SECTION 1

# The Diversity of Cells

*Most cells are so small they can't be seen by the naked eye. So how did scientists find cells? By accident, that's how! The first person to see cells wasn't even looking for them.*

All living things are made of tiny structures called cells. A **cell** is the smallest unit that can perform all the processes necessary for life. Because of their size, cells weren't discovered until microscopes were invented in the mid-1600s.

## READING WARM-UP

### Objectives

- State the parts of the cell theory.
- Explain why cells are so small.
- Describe the parts of a cell.
- Describe how eubacteria are different from archaebacteria.
- Explain the difference between prokaryotic cells and eukaryotic cells.

### Terms to Learn

cell
cell membrane
organelle
nucleus
prokaryote
eukaryote

## READING STRATEGY

**Reading Organizer** As you read this section, create an outline of the section. Use the headings from the section in your outline.

## Cells and the Cell Theory

Robert Hooke was the first person to describe cells. In 1665, he built a microscope to look at tiny objects. One day, he looked at a thin slice of cork. Cork is found in the bark of cork trees. The cork looked like it was made of little boxes. Hooke named these boxes *cells*, which means "little rooms" in Latin. Hooke's cells were really the outer layers of dead cork cells. Hooke's microscope and his drawing of the cork cells are shown in **Figure 1.**

Hooke also looked at thin slices of living plants. He saw that they too were made of cells. Some cells were even filled with "juice." The "juicy" cells were living cells.

Hooke also looked at feathers, fish scales, and the eyes of houseflies. But he spent most of his time looking at plants and fungi. The cells of plants and fungi have cell walls. This makes them easy to see. Animal cells do not have cell walls. This absence of cell walls makes it harder to see the outline of animal cells. Because Hooke couldn't see their cells, he thought that animals weren't made of cells.

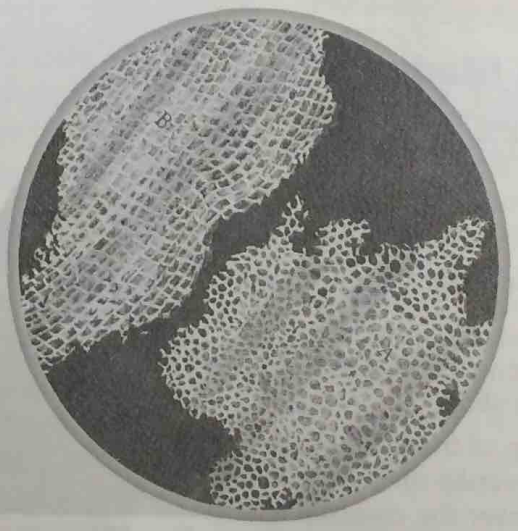


**Figure 1** *Hooke discovered cells using this microscope. Hooke's drawing of cork cells is shown to the right of his microscope.*

