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Cells: The Basic Units of Life

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About the **PHOTO**

Harmful bacteria may invade your body and make you sick. But wait—your white blood cells come to the rescue! In this image, a white blood cell (the large, yellowish cell) reaches out its pseudopod to destroy bacteria (the purple cells). The red discs are red blood cells.



PRE-READING **Activity**



Key-Term Fold Before you read the chapter, create the FoldNote entitled “Key-Term Fold” described in the **Study Skills** section of the Appendix. Write a key term from the chapter on each tab of the key-term fold. Under each tab, write the definition of the key term.





START-UP ACTIVITY

What Are Plants Made Of?

All living things, including plants, are made of cells. What do plant cells look like? Do this activity to find out.

Procedure

1. Tear off a **small leaf** from near the tip of an **Elodea sprig**.
2. Using **forceps**, place the whole leaf in a **drop of water** on a **microscope slide**.
3. Place a **coverslip** on top of the water drop by putting one edge of the coverslip on the slide near the water drop. Next, lower the coverslip slowly so that the coverslip does not trap air bubbles.
4. Place the slide on your **microscope**.
5. Using the lowest-powered lens first, find the plant cells. When you can see the cells under the lower-powered lens, switch to a higher-powered lens.
6. Draw a picture of what you see.

Analysis

1. Describe the shape of the *Elodea* cells. Are all of the cells in the *Elodea* the same?
2. Do you think human cells look like *Elodea* cells? How do you think they are different? How might they be similar?

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 archaeobacteria.
- Explain the difference between prokaryotic cells and eukaryotic cells.

Terms to Learn

cell	nucleus
cell membrane	prokaryote
organelle	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.

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.

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.

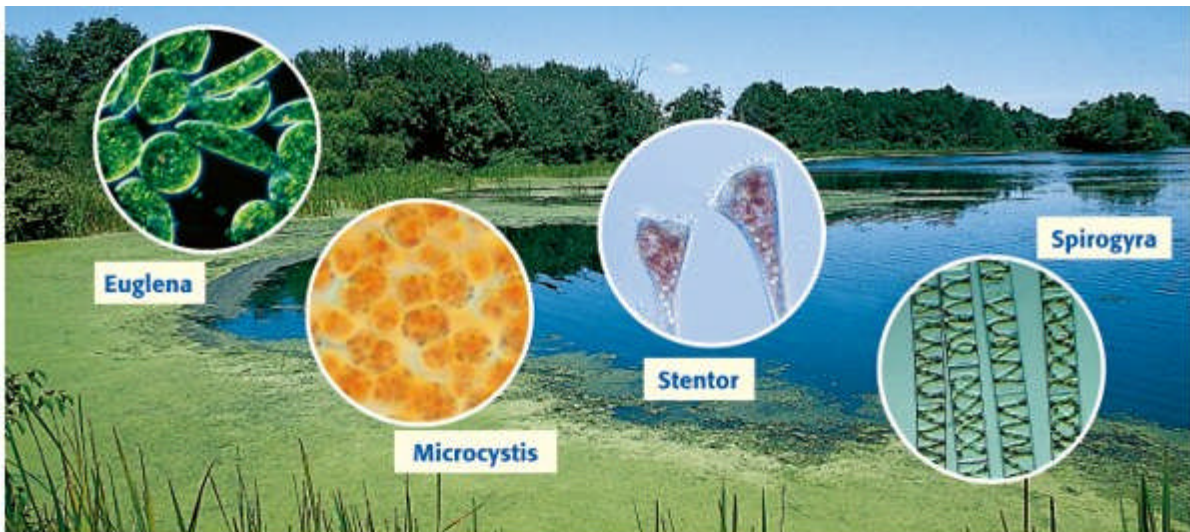


Figure 2 The green area at the edge of the pond is a layer of pond scum. This pond scum contains organisms called protists, such as those shown above.

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:

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

 **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.

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

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

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

Step 2: Calculate the volume.

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

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

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

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

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



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?

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.

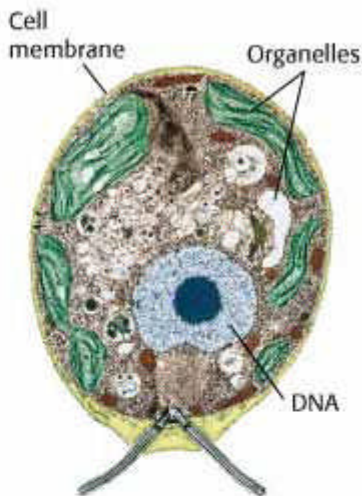


Figure 4 This green alga has organelles. The organelles and the fluid surrounding them make up the cytoplasm.

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

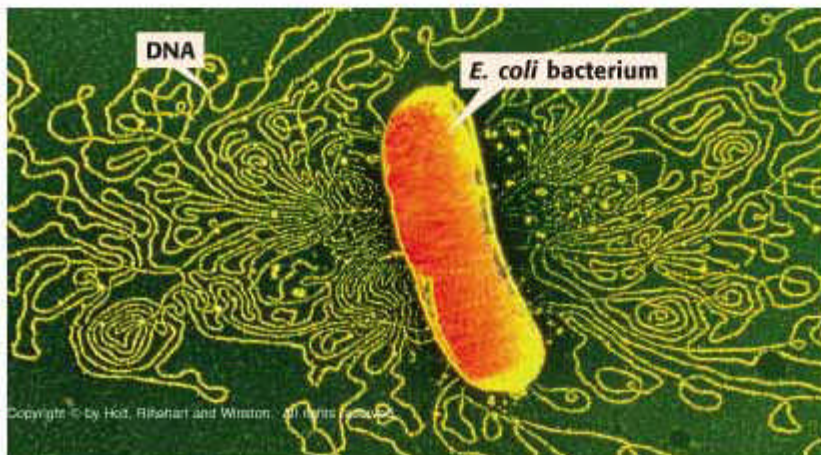


Figure 5 This photo shows an Escherichia coli bacterium. The bacterium's cell membrane has been treated so that the cell's DNA is released.

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.

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

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 *archaeobacteria* (AHR kee bak TIR ee uh).

Prokaryotes: Eubacteria and Archaeobacteria

Eubacteria and archaeobacteria 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**.

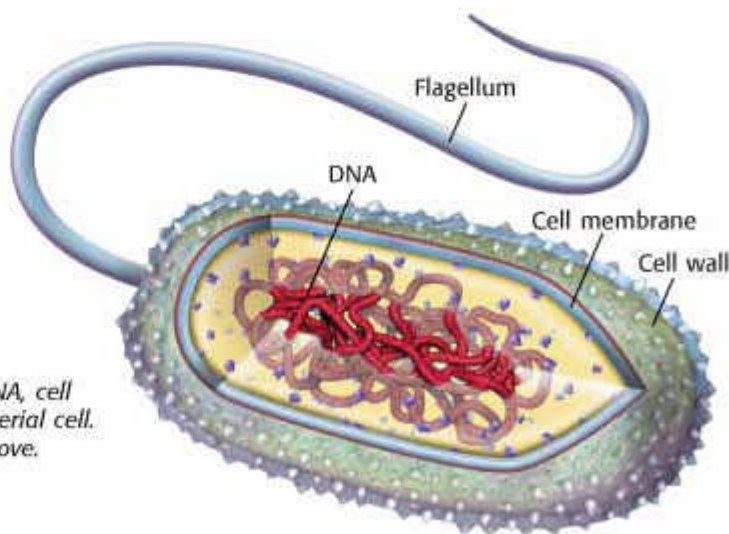


Figure 6 This diagram shows the DNA, cell membrane, and cell wall of a eubacterial cell. The flagellum helps the bacterium move.

