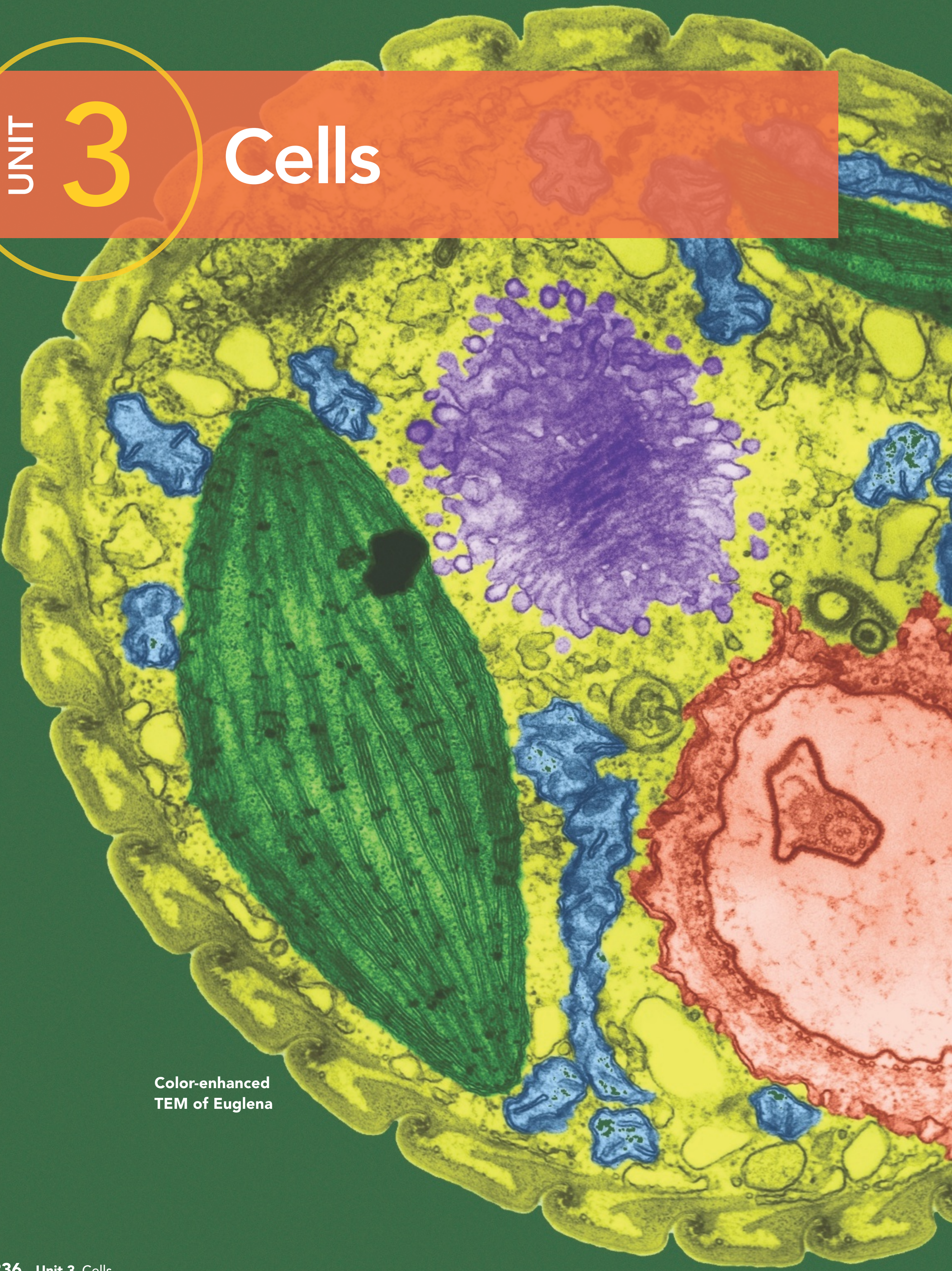
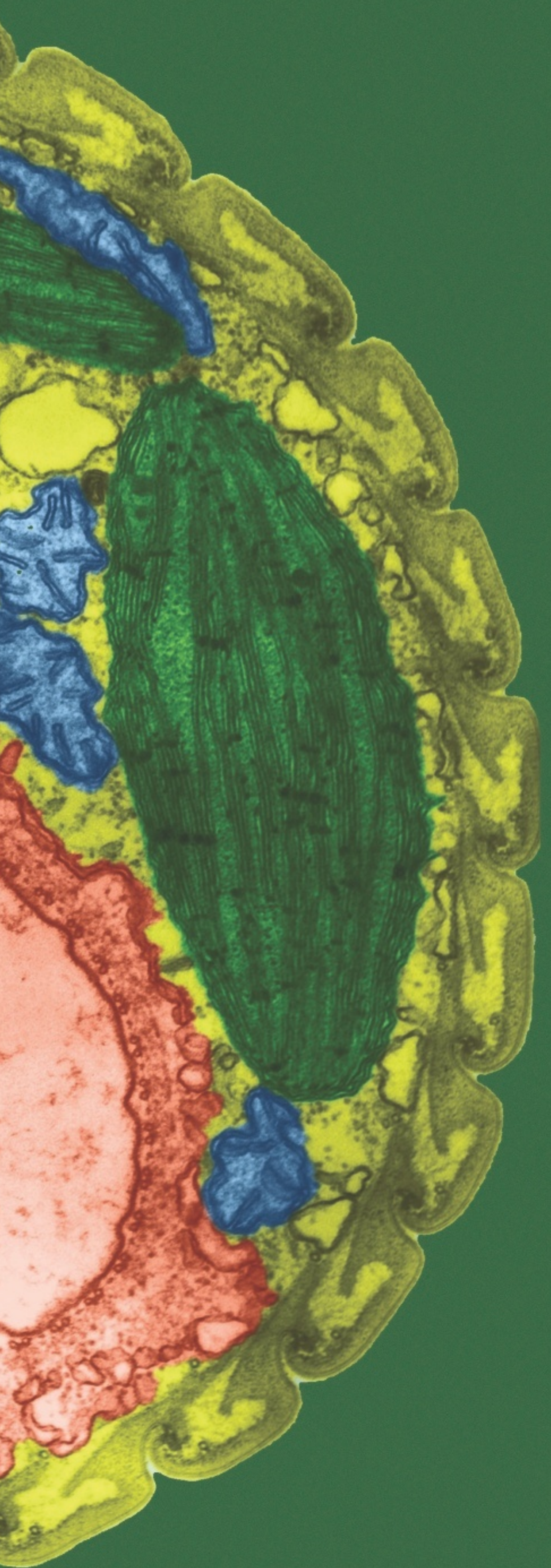
UNIT 3 Cells



Color-enhanced TEM of Euglena



Crosscutting Concepts Cells are the basic units of life. Every cell is a living system that can grow and reproduce, capture and transform energy, and pass along genetic information. The unity of life at the cellular level allows us to use organisms like bacteria, fruit flies, and even worms as model systems to learn how cells interact to produce the remarkable properties shared by all living things, including ourselves.

BOUNCE TO ACTIVATE

VIDEO

Author Ken Miller explains how a leaf uses solar energy to produce food.

POWER FROM Pond Scum

Fuel comes in many forms.

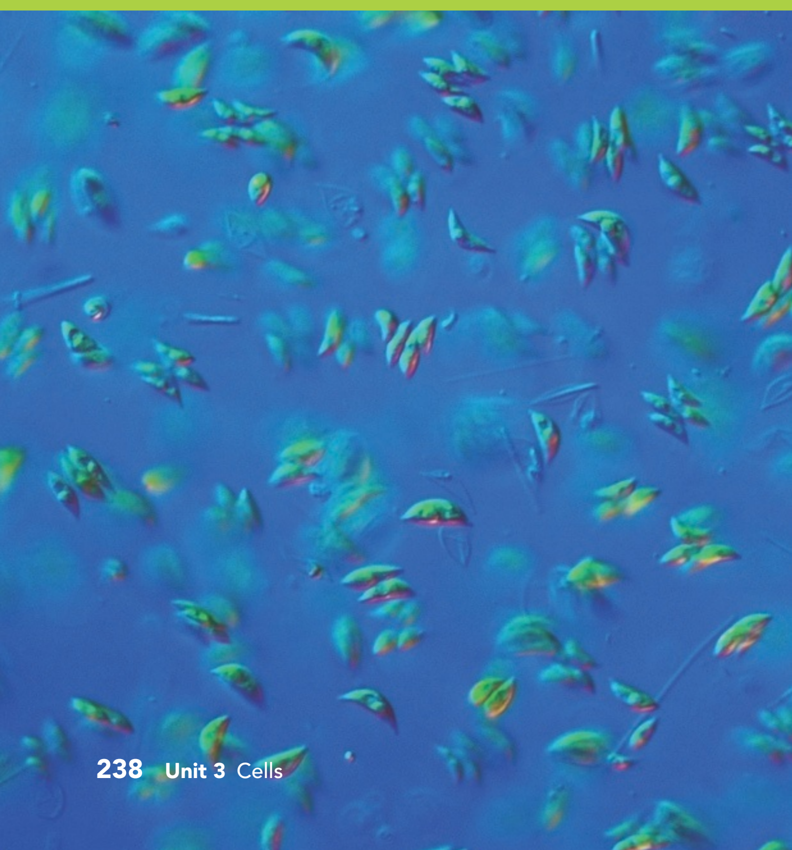
If you have burned wood logs in a campfire or a fireplace, then you have used biofuels. A biofuel is a fuel made from living matter. Unlike fossil fuels, such as coal and oil, a biofuel is renewable, meaning it can be replaced in a relatively short time. Today, engineers are looking at algae as a source of biofuel. Why algae? One of the reasons is that they are easy to raise. All they need is water, a few nutrients, and sunlight.

PROBLEM LAUNCH
Conduct research on algae as a biofuel. Report on different methods to maximize algal growth.

VIDEO

BOUNCE TO ACTIVATE

Watch a video about nonrenewable energy—where it comes from and is there a way to use a renewable source for fuel.



PROBLEM: What is the best way to grow algae for biofuel?

TO SOLVE THIS PROBLEM, perform these activities as they come up in the unit and record your findings in your Explorer's Journal.

LAB INVESTIGATION

Observe algal cells and classify cell structures. Discuss how algae live and grow.

AUTHENTIC READING

Read an article describing how companies plan to use algae to create biofuels in the future.

STEM PROJECT

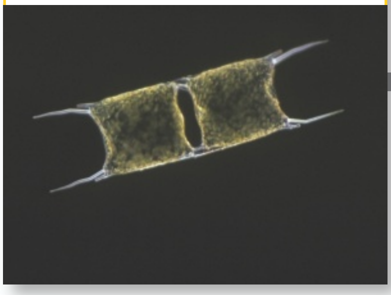
Design an experiment to raise algae efficiently and effectively. Then evaluate your technique for large-scale production.

INTERACTIVITY

Investigate the processes of photosynthesis and respiration in algae.

INTERACTIVITY

Explore cell division and reproduction of algal cells.



PROBLEM WRAP-UP

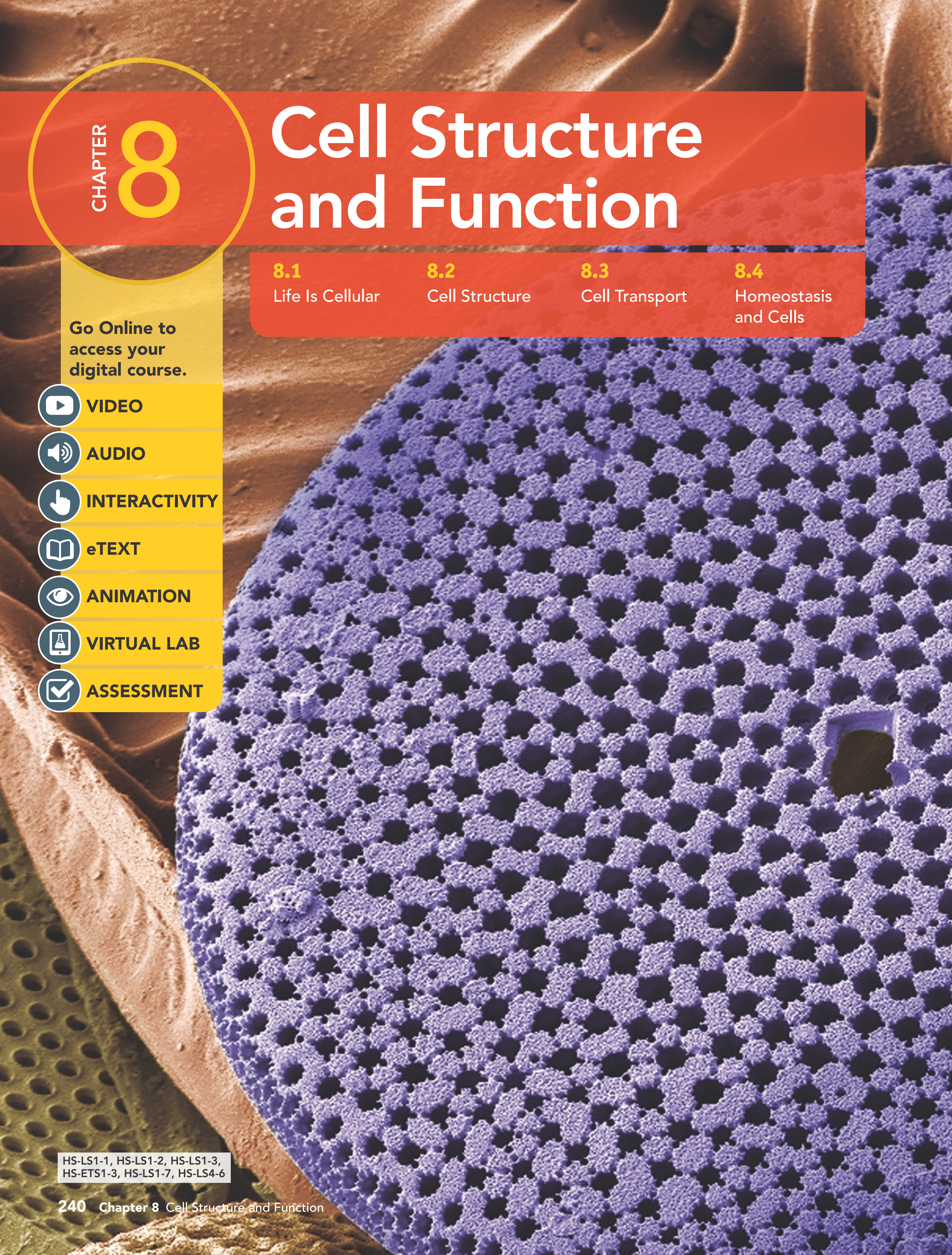
Present your findings, and prepare a report to a transportation company convincing them to use a biofuel made from algae for their vehicles.

CHAPTER 8

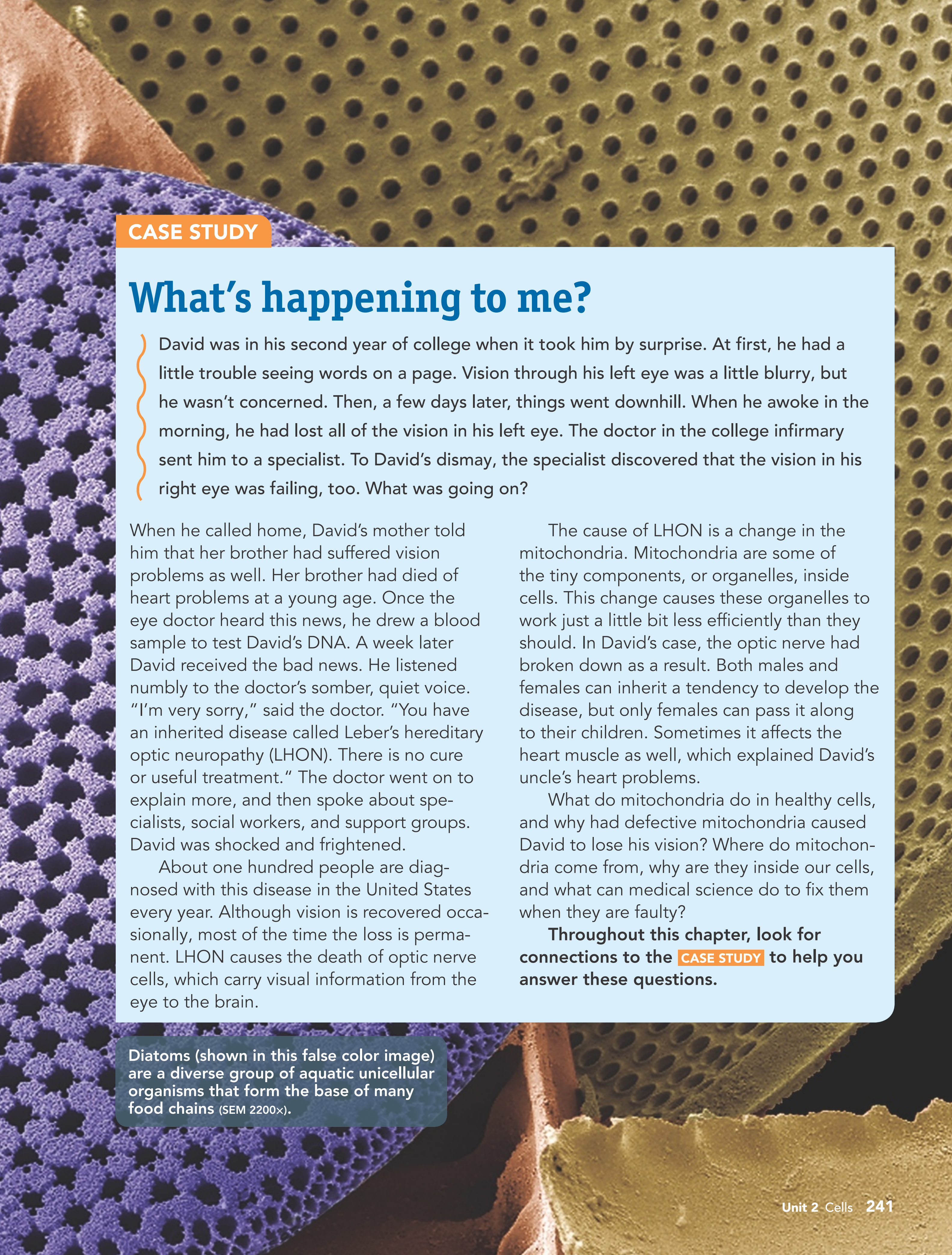
Cell Structure and Function

Go Online to access your digital course.

- VIDEO
- AUDIO
- INTERACTIVITY
- eTEXT
- ANIMATION
- VIRTUAL LAB
- ASSESSMENT



HS-LS1-1, HS-LS1-2, HS-LS1-3, HS-ETS1-3, HS-LS1-7, HS-LS4-6



CASE STUDY

What's happening to me?

David was in his second year of college when it took him by surprise. At first, he had a little trouble seeing words on a page. Vision through his left eye was a little blurry, but he wasn't concerned. Then, a few days later, things went downhill. When he awoke in the morning, he had lost all of the vision in his left eye. The doctor in the college infirmary sent him to a specialist. To David's dismay, the specialist discovered that the vision in his right eye was failing, too. What was going on?

When he called home, David's mother told him that her brother had suffered vision problems as well. Her brother had died of heart problems at a young age. Once the eye doctor heard this news, he drew a blood sample to test David's DNA. A week later David received the bad news. He listened numbly to the doctor's somber, quiet voice. "I'm very sorry," said the doctor. "You have an inherited disease called Leber's hereditary optic neuropathy (LHON). There is no cure or useful treatment." The doctor went on to explain more, and then spoke about specialists, social workers, and support groups. David was shocked and frightened.