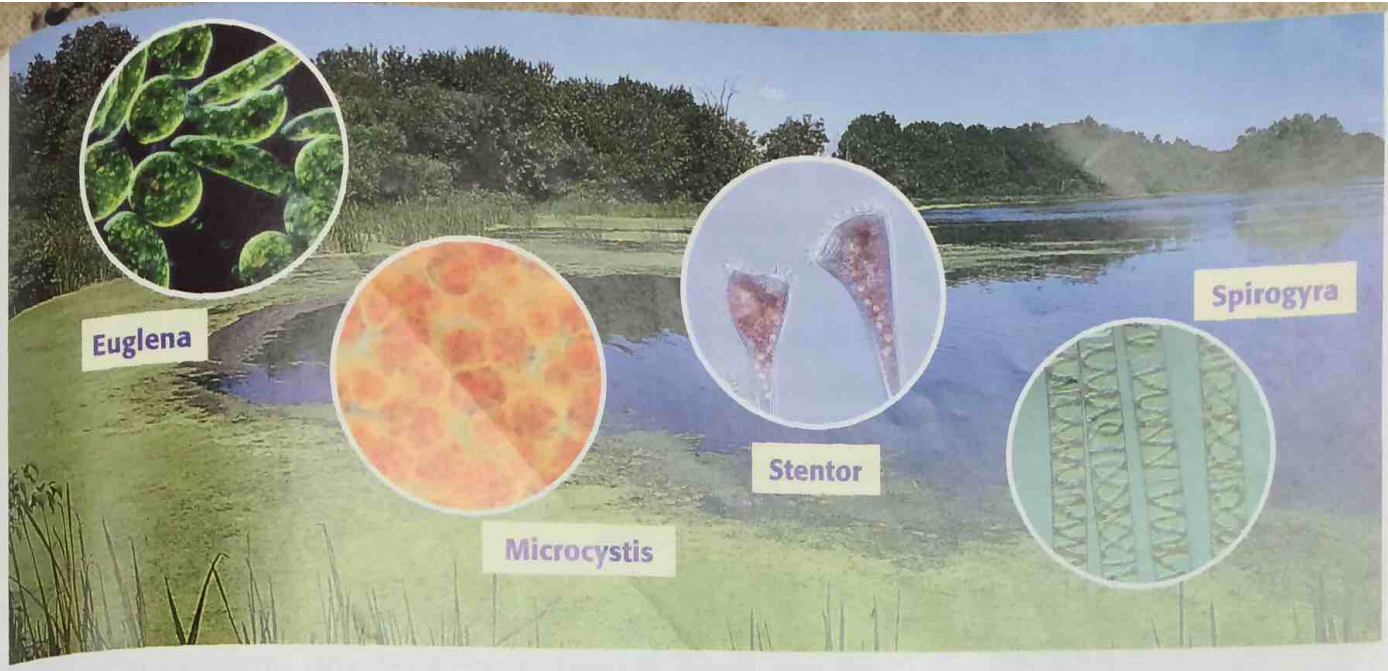



**Figure 2** *The green area at the edge of the pond is a layer of pond scum. This pond scum contains organisms called* protists, *such as those shown above.*

## Finding Cells in Other Organisms

In 1673, Anton van Leeuwenhoek (LAY vuhn HOOK), a Dutch merchant, made his own microscopes. Leeuwenhoek used one of his microscopes to look at pond scum. Leeuwenhoek saw small organisms in the water. He named these organisms *animalcules,* which means "little animals." Today, we call these single-celled organisms protists (PROH tists). Pond scum and some of the protists it contains are shown in **Figure 2.**

Leeuwenhoek also looked at animal blood. He saw differences in blood cells from different kinds of animals. For example, blood cells in fish, birds, and frogs are oval. Blood cells in humans and dogs are round and flat. Leeuwenhoek was also the first person to see bacteria. And he discovered that yeasts that make bread dough rise are single-celled organisms.

**cell** in biology, the smallest unit that can perform all life processes; cells are covered by a membrane and have DNA and cytoplasm

## The Cell Theory

Almost 200 years passed before scientists concluded that cells are present in all living things. Scientist Matthias Schleiden (mah THEE uhs SHLIE duhn) studied plants. In 1838, he concluded that all plant parts were made of cells. Theodor Schwann (TAY oh dohr SHVAHN) studied animals. In 1839, Schwann concluded that all animal tissues were made of cells. Soon after that, Schwann wrote the first two parts of what is now known as the *cell theory*.

- All organisms are made of one or more cells.
- The cell is the basic unit of all living things.

Later, in 1858, Rudolf Virchow (ROO dawlf FIR koh), a doctor, stated that all cells could form only from other cells. Virchow then added the third part of the cell theory.

- All cells come from existing cells.

**Reading Check** **What are the three parts of the cell theory?**
(*See the Appendix for answers to Reading Checks.*)

**CONNECTION TO Physics**

**Microscopes** The microscope Hooke used to study cells was much different from microscopes today. Research different kinds of microscopes, such as light microscopes, scanning electron microscopes (SEMs), and transmission electron microscopes (TEMs). Select one type of microscope. Make a poster or other presentation to show to the class. Describe how the microscope works and how it is used. Be sure to include images.

ACTIVITY

## Cell Size

Most cells are too small to be seen without a microscope. It would take 50 human cells to cover the dot on this letter *i*.