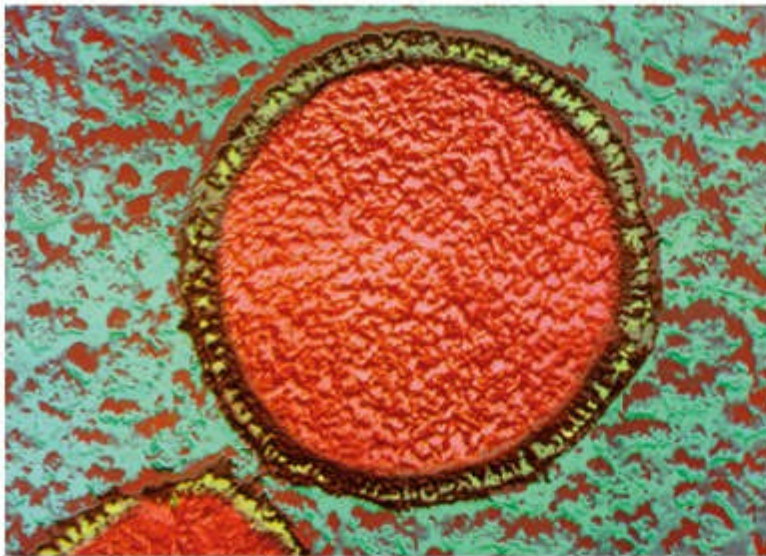


Figure 7 This photograph, taken with an electron microscope, is of an archaeobacterium that lives in the very high temperatures of deep-sea volcanic vents. The photograph has been colored so that the cell wall is green and the cell contents are pink.

Archaeobacteria

The second kind of prokaryote are the archaeobacteria. These organisms are also called *archaea* (ahr KEE uh). Archaeobacteria 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 archaeobacteria are different from bacteria. For example, archaeobacterial ribosomes are different from eubacterial ribosomes.

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

Three types of archaeobacteria are *heat-loving*, *salt-loving*, and *methane-making*. Methane is a kind of gas frequently found in swamps. Heat-loving and salt-loving archaeobacteria 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 archaeobacteria 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 archaeobacteria?

CONNECTION TO Social Studies

Where Do They Live?

While most archaeobacteria live in extreme environments, scientists have found that archaeobacteria live almost everywhere. Do research about archaeobacteria. Select one kind of archaeobacteria. 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 archaeobacteria or eubacteria

INTERNET ACTIVITY

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

Eukaryotic Cells and Eukaryotes

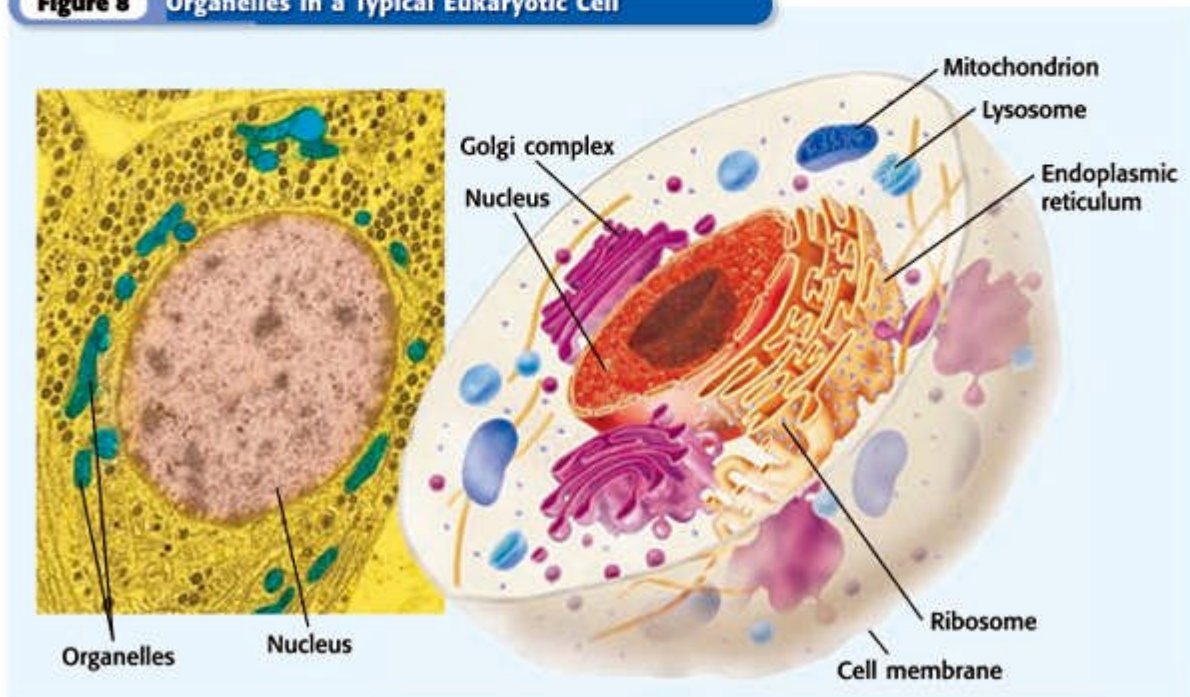
Eukaryotic cells are the largest cells. Most eukaryotic cells are still microscopic, but they are about 10 times larger than most bacterial cells. A typical eukaryotic cell is shown in **Figure 8**.

Unlike bacteria and archaeobacteria, 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 archaeobacteria 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?

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 archaeobacteria and eubacteria.
- Archaeobacterial 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

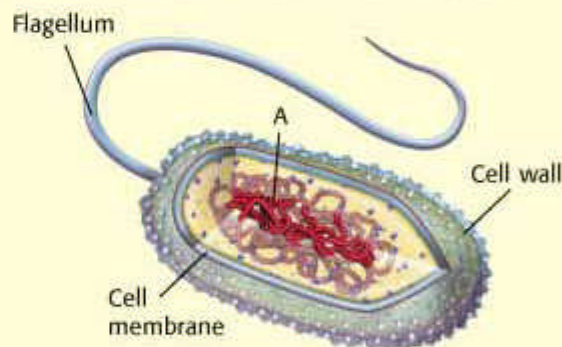
3. Cell size is limited by the
 - a. thickness of the cell wall.
 - b. size of the cell's nucleus.
 - c. cell's surface area-to-volume ratio.
 - d. amount of cytoplasm in the cell.
4. What are the three parts of the cell theory?
5. Name three structures that every cell has.
6. Give two ways in which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

SciLINKS

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Prokaryotic Cells
SciLinks code: HSM1225

READING WARM-UP

Objectives

- Identify the different parts of a eukaryotic cell.
- Explain the function of each part of a eukaryotic cell.

Terms to Learn

cell wall	mitochondrion
ribosome	Golgi complex
endoplasmic reticulum	vesicle
	lysosome

READING STRATEGY

Reading Organizer As you read this section, make a table comparing plant cells and animal cells.

cell wall a rigid structure that surrounds the cell membrane and provides support to the cell

Eukaryotic Cells

Most eukaryotic cells are small. For a long time after cells were discovered, scientists could not see what was going on inside cells. They did not know how complex cells are.

Now, scientists know a lot about eukaryotic cells. These cells have many parts that work together and keep the cell alive.

Cell Wall

Some eukaryotic cells have cell walls. A **cell wall** is a rigid structure that gives support to a cell. The cell wall is the outermost structure of a cell. Plants and algae have cell walls made of cellulose (SEL yoo LOHS) and other materials. *Cellulose* is a complex sugar that most animals can't digest.

The cell walls of plant cells allow plants to stand upright. In some plants, the cells must take in water for the cell walls to keep their shape. When such plants lack water, the cell walls collapse and the plant droops. **Figure 1** shows a cross section of a plant cell and a close-up of the cell wall.