About one hundred people are diagnosed with this disease in the United States every year. Although vision is recovered occasionally, most of the time the loss is permanent. LHON causes the death of optic nerve cells, which carry visual information from the eye to the brain.

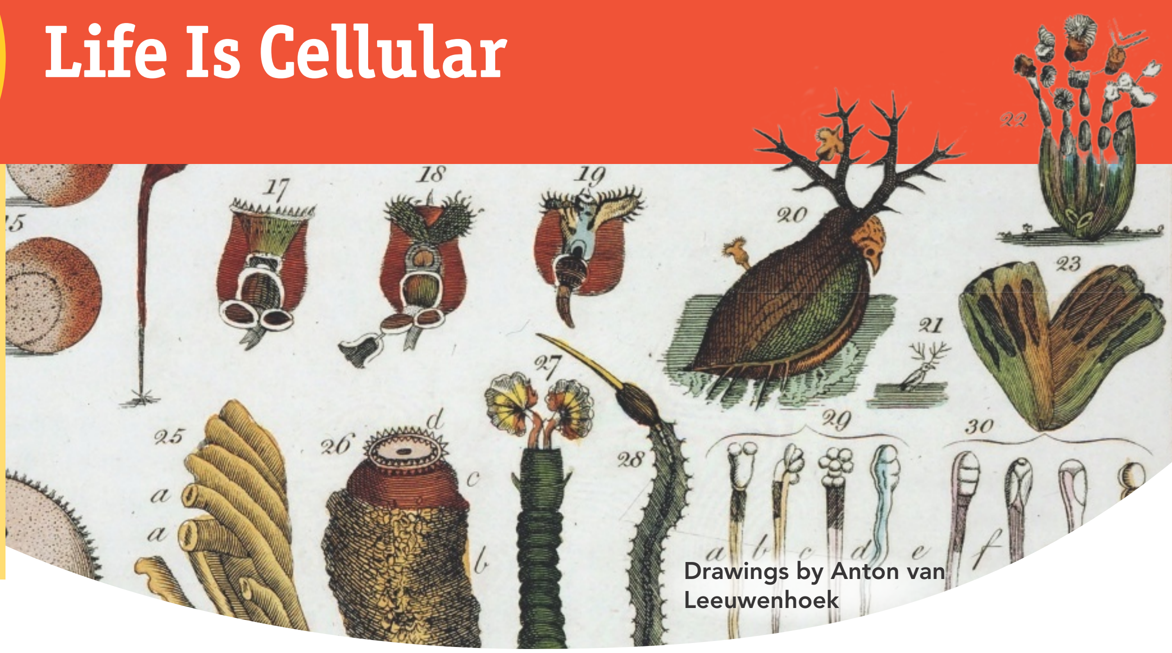
The cause of LHON is a change in the mitochondria. Mitochondria are some of the tiny components, or organelles, inside cells. This change causes these organelles to work just a little bit less efficiently than they should. In David's case, the optic nerve had broken down as a result. Both males and females can inherit a tendency to develop the disease, but only females can pass it along to their children. Sometimes it affects the heart muscle as well, which explained David's uncle's heart problems.

What do mitochondria do in healthy cells, and why had defective mitochondria caused David to lose his vision? Where do mitochondria come from, why are they inside our cells, and what can medical science do to fix them when they are faulty?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

Diatoms (shown in this false color image) are a diverse group of aquatic unicellular organisms that form the base of many food chains (SEM 2200×).

LESSON 8.1 Life Is Cellular



Drawings by Anton van Leeuwenhoek

KEY QUESTIONS

- *What are the main points of the cell theory?*
- *How do microscopes work?*
- *How do prokaryotic and eukaryotic cells differ?*

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

VOCABULARY

cell
cell theory
cell membrane
nucleus
eukaryote
prokaryote

READING TOOL

As you read, identify the main ideas and supporting details under each heading. Take notes in your **Biology Foundations Workbook.**

What's the smallest part of any living thing that still counts as being "alive"? Is a leaf alive? How about your big toe? What about a drop of blood? Can we just keep dividing living things into smaller and smaller parts, or is there a point at which what's left is no longer alive? As you will discover, there is such a limit: The smallest living unit of any organism is a cell.

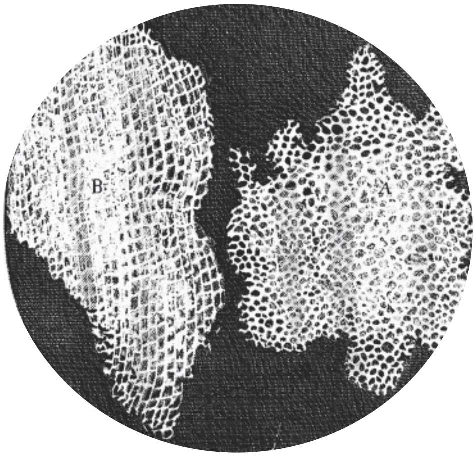
The Discovery of the Cell

"Seeing is believing" goes an old saying. It would be hard to find a better example of this than the discovery of the cell. Without the instruments to make them visible, cells remained unknown for most of human history. All of this changed with a dramatic advance in technology—the invention of the microscope.

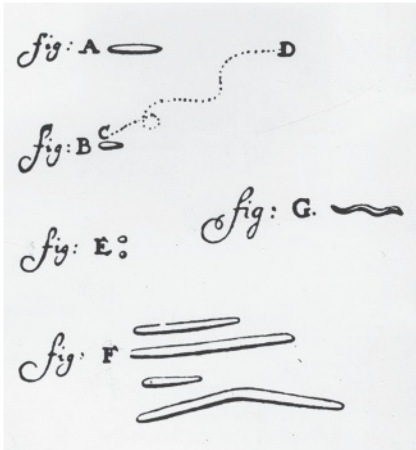
Early Microscopes In the late 1500s, eyeglass makers in Europe discovered that using several glass lenses in combination could magnify even the smallest objects. Before long, they had built the first true microscopes from these lenses, opening the door to the study of biology as we know it today.

In 1665, Robert Hooke, an Englishman, used an early microscope to look at a nonliving thin slice of cork, a plant material. Under the microscope, cork seemed to be made of thousands of tiny empty chambers, as shown in **Figure 8-1**. Hooke called the chambers "cells," because they reminded him of a monastery's tiny rooms. That term, *cell*, is used in biology to this day.

In Holland around the same time, Anton van Leeuwenhoek used a single-lens microscope to observe pond water and other things. To his amazement, the microscope revealed a fantastic world of tiny living organisms that seemed to be everywhere—in the water that he and his neighbors drank, and even in his own mouth.



Hooke's observations



Leeuwenhoek's observations

Figure 8-1

Early Microscope Images

Robert Hooke used a microscope to observe dead cells in thin sections of cork. Using a simple microscope, Anton van Leeuwenhoek was the first to observe living microorganisms. These drawings show some of the bacteria he found in his own mouth.

The Cell Theory Before long, it became clear that **cells** are the basic units of all living things. In 1838, German botanist Matthias Schleiden concluded that all plants are made of cells. The next year, German biologist Theodor Schwann stated that all animals are made of cells. In 1855, German physician Rudolf Virchow published the idea that new cells can be produced only from the division of existing cells. These discoveries, confirmed by many biologists, are summarized in the **cell theory**, a fundamental concept of biology.

The cell theory states:

- ***All living things are made up of cells.***
- ***Cells are the basic units of structure and function in living things.***
- ***New cells are produced from existing cells.***

READING CHECK **Summarize** How were cells discovered?

Quick Lab — Guided Inquiry

What Is a Cell?

1. Observe one prepared slide under the low-power lens of the microscope and then under the high-power lens. Sketch the structures you observe under both lenses.
2. Repeat step 1 with the other prepared slides. With your partner, discuss and ask questions about your observations.

ANALYZE AND CONCLUDE

1. **Compare and Contrast** What features do the cells you observed have in common? How are they different from one another?
2. **Use Models** Study Figure 8-5, which shows different types of cells and some of their structures. Which of these cells or structures do you think you observed and sketched?
3. **Classify** Review your sketches, and then classify the slides of cells into two or three groups. Explain your classification scheme.
4. **Ask Questions** Pose questions based on your observations that would help you better classify and identify the cells you studied.

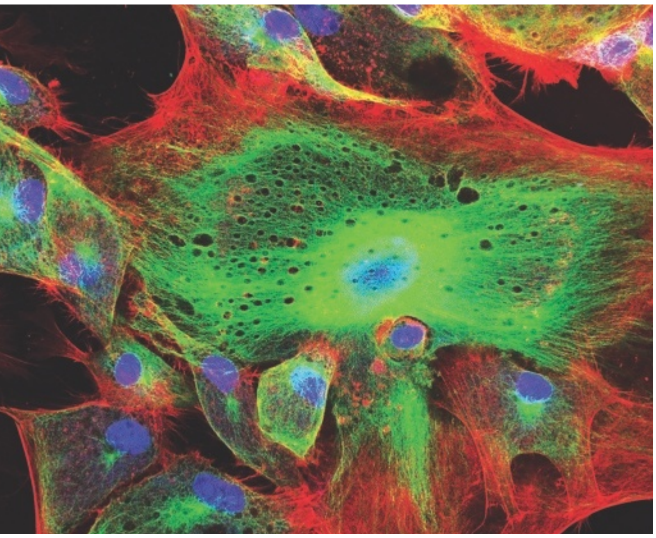
Exploring the Cell

Following in the footsteps of Hooke, Virchow, and others, modern biologists still use microscopes to explore the cell. But today's researchers use technology that is more powerful than the pioneers of biology could have ever imagined. ***Microscopes work by using beams of light or electrons to produce magnified images.***

Figure 8-2

Fluorescent Dyes

By treating cells with stains or dyes, a scientist can clearly identify large molecules and cell parts. Fluorescent dyes are especially useful for contrasting one cell part from another such as in these skin cells.



LM 500×

Light Microscopes

The type of microscope you are probably most familiar with is the compound light microscope. A typical light microscope allows light to pass through a specimen and uses two lenses to form an image. The first lens, called the objective lens, is located just above the specimen. This lens enlarges the image of the specimen. The second lens, called the ocular lens, magnifies this image still further. Unfortunately, light itself limits the detail, or resolution, of images in a microscope. Like all forms of radiation, light waves are diffracted, or scattered, as they pass through matter. Because of this, light microscopes can produce clear images of objects only to a magnification of about 1000 times.

Since most living cells are nearly transparent, chemical stains or dyes are used to help make cells and their parts visible. Many of the slides you'll examine in your biology class laboratory will be stained this way. A powerful variation on these staining techniques uses dyes that give off light of a particular color when viewed under specific wavelengths of light, a property called fluorescence. Fluorescent labels of different colors, shown in **Figure 8-2**, can be attached to certain molecules within the cell. These labels make it possible to locate and even watch molecules move around in a living cell.

Electron Microscopes

Light microscopes can be used to see cells and cell structures as small as 1 millionth of a meter—certainly pretty small! But what if scientists want to study something smaller than that, such as a virus or a DNA molecule? For that, they need electron microscopes. Instead of using light, electron microscopes use beams of electrons focused by magnetic fields. Electron microscopes offer much higher resolution than light microscopes. Some types of electron microscopes can be used to study cellular structures that are 1 billionth of a meter in size.

Electrons are easily scattered by molecules in the air, which means samples must be placed in a vacuum to be studied with an electron microscope. As a result, researchers must chemically preserve their samples. This means that electron microscopy, despite its higher resolution, can be used to examine only nonliving cells and tissues. The two major types of electron microscopes are transmission and scanning.

BUILD VOCABULARY

Academic Words The noun transmission means "the process of sending." This often implies that one thing is being sent through something else. In transmission electron microscopy, a beam of electrons is sent through a thin sample.

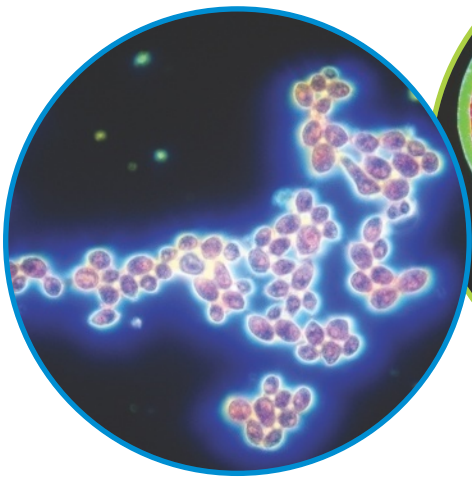
Transmission Electron Microscopes These microscopes make it possible to explore cell structures and large protein molecules. Beams of electrons can only pass through thin samples, so cells and tissues must be cut into extremely thin slices before they can be examined. This is the reason that such images often appear flat and two dimensional.

Scanning Electron Microscopes In these microscopes, a pencil-like beam of electrons is scanned over the surface of a specimen. Because the image is formed at the specimen's surface, samples do not have to be cut into thin slices to be seen. The scanning electron microscope produces stunning three-dimensional images of the specimen's surface.

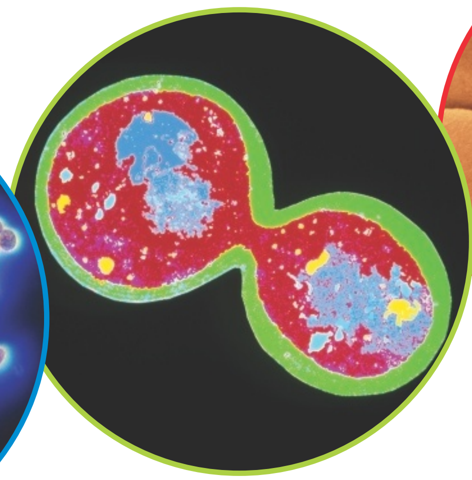
Look at **Figure 8-3**, which shows yeast cells as they look under a light microscope, a transmission electron microscope, and a scanning electron microscope. You may wonder why the cells appear to be different colors in each micrograph. (A micrograph is a photo of an object seen through a microscope.) The colors in light micrographs come from the cells themselves or from the stains and dyes used to highlight them. Electron micrographs, however, are actually black and white. Electrons, unlike light, don't come in colors. So scientists often use computer techniques to add "false color" to make certain structures stand out.

VIDEO

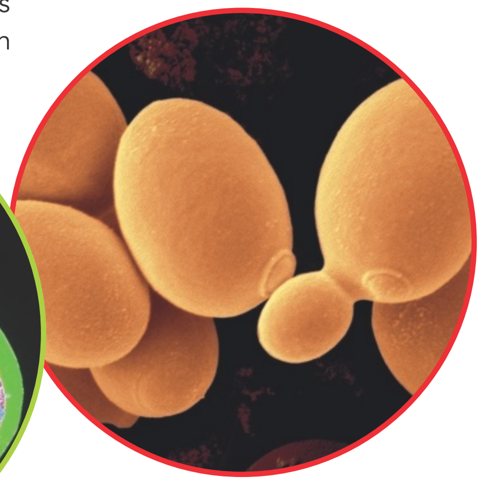
Learn about the advantages and disadvantages of a light microscope, a SEM, a TEM, and a stimulated emission depletion.



Light micrograph (LM)



Transmission electron micrograph (TEM)



Scanning electron micrograph (SEM)

INTERACTIVITY

Figure 8-3

Micrographs

Different types of microscopes can be used to examine cells. Here, yeast cells are shown in a light micrograph (LM 500×), a transmission electron micrograph (TEM 4375×), and a scanning electron micrograph (SEM 3750×).

In the past decade, new microscopes have been developed that use precise, computer controlled laser beams to scan across samples and gather very high resolution information. These instruments and techniques are making it possible to study living cells at a level of detail never possible before, opening up even more opportunities for research.

READING CHECK **Infer** If scientists were studying a structure found on the surface of yeast, which kind of microscope would they likely use?

READING TOOL

Draw a Venn diagram with two overlapping circles. As you read through the lesson, enter details in the diagram that are unique to prokaryotes and eukaryotes and details that are shared by them.

Prokaryotes and Eukaryotes

Cells come in an amazing variety of shapes and sizes, some of which are shown in **Figure 8-4**. Typical cells range from 5 to 50 micrometers (μm) in diameter. The smallest *Mycoplasma* bacteria, which are only 0.2 micrometer across, are so small they are difficult to see with even the best light microscope. In contrast, the giant amoeba *Chaos chaos* can be 1000 micrometers (1 millimeter) in diameter, large enough to see with the unaided eye as a tiny speck in pond water. Despite their differences, all cells, at some point in their lives, contain DNA, the molecule that carries biological information. In addition, all cells are surrounded by a thin flexible barrier called a **cell membrane**. (The cell membrane is sometimes called the *plasma membrane*, because many cells in the body are in direct contact with the fluid portion of the blood—the plasma.) There are other similarities as well, as you will learn in the next lesson.

Cells fall into two broad categories, depending on whether they contain a nucleus. The **nucleus** (plural: nuclei) is a large membrane-enclosed structure that contains genetic material in the form of DNA. DNA controls many of the cell's activities. **Eukaryotes** (yoo KAR ee ohts) are cells that enclose their DNA in nuclei. In contrast, **prokaryotes** (pro KAR ee ohts) are cells that do not enclose DNA in nuclei. **Figure 8-5** shows a typical prokaryotic cell and two typical eukaryotic cells.

Prokaryotes

Prokaryotic cells are generally smaller and simpler when compared with eukaryotic cells, although there are many exceptions to this rule. The organisms we commonly call bacteria are prokaryotes. ***Prokaryotic cells do not enclose their genetic material within a nucleus.*** Despite their simplicity, prokaryotes carry out every activity associated with living things. They grow, reproduce, and respond to the environment.

Prokaryotes perform very important roles in the environment. In fact, the very first photosynthetic organisms to appear on Earth, nearly 3 billion years ago, were cyanobacteria. The oxygen these prokaryotes released into the atmosphere forever changed Earth's environment, making possible plant and animal life as we know it.

Figure 8-4

Cell Size Is Relative

The human eye can see objects larger than about 0.5 mm. Most of what interests cell biologists, however, is much smaller than that. Microscopes make seeing the cellular and subcellular world possible.

