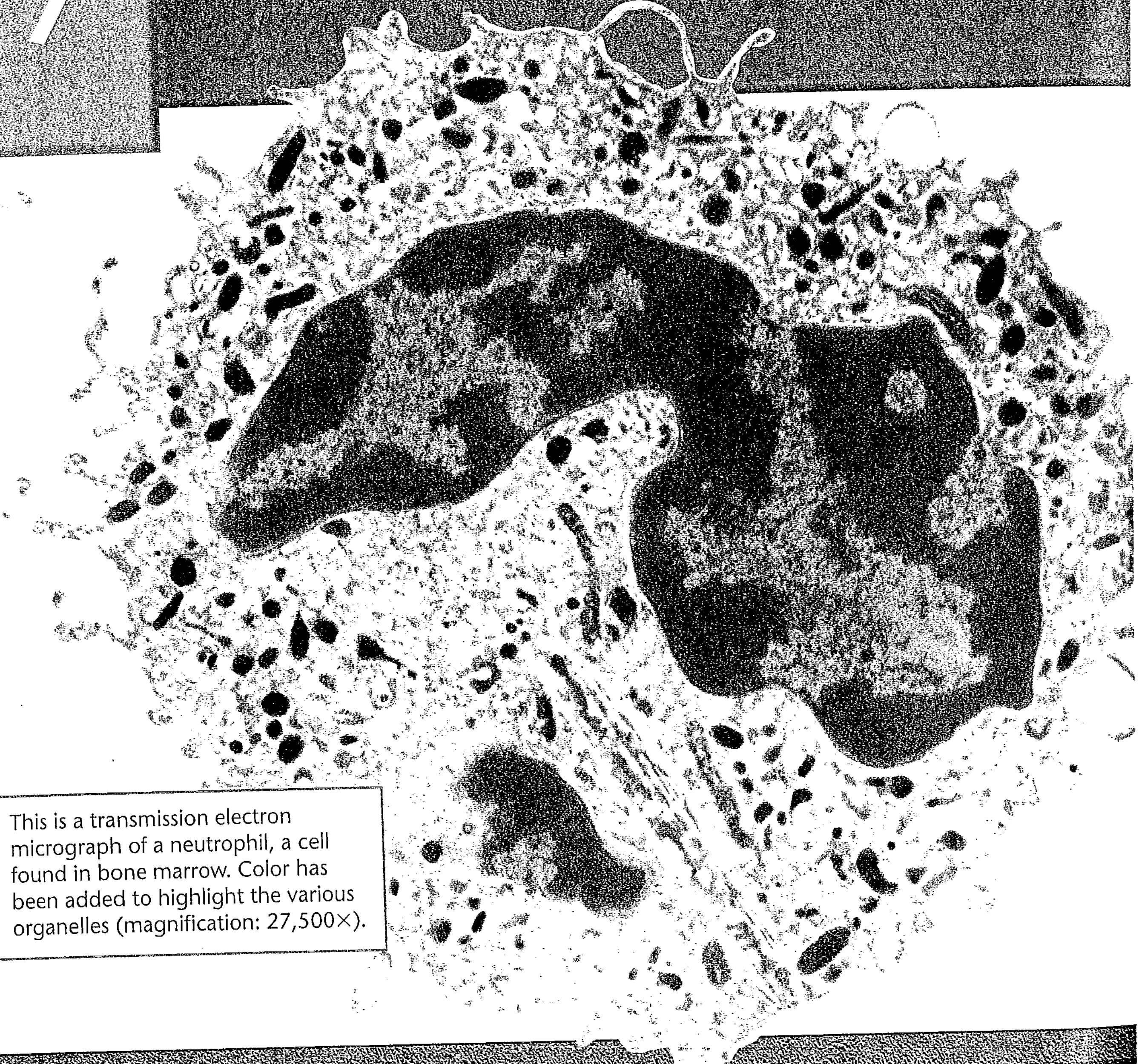
CHAPTER 7

Cell Structure and Function



This is a transmission electron micrograph of a neutrophil, a cell found in bone marrow. Color has been added to highlight the various organelles (magnification: 27,500×).