Fungi, including yeasts and mushrooms, also have cell walls. Some fungi have cell walls made of *chitin* (KIE tin). Other fungi have cell walls made from a chemical similar to chitin. Eubacteria and archaeobacteria also have cell walls, but those walls are different from plant or fungal cell walls.

Reading Check What types of cells have cell walls? (See the Appendix for answers to Reading Checks.)

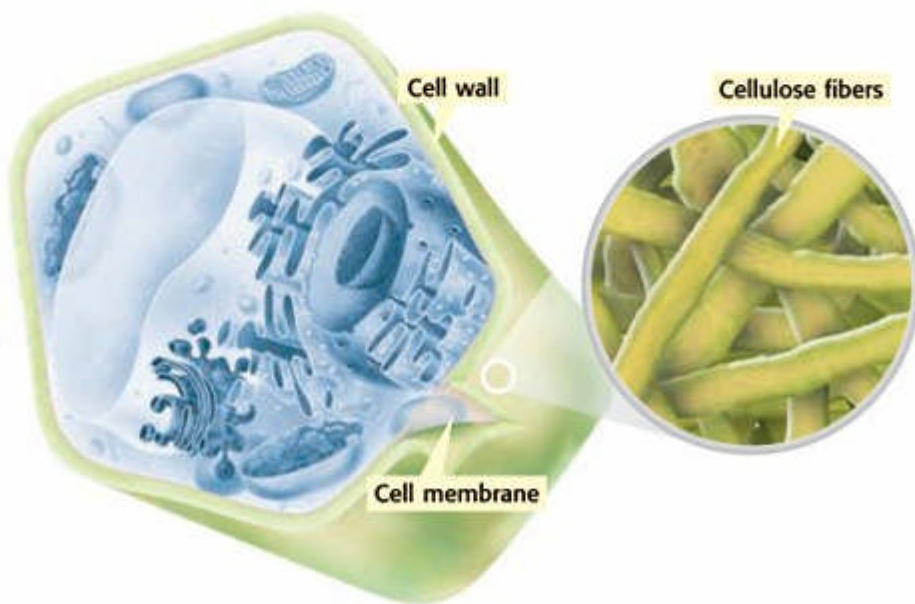


Figure 1 The cell walls of plant cells help plants retain their shape. Plant cell walls are made of cellulose.

Cell Membrane

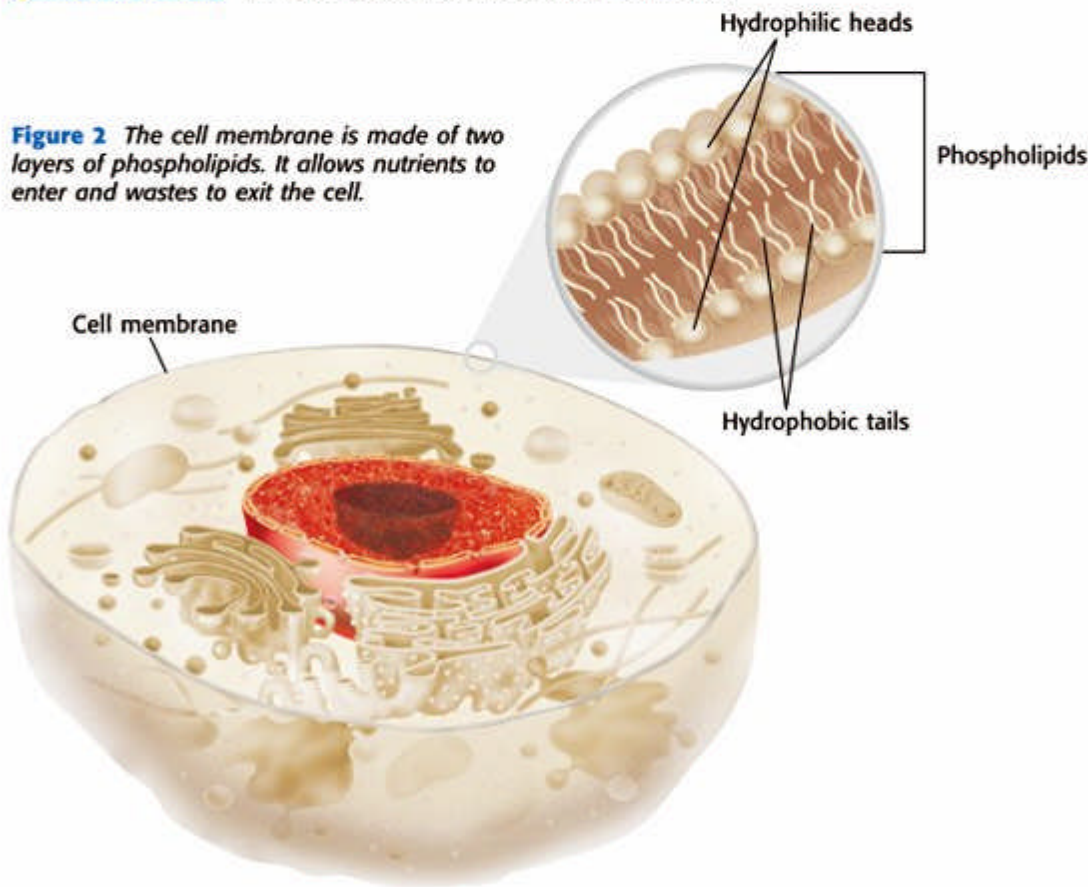
All cells have a cell membrane. The *cell membrane* is a protective barrier that encloses a cell. It separates the cell's contents from the cell's environment. The cell membrane is the outermost structure in cells that lack a cell wall. In cells that have a cell wall, the cell membrane lies just inside the cell wall.

The cell membrane contains proteins, lipids, and phospholipids. *Lipids*, which include fats and cholesterol, are a group of compounds that do not dissolve in water. The cell membrane has two layers of phospholipids (FAHS foh LIP idz), shown in **Figure 2**. A *phospholipid* is a lipid that contains phosphorus. Lipids are “water fearing,” or *hydrophobic*. Lipid ends of phospholipids form the inner part of the membrane. Phosphorus-containing ends of the phospholipids are “water loving,” or *hydrophilic*. These ends form the outer part of the membrane.

Some of the proteins and lipids control the movement of materials into and out of the cell. Some of the proteins form passageways. Nutrients and water move into the cell, and wastes move out of the cell, through these protein passageways.

✓ Reading Check What are two functions of a cell membrane?

Figure 2 The cell membrane is made of two layers of phospholipids. It allows nutrients to enter and wastes to exit the cell.



CONNECTION TO Language Arts

WRITING SKILL

The Great Barrier

In your science

journal, write a science fiction story about tiny travelers inside a person's body. These little explorers need to find a way into or out of a cell to solve a problem. You may need to do research to find out more about how the cell membrane works. Illustrate your story.

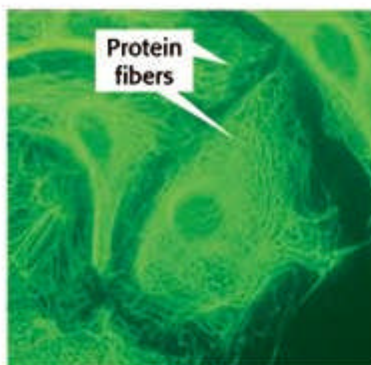


Figure 3 The cytoskeleton, made of protein fibers, helps a cell retain its shape, move in its environment, and move its organelles.

Cytoskeleton

The *cytoskeleton* (SIET oh SKEL uh tuhn) is a web of proteins in the cytoplasm. The cytoskeleton, shown in **Figure 3**, acts as both a muscle and a skeleton. It keeps the cell's membranes from collapsing. The cytoskeleton also helps some cells move.