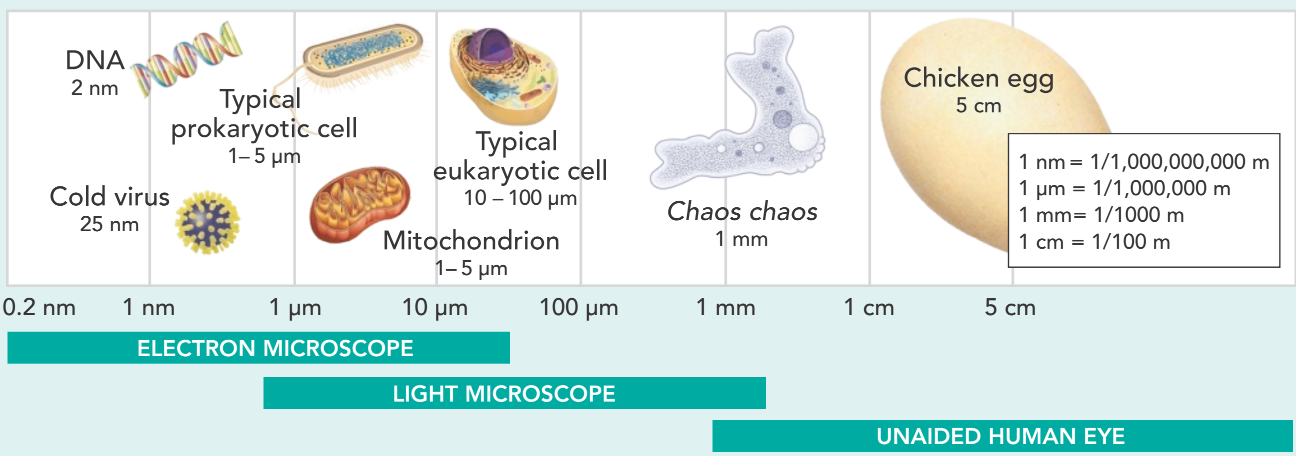
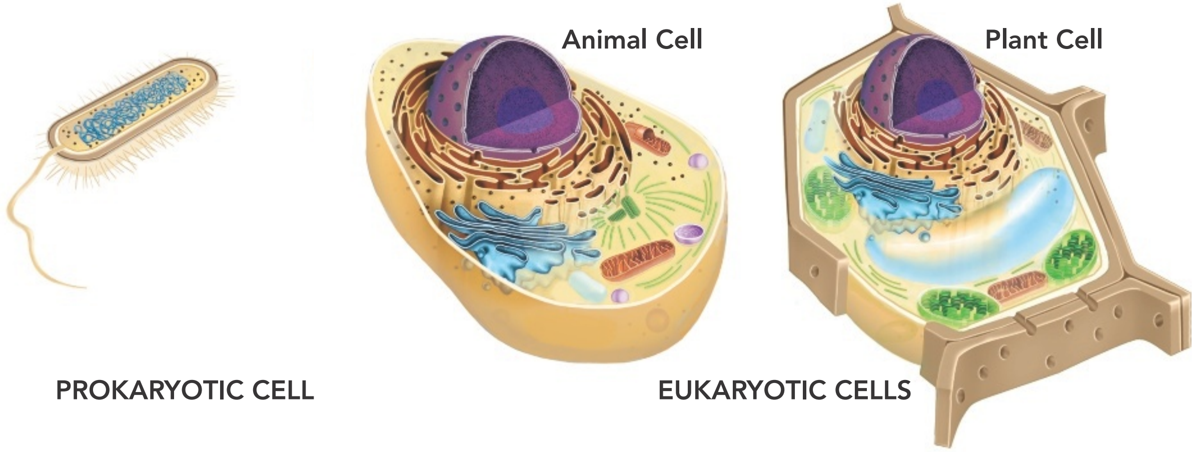


Figure 8-5
Prokaryotic and Eukaryotic Cells

In general, eukaryotic cells are larger and more complex than prokaryotic cells. Eukaryotic organisms include plants, animals, fungi, and many unicellular organisms.



Eukaryotes Eukaryotic cells are generally larger and more complex than prokaryotic cells. Most eukaryotic cells contain dozens of structures and internal membranes, and many are highly specialized. ***In eukaryotic cells, the nucleus separates the genetic material from the rest of the cell.*** Eukaryotes display great variety. Some, like the ones commonly called "protists," live solitary lives as unicellular organisms; others form large, multicellular organisms—plants, animals, and fungi.

In multicellular organisms, cells are specialized for specific tasks, such as support, communication, movement, or the production of proteins or other cell products. As a general rule, the cells of multicellular organisms cannot survive individually. They work together to complete the tasks of life.

INTERACTIVITY

Compare and contrast prokaryotes and eukaryotes, including their different DNA structures.

HS-LS1-2

LESSON 8.1 Review

KEY QUESTIONS

1. How did Hooke's work contribute to the cell theory?
2. What does it mean if a micrograph is "false-colored?"
3. What is the defining characteristic of eukaryotic cells? What types of organisms have eukaryotic cells?

CRITICAL THINKING

4. **Construct a Counter-Argument** A classmate argues that Schwann and Schleiden are responsible for the cell theory. How do you respond? Cite facts and use logical reasoning to support your argument.
5. **Ask Questions** You observe a tiny structure under a microscope. What question would you ask, and then investigate, to determine whether the structure was part of a living thing?
6. **Integrate Information** Review the micrographs of cells shown in **Figure 8-3**. What information about cells do these micrographs show? What information might the micrographs suggest, which might not be accurate?

LESSON

8.2 Cell Structure

KEY QUESTIONS

- *What is the role of the cell nucleus?*
- *What organelles help make and transport proteins and other macromolecules?*
- *What are the functions of vacuoles, lysosomes, and the cytoskeleton?*
- *What are the functions of chloroplasts and mitochondria?*
- *What is the function of the cell membrane?*

HS-LS1-1: Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.
HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.

VOCABULARY
cytoplasm • organelle
ribosome
endoplasmic reticulum
Golgi apparatus
vacuole • lysosome
cytoskeleton • chloroplast
mitochondrion
cell wall • lipid bilayer
selectively permeable

READING TOOL

Use the figures in this lesson to help you identify and describe each part of the cell. Fill in the graphic organizer in your **Biology Foundations Workbook.**

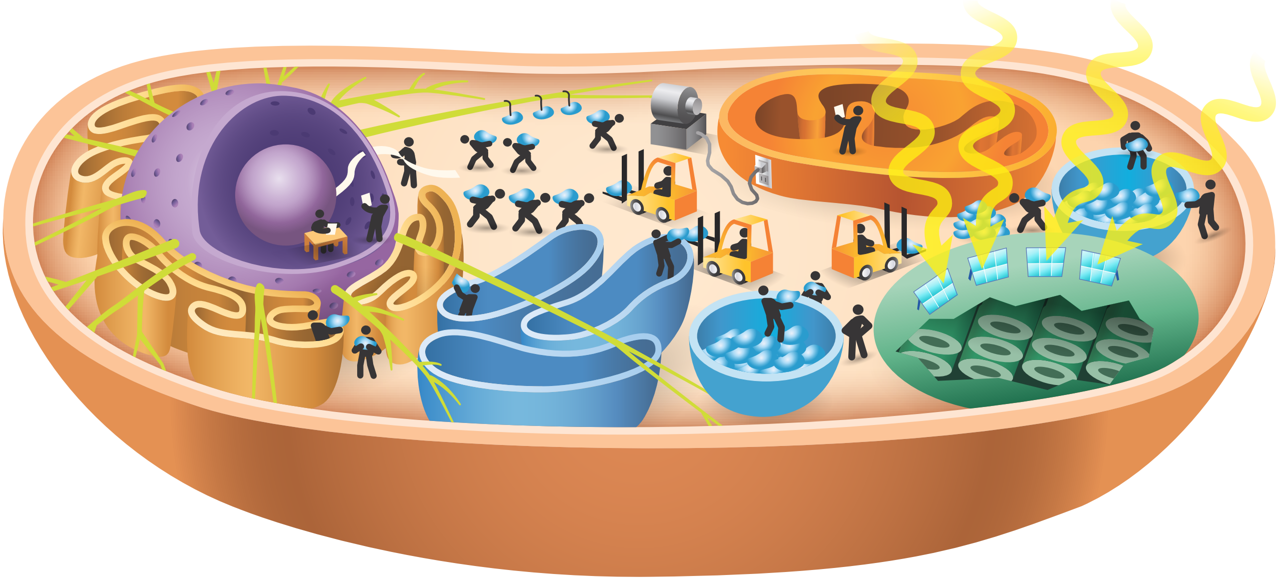
If you've ever visited or worked in a factory, you know it can be a puzzling place. Machines buzz and clatter; people move quickly in different directions. So much activity can be confusing. However, if you take the time to watch carefully, what might at first seem like chaos begins to make sense. The same is true for the living cell.

Cell Organization

A eukaryotic cell is a complex and busy place. But if you look closely at eukaryotic cells, patterns begin to emerge. For example, it's easy to divide each cell into two major parts: the nucleus and the cytoplasm. The **cytoplasm** is the portion of the cell outside the nucleus. Both the nucleus and the cytoplasm work together in the business of life. The interior of a prokaryotic cell, which lacks a nucleus, is also referred to as the cytoplasm.

In our discussion of cell structure, we will consider each major component of plant and animal eukaryotic cells—some of which are also found in prokaryotic cells—one by one. Because many of these structures act like specialized organs, they are known as **organelles**, literally "little organs." Understanding what each organelle does helps us understand the cell as a whole. A summary of cell structures and functions can be found at the end of this lesson.

Comparing the Cell to a Factory In some respects, the eukaryotic cell is much like a living version of a modern factory, as shown in **Figure 8-6**. The different organelles of the cell can be compared to the specialized machines and assembly lines of a factory. In addition, cell parts, like people and machines in factories, follow instructions and produce products. As you read about the organization of the cell, you'll find many places in which the comparison works so well that it will help you understand how cells function.



The Nucleus

In the same way that the main office controls a large factory, the nucleus is the control center of the cell. ***The nucleus contains nearly all the cell's DNA and, with it, the coded instructions for making proteins and other important molecules.*** Only eukaryotic cells have a nucleus. In prokaryotic cells, DNA is found in the cytoplasm.

The nucleus, shown in **Figure 8-7**, is surrounded by a nuclear envelope composed of two membranes. The nuclear envelope is dotted with thousands of nuclear pores, which allow material to move into and out of the nucleus. Like messages, instructions, and blueprints moving in and out of a factory's main office, a steady stream of proteins, the nucleic acid RNA, and other molecules move through the nuclear pores to and from the rest of the cell.

Chromosomes, which carry the cell's genetic information, are also found in the nucleus. Most of the time, the threadlike chromosomes are spread throughout the nucleus in the form of chromatin—a complex of DNA bound to proteins. When a cell divides, its chromosomes condense and can be seen under a microscope. Most nuclei also contain a small dense region known as the nucleolus (noo klee OH lus), where the assembly of ribosomes begins.

READING CHECK **Use an Analogy** How is a cell's cytoplasm like a factory floor?

Visual Analogy

Figure 8-6

The Cell as a Factory

Specialized machines enable a factory to function. Similarly, specialized structures in a cell enable a cell to carry out the processes of life.

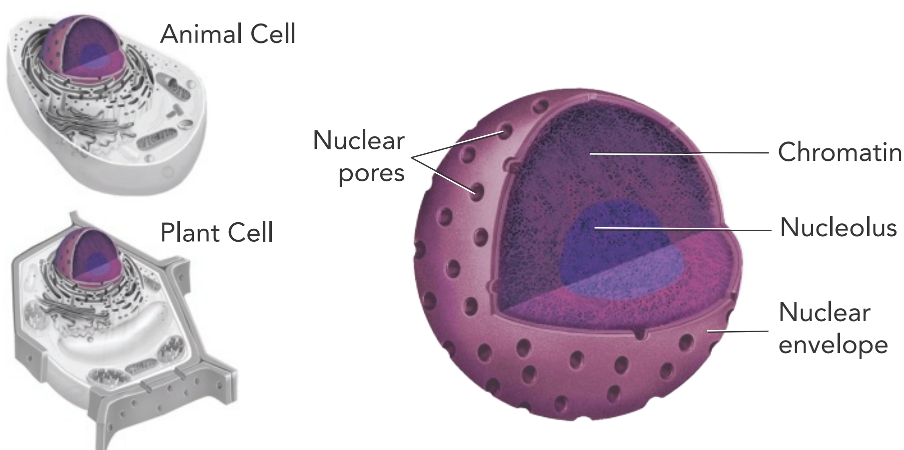
READING TOOL

Using Figure 8-6 and the cell-as-a-factory analogy, predict the function of each of the organelles. If you cannot identify the organelle by name, use its color in your description.

Figure 8-7

Nucleus

Both plant and animal cells have a nucleus. Like a factory's computing cloud or server room, the nucleus contains the information needed for a cell to function. A cell's information is in the form of DNA.



Organelles That Build Proteins

Life is a dynamic process, and living things are always at work synthesizing new molecules. Because proteins carry out so many of the essential functions of living things, including the synthesis of other macromolecules such as lipids and carbohydrates, a big part of the cell is devoted to their production and distribution. The process of making proteins is summarized in **Figure 8-8**.

Ribosomes One of the most important jobs carried out in the cellular "factory" is making proteins. ***Proteins are assembled on ribosomes.*** **Ribosomes** are small particles of RNA and protein found throughout the cytoplasm in both eukaryotes and prokaryotes. Ribosomes produce proteins by following coded instructions that come from DNA. Each ribosome, in its own way, is like a small machine in a factory, turning out proteins on orders that come from its DNA "boss." Cells that are especially active in protein synthesis often contain large numbers of ribosomes.

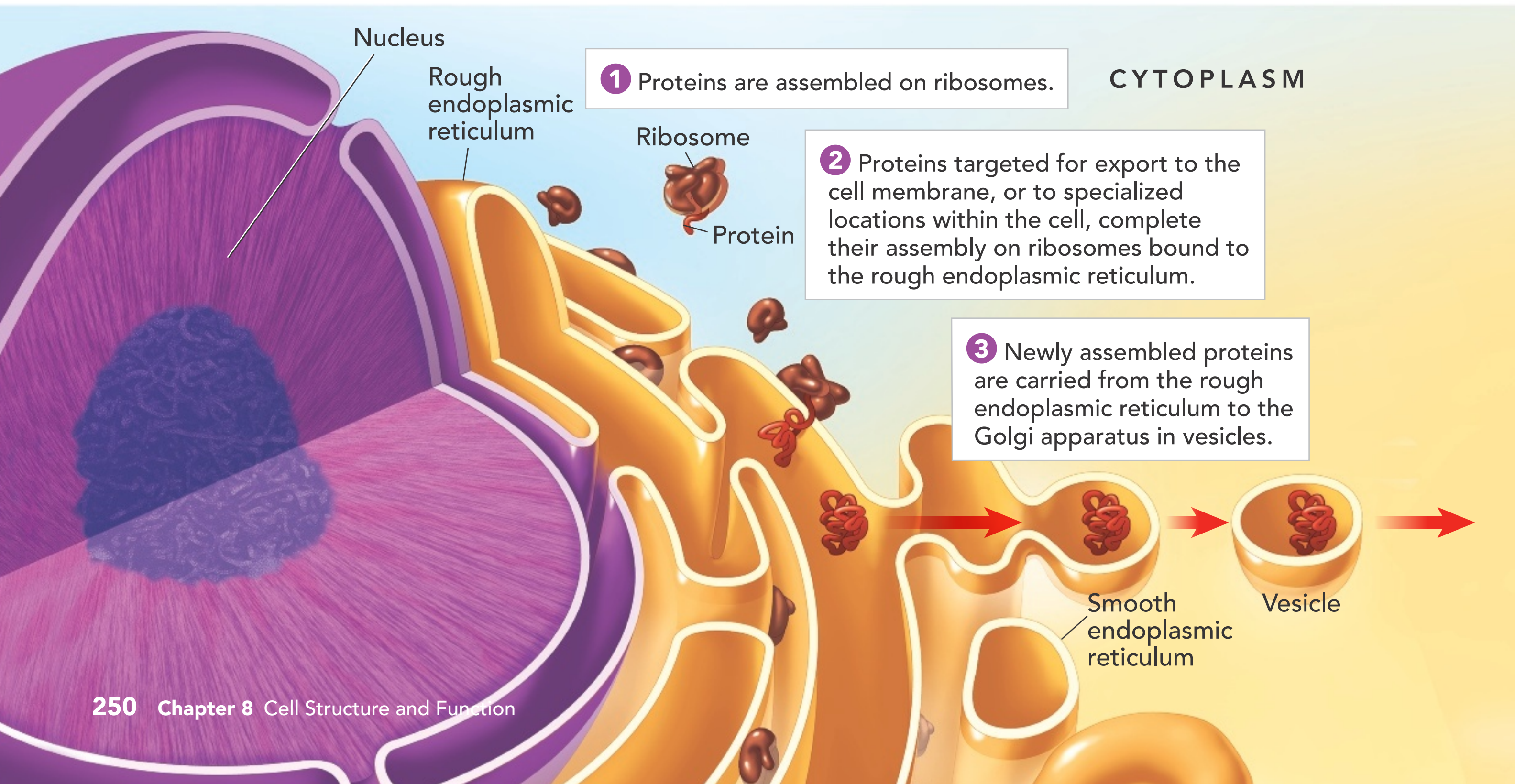
Endoplasmic Reticulum Eukaryotic cells contain an internal membrane system known as the **endoplasmic reticulum** (en doh PLAZ mik reh TIK yoo lum), or ER. The endoplasmic reticulum is where lipids, including those needed for the cell membrane, are synthesized, along with proteins and other materials that are exported from the cell.

The portion of the ER involved in the synthesis of proteins is called rough endoplasmic reticulum, or rough ER. It is given this name because of the ribosomes found on its surface. Newly made proteins leave these ribosomes and enter the rough ER, where they may be chemically modified.

Figure 8-8

Making Proteins

Together, ribosomes, the endoplasmic reticulum, and the Golgi apparatus synthesize, modify, package, and ship proteins.



Proteins made on the rough ER include those that will be released, or secreted, from the cell; many membrane proteins; and proteins destined for other specialized locations within the cell. Rough ER is abundant in cells that produce large amounts of protein for export. Other cellular proteins are made on "free" ribosomes, which are not attached to membranes.

The other portion of the ER is known as smooth endoplasmic reticulum (smooth ER) because ribosomes are not found on its surface. In many cells, the smooth ER contains collections of enzymes that perform specialized tasks, including the synthesis of lipids and the detoxification of drugs. Smooth ER also plays an important role in the synthesis of carbohydrates.

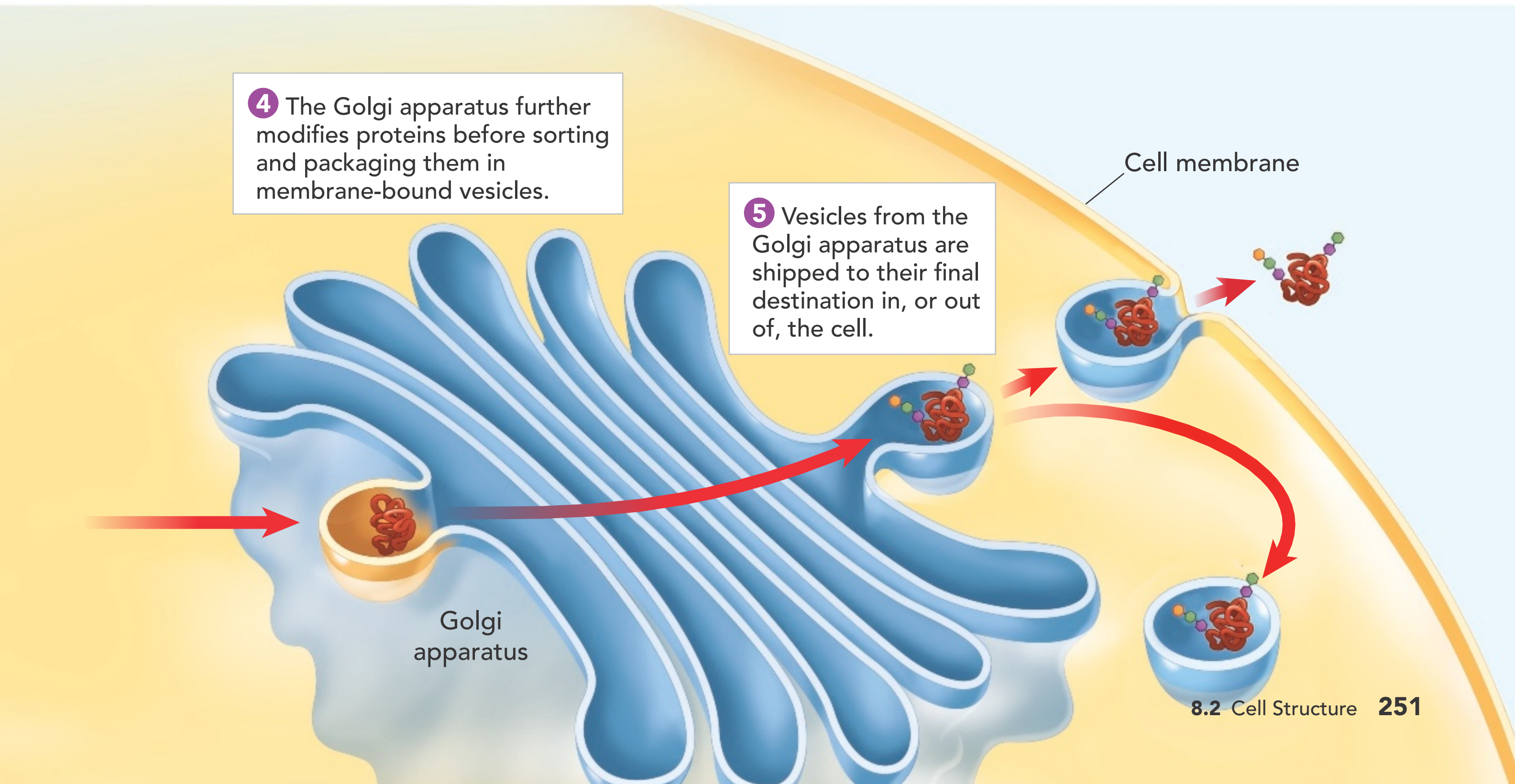
INTERACTIVITY

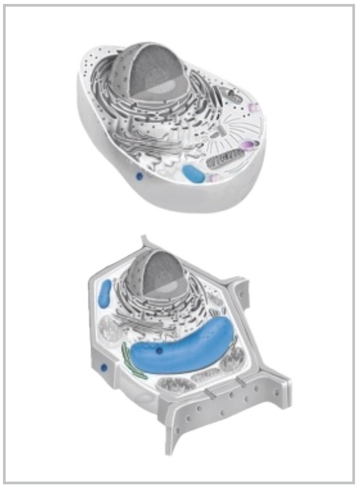
Build a cell and look at specialized cells under a microscope.