Inquiry Activity

What is a cell?

Procedure

1. Look through a microscope at a slide of a plant leaf or stem cross section. **CAUTION:** *Handle the microscope and slide carefully to avoid breaking them.* Sketch one or more cells. Record a description of their features, such as shape and internal parts.
2. Repeat step 1 with slides of nerve cells, bacteria, and paramecia.
3. Compare the cells by listing the characteristics they have in common and some of the differences among them.

Think About It

1. **Forming Operational Definitions** Use your observations to write a definition of "cell."
2. **Classifying** Classify the cells you observed into two or more groups. Explain what characteristics you used to put each cell in a particular group.

7–1 Life Is Cellular

Look closely at a part of a living thing, and what do you see? Hold a blade of grass up against the light, and you see tiny lines running the length of the blade. Examine the tip of your finger, and you see the ridges and valleys that make up fingerprints. Place an insect under a microscope, and you see the intricate structures of its wings and the spikes and bristles that protect its body. As interesting as these close-up views may be, however, they're only the beginning of the story. Look closer and deeper with a more powerful microscope, and you'll see that there is a common structure that makes up every living thing—the cell.

Guide for Reading

Key Concepts
- What is the cell theory?
- What are the characteristics of prokaryotes and eukaryotes?

Vocabulary
cell
cell theory
nucleus
eukaryote
prokaryote

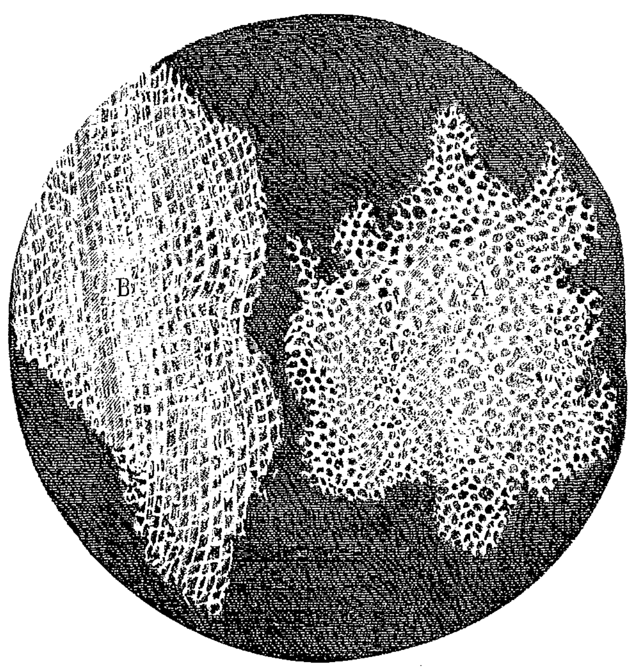
Reading Strategy: Finding Main Ideas
As you read, look for evidence to support the statement "The cell theory revolutionized how biologists thought about living things."

The Discovery of the Cell

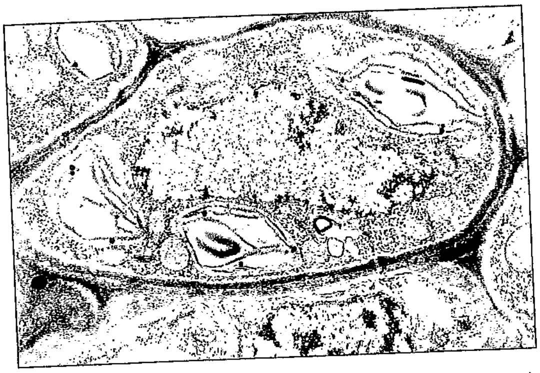
"Seeing is believing," an old saying goes. It would be hard to find a better example of this than the discovery of the cell. Without the instruments to make them visible, cells remained out of sight and, therefore, out of mind for most of human history. All of this changed with a dramatic advance in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