The cytoskeleton is made of three types of protein. One protein is a hollow tube. The other two are long, stringy fibers. One of the stringy proteins is also found in muscle cells.

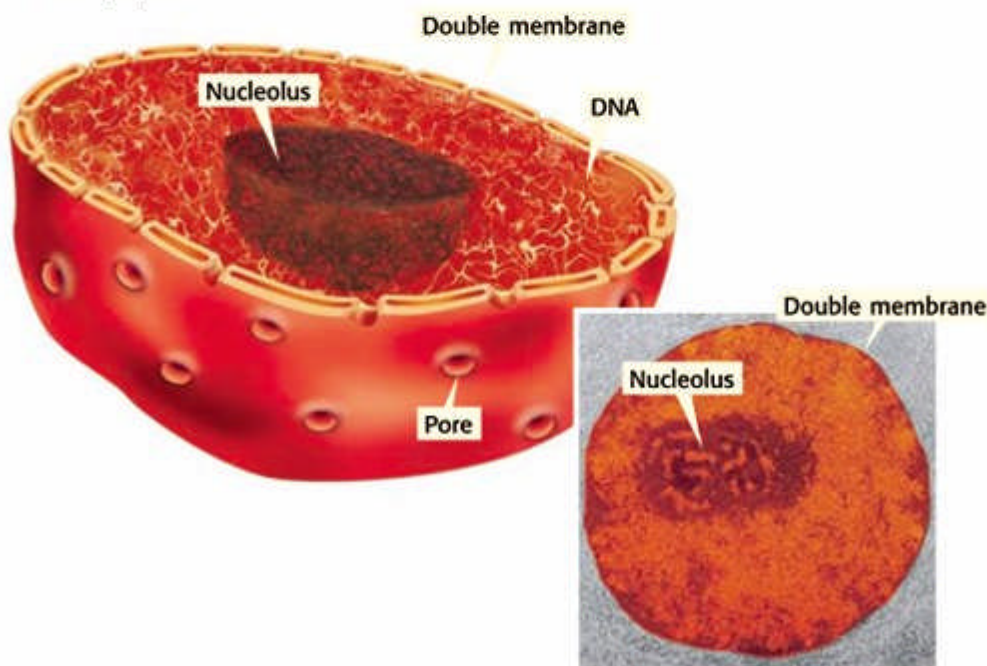
Reading Check What is the cytoskeleton?

Nucleus

All eukaryotic cells have the same basic membrane-bound organelles, starting with the nucleus. The *nucleus* is a large organelle in a eukaryotic cell. It contains the cell's DNA, or genetic material. DNA contains the information on how to make a cell's proteins. Proteins control the chemical reactions in a cell. They also provide structural support for cells and tissues. But proteins are not made in the nucleus. Messages for how to make proteins are copied from the DNA. These messages are then sent out of the nucleus through the membranes.

The nucleus is covered by two membranes. Materials cross this double membrane by passing through pores. **Figure 4** shows a nucleus and nuclear pores. The nucleus of many cells has a dark area called the nucleolus (noo KLEE uh luhs). The *nucleolus* is where a cell begins to make its ribosomes.

Figure 4 The nucleus contains the cell's DNA. Pores allow materials to move between the nucleus and the cytoplasm.



Ribosomes

Organelles that make proteins are called **ribosomes**. Ribosomes are the smallest of all organelles. And there are more ribosomes in a cell than there are any other organelles. Some ribosomes float freely in the cytoplasm. Others are attached to membranes or the cytoskeleton. Unlike most organelles, ribosomes are not covered by a membrane.

Proteins are made within the ribosomes. Proteins are made of amino acids. An *amino acid* is any one of about 20 different organic molecules that are used to make proteins. All cells need proteins to live. All cells have ribosomes.

Endoplasmic Reticulum

Many chemical reactions take place in a cell. Many of these reactions happen on or in the endoplasmic reticulum (EN doh PLAZ mik ri TIK yuh luhm). The **endoplasmic reticulum**, or ER, is a system of folded membranes in which proteins, lipids, and other materials are made. The ER is shown in **Figure 5**.

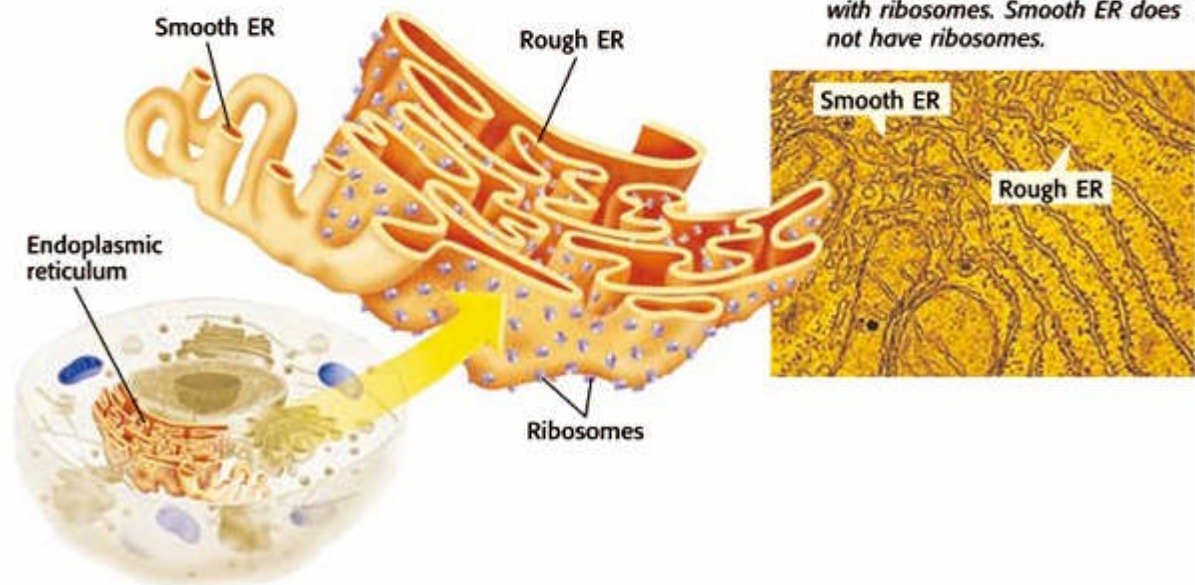
The ER is part of the internal delivery system of the cell. Its folded membrane contains many tubes and passageways. Substances move through the ER to different places in the cell.

Endoplasmic reticulum is either rough ER or smooth ER. The part of the ER covered in ribosomes is rough ER. Rough ER is usually found near the nucleus. Ribosomes on rough ER make many of the cell's proteins. The ER delivers these proteins throughout the cell. ER that lacks ribosomes is smooth ER. The functions of smooth ER include making lipids and breaking down toxic materials that could damage the cell.

ribosome cell organelle composed of RNA and protein; the site of protein synthesis

endoplasmic reticulum 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

Figure 5 The endoplasmic reticulum (ER) is a system of membranes. Rough ER is covered with ribosomes. Smooth ER does not have ribosomes.



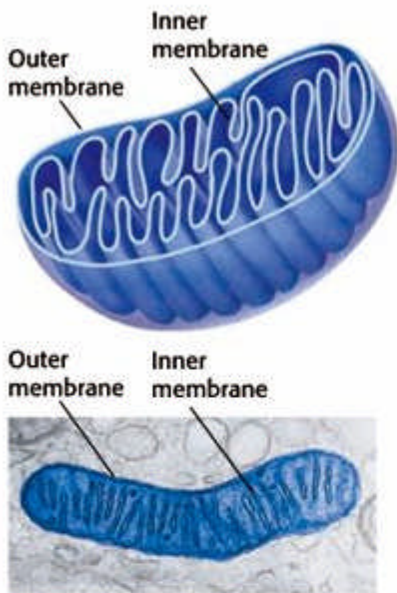


Figure 6 Mitochondria break down sugar and make ATP. ATP is produced on the inner membrane.

mitochondrion in eukaryotic cells, the cell organelle that is surrounded by two membranes and that is the site of cellular respiration

Figure 7 Chloroplasts harness and use the energy of the sun to make sugar. A green pigment—chlorophyll—traps the sun's energy.