### A Few Large Cells

Most cells are small. A few, however, are big. The yolk of a chicken egg, shown in **Figure 3,** is one big cell. The egg can be this large because it does not have to take in more nutrients.

### Many Small Cells

There is a physical reason why most cells are so small. Cells take in food and get rid of wastes through their outer surface. As a cell gets larger, it needs more food and produces more waste. Therefore, more materials pass through its outer surface.

As the cell's volume increases, its surface area grows too. But the cell's volume grows faster than its surface area. If a cell gets too large, the cell's surface area will not be large enough to take in enough nutrients or pump out enough wastes. So, the area of a cell's surface—compared with the cell's volume—limits the cell's size. The ratio of the cell's outer surface area to the cell's volume is called the *surface area–to-volume ratio,* which can be calculated by using the following equation:

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

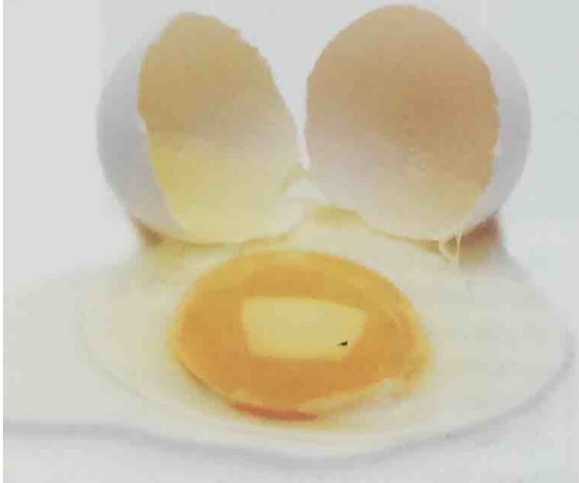


**Figure 3** *The white and yolk of this chicken egg provide nutrients for the development of a chick.*

**Reading Check** **Why are most cells small?**

## MATH FOCUS

**Surface Area–to-Volume Ratio** Calculate the surface area–to-volume ratio of a cube whose sides measure 2 cm.

**Step 1:** Calculate the surface area.

$\textit{surface area of cube} = \textit{number of sides} \times \textit{area of side}$

$\textit{surface area of cube} = 6 \times (2\text{ cm} \times 2\text{ cm})$

$\textit{surface area of cube} = 24\text{ cm}^2$

**Step 2:** Calculate the volume.

$\textit{volume of cube} = \textit{side} \times \textit{side} \times \textit{side}$

$\textit{volume of cube} = 2\text{ cm} \times 2\text{ cm} \times 2\text{ cm}$

$\textit{volume of cube} = 8\text{ cm}^3$

**Step 3:** Calculate the surface area–to-volume ratio.

$$\textit{surface area–to-volume ratio} = \frac{\textit{surface area}}{\textit{volume}} = \frac{24}{8} = \frac{3}{1}$$

**Now It's Your Turn**

1. Calculate the surface area–to-volume ratio of a cube whose sides are 3 cm long.
2. Calculate the surface area–to-volume ratio of a cube whose sides are 4 cm long.
3. Of the cubes from questions 1 and 2, which has the greater surface area–to-volume ratio?
4. What is the relationship between the length of a side and the surface area–to-volume ratio of a cell?

## Parts of a Cell

Cells come in many shapes and sizes. Cells have many different functions. But all cells have the following parts in common.

### The Cell Membrane and Cytoplasm

All cells are surrounded by a cell membrane. The **cell membrane** is a protective layer that covers the cell's surface and acts as a barrier. It separates the cell's contents from its environment. The cell membrane also controls materials going into and out of the cell. Inside the cell is a fluid. This fluid and almost all of its contents are called the *cytoplasm* (SIET oh PLAZ uhm).

### Organelles

Cells have organelles that carry out various life processes. **Organelles** are structures that perform specific functions within the cell. Different types of cells have different organelles. Most organelles are surrounded by membranes. For example, the algal cell in **Figure 4** has membrane-bound organelles. Some organelles float in the cytoplasm. Other organelles are attached to membranes or other organelles.