Early Microscopes It was not until the mid-1600s that scientists began to use microscopes to observe living things. In 1665, Englishman Robert Hooke used an early compound microscope to look at a thin slice of cork, a plant material. Under the microscope, cork seemed to be made of thousands of tiny, empty chambers. Hooke called these chambers "cells" because they reminded him of a monastery's tiny rooms, which were called cells. The term *cell* is used in biology to this day. Today we know that cells are not empty chambers, but contain living matter. One of Hooke's illustrations of cells is shown in **Figure 7–1.**

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, even in the very water he and his neighbors drank.



▶ **Figure 7–1** Using an early microscope, Hooke made this drawing of cork cells. In Hooke's drawings, the cells look like empty chambers because he was looking at dead plant matter. Today, we know that living cells are made up of many structures.



(magnification: 12,000×)

▲ **Figure 7–2** The cell theory states that cells are the basic units of all living things. This cell is from a plant leaf. Compare this micrograph with Hooke's drawing in **Figure 7–1**.

The Cell Theory Soon, numerous observations made it clear that **cells** were the basic units of life. In 1838, German botanist Matthias Schleiden concluded that all plants were made of cells like the one in **Figure 7–2.** The next year, German biologist Theodor Schwann stated that all animals were made of cells. In 1855, the German physician Rudolf Virchow concluded that new cells could be produced only from the division of existing cells. These discoveries, confirmed by other biologists, are summarized in the **cell theory,** a fundamental concept of biology. **The cell theory states:**

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

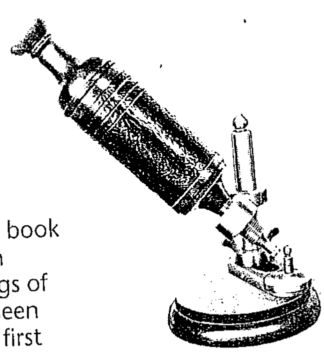
Exploring the Cell

Following in the footsteps of Hooke, Virchow, and others, modern biologists still use microscopes to explore the cell. However, today's researchers use microscopes and techniques more powerful than the pioneers of biology could have imagined. Researchers can use fluorescent labels and light microscopy to follow molecules moving through the cell. Confocal light microscopy, which scans cells with a laser beam, makes it possible to build three-dimensional images of cells and their parts. High-resolution video technology makes it easy to produce movies of cells as they grow, divide, and develop.

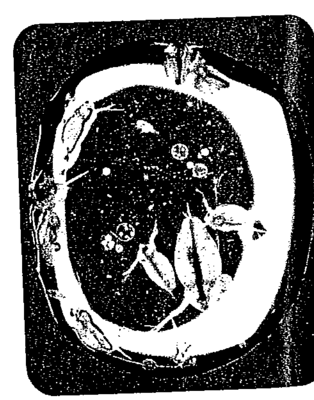
Biology and History

The History of the Cell

The observations and conclusions of many scientists helped to develop the current understanding of the cell.



1665
Robert Hooke
Hooke publishes his book *Micrographia,* which contains his drawings of sections of cork as seen through one of the first microscopes.



1674
Anton van Leeuwenhoek
Leeuwenhoek observes tiny living organisms in drops of pond water through his simple microscope.

1600 1700 1800

These new technologies make it possible for researchers to study the structure and movement of living cells in great detail. Unfortunately, light itself limits the detail, or resolution, of images that can be made with the light microscope. Like all forms of radiation, light waves are diffracted, or scattered, as they pass through matter, making it impossible to visualize tiny structures such as proteins and viruses with light microscopy.

Electron Microscopes By contrast, electron microscopes are capable of revealing details as much as 1000 times smaller than those visible in light microscopes because the wavelengths of electrons are much shorter than those of light. Transmission electron microscopes (TEMs) make it possible to explore cell structures and large protein molecules. Because beams of electrons can only pass through thin samples, cells and tissues must be cut first into ultrathin slices before they can be examined under a microscope.