Golgi Apparatus

In eukaryotic cells, proteins produced in the rough ER move next into an organelle called the **Golgi apparatus**, which appears as a stack of flattened membranes. As proteins leave the rough ER, molecular "address tags" get them to the right destinations. As these tags are "read" by the cell, the proteins are bundled into tiny membrane-enclosed structures called vesicles that bud from the ER and carry the proteins to the Golgi apparatus. ***The Golgi apparatus modifies, sorts, and packages proteins and other materials from the endoplasmic reticulum for storage in the cell or release from the cell.*** The Golgi apparatus is somewhat like a customization shop, where the finishing touches are put on proteins before they are ready to leave the "factory." From the Golgi apparatus, proteins are "shipped" to their final destinations inside or outside the cell.

READING CHECK **Identify** Does the rough ER or the smooth ER send proteins on to the Golgi apparatus?





Organelles That Store, Clean Up, and Support

Cells have many functions to perform other than building and transporting proteins. Structures such as vacuoles, vesicles, lysosomes, and the cytoskeleton represent the cellular factory's storage space, cleanup crew, and support structures.

Vacuoles and Vesicles Every factory needs a place to store things, and so does every cell. Many cells contain **vacuoles**, which are large saclike, membrane-enclosed structures. ***Vacuoles store materials like water, salts, proteins, and carbohydrates.*** In many plant cells, there is a single large central vacuole filled with liquid. The pressure of the central vacuole in these cells increases their rigidity, making it possible for plants to support heavy structures, such as leaves and flowers. **Figure 8-9** shows a typical plant cell's central vacuole.

Vacuoles are found in many eukaryotic cells. The paramecium in Figure 8-9 contains an organelle called a contractile vacuole, which pumps excess water out of the cell.

In addition, nearly all eukaryotic cells contain smaller membrane-enclosed structures called vesicles. Vesicles store and move materials between cell organelles, as well as to and from the cell surface.

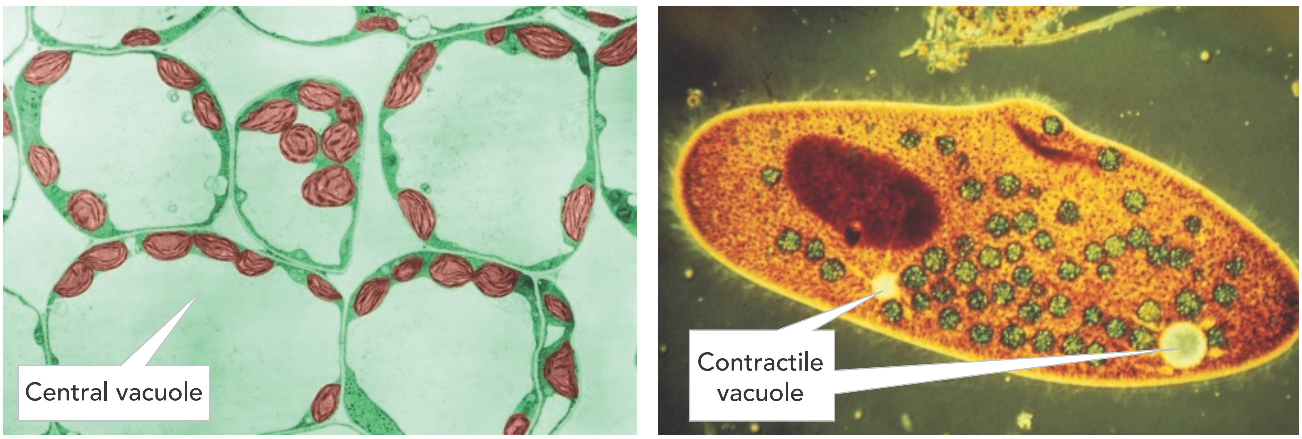


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Figure 8-9
Vacuoles

Because water does not compress, a plant cell's fluid-filled central vacuole provides strength and support. A paramecium's star-shaped contractile vacuoles contract rhythmically to pump excess water out of the cell. **Infer** What could happen to a plant if its central vacuoles shrunk due to water loss?

Lysosomes Even the neatest, cleanest factory needs a cleanup crew, and that's where lysosomes come in. **Lysosomes** are small organelles filled with enzymes. ***Lysosomes break down lipids, carbohydrates, and proteins into small molecules that can be used by the rest of the cell.*** They are also involved in breaking down organelles that have outlived their usefulness. Lysosomes perform the vital function of removing "junk" that might otherwise accumulate and clutter up the cell. A number of rare but serious human diseases can be traced to lysosomes that fail to function properly. Biologists once thought only animal cells contained lysosomes, but it is now clear that a few types of plant cells contain them as well.

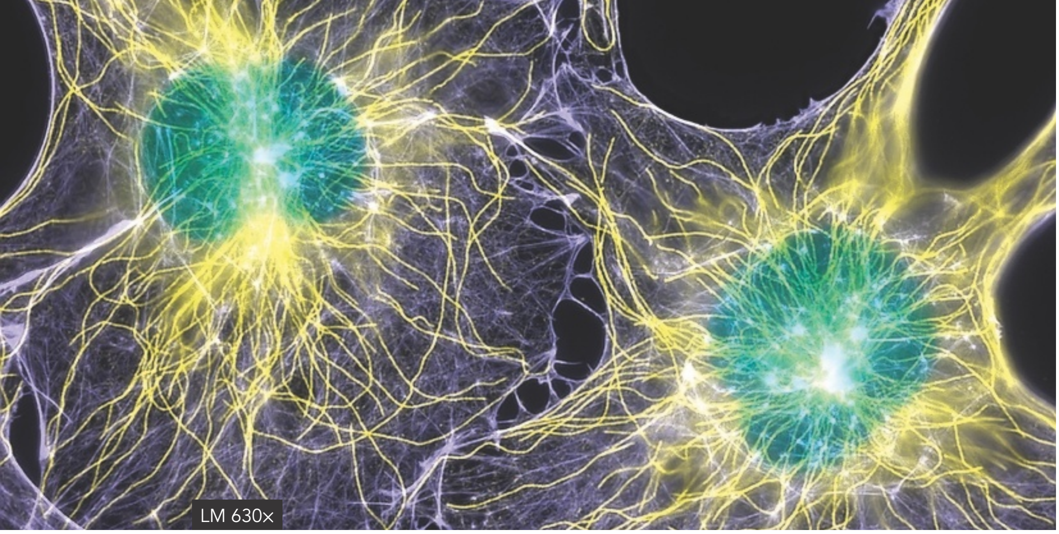

Figure 8-10
Cytoskeleton

The cytoskeleton supports and gives shape to the cell and is involved in many forms of cell movement. These connective tissue fibroblast cells have been treated with fluorescent labels that bind to certain proteins. Microfilaments are pale purple, microtubules are yellow, and the nuclei are green.

The Cytoskeleton A factory building is supported by steel or cement beams and by columns that hold up its walls and roof. Eukaryotic cells are given their shape and internal organization by a network of protein filaments known as the **cytoskeleton**. Certain parts of the cytoskeleton also help transport materials between different parts of the cell, much like the conveyor belts that carry materials from one part of a factory to another. Cytoskeletal components may also be involved in moving the entire cell, as in cell flagella and cilia. ***The cytoskeleton helps the cell maintain its shape and is also involved in movement.*** Fluorescence imaging, as seen in **Figure 8-10**, clearly shows the complexity of a cell's cytoskeletal network. Microfilaments (pale purple) and microtubules (yellow) are two of the principal protein filaments that make up the cytoskeleton.

Microfilaments Microfilaments are threadlike structures made up of a protein called actin. They form extensive networks in some cells and produce a tough, flexible framework that supports the cell. Microfilaments also help cells move. Microfilament assembly and disassembly are responsible for the cytoplasmic movements that allow amoebas and other cells to crawl along surfaces.

Microtubules Microtubules are hollow structures made up of proteins known as tubulins. In many cells, they play critical roles in maintaining cell shape. Microtubules are also important in cell division, where they form a structure known as the mitotic spindle, which helps to separate chromosomes. In animal cells, organelles called centrioles are also formed from tubulins. Centrioles are located near the nucleus and help organize cell division. Centrioles are not found in plant cells.

Microtubules also help build projections from the cell surface—known as cilia (singular: cilium) and flagella (singular: flagellum)—that enable cells to swim rapidly through liquid. The microtubules in cilia and flagella are arranged in a "9 + 2" pattern, as shown in **Figure 8-11**. Small cross-bridges between the microtubules in these organelles use chemical energy to pull on, or slide along, the microtubules, producing controlled movements.

READING CHECK **Use an Analogy** How is a cell's cytoskeleton like the girders and beams of a warehouse?

BUILD VOCABULARY

Prefixes The prefix *cyto-* refers to cells. The cytoskeleton acts like a skeleton for the cell.

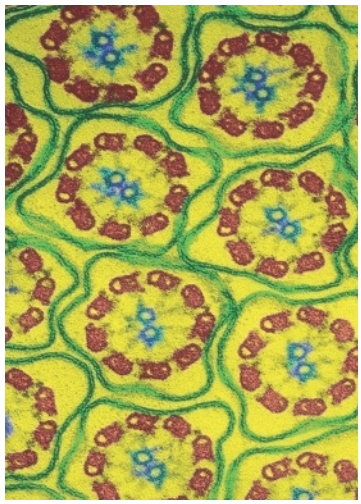
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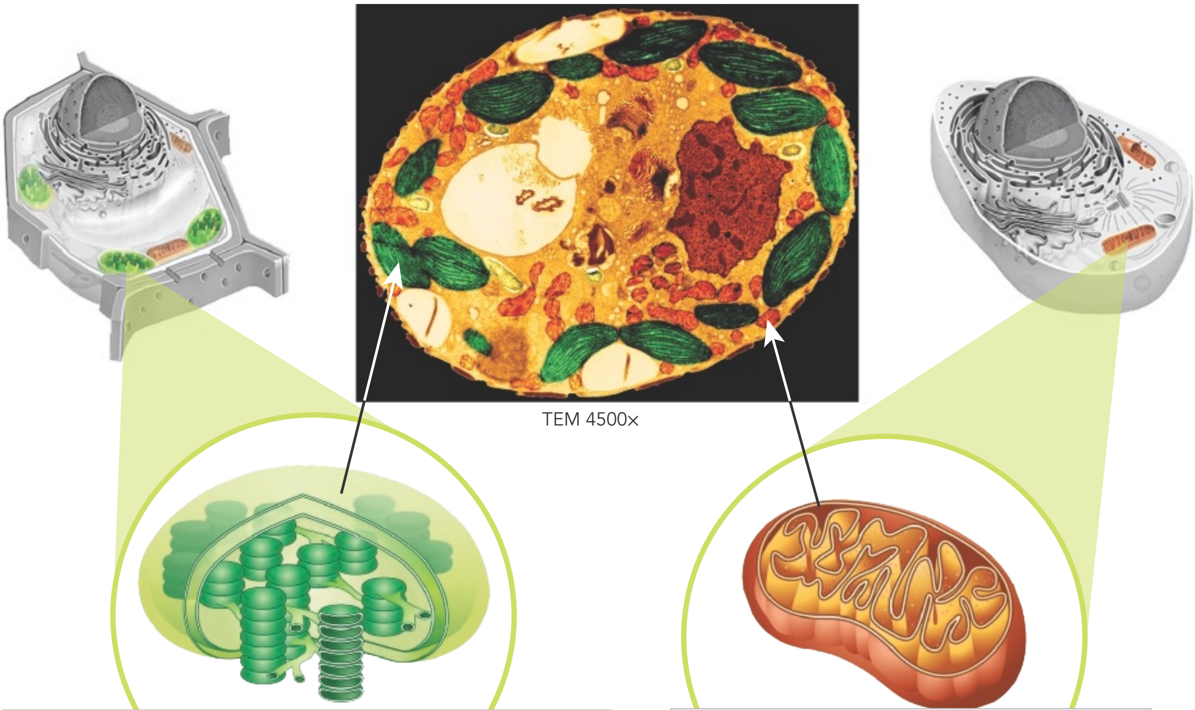
Figure 8-11
The "9 + 2" Pattern of Microtubules

The microtubules in eukaryotic cilia and flagella are arranged in a "9 + 2" pattern. In this micrograph showing the cross section of a group of cilia, you can clearly see the 9 + 2 arrangement of the microtubules.



Cellular Solar Panels
Chloroplasts, found in plants and some other organisms such as algae, convert energy from the sun into chemical energy that is stored in food.

Cellular Power Plants
Mitochondria convert chemical energy stored in food into a form that can be used easily by the cell.

CASE STUDY

Figure 8-12

Cellular Powerhouses

Chloroplasts and mitochondria are both involved in energy conversion processes within the cell. **Infer** Some types of cells require more energy than others to perform their functions. What could the effect be if the mitochondria in these cells did not function correctly?

Organelles That Capture and Release Energy

All living things require a source of energy. That makes energy conversion one of the most important processes in the cell. Factories are hooked up to the local power company, but how do cells get their energy? Most cells are powered by food molecules that are built using energy that ultimately comes from sunlight.

Chloroplasts Plants and some other organisms contain chloroplasts (KLAWR uh plasts). **Chloroplasts** are the biological equivalents of solar power plants. ***Chloroplasts capture the energy from sunlight and convert it into chemical energy stored in food during photosynthesis.*** Two membranes surround chloroplasts. Inside the organelle are large stacks of other membranes, which contain the green pigment chlorophyll.

Mitochondria Nearly all eukaryotic cells, including plants, contain mitochondria (myt oh KAHN dree uh; singular: mitochondrion). **Mitochondria** are the power plants of the cell. ***Mitochondria convert the chemical energy stored in food molecules into compounds that are more convenient for the cell to use.*** Like chloroplasts, two membranes—an outer membrane and an inner membrane—enclose mitochondria. The inner membrane is folded up inside the organelle, as shown in **Figure 8-12**.

Figure 8-13

Lynn Margulis (1938–2011)

Lynn Margulis hypothesized that chloroplasts and mitochondria are descended from free-living prokaryotes that were engulfed by ancestral eukaryotes.

One of the most interesting aspects of mitochondria is the way in which they are inherited. In humans, all or nearly all of our mitochondria originate from the cytoplasm of the ovum, or egg cell. This means that when your relatives are discussing which side of the family should take credit for your best characteristics, you can tell them that you got your mitochondria from Mom!

Another interesting point: Chloroplasts and mitochondria contain some of their own genetic information in the form of small DNA molecules. This observation led biologist Lynn Margulis, shown in **Figure 8-13**, to suggest that both organelles are descended from prokaryotic cells that once lived independently. Her idea, known as the endosymbiotic theory, is that ancient bacteria and photosynthetic cyanobacteria took up residence inside the earliest eukaryotes. This means that both chloroplasts and our own mitochondria owe their existence to the mutualistic relationship established between these cells more than a billion years ago. It also means that genetic changes in human mitochondria can affect the health of our cells and our bodies. One such change in mitochondrial DNA is responsible for LHON, the disorder described in this chapter's Case Study.

READING CHECK **Use an Analogy** How are chloroplasts like solar panels? How are mitochondria like electric power plants?

Quick Lab

Open-Ended Inquiry

How Can You Make a Model of a Cell?

1. Work together as a class to make a room-sized model of a plant cell. Begin by reviewing the structure of the plant cell shown in **Figure 8-16**. With a partner or a small group, choose a cell part or an organelle to model.
2. Using materials of your choice, make a three-dimensional model of the cell part or organelle.
3. Label an index card with the name of your cell structure or organelle. List its main features and functions, including how it interacts with other organelles. Attach the card to your model.
4. Attach your model to an appropriate place in the room. If possible, attach your model to another related cell part or organelle.

ANALYZE AND CONCLUDE

1. **Calculate** Assume that a typical plant cell is 50 micrometers wide (50×10^{-6} m). Calculate the scale of your classroom cell model. (**Hint:** Divide the width of the classroom by the width of a cell, making sure to use the same units.)
2. **Specify Design Constraints** How is your model cell part or organelle similar to the real cell part or organelle? Describe any design constraints that caused your model cell part or organelle to be different from the real cell part or organelle.
3. **Evaluate Models** Exchange models with another group. Evaluate the strengths and limitations of the model. Use the evaluation to suggest improvements for your model.

Cellular Boundaries

A working factory needs walls and a roof to protect it from the environment outside and also to serve as a barrier that keeps its products safe and secure until they are ready to be shipped out. Cells have similar needs, and they meet them in a similar way. As you have learned, all cells are surrounded by a barrier known as the cell membrane. Many cells, including most prokaryotes, also produce a strong supporting layer around the membrane known as a **cell wall**.

INTERACTIVITY

Compare and contrast structures in animal and plant cells.

Cell Walls Many organisms have cell walls that lie just outside their cell membranes. The main function of the cell wall is to support, shape, and protect the cell. Most prokaryotes and many eukaryotes, including plants and fungi, have cell walls, although animal cells do not. Most cell walls are porous enough to allow water, oxygen, carbon dioxide, and certain other substances to pass through easily.

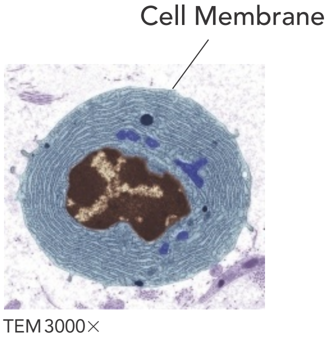
Cell walls provide much of the strength needed for plants to stand against the force of gravity. In trees and other large plants, nearly all of the tissue we call wood is made up of cell walls. The cellulose fiber used for paper as well as the lumber used for building comes from these walls. So if you are reading these words from a sheet of paper in a book resting on a wooden desk, you've got cell walls all around you.

