

cell membrane (154)
cytoplasm (154)
ribosome (154)
prokaryote (154)
eukaryote (155)
nucleus (155)
organelle (155)

2 Inside the Eukaryotic Cell

- The cytoskeleton helps the cell move, keep its shape, and organize its parts.
- DNA instructions are copied as RNA messages, which leave the nucleus. In the cytoplasm, ribosomes use the RNA messages to assemble proteins.
- The endoplasmic reticulum and the Golgi apparatus are organelles that prepare proteins for extracellular export.
- Vesicles help maintain homeostasis by storing and releasing various substances as the cell needs them.
- The energy for cellular functions is produced by chemical reactions that occur in the mitochondria and chloroplasts.



Key Terms

vesicle (158)
endoplasmic reticulum (158)
Golgi apparatus (158)
vacuole (160)
chloroplast (161)
mitochondrion (161)

3 From Cell to Organism

- The different organelles and features of cells enable organisms to function in unique ways in different environments.
- Plants and animals have many highly specialized cells that are arranged into tissues, organs, and organ systems.
- A multicellular organism is composed of many individual, permanently associated cells that coordinate their activities.

Key Terms

flagellum (162)
tissue (164)
organ (164)
organ system (165)
colonial organism (165)