With scanning electron microscopes (SEMs), a pencil-like beam of electrons is scanned over the surface of a specimen. For SEM images, specimens do not have to be cut into thin slices to be visualized. The scanning electron microscope produces stunning three-dimensional images of cells. Because electrons are easily scattered by molecules in the air, samples examined in both types of electron microscopes must be placed in a vacuum in order to be studied. As a result, researchers chemically preserve their samples first and then carefully remove all of the water before placing them in the microscope. This means that electron microscopy can be used to visualize only nonliving, preserved cells and tissues.

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Writing in Science

Use the library or the Internet to research a new discovery relating to the cell or its structures. Be sure to include the scientist(s) responsible for the discovery. Then, present your findings in the form of an oral report.

1839
Theodor Schwann
Schwann concludes that all animals are made up of cells.

1838
Matthias Schleiden
Schleiden concludes that all plants are made up of cells.

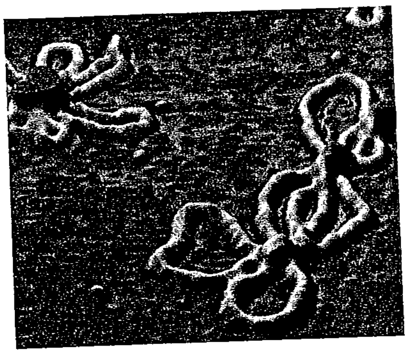
1855
Rudolph Virchow
Virchow proposes that all cells come from existing cells, completing the cell theory.

1970
Lynn Margulis
Margulis proposes the idea that certain organelles, tiny structures within some cells, were once free-living cells themselves.

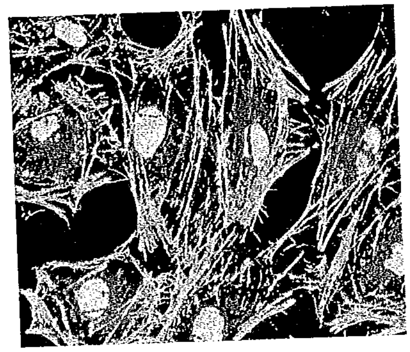
1800 1900 2000

FIGURE 7–3 VARIETY OF MICROGRAPHS

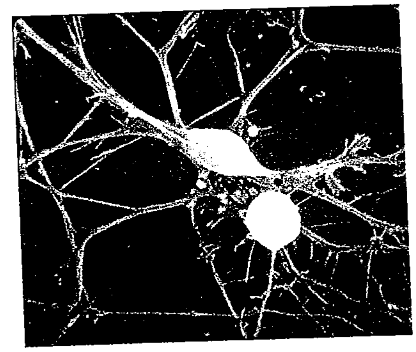
Different types of microscopes produce a variety of images of cells and cell parts.



Scanning Probe Micrograph
A scanning probe microscope scans a tiny probe just above the surface of a sample and produces an image by recording the position of the probe. These powerful instruments can even visualize single molecules, such as DNA, on carefully prepared surfaces. (magnification: 320,000X)



Confocal Light Micrograph
Confocal light microscopes construct images by scanning cells with a computer-controlled laser beam. In this fluorescent confocal light micrograph of HeLa cells, researchers attached fluorescent labels to the different molecules. By doing this, researchers can follow molecules as they move through a living cell. (magnification: 500X)



Scanning Electron Micrograph
Scanning electron microscopes produce three-dimensional images of the surfaces of cells, such as these neurons, and tissues. (magnification: 8900X)

Scanning Probe Microscopes In the 1990s, researchers perfected a new class of microscopes that produce images by tracing the surfaces of samples with a fine probe. These scanning probe microscopes have revolutionized the study of surfaces and made it possible to observe single atoms. Unlike electron microscopes, scanning probe microscopes can operate in ordinary air and can even show samples in solution. Researchers have already used scanning probe microscopes to image DNA and protein molecules as well as a number of important biological structures.