**Reading Check** What are organelles?

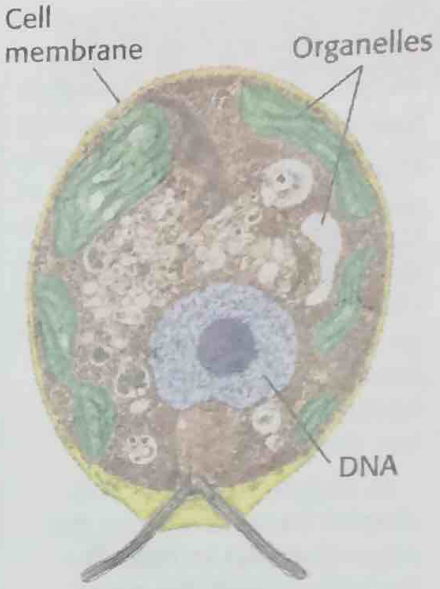



**Figure 4** *This green alga has organelles. The organelles and the fluid surrounding them make up the cytoplasm.*

### Genetic Material

All cells contain DNA (deoxyribonucleic acid) at some point in their life. *DNA* is the genetic material that carries information needed to make new cells and new organisms. DNA is passed on from parent cells to new cells and controls the activities of a cell. **Figure 5** shows the DNA of a bacterium.

In some cells, the DNA is enclosed inside an organelle called the **nucleus.** For example, your cells have a nucleus. In contrast, bacterial cells do *not* have a nucleus.

In humans, mature red blood cells lose their DNA. Red blood cells are made inside bones. When red blood cells are first made, they have a nucleus with DNA. But before they enter the bloodstream, red blood cells lose their nucleus and DNA. They survive with no new instructions from their DNA.

**cell membrane** a phospholipid layer that covers a cell's surface; acts as a barrier between the inside of a cell and the cell's environment

**organelle** one of the small bodies in a cell's cytoplasm that are specialized to perform a specific function

**nucleus** in a eukaryotic cell, a membrane-bound organelle that contains the cell's DNA and that has a role in processes such as growth, metabolism, and reproduction

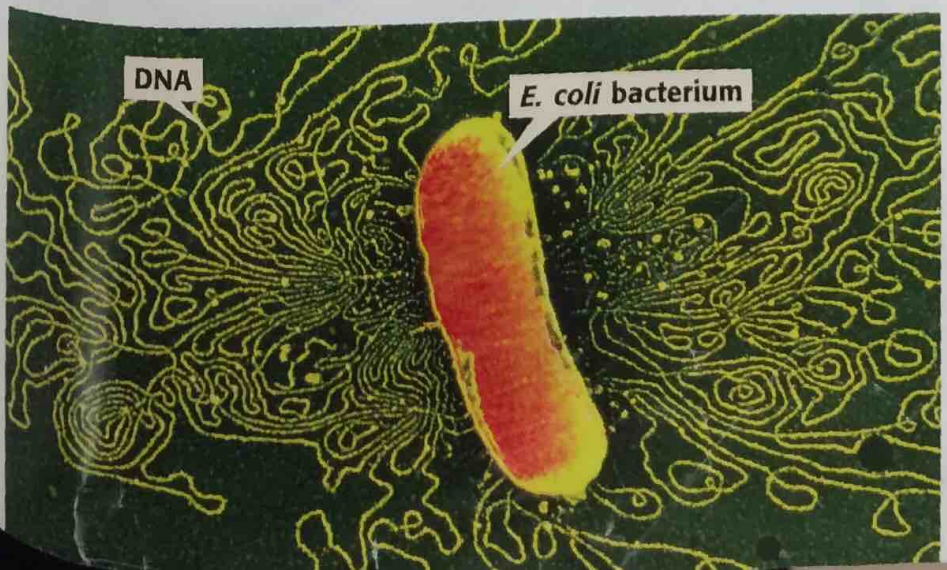



**Figure 5** *This photo shows an* Escherichia coli *bacterium. The bacterium's cell membrane has been treated so that the cell's DNA is released.*

## Two Kinds of Cells

All cells have cell membranes, organelles, cytoplasm, and DNA in common. But there are two basic types of cells—cells without a nucleus and cells with a nucleus. Cells with no nucleus are *prokaryotic* (proh KAR ee AHT ik) *cells*. Cells that have a nucleus are *eukaryotic* (yoo KAR ee AHT ik) *cells*. Prokaryotic cells are further classified into two groups: *eubacteria* (yoo bak TIR ee uh) and *archaebacteria* (AHR kee bak TIR ee uh).