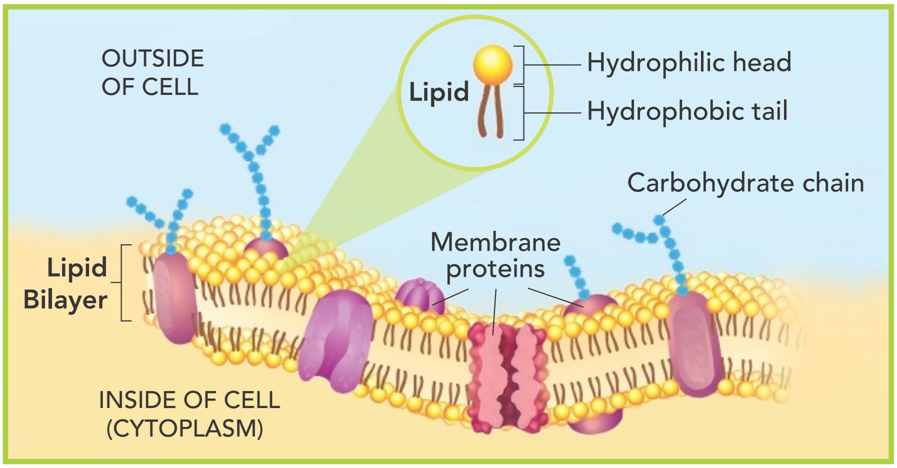
Cell Membranes All cells contain cell membranes, generally made up of a double-layered sheet called a lipid bilayer, as shown in **Figure 8-14**. The **lipid bilayer** gives cell membranes a flexible structure that forms a strong barrier between the cell and its surroundings. ***The cell membrane regulates what enters and leaves the cell and also protects and supports the cell.***

Figure 8-14

Cell Membrane

Every cell has a membrane that regulates the movement of materials. Nearly all cell membranes are made up of a lipid bilayer in which proteins and carbohydrates are embedded.





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The Properties of Lipids The layered structure of cell membranes reflects the chemical properties of the lipids that make them up. You may recall that many lipids have oily fatty acid chains attached to chemical groups that interact strongly with water. In the language of a chemist, the fatty acid portions of this kind of lipid are hydrophobic (hy druh FOH bik), or "water-hating," while the opposite end of the molecule is hydrophilic (hy druh FIL ik), or "water-loving." When these lipids, which are common in cell membranes, are mixed with water, their hydrophobic fatty acid "tails" cluster together, while their hydrophilic "heads" are attracted to water. A lipid bilayer is the result. As you can see in Figure 8-14, the head groups of lipids are exposed on both sides of the membrane, while the fatty acid tails form an oily layer inside the membrane that keeps water from passing across it.

Although many substances can cross cell membranes, some are too large or too strongly charged to cross the lipid bilayer. If a substance is able to cross a membrane, the membrane is said to be permeable to it. A membrane is impermeable to substances that cannot pass across it. Most cell membranes are **selectively permeable**, meaning that some substances can pass across them and others cannot. Selectively permeable membranes are also called semipermeable membranes.

The Fluid Mosaic Model Protein molecules are embedded in the lipid bilayer of most cell membranes. Carbohydrate molecules are attached to many of these proteins. Because the proteins embedded in the lipid bilayer can move around and "float" among the lipids, and because so many different kinds of molecules make up the cell membrane, scientists describe the cell membrane as a "fluid mosaic." (A mosaic is a kind of art, such as the example shown in **Figure 8-15**, that involves putting bits and pieces of different colors or materials together.) Some of these proteins form channels and pumps that help to move material across the cell membrane. Many of the carbohydrate molecules act like chemical identification cards, allowing individual cells to identify one another. Some proteins attach directly to the cytoskeleton, enabling cells to respond to their environment by using their membranes to help move or change shape.

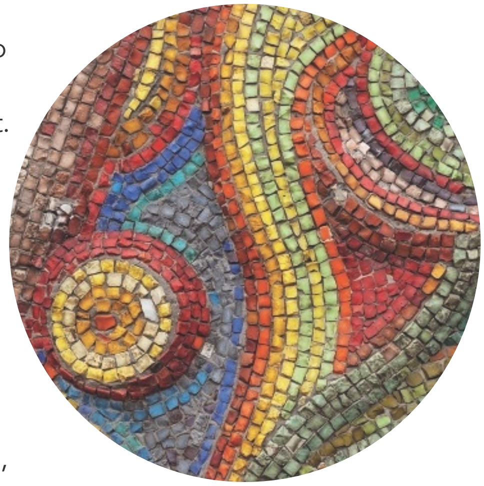


Figure 8-15

Mosaic

Mosaics are made by assembling small pieces of different colors and types of materials. Similarly, cell membranes are made up of different kinds of molecules.

HS-LS1-1, HS-LS1-2

LESSON 8.2 Review

KEY QUESTIONS

1. What are the two major parts of a eukaryotic cell?
2. Describe the steps in making, packaging, and exporting a protein from a cell.
3. Compare the role of vacuoles and lysosomes in a cell.
4. Explain why plant cells require both chloroplasts and mitochondria to meet their energy needs.
5. Explain how the structure of a cell's membrane is related to its function.

CRITICAL THINKING

6. **Develop a Model** Using Figure 8-16 on the next page as a guide, draw your own models of a prokaryotic cell, a plant cell, and an animal cell. Then use each of the vocabulary words from this lesson to label your cells. Describe any differences between the models in Figure 8-16 and your models.
7. **Cite Evidence** What evidence supports the argument that ancestors of mitochondria and chloroplasts once lived as independent organisms?

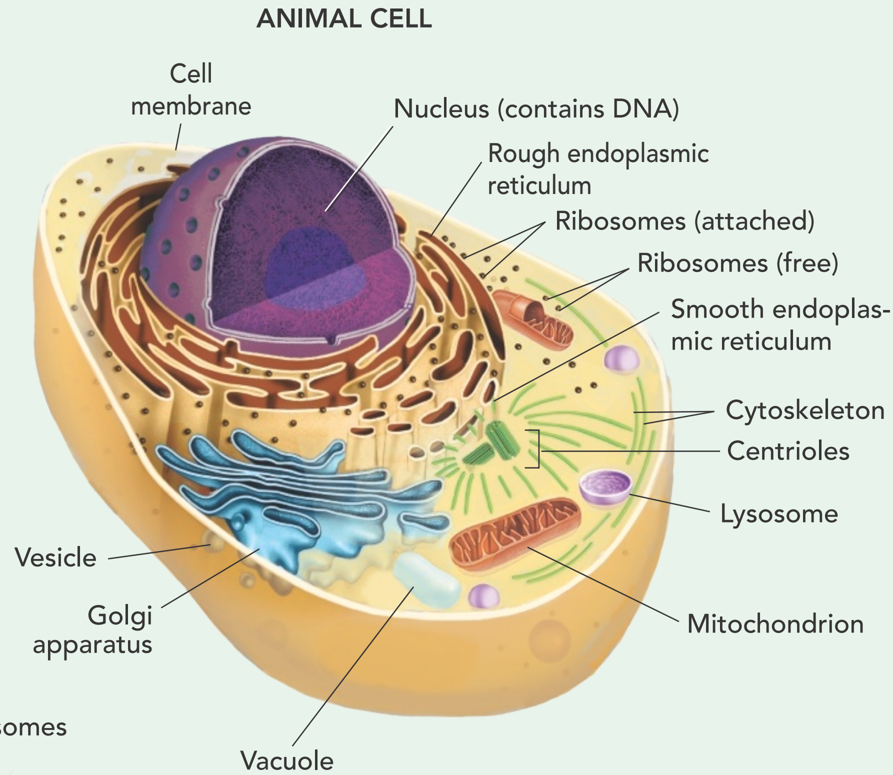
INTERACTIVITY

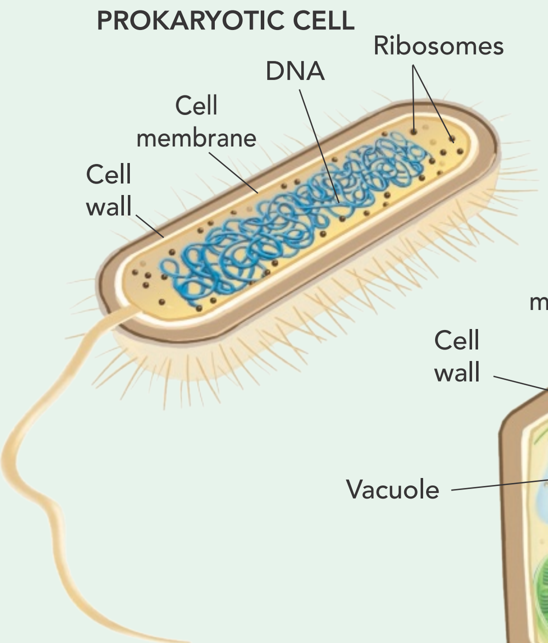
Visual Summary

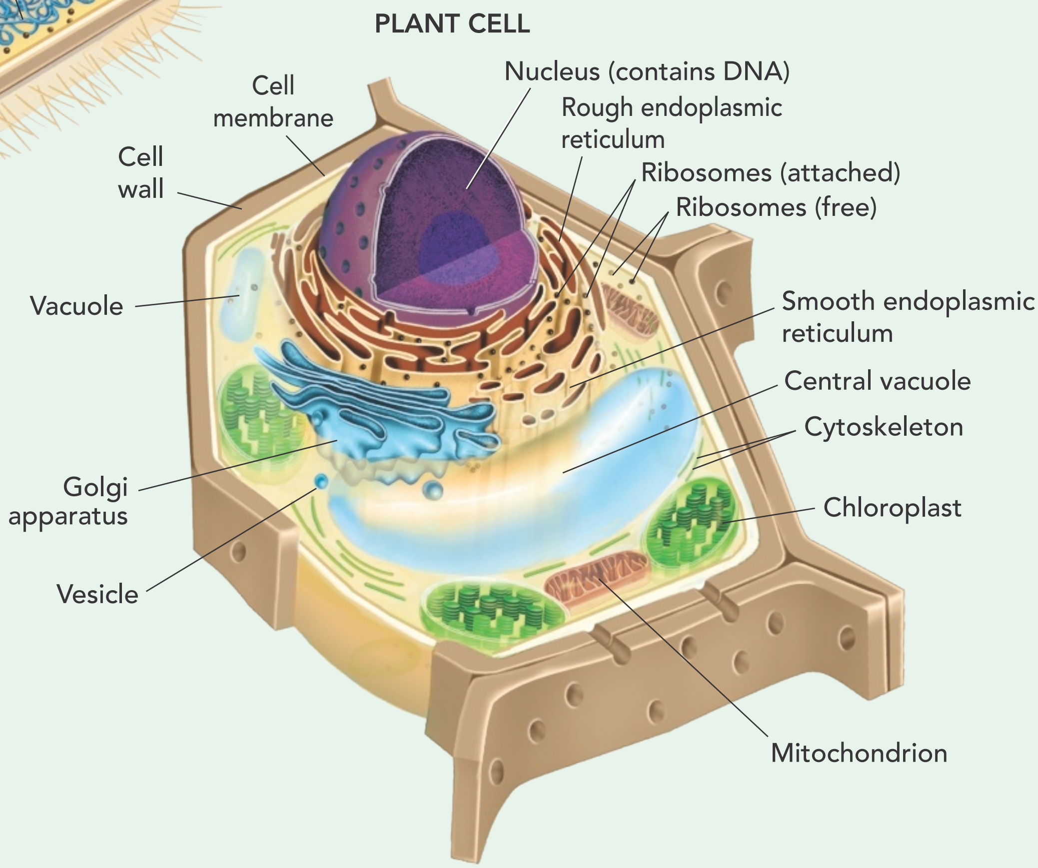
Figure 8-16

Comparing Typical Cells

Eukaryotic cells have many different kinds of organelles. Some of these organelles are also found in prokaryotic cells. The table on the facing page compares prokaryotic cells, animal cells, and plant cells.



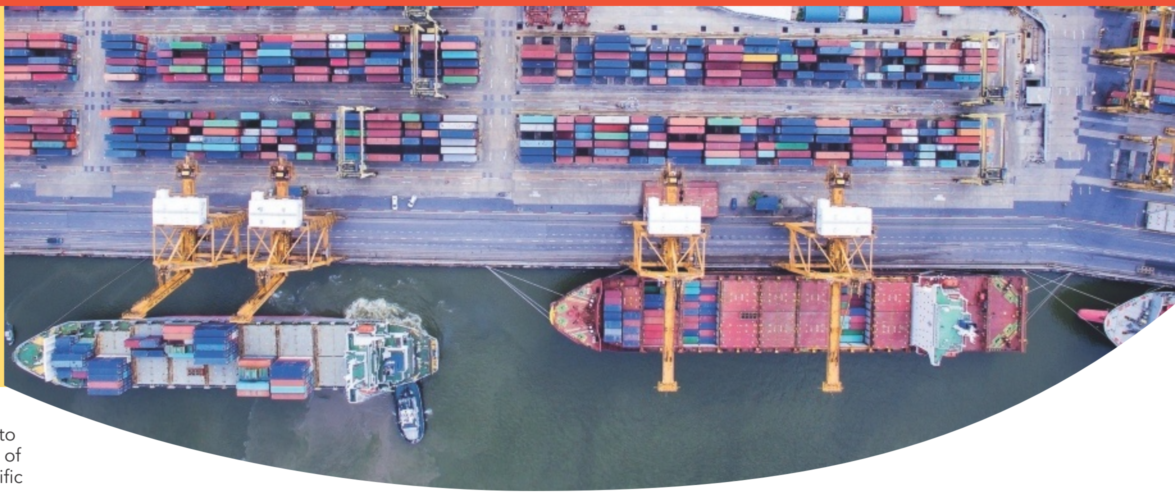




	Structure	Function	Prokaryote	Eukaryote: Animal	Eukaryote: Plant
Cellular Control Center	Nucleus	Contains DNA	Prokaryote DNA is found in cytoplasm.	✓	✓
Organelles That Build Proteins	Ribosomes	Synthesize proteins	✓	✓	✓
	Endoplasmic reticulum	Assembles proteins and lipids		✓	✓
	Golgi apparatus	Modifies, sorts, and packages proteins and lipids for storage or transport out of the cell		✓	✓
Organelles That Store, Clean-Up, and Support	Vacuoles and vesicles	Store materials	✓	✓	✓
	Lysosomes	Break down and recycle macromolecules		✓	✓ (Rare)
	Cytoskeleton	Maintains cell shape; moves cell parts; helps cells move	Prokaryotic cells have protein filaments similar to actin and tubulin	✓	✓
	Centrioles	Organize cell division		✓	
Organelles That Capture and Release Energy	Chloroplasts	Convert solar energy to chemical energy stored in food	In some prokaryotic cells, photosynthesis occurs in association with internal photosynthetic membranes.		✓
	Mitochondria	Convert chemical energy in food to usable compounds	Prokaryotes carry out these reactions in the cytoplasm rather than in specialized organelles.	✓	✓
Cellular Boundaries	Cell wall	Shapes, supports, and protects the cell	✓		✓
	Cell membrane	Regulates materials entering and leaving cell; protects and supports cell	✓	✓	✓

LESSON

8.3 Cell Transport



KEY QUESTIONS

- *How does passive transport work?*
- *How does active transport work?*

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

VOCABULARY
homeostasis
diffusion
facilitated diffusion
aquaporin
osmosis
isotonic
hypertonic
hypotonic
osmotic pressure

READING TOOL

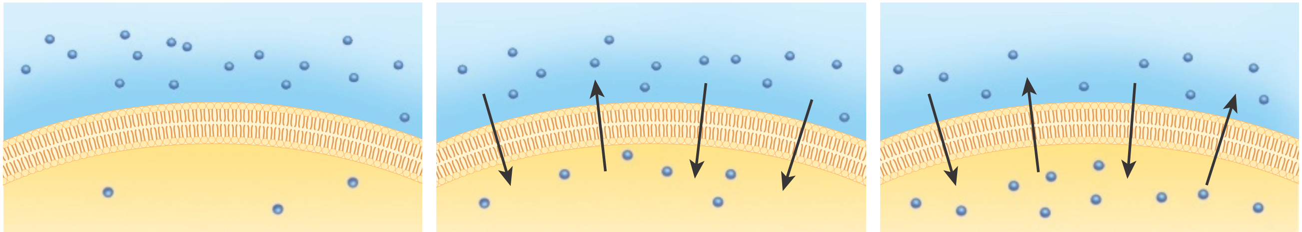
As you read, compare and contrast passive and active transport. Complete the Venn Diagram in your **Biology Foundations Workbook.**

In the previous lesson, we compared cell walls and cell membranes to the roof and walls of a factory. When you think about how cells move materials in and out, it might be more helpful to think of a cell as a nation. The boundaries of a nation are its borders, and nearly every nation tries to regulate and control the goods that move across its borders, like the shipping containers seen here entering and leaving a seaport. Each cell has its own border, which separates the cell from its surroundings and also determines what comes in and what goes out. How can a cell separate itself from its environment and still allow materials to enter and leave? That's where the transport of molecules across its border, the cell membrane, comes in.

Passive Transport

Every living cell exists in a liquid environment. One of the most important processes carried out by the cell membrane is to keep a cell in homeostasis. **Homeostasis** is a state of relatively constant internal physical and chemical conditions. It does this by regulating the movement of molecules and other substances from one side of the membrane to the other side.

Diffusion The cytoplasm consists of many different substances dissolved in water. In any solution, solute particles move constantly. They collide with one another and tend to spread out randomly. As a result, the particles tend to move from an area where they are more concentrated to an area where they are less concentrated. When you add sugar to coffee or tea, for example, the sugar molecules move away from their original positions in the sugar crystals and disperse throughout the hot liquid. The process by which particles move from an area of higher concentration to an area of lower concentration is known as **diffusion** (dih FYOO zhun). Diffusion is the driving force behind the movement of many substances across the cell membrane.



There is a higher concentration of solute on one side of the membrane than on the other.

Diffusion causes a net movement of solute particles from the side of the membrane with the higher solute concentration to the side with the lower solute concentration.

Once equilibrium is reached, solute particles continue to diffuse across the membrane in both directions but at approximately equal rates, so there is no net change in solute concentration.

Figure 8-17

Diffusion

Diffusion is the process by which molecules move from an area of higher concentration to an area of lower concentration. The cell does not use energy during this process.

Figure 8-17 shows a substance that can cross the cell membrane. Its molecules will tend to move toward the area where it is less concentrated until it is evenly distributed. Equilibrium is reached when the concentration of the substance on both sides of the cell membrane is the same. Even at equilibrium, molecules continue to move across the membrane in both directions. However, there is no further net change in the concentration on either side.

Diffusion depends on random molecular movements. Therefore, substances diffuse across membranes without requiring the cell to use additional energy. ***The movement of molecules across the cell membrane without using cellular energy is called passive transport.***

Facilitated Diffusion Since cell membranes are built around lipid bilayers, the molecules that pass through them most easily are small and uncharged. These properties allow them to dissolve in the membrane's lipid environment. But many charged ions, like Cl^-, and large molecules, like the sugar glucose, seem to pass through cell membranes very quickly, as if they have a shortcut.

How does this happen? Proteins in the cell membrane act as carriers, or channels, making it easy for certain molecules to cross. Red blood cells, for example, have protein carriers that allow the sugar glucose to pass through them in either direction. These channels facilitate, or help, the diffusion of glucose across the membrane. In **facilitated diffusion**, molecules that cannot directly diffuse across the membrane pass through special protein channels. Hundreds of different proteins allow substances to cross cell membranes. Although facilitated diffusion is fast and specific to certain molecules, it is still diffusion, so it does not require any use of the cell's energy.

READING CHECK **Compare** What is the difference between diffusion and facilitated diffusion?

HS-LS1-3

Exploration Lab

Open-ended Inquiry

Detecting Diffusion

Problem How can you model the diffusion of solutes across a cell membrane?

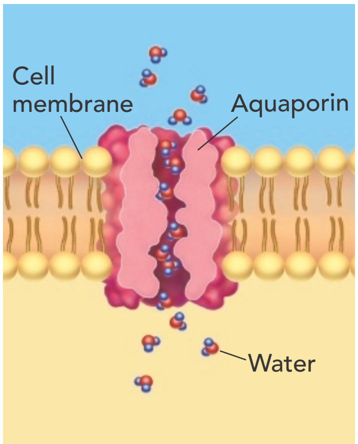
In this lab, you will use dialysis tubing to model a cell membrane. You will use the model to determine the role of cellular transport in maintaining homeostasis.