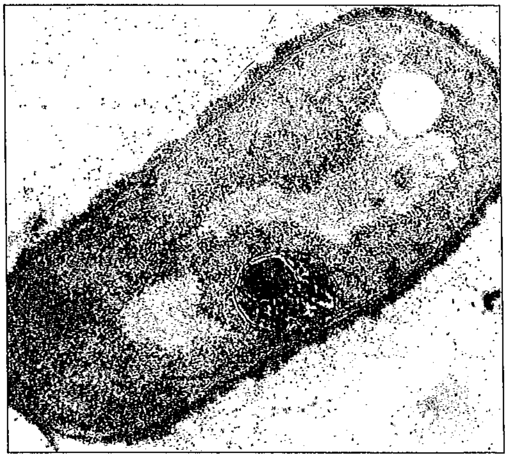
Prokaryotes and Eukaryotes

Cells come in a great variety of shapes and an amazing range of sizes. Although typical cells range from 5 to 50 micrometers in diameter, the tiniest mycoplasma bacteria are only 0.2 micrometers across, so small that they are difficult to see under even the best light microscopes. In contrast, the giant amoeba *Chaos chaos* may be 1000 micrometers in diameter, large enough to be seen with the unaided eye as a tiny speck in pond water. Despite their differences, all cells have two characteristics in common. They are surrounded by a barrier called a cell membrane; and, at some point in their lives, they contain the molecule that carries biological information—DNA.

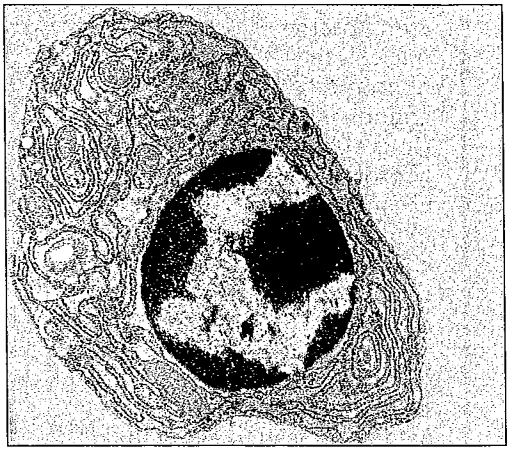
Cells fall into two broad categories, depending on whether they contain a nucleus. The **nucleus** (plural: nuclei) is a large membrane-enclosed structure that contains the cell's genetic material in the form of DNA. The nucleus controls many of the cell's activities. **Eukaryotes** (yoo-KAR-ee-ohts) are cells that contain nuclei. **Prokaryotes** (pro-KAR-ee-ohts) are cells that do not contain nuclei. Both words derive from the Greek words *karyon,* meaning "kernel," or nucleus, and *eu,* meaning "true," or *pro,* meaning "before." These words reflect the idea that prokaryotic cells evolved before nuclei developed.

Prokaryotes Prokaryotic cells are generally smaller and simpler than eukaryotic cells, although there are many exceptions to this rule. **Prokaryotic cells have genetic material that is not contained in a nucleus.** Some prokaryotes contain internal membranes, but prokaryotes are generally less complicated than eukaryotes. Despite their simplicity, prokaryotes carry out every activity associated with living things. They grow, reproduce, respond to the environment, and some can even move by gliding along surfaces or swimming through liquids. The organisms we call bacteria are prokaryotes.

Eukaryotes Eukaryotic cells are generally larger and more complex than prokaryotic cells. As you can see in **Figure 7–4,** eukaryotic cells generally contain dozens of structures and internal membranes, and many are highly specialized. **Eukaryotic cells contain a nucleus in which their genetic material is separated from the rest of the cell.** Eukaryotes display great variety. Some eukaryotes live solitary lives as unicellular organisms. Others form large, multicellular organisms. Plants, animals, fungi, and protists are eukaryotes.



(magnification: 18,300×)



(magnification: 350×)

Figure 7–4 The cells of eukaryotes have a nucleus, but the cells of prokaryotes do not. Notice how many more structures are located in the eukaryotic cell (bottom) as compared with the prokaryotic cell (top).