## Prokaryotes: Eubacteria and Archaebacteria

Eubacteria and archaebacteria are prokaryotes (pro KAR ee ohts). **Prokaryotes** are single-celled organisms that do not have a nucleus or membrane-bound organelles.

### Eubacteria

The most common prokaryotes are eubacteria (or just *bacteria*). Bacteria are the world's smallest cells. These tiny organisms live almost everywhere. Bacteria do not have a nucleus, but they do have DNA. A bacteria's DNA is a long, circular molecule, shaped sort of like a rubber band. Bacteria have no membrane-covered organelles. But they do have ribosomes. *Ribosomes* are tiny, round organelles made of protein and other material.

Bacteria also have a strong, weblike exterior cell wall. This wall helps the cell retain its shape. A bacterium's cell membrane is just inside the cell wall. Together, the cell wall and cell membrane allow materials into and out of the cell.

Some bacteria live in the soil and water. Others live in, or on, other organisms. For example, you have bacteria living on your skin and teeth. You also have bacteria living in your digestive system. These bacteria help the process of digestion. A typical bacterial cell is shown in **Figure 6.**

**prokaryote** an organism that consists of a single cell that does not have a nucleus

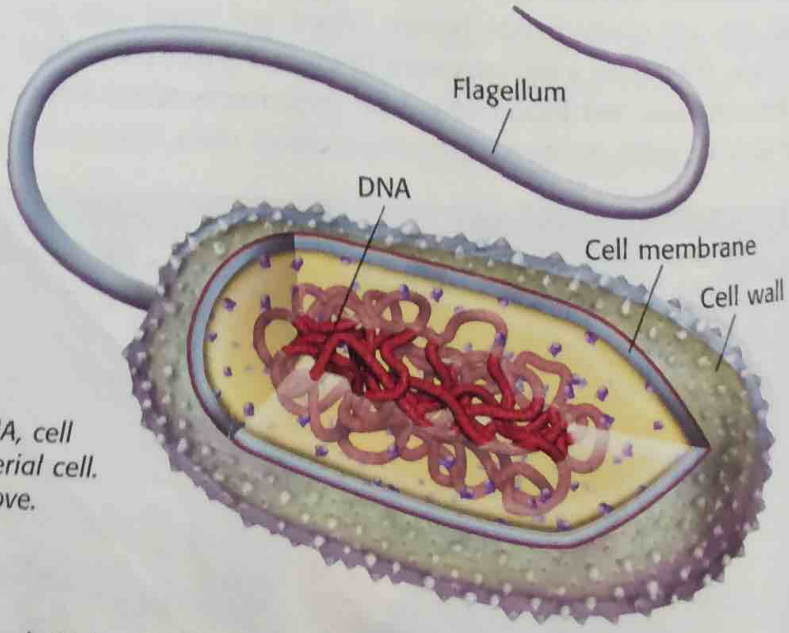



**Figure 6** *This diagram shows the DNA, cell membrane, and cell wall of a eubacterial cell. The flagellum helps the bacterium move.*

### Quick Lab

**Bacteria in Your Lunch?**

Most of the time, you don't want bacteria in your food. Many bacteria make toxins that will make you sick. However, some foods—such as yogurt—are supposed to have bacteria in them! The bacteria in these foods are not dangerous.

In yogurt, masses of rod-shaped bacteria feed on the sugar (lactose) in milk. The bacteria convert the sugar into lactic acid. Lactic acid causes milk to thicken. This thickened milk makes yogurt.

1. Using a **cotton swab**, put a **small dot of yogurt** on a **microscope slide.**
2. Add a **drop of water.** Use the cotton swab to stir.
3. Add a **coverslip.**
4. Use a **microscope** to examine the slide. Draw what you observe.