You can find this lab in your digital course.

Figure 8-18

Aquaporins

Aquaporins assist the movement of water molecules through the cell membrane.



INTERACTIVITY

Investigate the movement of water during osmosis.

Figure 8-19

Osmosis

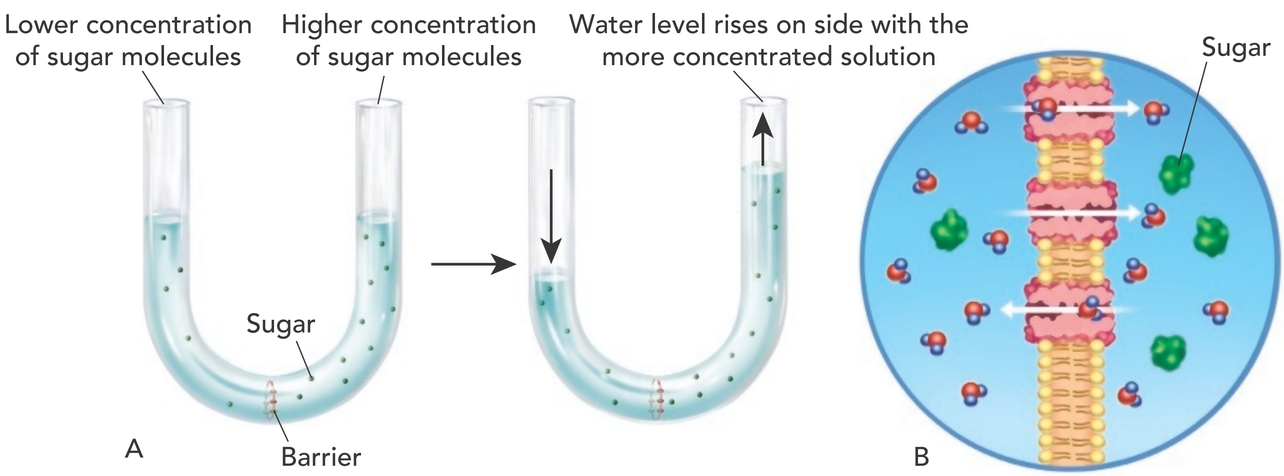
Osmosis is a form of facilitated diffusion. **A.** In a laboratory experiment, water moves through a selectively permeable barrier from lower to higher solute concentration. **B.** In the cell, water passes by osmosis through aquaporins embedded in the cell membrane.

Osmosis: An Example of Facilitated Diffusion

In the 1990s, researchers discovered that water should be added to the list of molecules that enter cells by facilitated diffusion. Recall that the inside of a cell's lipid bilayer is hydrophobic. As a result, water molecules cannot easily diffuse through the cell membrane. However, many cells contain water channel proteins, known as **aquaporins** (ak wuh PAW rinz), that allow water to pass right through them, as shown in **Figure 8-18**. The movement of water through cell membranes by facilitated diffusion plays a role in an extremely important biological process—the process of osmosis.

Osmosis is the diffusion of water through a selectively permeable membrane. In osmosis, as in other forms of diffusion, molecules move from an area of higher concentration to an area of lower concentration. The only difference is that the molecules moving in the case of osmosis are water molecules, not solute molecules.

How Osmosis Works Look at the experimental setup in **Figure 8-19A**. The barrier is permeable to water but not to sugar. This means that water can cross the barrier in both directions, but sugar cannot. To start, there are more sugar molecules on the right side of the barrier than on the left side. Therefore, the concentration of water is lower on the right, where more of the solution is made of sugar. Although water molecules move in both directions across the membrane, there is a net transport of water toward the concentrated sugar solution. Water will tend to move across the membrane until equilibrium is reached. At that point, the concentrations of water and sugar will be the same on both sides of the membrane. When this happens, the two solutions will be **isotonic**, which means "same strength." Note that "strength" refers to the amount of solute, not water. When the experiment began, the more concentrated sugar solution on the right side of the tube was **hypertonic**, or "above strength," compared to the left side. So the dilute sugar solution was **hypotonic**, or "below strength." **Figure 8-19B** shows how osmosis works across a cell membrane.



Osmotic Pressure Driven by differences in solute concentration, the net movement of water out of or into a cell produces a force known as **osmotic pressure**. As shown in **Figure 8-20**, osmotic pressure can cause an animal cell in a hypertonic solution to shrink and one in a hypotonic solution to swell. Because cells contain salts, sugars, proteins, and other dissolved molecules, they are almost always hypertonic to fresh water. As a result, water tends to move quickly into a cell surrounded by fresh water, causing it to swell. Eventually, the cell may burst like an overinflated balloon. In plant cells, osmotic pressure can cause changes in the size of the central vacuole, which shrinks or swells as water moves into or out of the cell.

Fortunately, cells in large organisms are not in danger of bursting, because most of them do not come in contact with fresh water. Instead, the cells are bathed in blood or other isotonic fluids. The concentrations of dissolved materials in these isotonic fluids are roughly equal to those in the cells themselves.

What happens when cells do come in contact with fresh water? Some, like the eggs laid in fresh water by fish and frogs, lack water channels. As a result, water moves into them so slowly that osmotic pressure is not a problem. Others, including bacteria and plant cells, are surrounded by tough walls. The cell walls prevent the cells from expanding, even under tremendous osmotic pressure. Notice how the plant cell in Figure 8-20 holds its shape in both hypertonic and hypotonic solutions, but the animal red blood cell does not. However, increased osmotic pressure does make plant cells extremely vulnerable to cell wall injuries.

READING CHECK Summarize In your own words, explain why osmosis is really just a special case of facilitated diffusion.

BUILD VOCABULARY

Academic Words The word pressure means "force applied over an area." Water pressure is caused by the force of water molecules hitting the sides of their container. Osmotic pressure is caused by the difference in the forces of water molecules hitting either side of the cell membrane.

INTERACTIVITY

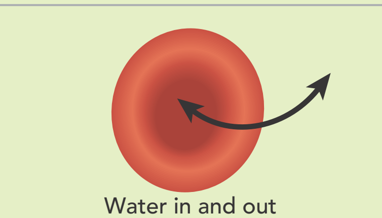
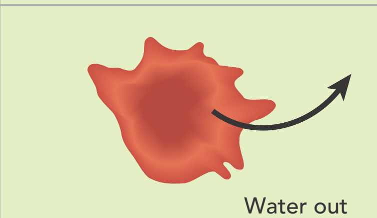
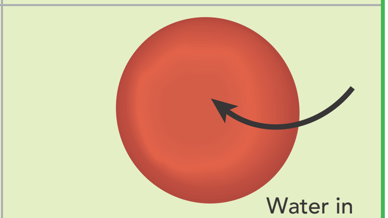
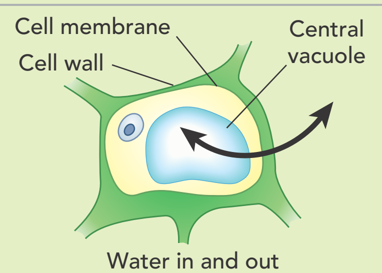
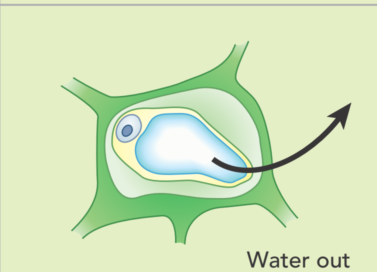
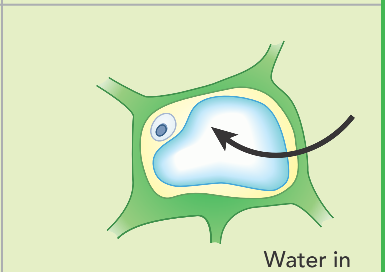
Discover how cell transport occurs in plants when they are exposed to different conditions.

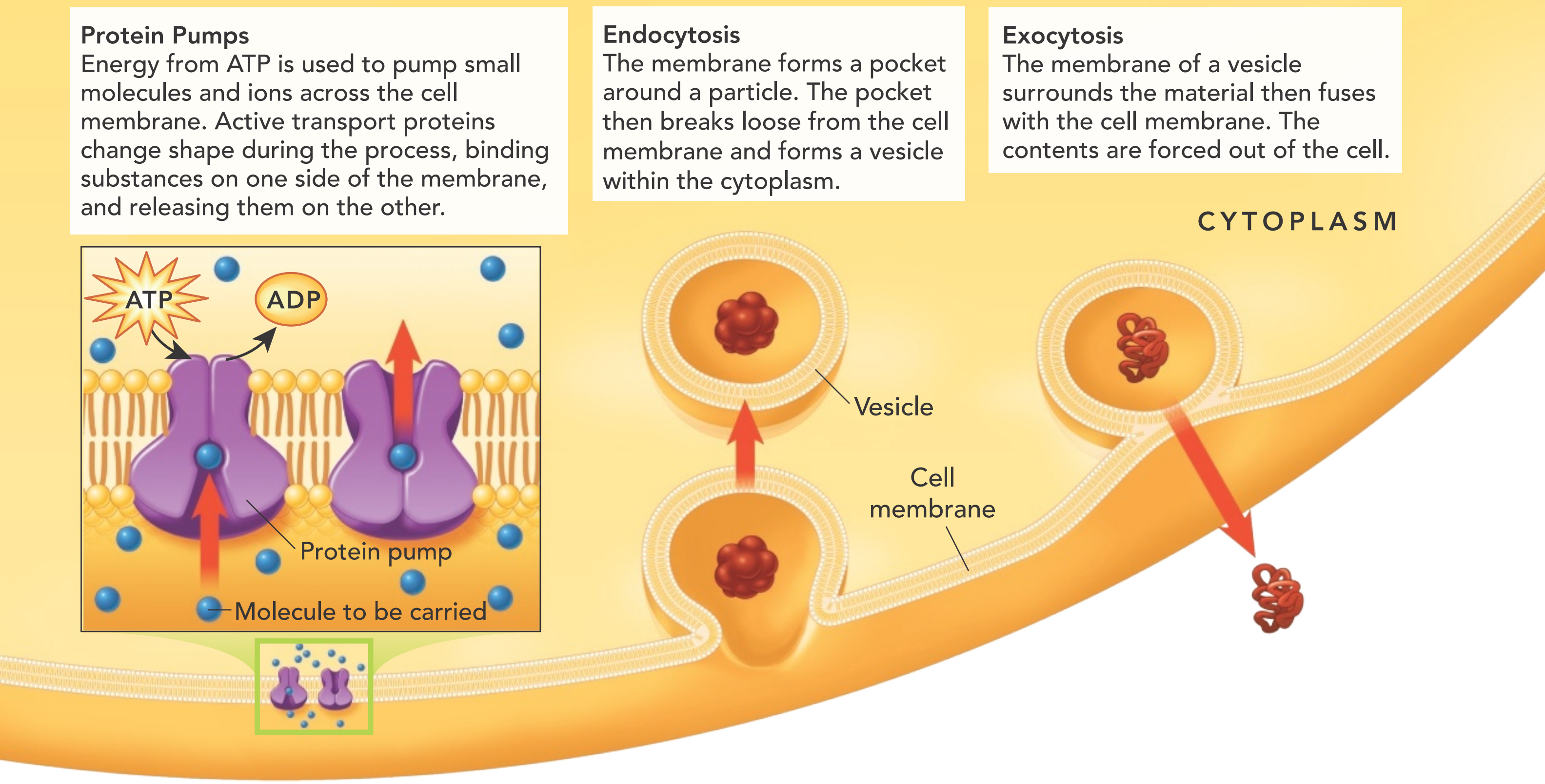
Figure 8-20

Osmotic Pressure

Different solute concentrations inside and outside of the cell can lead to a net loss or net gain of water.

The Effects of Osmosis on Cells

Solution	**Isotonic:** The concentration of solutes is the same inside and outside the cell. Water molecules move equally in both directions.	**Hypertonic:** The solution has a higher solute concentration than the cell. A net movement of water molecules out of the cell causes it to shrink.	**Hypotonic:** The solution has a lower solute concentration than the cell. A net movement of water molecules into the cell causes it to swell.
Animal Cell			
Plant Cell			



ANIMATION

Visual Summary

Figure 8-21

Active Transport

Energy from the cell is needed to move substances against a concentration difference.

Compare and Contrast What are the similarities and differences between facilitated diffusion and active transport by a protein pump?

Active Transport

Although diffusion is useful, cells sometimes must transport materials against a concentration difference. ***The movement of materials against a concentration difference is known as active transport, and it requires energy.*** The active transport of small molecules or ions across a cell membrane is generally carried out by transport proteins—protein pumps—that are found in the membrane. Larger molecules and clumps of material can also be actively transported across the cell membrane by processes known as endocytosis and exocytosis. The transport of these larger materials sometimes involves changes in the shape of the cell membrane. The major types of active transport are shown in **Figure 8-21**.

Molecular Transport Small molecules and ions are carried across membranes by proteins in the membrane that act like pumps. Many cells use protein pumps to move calcium, potassium, and sodium ions across cell membranes. Cells spend a considerable portion of their energy use on molecular transport. The use of energy in these systems enables cells to concentrate substances in a particular location, even when the forces of diffusion might tend to move these substances in the opposite direction.

Bulk Transport Larger molecules and even solid clumps of material can be transported by movements of the cell membrane known as bulk transport. Bulk transport can take several forms, depending on the size and shape of the material moved into or out of the cell.

Endocytosis Endocytosis (en doh sy TOH sis) is the process of taking material into the cell by means of infoldings, or pockets, of the cell membrane. Figure 8-21 shows how the pocket that results breaks loose from the cell membrane and forms a vesicle or vacuole within the cytoplasm. Large molecules, clumps of food, and even whole cells can be taken up in this way.

Phagocytosis (fag oh sy TOH sis) is a type of endocytosis in which extensions of cytoplasm surround a particle and package it within a food vacuole. The cell then engulfs it. White blood cells use phagocytosis to remove damaged or foreign cells and destroy them. Amoebas use this method for taking in food, as shown in **Figure 8-22**. Engulfing material in this way requires a considerable amount of energy and is considered a form of active transport.

Many cells take up liquid from the surrounding environment in a process similar to phagocytosis. During a type of endocytosis called pinocytosis (py nuh sy TOH sis), tiny pockets form along the cell membrane, fill with liquid, and pinch off to form vacuoles.

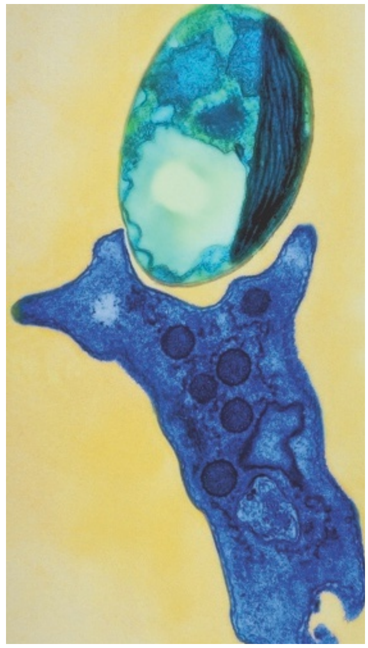
Exocytosis Many cells also release large amounts of material, a process known as exocytosis (ek soh sy TOH sis). During exocytosis, the membrane of the vesicle or vacuole surrounding the material fuses with the cell membrane, forcing the contents out of the cell. The removal of water by means of a contractile vacuole is one example of this kind of active transport.

From its simple beginnings, life has spread to every corner of our planet, penetrating deep below Earth's surface and far beneath the surface of the seas. The diversity of life is so great that you might have to remind yourself that all living things are composed of cells, have the same basic chemical makeup, and even contain the same kinds of organelles. This does not mean that all living things are the same. As you'll discover in Lesson 8.4, differences arise from the ways in which cells are specialized and the ways in which cells associate with one another to form multicellular organisms.

Figure 8-22

Phagocytosis

An amoeba (blue) is consuming an algal cell using phagocytosis. The amoeba will surround the algal cell. Then chemicals inside the amoeba will break down the algal cell for nutrients and energy.



TEM 3000×

READING TOOL

Without using the word *endocytosis*, summarize how a white blood cell would engulf a damaged cell.

HS-LS1-2, HS-LS1-3

LESSON 8.3 Review

KEY QUESTIONS

1. Describe how molecules enter and leave a cell without the use of the cell's energy.
2. Describe the two major types of active transport.

CRITICAL THINKING

3. **Construct an Explanation** Water molecules diffuse through the cell membrane through aquaporins. How are these proteins helpful in osmosis?
4. **Apply Scientific Reasoning** How are the transport problems of a freshwater organism different from those of a saltwater organism?
5. **Develop Models** A student draws a fence with several gates as part of a model of cellular transport. Explain what the fence and the gates represent, relating their structures to their functions. Explain how the model could represent both active transport using protein pumps and facilitated diffusion.

LESSON 8.4

Homeostasis and Cells

SEM 750×

KEY QUESTIONS

- *How do single-celled organisms maintain homeostasis?*
- *How do the cells of a multicellular organism work together to maintain homeostasis?*

HS-LS1-2: Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.
HS-LS1-3: Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

VOCABULARY
tissue
organ
organ system
receptor

READING TOOL

As you read the text, fill in the graphic organizer in your **Biology Foundations Workbook** to show the progression from specialized cells to organ systems.

Cells are the basic living units of all organisms, but sometimes a single cell actually is the organism. In fact, in terms of their numbers, unicellular organisms dominate life on Earth. This false-color micrograph shows a type of plankton (in blue). Plankton are unicellular marine organisms that do everything you would expect a living thing to do.

The Cell as an Organism

Just like other living things, unicellular organisms must maintain homeostasis, relatively constant internal physical and chemical conditions. ***To maintain homeostasis, unicellular organisms grow, respond to the environment, transform energy, and reproduce.***

Unicellular organisms include both prokaryotes and eukaryotes. Prokaryotes, especially bacteria, are remarkably adaptable. Bacteria live almost everywhere—in the soil, on leaves, in the ocean, in the air, even within the human body.

Many eukaryotes, like amoebas and many algae, also live as single cells. Yeasts, or unicellular fungi, are common worldwide. Yeasts play an important role in breaking down complex nutrients, making them available for other organisms. People use yeasts to make bread and other foods.

Prokaryote or eukaryote, homeostasis is still an issue for each unicellular organism. A tiny cell in a pond or on the surface of your pencil still needs to find sources of energy or food, to keep concentrations of water and minerals within certain levels, and to respond quickly to changes in its environment. The microscopic world around us is filled with unicellular organisms that successfully maintain homeostatic balance.

Multicellular Life

Unlike most unicellular organisms, the cells of humans and other multicellular organisms do not live on their own. They are interdependent. Like the members of a baseball team, they work together. In baseball, each player occupies a particular position: pitcher, catcher, infielder, outfielder. To play the game effectively, players and coaches communicate with one another by sending and receiving signals. Cells in a multicellular organism work the same way. ***The cells of multicellular organisms become specialized for particular tasks and communicate with one another to maintain homeostasis***.

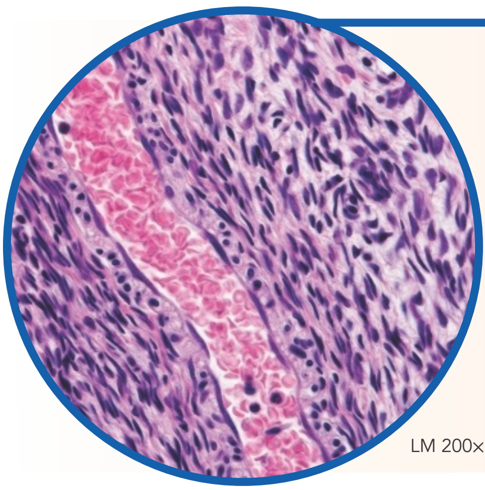
INTERACTIVITY

Learn about cell differentiation and cell specialization.