Mitochondria

A mitochondrion (MIET oh KAHN drie uhn) is the main power source of a cell. A **mitochondrion** is the organelle in which sugar is broken down to produce energy. Mitochondria are covered by two membranes, as shown in **Figure 6**. Energy released by mitochondria is stored in a substance called *ATP* (adenosine triphosphate). The cell then uses *ATP* to do work. *ATP* can be made at several places in a cell. But most of a cell's *ATP* is made in the inner membrane of the cell's mitochondria.

Most eukaryotic cells have mitochondria. Mitochondria are the size of some bacteria. Like bacteria, mitochondria have their own DNA, and mitochondria can divide within a cell.

Reading Check Where is most of a cell's *ATP* made?

Chloroplasts

Animal cells cannot make their own food. Plants and algae are different. They have chloroplasts (KLAWR uh PLASTS) in some of their cells. *Chloroplasts* are organelles in plant and algae cells in which photosynthesis takes place. Like mitochondria, chloroplasts have two membranes and their own DNA. A chloroplast is shown in **Figure 7**. *Photosynthesis* is the process by which plants and algae use sunlight, carbon dioxide, and water to make sugar and oxygen.

Chloroplasts are green because they contain *chlorophyll*, a green pigment. Chlorophyll is found inside the inner membrane of a chloroplast. Chlorophyll traps the energy of sunlight, which is used to make sugar. The sugar produced by photosynthesis is then used by mitochondria to make *ATP*.

Golgi Complex

The organelle that packages and distributes proteins is called the **Golgi complex** (GOHL jee KAHM PLEKS). It is named after Camillo Golgi, the Italian scientist who first identified the organelle.

The Golgi complex looks like smooth ER, as shown in **Figure 8**. Lipids and proteins from the ER are delivered to the Golgi complex. There, the lipids and proteins may be modified to do different jobs. The final products are enclosed in a piece of the Golgi complex's membrane. This membrane pinches off to form a small bubble. The bubble transports its contents to other parts of the cell or out of the cell.

Cell Compartments

The bubble that forms from the Golgi complex's membrane is a vesicle. A **vesicle** (VES i kuhl) is a small sac that surrounds material to be moved into or out of a cell. All eukaryotic cells have vesicles. Vesicles also move material within a cell. For example, vesicles carry new protein from the ER to the Golgi complex. Other vesicles distribute material from the Golgi complex to other parts of the cell. Some vesicles form when part of the cell membrane surrounds an object outside the cell.

Golgi complex cell organelle that helps make and package materials to be transported out of the cell

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

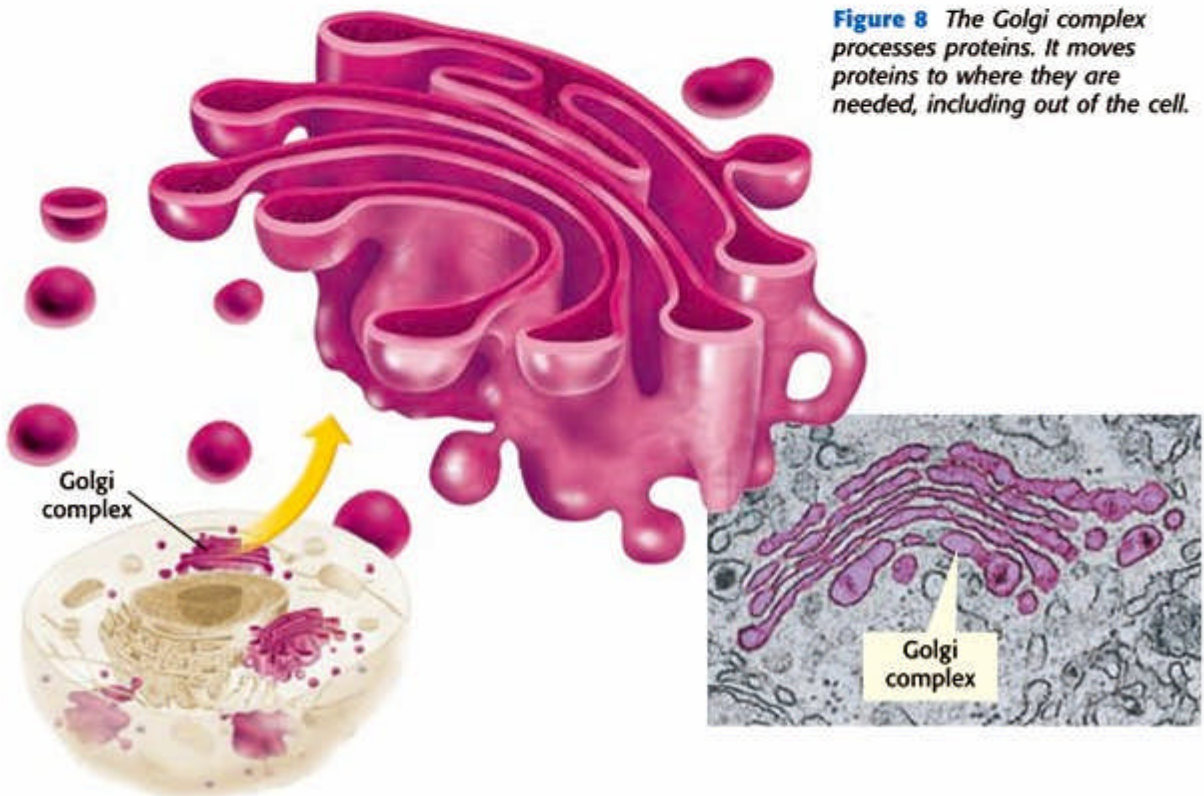


Figure 8 The Golgi complex processes proteins. It moves proteins to where they are needed, including out of the cell.

Figure 9
Lysosomes digest materials inside a cell. In plant and fungal cells, vacuoles often perform the same function.



lysosome a cell organelle that contains digestive enzymes.

Cellular Digestion

Lysosomes (LIE suh SOHMZ) are vesicles that are responsible for digestion inside a cell. **Lysosomes** are organelles that contain digestive enzymes. They destroy worn-out or damaged organelles, get rid of waste materials, and protect the cell from foreign invaders. Lysosomes, which come in a wide variety of sizes and shapes, are shown in **Figure 9**.









Lysosomes are found mainly in animal cells. When eukaryotic cells engulf particles, they enclose the particles in vesicles. Lysosomes bump into these vesicles and pour enzymes into them. These enzymes digest the particles in the vesicles.

Reading Check Why are lysosomes important?

Vacuoles

A *vacuole* (VAK yoo OHL) is a large vesicle. In plant and fungal cells, some vacuoles act like large lysosomes. They store digestive enzymes and aid in digestion within the cell. Other vacuoles in plant cells store water and other liquids. Vacuoles that are full of water, such as the one in **Figure 9**, help support the cell. Some plants wilt when their vacuoles lose water. **Table 1** shows some organelles and their functions.