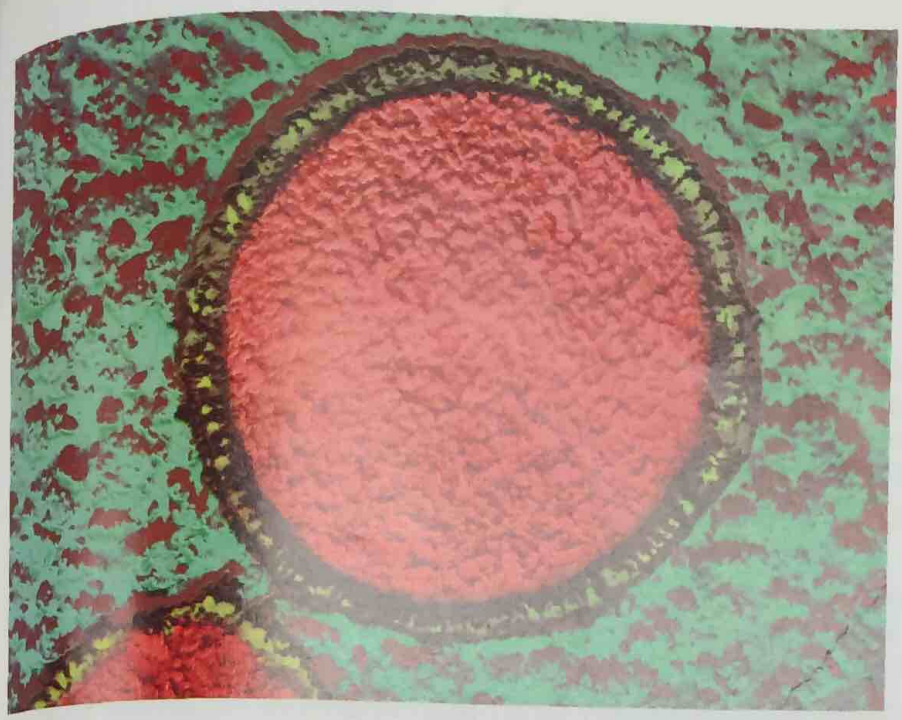


**Figure 7** *This photograph, taken with an electron microscope, is of an archaebacterium that lives in the very high temperatures of deep-sea volcanic vents. The photograph has been colored so that the cell wall is green and the cell contents are pink.*

## Archaebacteria

The second kind of prokaryote are the archaebacteria. These organisms are also called *archaea* (ahr KEE uh). Archaebacteria are similar to bacteria in some ways. For example, both are single-celled organisms. Both have ribosomes, a cell membrane, and circular DNA. And both lack a nucleus and membrane-bound organelles. But archaebacteria are different from bacteria. For example, archaebacterial ribosomes are different from eubacterial ribosomes.

Archaebacteria are similar to eukaryotic cells in some ways, too. For example, archaebacterial ribosomes are more like the ribosomes of eukaryotic cells. But archaebacteria also have some features that no other cells have. For example, the cell wall and cell membranes of archaebacteria are different from the cell walls of other organisms. And some archaebacteria live in places where no other organisms could live.

Three types of archaebacteria are *heat-loving*, *salt-loving*, and *methane-making*. Methane is a kind of gas frequently found in swamps. Heat-loving and salt-lovng archaebacteria are sometimes called extremophiles. *Extremophiles* live in places where conditions are extreme. They live in very hot water, such as in hot springs, or where the water is extremely salty. **Figure 7** shows one kind of methane-making archaebacteria that lives deep in the ocean near volcanic vents. The temperature of the water from those vents is extreme: it is above the boiling point of water at sea level.

**Reading Check** **What is one difference between eubacteria and archaebacteria?**

It . . .
r first?

**CONNECTION TO Social Studies**

**Where Do They Live?**
While most archaebacteria live in extreme environments, scientists have found that archaebacteria live almost everywhere. Do research about archaebacteria. Select one kind of archaebacteria. Create a poster showing the geographical location where the organism lives, describing its physical environment, and explaining how it survives in its environment.