Cell Specialization

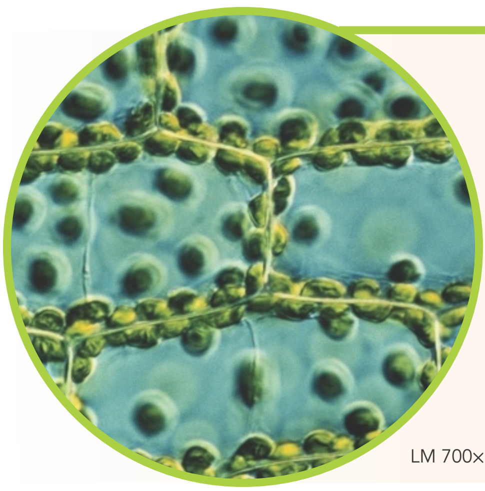
Although we each began life as a single cell, that cell grew and divided to give rise to many other cells. The new cells became specialized, with different cell types playing different roles. Some cells became specialized to move. Other cells react to the environment. Still other cells produce substances needed by the rest of the body. No matter what its role, each specialized cell contributes to homeostasis in a multicellular organism.

READING CHECK **Compare** How does homeostasis compare between unicellular and multicellular organisms?



LM 200×

Specialized Animal Cells All of your cells need oxygen, and they release carbon dioxide as waste. Carrying gases to and from the body is the job of red blood cells, which are shown in pink in the micrograph. These cells flow through blood vessels of varying lengths and widths. In this micrograph, the cells in the wall of the blood vessel and surrounding tissue are stained purple. Notice that the vessel is wide enough for many red blood cells to pass together. The path through the narrowest vessels, called capillaries, is only as wide as a single red blood cell.



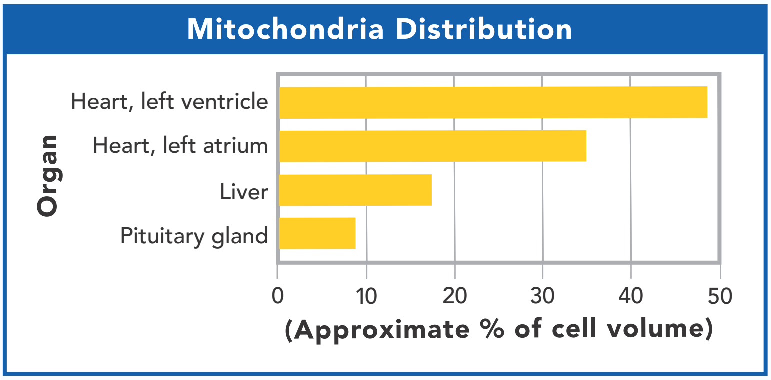
LM 700×

Specialized Plant Cells This micrograph shows plant cells that contain many green, oval-shaped structures. These structures are chloroplasts, the organelles where photosynthesis occurs. Specialized cells with numerous chloroplasts typically make up the leaves of most plants. Cells in other plant parts have few if any chloroplasts, and are specialized for other purposes. Root cells have tiny hairs on their outer layer, which help take in water. In some flowers, certain cells are specialized for making sweet-smelling nectar, which attracts animal pollinators.

CASE STUDY Analyzing Data

Mitochondria in a Mouse

Some cells have more mitochondria than others. Scientists isolated the mitochondria from mouse cells and then calculated the percentage of the cell that mitochondria would fill by volume. The greater the percentage, the more mitochondria in the cell. The bar graph shows the results.



1. **Interpret Graphs** Compare the distribution of mitochondria in the four organs, or organ parts, shown in the graph.
2. **Draw Conclusions** How is it useful for organisms to have an uneven distribution of mitochondria among their cells?
3. **Infer** Which of these tissues would be most vulnerable to problems caused by defective mitochondria? Explain.

READING TOOL

Draw a concept map to model the levels of organization. Use the model to illustrate the interactions between cells, tissues, organs, and an organ system.

Levels of Organization The specialized cells of multicellular organisms are organized into tissues, then into organs, and finally into organ systems, as shown in **Figure 8-23**. A **tissue** is a group of similar cells that perform a particular function. Many tasks in the body are too complicated to be carried out by just one type of tissue. In these cases, many groups of tissues work together as an **organ**. For example, the brain is an individual organ. It is made of nerve tissue, as well as fat tissue and blood vessels. Each type of tissue performs an essential task to help the organ function. In most cases, an organ completes a series of specialized tasks. A group of organs that work together to perform a specific function is called an **organ system**. For example, the brain, spinal cord, and nerves throughout the body work together as the nervous system.

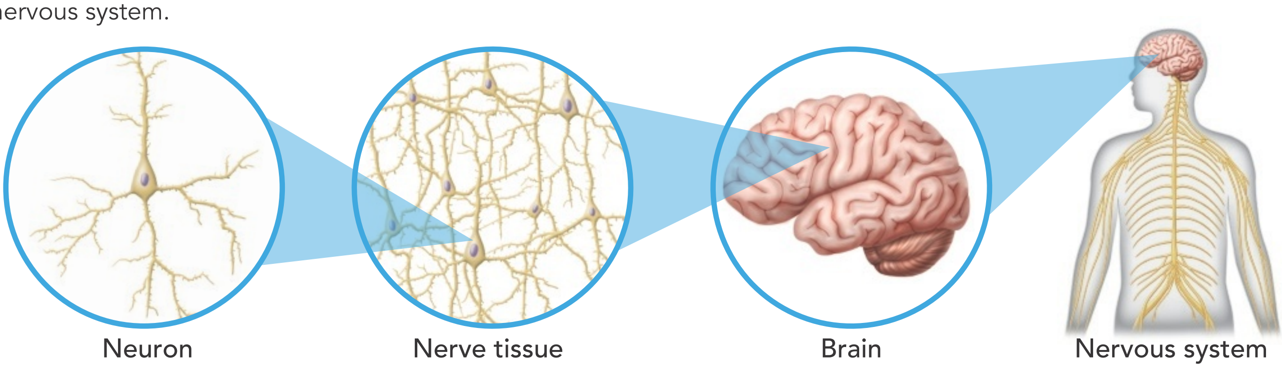
The organization of the body's cells into tissues, organs, and organ systems creates a division of labor among those cells that allows the organism to maintain homeostasis. Specialization and interdependence are two of the remarkable attributes of living things. Appreciating these characteristics is an important step in understanding the nature of living things.

INTERACTIVITY

Figure 8-23

Levels of Organization

Nerve cells, or neurons, make up nerve tissue. Tissues combine to make up organs, such as the brain. The brain, spinal cord, and nerves make up the nervous system.



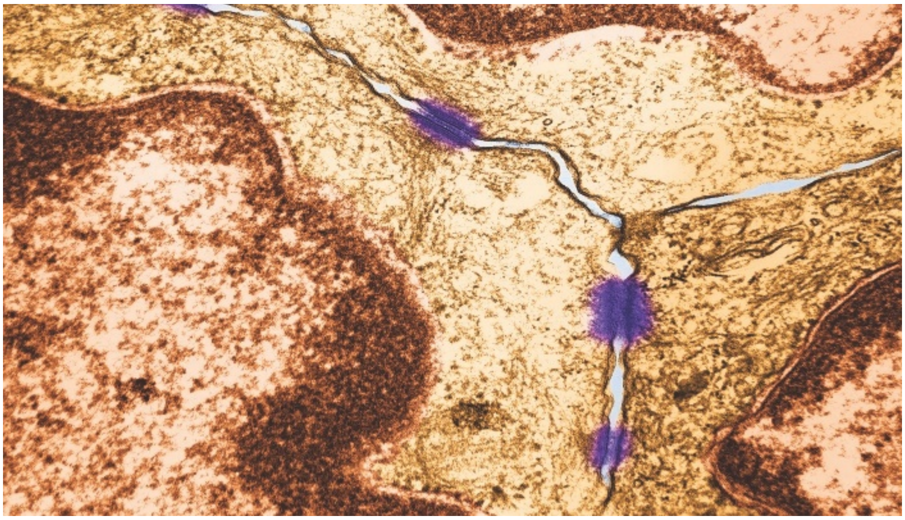


Figure 8-24

Cellular Junctions

Some cellular junctions hold cells together in tight formations. This micrograph shows junctions between epithelial cells in the human body. (TEM 47,500x).

Cellular Communication Cells in a large organism communicate by means of chemical signals that are passed from one cell to another. These cellular signals can speed up or slow down the activities of the cells that receive them and can even cause a cell to change what it is doing in a most dramatic way.

Certain cells in the heart, the liver, and other organs form connections, or cellular junctions, to neighboring cells. Some of these junctions, such as those shown in **Figure 8-24**, hold cells together firmly. Others allow small molecules carrying chemical messages or signals to pass directly from one cell to the next. To respond to one of these chemical signals, a cell must have a **receptor** to which the signaling molecule can bind. Some receptors are on the cell membrane. Receptors for other types of signals are inside the cytoplasm.

In many animals, impulses carried by nerve cells, or neurons, carry messages rapidly from one part of the body to another. An example is the optic nerve, which carries visual information from the eye to the brain. A steady supply of energy, produced by mitochondria, is necessary to keep neurons functioning. Without enough energy, neurons may fail to function and even die. This is what happens as a result of the defective mitochondria caused by LHON.

VIDEO

Explore how cystic fibrosis starts as a problem with cell transport that leads to problems with homeostasis at the organism level.

BUILD VOCABULARY

Related Words The term **receptor** is related to the verb *receive*, which means "to accept or take." A receptor accepts and responds to molecular signals.

HS-LS1-2, HS-LS1-3

LESSON 8.4 Review

KEY QUESTIONS

1. In what ways do single-celled organisms maintain homeostasis?
2. What are two ways the cells of multicellular organisms enable the organism to maintain homeostasis?

CRITICAL THINKING

3. **Construct an Argument** Give three reasons supported by the text that "specialization and interdependence" could be considered the keys to homeostasis in a multicellular organism.
4. **Evaluate a Model** Review Figure 8-23. How well does the diagram represent the levels of organization of multicellular organisms? How could the model be improved?
5. **Use Analogies** Think of an example from your own life such as school, sports, or an extracurricular activity. Develop an analogy to explain why specialization and communication are as important to that activity as they are to a cell.
6. **CASE STUDY** Explain the relationship among homeostasis, defective mitochondria, and the symptoms caused by LHON.

CASE STUDY WRAP-UP

What's happening to me?

LHON is an inherited mitochondrial disorder. How could a mitochondrial defect be related to vision and heart problems?

HS-LS1-1, CCSS.ELA-LITERACY.RST.9-10.1, CCSS.ELA-LITERACY.RST.9-10.7

Make Your Case

Mitochondria are organelles in cells throughout the body. LHON is caused by a defect in mitochondrial DNA that affects their function as energy-generating organelles. How might this be linked to the symptoms of LHON? And how might it be possible to prevent this disorder from being passed from parent to child?

Construct an Explanation

1. **Cite Evidence** Although the genes that cause LHON are found in cells throughout the body, LHON especially affects specific cells in the eyes and heart. Why do you think that tissues with these cells are among the first to fail as a result of defective mitochondria? Cite evidence from the text to support your claim.
2. **Construct an Explanation** Draw an illustration that explains the procedure described in Technology on the Case. Then, using your illustration and evidence from the text, construct an explanation for how this procedure prevents the transmission of LHON from one generation to the next.

This image shows how the world may look to a person with LHON.

Technology on the Case

Stopping LHON Before It Starts

In vitro fertilization (IVF) is a technique many couples have used to help them have children. Sperm from the father are mixed with an egg cell from the mother in the laboratory. If fertilization is successful, the growing cluster of cells is implanted into the mother's uterus, where it develops into a baby. Scientists have used this technique to develop a way to prevent mitochondrial diseases from being passed from mother to child.

The method involves removing the nucleus from an egg cell and transferring it to the cytoplasm of an egg cell from a third parent: a female donor with healthy mitochondria. That egg cell is then fertilized with sperm from the father, and implanted back into the mother who provided the egg nucleus as it develops.

If the procedure is successful, the child that results will inherit nearly all of his or her genes from the mother and father, but the mitochondrial DNA (0.2% of all DNA) will come from the cytoplasm donor. In 2016, the first baby was born who was the result of this technique.

The United Kingdom has approved this technique to help women at risk of passing mitochondrial disorders to their offspring. While this practice might indeed help to eliminate such disorders, it also raises moral and ethical issues. The technique allows physicians to make permanent, heritable changes to human beings.

Careers on the Case

Work Toward a Solution

New technologies sometimes raise complex societal issues. Many careers combine both knowledge and understanding of cells and ethics.

Bioethicist

As medical technology develops, serious ethical and moral issues often arise. Bioethicists are trained to deal with issues involving biology, philosophy, and moral reasoning. They advise medical institutions and government agencies on questions of ethics.

VIDEO

Learn more about careers in bioethics and related fields.

CHAPTER 8
STUDY GUIDE

Lesson Review

Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

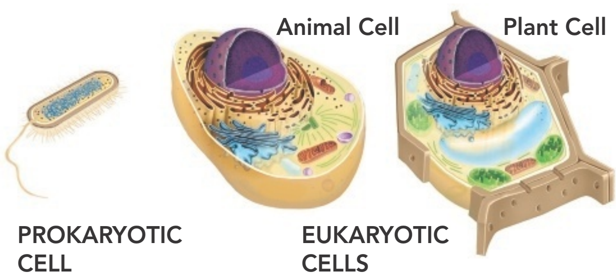
8.1 Life Is Cellular

The smallest living unit of any organism is the cell. Most cells can be seen only with the aid of a microscope. The cell theory states that all living things are made up of cells; cells are the basic units of structure and function in living things; and new cells are produced from existing cells.

Cells were discovered in the 1600s. As microscopes were improved, scientists learned about the parts of the cell and how cells function. Today, electron microscopes can show cell structures as small as 1 billionth of a meter wide.

All cells contain DNA at some point and are surrounded by a cell membrane. Eukaryotic cells are usually larger and more complex than prokaryotic cells. In eukaryotic cells, the nucleus separates the genetic material from the rest of the cell. Prokaryotic cells do not have a nucleus.

- cell
- cell theory
- cell membrane
- nucleus
- eukaryote
- prokaryote



Compare and Contrast How are the three types of cells shown here alike? How are they different?

8.2 Cell Structure

All cells have specialized structures called organelles. Eukaryotic cells have a nucleus, which contains nearly all the cell's DNA and is the control center of the cell. Proteins are assembled on the ribosomes. Cell membrane proteins and lipids are made in association with the endoplasmic reticulum. The Golgi apparatus sorts and packages proteins and other materials from the endoplasmic reticulum for use inside or outside the cell.

Vacuoles store water, salts, proteins, and carbohydrates. Lysosomes contain enzymes to break down these nutrients in the cell. The cytoskeleton maintains shape in eukaryotic cells and is involved in movement.

In plant cells, chloroplasts use sunlight to produce energy rich compounds. Mitochondria convert chemical energy into compounds the cell can use.

Cell walls surround cell membranes and support and protect plant, fungal, and prokaryotic cells. Cell membranes, which regulate the substances that enter and leave the cell, are made up of a flexible lipid bilayer and are selectively permeable.

- cytoplasm
- organelle
- ribosome
- endoplasmic reticulum
- Golgi apparatus
- vacuole
- lysosome
- cytoskeleton
- chloroplast
- mitochondrion
- cell wall
- lipid bilayer
- selectively permeable

Use Visuals Write a caption to accompany this art piece. The caption should include the ultimate product produced by these three structures and their individual functions.

8.3 Cell Transport

Homeostasis refers to the relatively constant internal physical and chemical conditions of an organism. The cell membrane regulates substances that move across it. The movement of molecules across the cell membrane without the use of energy is called passive transport. During diffusion, substances move from an area of higher concentration to an area of lower concentration. During facilitated diffusion, molecules move through protein channels in the cell membrane.

Water moves through channels called aquaporins during osmosis. When the solutions on either side of a membrane are the same in concentration, they are isotonic. A more concentrated solution is hypertonic; a more dilute solution is hypotonic.

The movement of material against a concentration difference requires energy and is called active transport. Molecular transport of small molecules is carried out by proteins in the cell membrane. Larger molecules enter the cell by endocytosis and exit the cell by exocytosis.

- homeostasis
- diffusion
- facilitated diffusion
- aquaporin
- osmosis
- isotonic
- hypertonic
- hypotonic
- osmotic pressure

Identify Patterns What do all forms of active transport have in common?

8.4 Homeostasis and Cells

Like other living things, unicellular organisms must maintain homeostasis. To do so, they grow, respond to the environment, use energy, and reproduce. There are both prokaryotic and eukaryotic unicellular organisms. Unicellular eukaryotes include protists, some algae, and some fungi.

In multicellular organisms, such as plants and animals, cells become specialized to perform specific tasks. The different cells communicate and work with each other to maintain homeostasis.

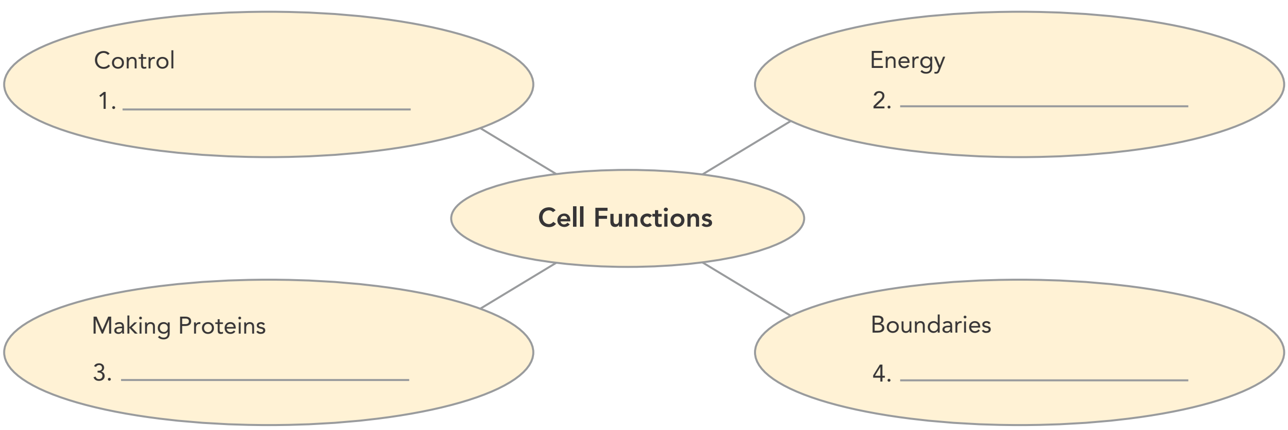
Specialized cells are organized into tissues, organs, and organ systems. A tissue is a group of similar cells that perform a function. An organ is made up of many groups of tissues that work together. An organ system is composed of a group of organs that work together to carry out a task.