Table 1 Organelles and Their Functions

 <p>Nucleus the organelle that contains the cell's DNA and is the control center of the cell</p>	 <p>Chloroplast the organelle that uses the energy of sunlight to make food</p>
 <p>Ribosome the organelle in which amino acids are hooked together to make proteins</p>	 <p>Golgi complex the organelle that processes and transports proteins and other materials out of cell</p>
 <p>Endoplasmic reticulum the organelle that makes lipids, breaks down drugs and other substances, and packages proteins for Golgi complex</p>	 <p>Vacuole the organelle that stores water and other materials</p>
 <p>Mitochondria the organelle that breaks down food molecules to make ATP</p>	 <p>Lysosome the organelle that digests food particles, wastes, cell parts, and foreign invaders</p>

SECTION Review

Summary



- Eukaryotic cells have organelles that perform functions that help cells remain alive.
- All cells have a cell membrane. Some cells have a cell wall. Some cells have a cytoskeleton.
- The nucleus of a eukaryotic cell contains the cell's genetic material, DNA.
- Ribosomes are the organelles that make proteins. Ribosomes are not covered by a membrane.
- The endoplasmic reticulum (ER) and the Golgi complex make and process proteins before the proteins are transported to other parts of the cell or out of the cell.
- Mitochondria and chloroplasts are energy-producing organelles.
- Lysosomes are organelles responsible for digestion within a cell. In plant cells, organelles called *vacuoles* store cell materials and sometimes act like large lysosomes.

Using Key Terms

1. In your own words, write a definition for each of the following terms: *ribosome*, *lysosome*, and *cell wall*.

Understanding Key Ideas

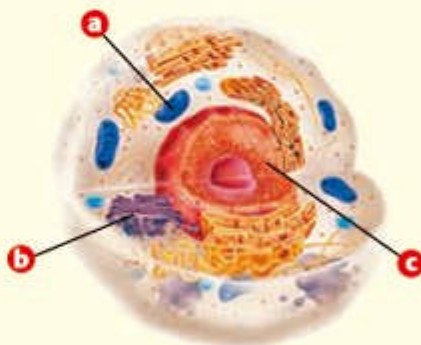
2. Which of the following are found mainly in animal cells?
 - a. mitochondria
 - b. lysosomes
 - c. ribosomes
 - d. Golgi complexes
3. What is the function of a Golgi complex? What is the function of the endoplasmic reticulum?

Critical Thinking

4. **Making Comparisons** Describe three ways in which plant cells differ from animal cells.
5. **Applying Concepts** Every cell needs ribosomes. Explain why.
6. **Predicting Consequences** A certain virus attacks the mitochondria in cells. What would happen to a cell if all of its mitochondria were destroyed?
7. **Expressing Opinions** Do you think that having chloroplasts gives plant cells an advantage over animal cells? Support your opinion.

Interpreting Graphics

Use the diagram below to answer the questions that follow.



8. Is this a diagram of a plant cell or an animal cell? Explain how you know.
9. What organelle does the letter *b* refer to?

SCILINKS.

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For a variety of links related to this chapter, go to www.scilinks.org

Topic: Eukaryotic Cells
SciLinks code: HSM0541

READING WARM-UP

Objectives

- List three advantages of being multicellular.
- Describe the four levels of organization in living things.
- Explain the relationship between the structure and function of a part of an organism.

Terms to Learn

tissue	organism
organ	structure
organ system	function

READING STRATEGY

Paired Summarizing Read this section silently. In pairs, take turns summarizing the material. Stop to discuss ideas that seem confusing.

The Organization of Living Things

In some ways, organisms are like machines. Some machines have just one part. But most machines have many parts. Some organisms exist as a single cell. Other organisms have many—even trillions—of cells.

Most cells are smaller than the period that ends this sentence. Yet, every cell in every organism performs all the processes of life. So, are there any advantages to having many cells?

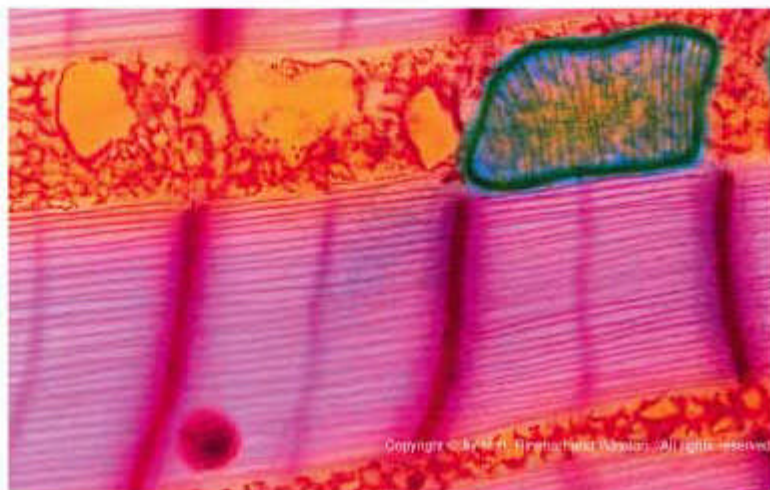
The Benefits of Being Multicellular

You are a *multicellular organism*. This means that you are made of many cells. Multicellular organisms grow by making more small cells, not by making their cells larger. For example, an elephant is bigger than you are, but its cells are about the same size as yours. An elephant just has more cells than you do. Some benefits of being multicellular are the following:

- **Larger Size** Many multicellular organisms are small. But they are usually larger than single-celled organisms. Larger organisms are prey for fewer predators. Larger predators can eat a wider variety of prey.
- **Longer Life** The life span of a multicellular organism is not limited to the life span of any single cell.
- **Specialization** Each type of cell has a particular job. Specialization makes the organism more efficient. For example, the cardiac muscle cell in **Figure 1** is a specialized muscle cell. Heart muscle cells contract and make the heart pump blood.

Reading Check List three advantages of being multicellular. (See the Appendix for answers to Reading Checks.)

Figure 1 This photomicrograph shows a small part of one heart muscle cell. The green line surrounds one of many mitochondria, the powerhouses of the cell. The pink areas are muscle filaments.



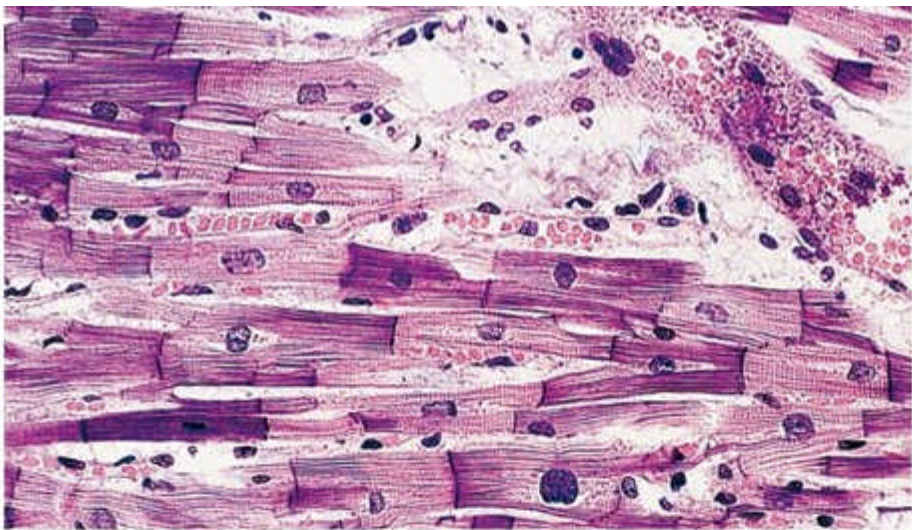


Figure 2 This photomicrograph shows cardiac muscle tissue. Cardiac muscle tissue is made up of many cardiac cells.

Cells Working Together

A **tissue** is a group of cells that work together to perform a specific job. The material around and between the cells is also part of the tissue. The cardiac muscle tissue, shown in **Figure 2**, is made of many cardiac muscle cells. Cardiac muscle tissue is just one type of tissue in a heart.