**ACTIVITY**

**eukaryote** an organism made up of cells that have a nucleus enclosed by a membrane; eukaryotes include animals, plants, and fungi, but not archaebacteria or eubacteria

## Eukaryotic Cells and Eukaryotes

Eukaryotic cells are the largest cells. Most eukaryotic cells are still microscopic, but they are about 10 times larger than most bacterial cells. A typical eukaryotic cell is shown in **Figure 8.**

Unlike bacteria and archaebacteria, eukaryotic cells have a nucleus. The nucleus is one kind of membrane-bound organelle. A cell's nucleus holds the cell's DNA. Eukaryotic cells have other membrane-bound organelles as well. Organelles are like the different organs in your body. Each kind of organelle has a specific job in the cell. Together, organelles, such as the ones shown in **Figure 8,** perform all the processes necessary for life.

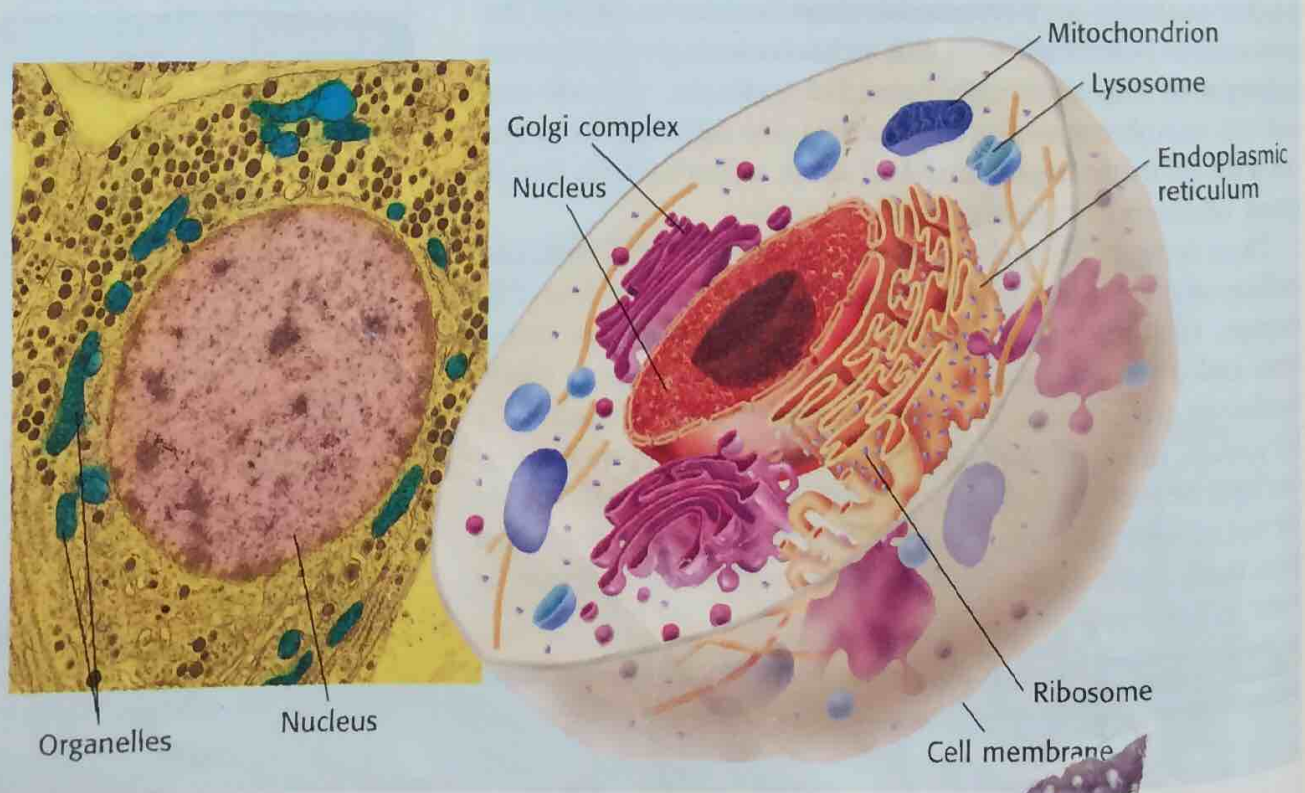
All living things that are not bacteria or archaebacteria are made of one or more eukaryotic cells. Organisms made of eukaryotic cells are called **eukaryotes.** Many eukaryotes are multicellular. *Multicellular* means "many cells." Multicellular organisms are usually larger than single-cell organisms. So, most organisms you see with your naked eye are eukaryotes. There are many types of eukaryotes. Animals, including humans, are eukaryotes. So are plants. Some protists, such as amoebas, are single-celled eukaryotes. Other protists, including some types of green algae, are multicellular eukaryotes. Fungi are organisms such as mushrooms or yeasts. Mushrooms are multicellular eukaryotes. Yeasts are single-celled eukaryotes.