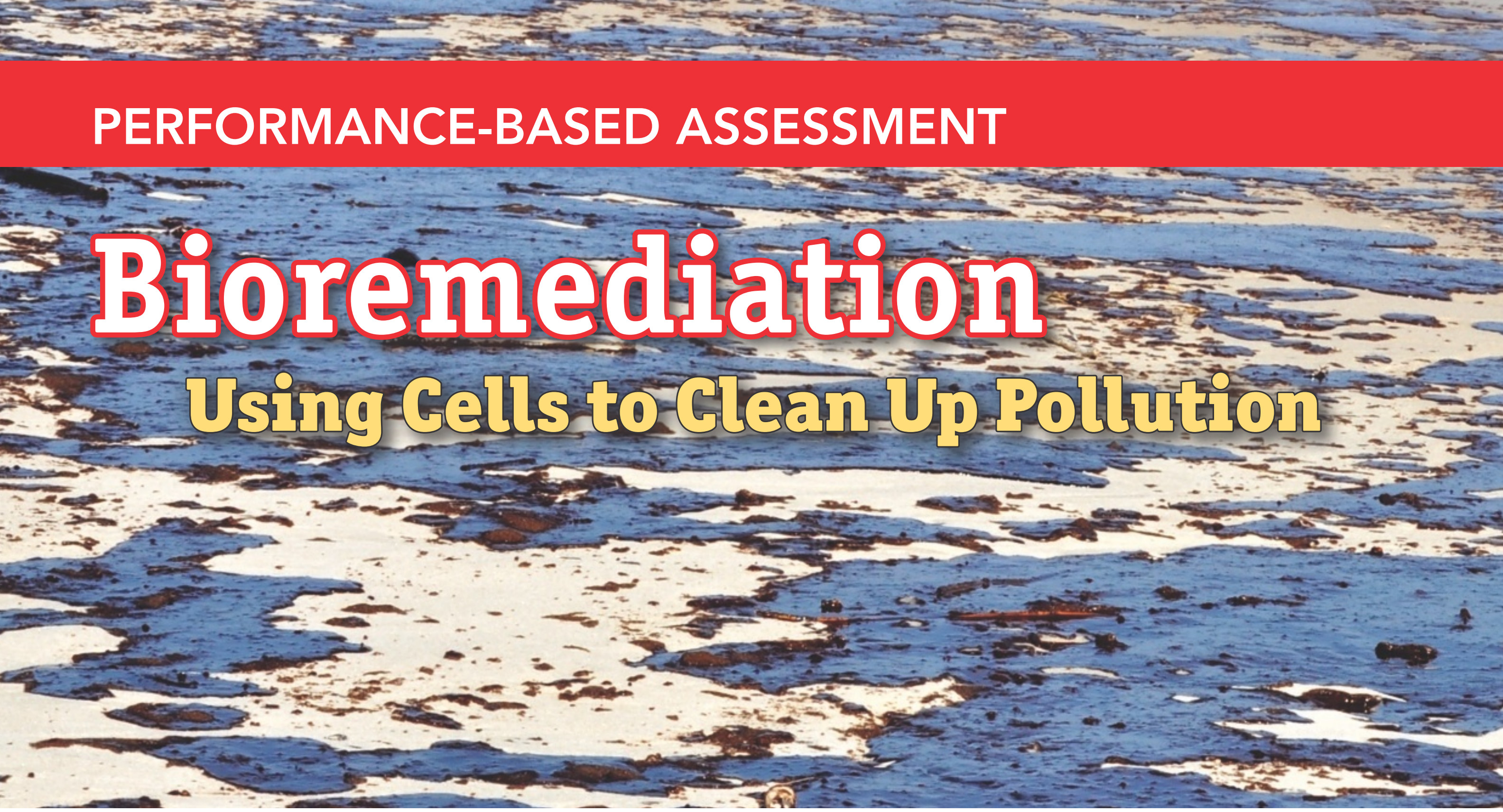
- tissue
- organ
- organ system
- receptor

Synthesize Information How is the pumping action of contractile vacuoles an example of how a cell maintains homeostasis?

Organize Information

Complete the concept map by listing the cell structures that are involved in each function.





PERFORMANCE-BASED ASSESSMENT

Bioremediation

Using Cells to Clean Up Pollution

Evaluate a Solution

HS-ETS1-3, HS-LS1-7, HS-LS4-6, CCSS.ELA-LITERACY.WHST.9-10.4, CCSS.ELA-LITERACY.WHST.9-10.8

STEM As you read in this chapter, all cells break apart food molecules to gain energy. Have you ever wondered which molecules are useful as food, and which molecules are not useful? For many cells, useful foods come in a wider variety than you might guess.

Consider cellulose and lignin, two compounds that provide the toughness in wood, leaves, and other plant parts. Humans and most other animals lack the enzymes to break apart cellulose and lignin, which is why you cannot live on a diet of paper scraps and wood shavings. However, both compounds are useful foods for decomposers, a group of organisms that includes bacteria, protists, and fungi. Unlike other organisms, the decomposers make enzymes that can break apart the chemical bonds that hold cellulose and lignin together. Their actions serve to clean up dead wood, fallen leaves, and other discarded plant parts.

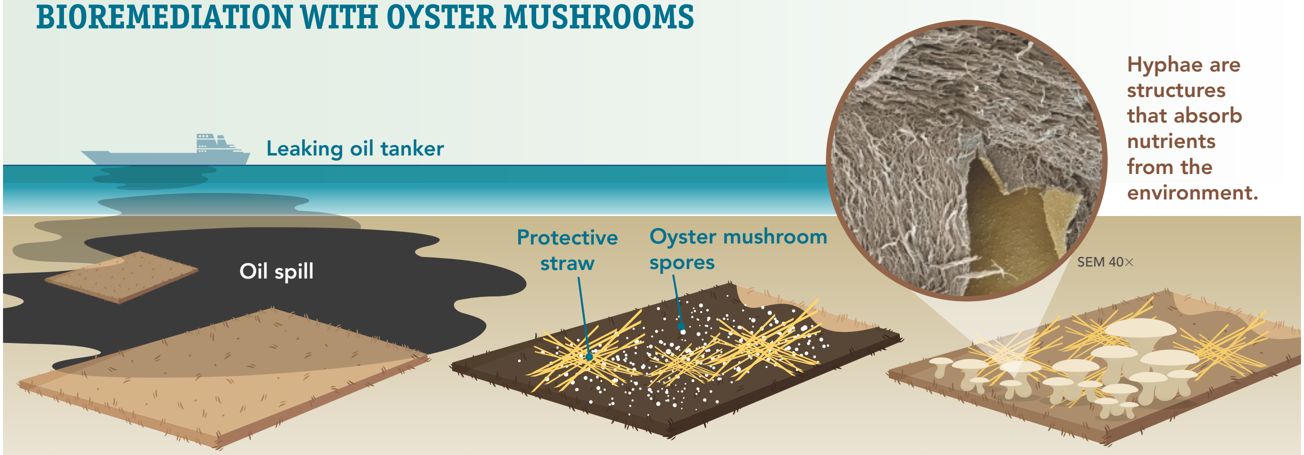
Today, scientists and engineers are finding new uses for the "clean up" abilities of bacteria, protists, and fungi. One of these uses is the cleaning up of pollutants and toxic wastes! The term *bioremediation* is used to describe any clean-up process that involves living things. Some bacteria can remove heavy metals, such as lead, from a contaminated area. Fungi are useful for bioremediation because of the powerful enzymes they release. The enzymes can break apart pesticides, dyes, and toxic byproducts from paper-making and other industrial processes. Some fungi can be used to absorb oil from an oil spill.

In 2007, a shipping accident spilled more than 190,000 liters of oil into San Francisco Bay. Bioremediation with fungi was used to clean up oil that washed ashore. Study the steps of the process, and then answer the questions.

1. **Define the Problem** What problem is this solution addressing?
2. **Ask Questions** What questions might engineers ask to help them gather information about the problem and any potential solution?

ENGINEERING PROJECT

BIOREMEDIATION WITH OYSTER MUSHROOMS



1 Oil Collection Workers spread mats of hair to soak up oil.

2 Seeding the Mats Mushroom spores mixed with protective materials are spread on the oil-soaked hair mats.

3 Oil Removed Mushrooms develop from the spores and consume the oil as they grow.

3. **Conduct Research** Look online for more information about the use of bioremediation, either to clean up oil spills or for other purposes. Compare the benefits and drawbacks of a bioremediation solution with those of other types of solutions that engineers proposed or considered.

4. **Communicate** Write a one-page essay or develop a computer presentation to share your findings. Address the following questions, as well as other questions that you researched.

- How well do you think bioremediation achieves the goal of cleaning up pollution?
- What are the costs and benefits of the bioremediation solution that you researched?
- Scientists have used genetic technology to develop strains of bacteria that are especially suited for cleaning up oil spills. How would you evaluate the use of this technology for this purpose?

CHAPTER 8
ASSESSMENT

KEY QUESTIONS AND TERMS

8.1 Life Is Cellular

HS-LS1-2

1. Despite differences in size and shape, at some point all cells have DNA and a
   a. cell wall. **c.** mitochondrion.
   b. cell membrane. **d.** nucleus.
2. German scientists Schleiden and Schwann determined that the basic unit of structure and function in living things is the
   a. atom. **c.** cell.
   b. molecule. **d.** nucleus.
3. What basic concept of biology includes the idea that new cells can be produced only by the division of existing cells?
4. How does a light microscope work?
5. Why are microscopes useful tools in biology?
6. Identify evidence that this micrograph is from a scanning electron microscope.

7. If you wanted to observe a living organism—an amoeba for example—which type of microscope would you use?
8. In what important way are prokaryotic cells and eukaryotic cells different?

8.2 Cell Structure

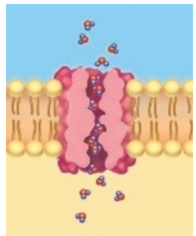
HS-LS1-1, HS-LS1-2

9. The portion of the cell outside the nucleus is called the
   a. organelle. **c.** nucleolus.
   b. cytoplasm. **d.** ribosome.
10. Proteins are assembled on
    a. ribosomes. **c.** lysosomes.
    b. vacuoles. **d.** centrioles.
11. Which of the following structures convert light energy into chemical energy stored in food?

a.


c.


b.


d.


12. Which organelles are known as the "power plants" of the cell because they transfer chemical energy from food to compounds the cell can use?
    a. mitochondria
    b. ribosomes
    c. lysosomes
    d. vacuoles
13. Which two organelles are involved in the movement of a cell in its environment?
    a. microtubules and centrioles
    b. flagella and cilia
    c. centrioles and the cell wall
    d. cytoskeleton and lysosomes
14. Identify the structural and functional differences between the rough endoplasmic reticulum and the smooth endoplasmic reticulum.
15. How are the functions of vacuoles and lysosomes different?
16. What is the process by which chloroplasts capture the sun's energy and convert it into food that contains chemical energy?
17. What is the function of the Golgi apparatus?
18. What is the function of the cytoskeleton?
19. Describe the structure of the cell membrane.
20. For each of the following, indicate if the structure is found only in eukaryotes, or if it is found in eukaryotes and prokaryotes: cell membrane, mitochondria, ribosome, Golgi apparatus, nucleus, cytoplasm, and DNA.

8.3 Cell Transport

HS-LS1-2, HS-LS1-3

21. The relatively constant internal physical and chemical conditions that all organisms must maintain to survive is known as
a. osmosis. **c**. homeostasis.
b. endocytosis. **d**. exocytosis.

22. Solute particles move from an area of higher concentration to an area of lower concentration in a process called
a. osmosis. **c**. diffusion.
b. transport. **d**. equilibrium.

23. Large molecules such as glucose move across cell membranes through special protein channels during
a. active transport.
b. facilitated diffusion.
c. osmosis.
d. bulk transport.

24. What is the term that describes the diffusion of water through a selectively permeable membrane?

25. Explain why cells are almost always hypertonic to fresh water.

26. What is the main difference between passive transport and active transport of materials across a cell membrane?

27. What are the two types of active transport, and how do they differ?

8.4 Homeostasis and Cells

HS-LS1-2, HS-LS1-3

28. Which type of organism consists of specialized cells?
a. unicellular prokaryotes
b. multicellular prokaryotes
c. unicellular eukaryotes
d. multicellular eukaryotes

29. All unicellular organisms
a. are prokaryotes.
b. are bacteria.
c. reproduce.
d. have a nucleus.

30. In what way does specialization of cells contribute to maintaining homeostasis in multicellular organisms?

31. Describe the levels of organization in a multicellular organism.

32. In general, how do cells in a multicellular organism communicate?

CRITICAL THINKING

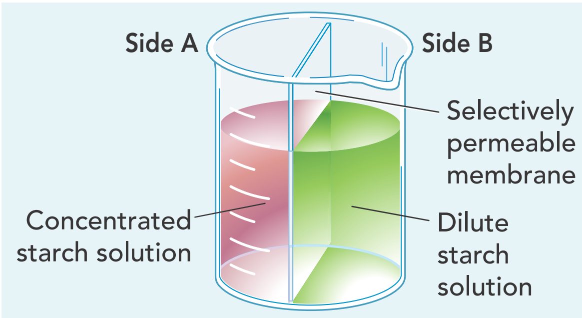
HS-LS1-1, HS-LS1-2, HS-LS1-3

33. Evaluate Models Cells are often compared to factories. How is a factory a useful model for explaining the cell?

34. Evaluate Reasoning A student is asked to classify examples of cells based on prepared microscope slides. The student classifies the cells according to their most prominent color. Evaluate the student's classification scheme.

35. Construct an Explanation In a multicellular organism, the DNA in every cell is essentially the same. How does the cell theory help explain this?

36. Apply Scientific Reasoning The beaker shown here has a membrane that separates two solutions. Water can pass through the membrane, but starch cannot pass through it. How will the fluid levels change over time? Explain your prediction.



37. Critique In constructing a model of a plant cell, a student surrounds the model with plastic bricks. The bricks represent the cell wall. How could the model be improved to represent the cell wall more accurately?

38. Synthesize Information Why is intercellular communication essential for a multicellular organism to function properly?

39. Infer Pacemakers are devices that help keep heart muscles contracting at a steady rate. If a person needs a pacemaker, what does that suggest about his or her heart cells' ability to send and receive messages?

40. Plan an Investigation You want to know how temperature affects the rate of diffusion. Describe an investigation that would provide evidence to support a conclusion. Include simple materials such as water and food coloring.

CHAPTER 8
ASSESSMENT

CROSSCUTTING CONCEPTS

41. **Connect to Nature of Science** What are the statements of the cell theory? Based on what you learned in Chapter 1, describe how the history of its development is typical of the process of science.

42. **Systems and System Models** The nucleus of the cell is often compared to the control center or main office of a factory. How is this model accurate? What are its limitations?

43. **Structure and Function** Why are cell walls useful in plant cells but not animal cells?

44. **Scale, Proportion, and Quantity** Review Figure 8-23, which shows the levels of organization in the human body. Use your own words to define levels of organization in a way that applies to all multicellular organisms.

MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.HSN.Q.A.1

Use the data table to answer questions 45–47.
Note: 1 micrometer (μm) = 10^{-6} meter

Cell Sizes

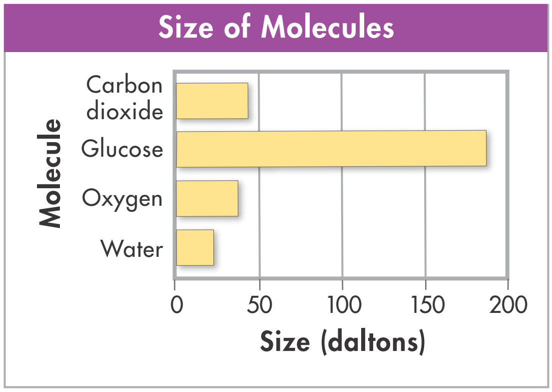
Cell	Approximate Diameter
Escherichia coli (bacterium)	0.5–0.8 μm
Human erythrocyte (red blood cell)	6–8 μm
Human ovum (egg cell)	100 μm
Saccharomyces cerevisiae (yeast)	5–10 μm
Streptococcus pneumoniae (bacterium)	0.5–1.3 μm

45. **Interpret Data** Classify each of the cells listed in the table as either prokaryotic or eukaryotic.

46. **Calculate** The width of a human hair is about 17 micrometers. How many human erythrocytes could fit across the width of a hair? How many *E. coli* bacteria could fit?

47. **Infer** *Chlamydomonas reinhardtii* is a single-celled organism with an approximate diameter of 10 μm. Is the organism more likely to be a prokaryote or a eukaryote? Explain.

Most materials entering the cell pass across the cell membrane by diffusion. In general, the larger the molecule, the slower the molecule diffuses across the membrane. The graph shows the sizes of several molecules that can diffuse across a lipid bilayer. Use the graph to answer questions 48 and 49.



48. **Calculate** By approximately what percentage is a molecule of carbon dioxide smaller than a molecule of glucose?

49. **Predict** Which of the following is a logical prediction based on the graph shown? Explain.
a. Cells contain more glucose than oxygen.
b. Glucose molecules must cross the cell membrane by active transport.
c. Carbon dioxide crosses the cell membrane faster than glucose.

LANGUAGE ARTS CONNECTIONS

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2

50. **Produce Clear Writing** Write a paragraph that defines and describes the cell theory. Include a familiar organism, such as a tree or a cat, as an example to illustrate the theory.

51. **Write Informative Texts** Write a paragraph that describes how cell parts work together to assemble proteins.

Read About Science

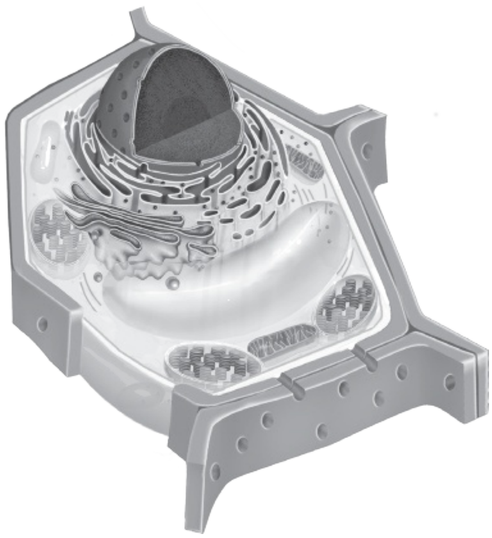
CCSS.ELA-LITERACY.RST.9-10.7

52. **Integrate With Visuals** Choose one of the cell diagrams from the chapter and its accompanying passage. How does the diagram illustrate the structures and functions described in the passage? How does the diagram support other information in the chapter?

CHAPTER 8

END-OF-COURSE TEST PRACTICE

1. A student is developing a model that shows the steps of protein synthesis. The model should include activities in which three structures?
   A. ribosomes, rough endoplasmic reticulum, Golgi apparatus
   B. nucleus, Golgi apparatus, mitochondria
   C. mitochondria, rough endoplasmic reticulum, nucleus
   D. Golgi apparatus, nucleus, lysosome
   E. nucleus, cytoskeleton, cell membrane
2. This model of a plant cell shows the structures that are likely to be observed in a typical plant cell. Cells from actual plants may differ from the model if the cells are specialized for specific functions.



   How could this model be changed to best represent a specialized leaf cell?
   A. Remove the cell wall because only cells in plant stems have cell walls.
   B. Remove the mitochondria because leaf cells don't need much energy.
   C. Add tiny hairs because leaf cells need to take in water.
   D. Add chloroplasts because leaves are where photosynthesis occurs.
   E. Remove the cell membrane because a leaf cell has a cell wall instead of a cell membrane.
3. Which of the following processes is directly controlled by the cell nucleus?
   A. Osmosis because the nucleus has nuclear pores that allow water to move in and out.
   B. Energy production because the nucleus contains mitochondria.
   C. Cell membrane assembly because the cell membrane is made from the nuclear envelope.
   D. Waste removal because a steady stream of molecules moves out of the nucleus.
   E. Protein synthesis because DNA in the nucleus contains the instructions for making proteins.
4. In an investigation, plant cells are placed in water that has been tinted blue. The investigators observe the color of the cells changing to blue. What additional observation would be evidence that the cells maintain homeostasis in response to this change?
   A. The cells burst apart.
   B. The cell membranes shrinks away from the cell walls.
   C. The central vacuole in the cells increases in size.
   D. The cells pumps out water by endocytosis.
   E. The cells pump in additional water until they burst apart.

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With...				
Question	1	2	3	4
See Lesson	8.2	8.4	8.2	8.3, 8.4
Performance Expectation	HS-LS1-2	HS-LS1-2	HS-LS1-1	HS-LS1-3