Animals have four basic types of tissues: nerve tissue, muscle tissue, connective tissue, and protective tissue. In contrast, plants have three types of tissues: transport tissue, protective tissue, and ground tissue. Transport tissue moves water and nutrients through a plant. Protective tissue covers the plant. It helps the plant retain water and protects the plant against damage. Photosynthesis takes place in ground tissue.

Tissues Working Together

A structure that is made up of two or more tissues working together to perform a specific function is called an **organ**. For example, your heart is an organ. It is made mostly of cardiac muscle tissue. But your heart also has nerve tissue and tissues of the blood vessels that all work together to make your heart the powerful pump that it is.

Another organ is your stomach. It also has several kinds of tissue. In the stomach, muscle tissue makes food move in and through the stomach. Special tissues make chemicals that help digest your food. Connective tissue holds the stomach together, and nervous tissue carries messages back and forth between the stomach and the brain. Other organs include the intestines, brain, and lungs.

Plants also have different kinds of tissues that work together as organs. A leaf is a plant organ that contains tissue that traps light energy to make food. Other examples of plant organs are stems and roots.

 **Reading Check** What is an organ?

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

MATH PRACTICE

A Pet Protist

Imagine that you have a tiny box-shaped protist for a pet. To care for your pet protist properly, you have to figure out how much to feed it. The dimensions of your protist are roughly $25\ \mu\text{m} \times 20\ \mu\text{m} \times 2\ \mu\text{m}$. If seven food particles per second can enter through each square micrometer of surface area, how many particles can your protist eat in 1 min?

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

organism a living thing; anything that can carry out life processes independently

structure the arrangement of parts in an organism

function the special, normal, or proper activity of an organ or part

Organs Working Together

A group of organs working together to perform a particular function is called an **organ system**. Each organ system has a specific job to do in the body.

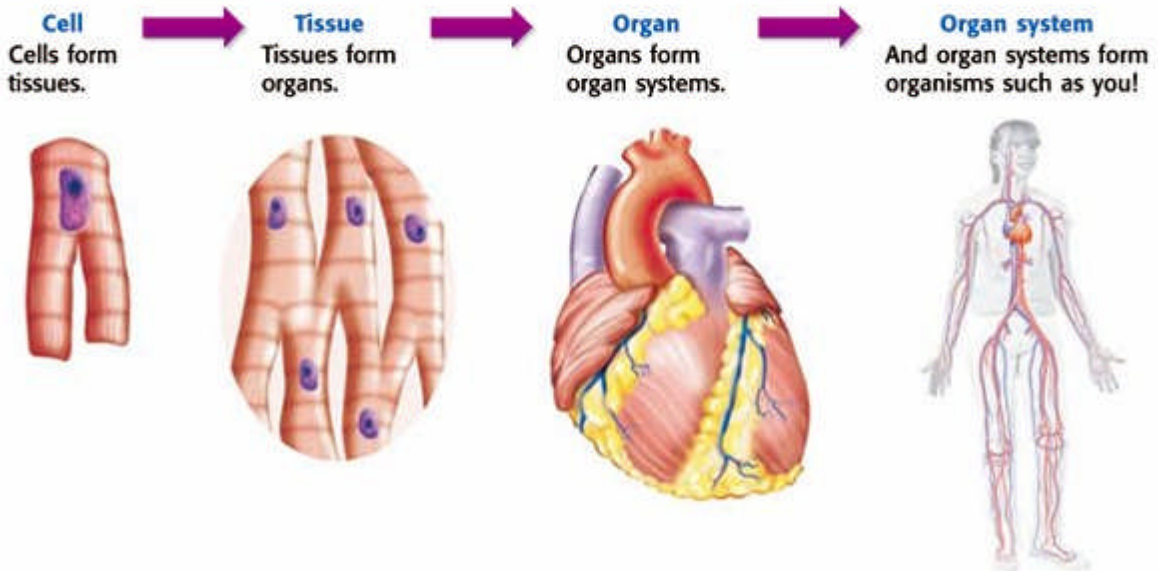
For example, the digestive system is made up of several organs, including the stomach and intestines. The digestive system's job is to break down food into small particles. Other parts of the body then use these small particles as fuel. In turn, the digestive system depends on the respiratory and cardiovascular systems for oxygen. The cardiovascular system, shown in **Figure 3**, includes organs and tissues such as the heart and blood vessels. Plants also have organ systems. They include leaf systems, root systems, and stem systems.

 **Reading Check** List the levels of organization in living things.

Organisms

Anything that can perform life processes by itself is an **organism**. An organism made of a single cell is called a *unicellular organism*. Bacteria, most protists, and some kinds of fungi are unicellular. Although some of these organisms live in colonies, they are still unicellular. They are unicellular organisms living together, and all of the cells in the colony are the same. Each cell must carry out all life processes in order for that cell to survive. In contrast, even the simplest multicellular organism has specialized cells that depend on each other for the organism to survive.

Figure 3 Levels of Organization in the Cardiovascular System

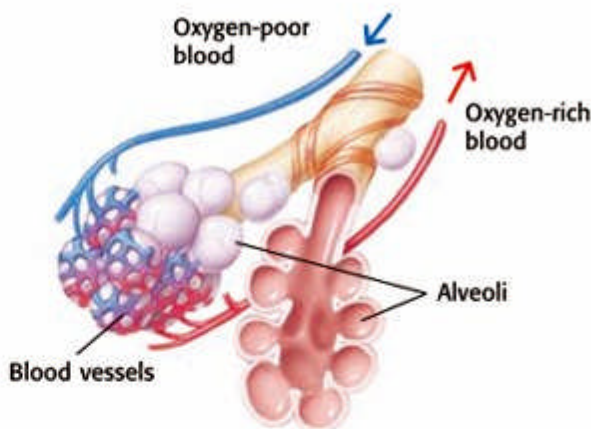


Structure and Function

In organisms, structure and function are related. **Structure** is the arrangement of parts in an organism. It includes the shape of a part and the material of which the part is made. **Function** is the job the part does. For example, the structure of the lungs is a large, spongy sac. In the lungs, there are millions of tiny air sacs called *alveoli*. Blood vessels wrap around the alveoli, as shown in **Figure 4**. Oxygen from air in the alveoli enters the blood. Blood then brings oxygen to body tissues. Also, in the alveoli, carbon dioxide leaves the blood and is exhaled.

The structures of alveoli and blood vessels enable them to perform a function. Together, they bring oxygen to the body and get rid of its carbon dioxide.

Figure 4 The Structure and Function of Alveoli



SECTION Review

Summary

- Advantages of being multicellular are larger size, longer life, and cell specialization.
- Four levels of organization are cell, tissue, organ, and organ system.
- A *tissue* is a group of cells working together. An *organ* is two or more tissues working together. An *organ system* is two or more organs working together.
- In organisms, a part's structure and function are related.

Using Key Terms

- Use each of the following terms in a separate sentence: *tissue*, *organ*, and *function*.

Understanding Key Ideas

- What are the four levels of organization in living things?
 - cell, multicellular, organ, organ system
 - single cell, multicellular, tissue, organ
 - larger size, longer life, specialized cells, organs
 - cell, tissue, organ, organ system

Math Skills

- One multicellular organism is a cube. Each of its sides is 3 cm long. Each of its cells is 1 cm^3 . How many cells does it have? If each side doubles in length, how many cells will it then have?

Critical Thinking

- Applying Concepts** Explain the relationship between structure and function. Use alveoli as an example. Be sure to include more than one level of organization.
- Making Inferences** Why can multicellular organisms be more complex than unicellular organisms? Use the three advantages of being multicellular to help explain your answer.

SciLINKS

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Topic: Organization of Life
SciLinks code: HSM1080

Model-Making Lab



OBJECTIVES

Explore why a single-celled organism cannot grow to the size of an elephant.