**Reading Check** **How are eukaryotes different from prokaryotes?**

**INTERNET ACTIVITY**

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HL5CELW.**

**Figure 8** **Organelles in a Typical Eukaryotic Cell**



SECTION
# Review

## Summary

- Cells were not discovered until microscopes were invented in the 1600s.
- Cell theory states that all organisms are made of cells, the cell is the basic unit of all living things, and all cells come from other cells.
- All cells have a cell membrane, cytoplasm, and DNA.
- Most cells are too small to be seen with the naked eye. A cell's surface area–to-volume ratio limits the size of a cell.
- The two basic kinds of cells are prokaryotic cells and eukaryotic cells. Eukaryotic cells have a nucleus and membrane-bound organelles. Prokaryotic cells do not.
- Prokaryotes are classified as archaebacteria and eubacteria.
- Archaebacterial cell walls and ribosomes are different from the cell walls and ribosomes of other organisms.
- Eukaryotes can be single-celled or multicellular.

### Using Key Terms

1. In your own words, write a definition for the term *organelle*.
2. Use the following terms in the same sentence: *prokaryotic*, *nucleus*, and *eukaryotic*.

### Understanding Key Ideas

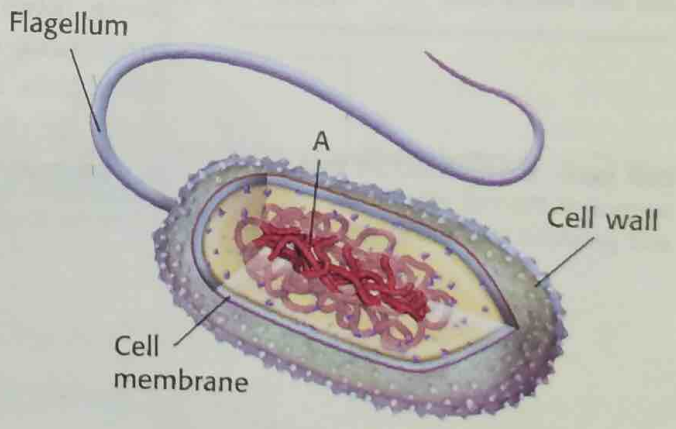
3. Cell size is limited by the
   - **a.** thickness of the cell wall.
   - **b.** size of the cell's nucleus.
   - **c.** cell's surface area–to-volume ratio.
   - **d.** amount of cytoplasm in the cell.
4. What are the three parts of the cell theory?
5. Name three structures that every cell has.
6. Give two ways in which archaebacteria are different from bacteria.

### Critical Thinking

7. **Applying Concepts** You have discovered a new single-celled organism. It has a cell wall, ribosomes, and long, circular DNA. Is it a eukaryote or a prokaryote cell? Explain.
8. **Identifying Relationships** One of your students brings you a cell about the size of the period at the end of this sentence. It is a single cell, but it also forms chains. What characteristics would this cell have if the organism is a eukaryote? If it is a prokaryote? What would you look for first?

### Interpreting Graphics

The picture below shows a particular organism. Use the picture to answer the questions that follow.




9. What type of organism does the picture represent? How do you know?
10. Which structure helps the organism move?
11. What part of the organism does the letter *A* represent?

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