Create a model of a cell to illustrate the concept of surface area-to-volume ratio.

MATERIALS

- calculator (optional)
- cubic cell patterns
- heavy paper or poster board
- sand, fine
- scale or balance
- scissors
- tape, transparent

SAFETY



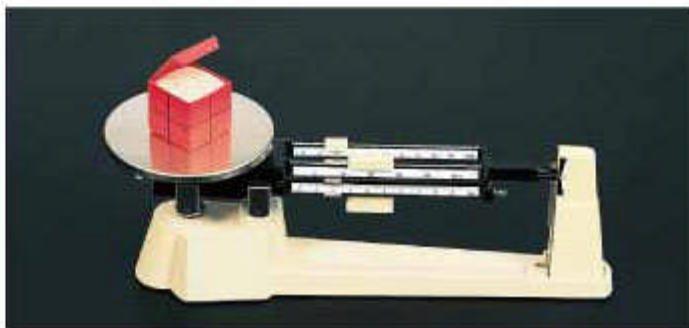
Elephant-Sized Amoebas?

An amoeba is a single-celled organism. Like most cells, amoebas are microscopic. Why can't amoebas grow as large as elephants? If an amoeba grew to the size of a quarter, the amoeba would starve to death. To understand how this can be true, build a model of a cell and see for yourself.



Procedure

- 1 Use heavy paper or poster board to make four cube-shaped cell models from the patterns supplied by your teacher. Cut out each cell model, fold the sides to make a cube, and tape the tabs on the sides. The smallest cell model has sides that are each one unit long. The next larger cell has sides of two units. The next cell has sides of three units, and the largest cell has sides of four units. These paper models represent the cell membrane, the part of a cell's exterior through which food and wastes pass.





Data Table for Measurements

Length of side	Area of one side ($A = S \times S$)	Total surface area of cube cell ($TA = S \times S \times 6$)	Volume of cube cell ($V = S \times S \times S$)	Mass of filled cube cell
1 unit	1 unit ²	6 unit ²	1 unit ³	
2 unit				
3 unit				
4 unit				

Key to Formula Symbols

- S = the length of one side
- A = area
- 6 = number of sides
- V = volume
- TA = total area

- 2 Copy the data table shown above. Use each formula to calculate the data about your cell models. Record your calculations in the table. Calculations for the smallest cell have been done for you.
- 3 Carefully fill each model with fine sand until the sand is level with the top edge of the model. Find the mass of the filled models by using a scale or a balance. What does the sand in your model represent?
- 4 Record the mass of each filled cell model in your Data Table for Measurements. (Always remember to use the appropriate mass unit.)

- 4 **Interpreting Information** As a cell grows larger, does the total surface area-to-mass ratio increase, decrease, or stay the same?
- 5 **Drawing Conclusions** Which is better able to supply food to all the cytoplasm of the cell: the cell membrane of a small cell or the cell membrane of a large cell? Explain your answer.
- 6 **Evaluating Data** In the experiment, which is better able to feed all of the cytoplasm of the cell: the cell membrane of a cell that has high mass or the cell membrane of a cell that has low mass? You may explain your answer in a verbal presentation to the class, or you may choose to write a report and illustrate it with drawings of your models.

Analyze the Results

- 1 **Constructing Tables** Make a data table like the one shown at right.
- 2 **Organizing Data** Use the data from your Data Table for Measurements to find the ratios for each of your cell models. For each of the cell models, fill in the Data Table for Ratios .

Draw Conclusions

- 3 **Interpreting Information** As a cell grows larger, does the ratio of total surface area to volume increase, decrease, or stay the same?

Data Table for Ratios

Length of side	Ratio of total surface area to volume	Ratio of total surface area to mass
1 unit		
2 unit		
3 unit		
4 unit		

DO NOT WRITE IN BOOK



Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

cell	organ
cell membrane	prokaryote
organelles	eukaryote
cell wall	tissue
structure	function

- 1 A(n) ___ is the most basic unit of all living things.
- 2 The job that an organ does is the ___ of that organ.
- 3 Ribosomes and mitochondria are types of ___.
- 4 A(n) ___ is an organism whose cells have a nucleus.
- 5 A group of cells working together to perform a specific function is a(n) ___.
- 6 Only plant cells have a(n) ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

- 7 Which of the following best describes an organ?
 - a. a group of cells that work together to perform a specific job
 - b. a group of tissues that belong to different systems
 - c. a group of tissues that work together to perform a specific job
 - d. a body structure, such as muscles or lungs
- 8 The benefits of being multicellular include
 - a. small size, long life, and cell specialization.
 - b. generalized cells, longer life, and ability to prey on small animals.
 - c. larger size, more enemies, and specialized cells.
 - d. longer life, larger size, and specialized cells.
- 9 In eukaryotic cells, which organelle contains the DNA?
 - a. nucleus
 - b. Golgi complex
 - c. smooth ER
 - d. vacuole
- 10 Which of the following statements is part of the cell theory?
 - a. All cells suddenly appear by themselves.
 - b. All cells come from other cells.
 - c. All organisms are multicellular.
 - d. All cells have identical parts.
- 11 The surface area-to-volume ratio of a cell limits
 - a. the number of organelles that the cell has.
 - b. the size of the cell.
 - c. where the cell lives.
 - d. the types of nutrients that a cell needs.
- 12 Two types of organisms whose cells do not have a nucleus are
 - a. prokaryotes and eukaryotes.
 - b. plants and animals.
 - c. eubacteria and archaeobacteria.
 - d. single-celled and multicellular organisms.



Short Answer

- 13 Explain why most cells are small.
- 14 Describe the four levels of organization in living things.
- 15 What is the difference between the structure of an organ and the function of the organ?
- 16 Name two functions of a cell membrane.
- 17 What are the structure and function of the cytoskeleton in a cell?

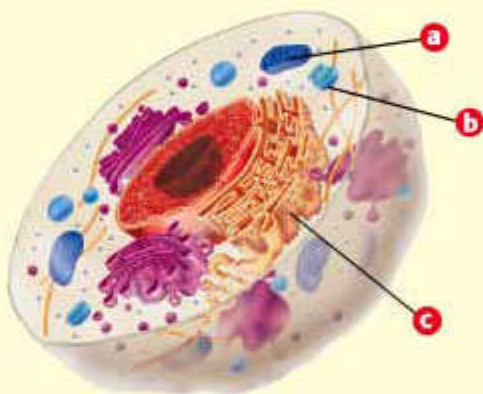
CRITICAL THINKING

- 18 **Concept Mapping** Use the following terms to create a concept map: *cells, organisms, Golgi complex, organ systems, organs, nucleus, organelle, and tissues.*
- 19 **Making Comparisons** Compare and contrast the functions of the endoplasmic reticulum and the Golgi complex.
- 20 **Identifying Relationships** Explain how the structure and function of an organism's parts are related. Give an example.
- 21 **Evaluating Hypotheses** One of your classmates states a hypothesis that all organisms must have organ systems. Is your classmate's hypothesis valid? Explain your answer.
- 22 **Predicting Consequences** What would happen if all of the ribosomes in your cells disappeared?

- 23 **Expressing Opinions** Scientists think that millions of years ago the surface of the Earth was very hot and that the atmosphere contained a lot of methane. In your opinion, which type of organism, a eubacterium or an archaebacterium, is the older form of life? Explain your reasoning.

INTERPRETING GRAPHICS

Use the diagram below to answer the questions that follow.



- 24 What is the name of the structure identified by the letter *a*?
- 25 Which letter identifies the structure that digests food particles and foreign invaders?
- 26 Which letter identifies the structure that makes proteins, lipids, and other materials and that contains tubes and passageways that enable substances to move to different places in the cell?