7–1 Section Assessment

1. **Key Concept** What three statements make up the cell theory?
2. **Key Concept** What are the differences between prokaryotic cells and eukaryotic cells?
3. Compare the processes used to produce a TEM and an SEM.
4. What structures do all cells have?
5. **Critical Thinking Inferring** How did the invention of the microscope help the development of the cell theory?

Thinking Visually

Constructing a Chart

Make a three-column chart comparing prokaryotes with eukaryotes. In the first column, list the traits found in all cells. In the second column, list the features of prokaryotes. In the third column, list the features of eukaryotes.

7–2 Eukaryotic Cell Structure

Guide for Reading

Key Concept
- What are the functions of the major cell structures?

Vocabulary
organelle
cytoplasm
nuclear envelope
chromatin
chromosome
nucleolus
ribosome
endoplasmic reticulum
Golgi apparatus
lysosome
vacuole
mitochondrion
chloroplast
cytoskeleton
centriole

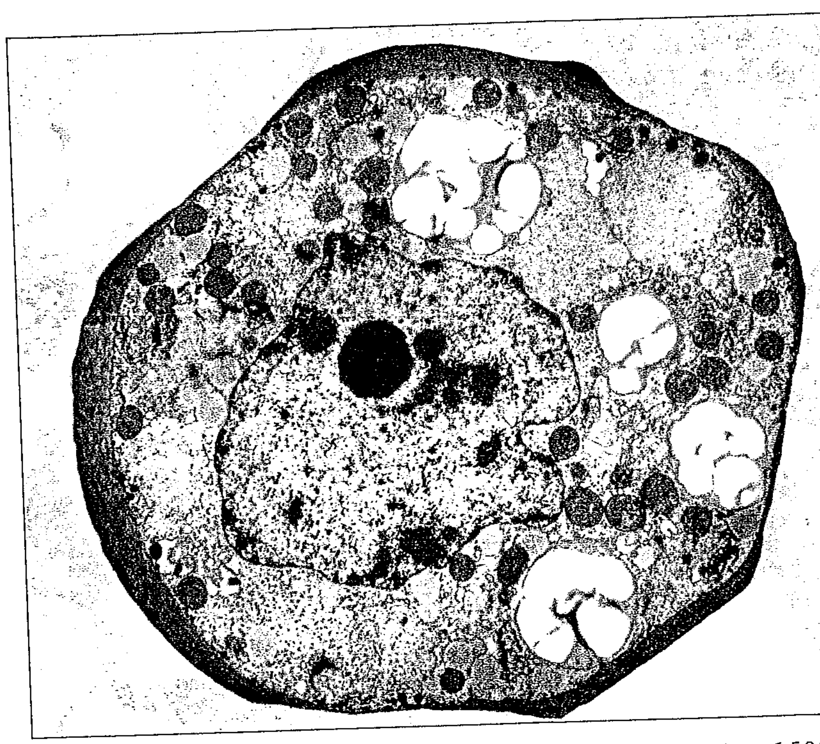
Reading Strategy: Building Vocabulary
Before you read, preview the vocabulary by skimming the section and making a list of the highlighted boldface terms. Leave space to make notes as you read.

At first glance, a factory is a puzzling place. A bewildering variety of machines buzz and clatter, people move quickly in different directions, and the sheer diversity of so much activity can be confusing. However, if you take your time and watch carefully, before long you will begin to identify patterns. What might at first have seemed like chaos suddenly begins to make sense.

Comparing the Cell to a Factory

In some respects, the eukaryotic cell is like a factory. The first time you look at a microscope image of a cell, such as the one in **Figure 7–5**, the cell seems impossibly complex. Look closely at a eukaryotic cell, however, and patterns begin to emerge. To see those patterns more clearly, we'll look at some structures that are common to eukaryotic cells, shown in **Figure 7–6.** Because many of these structures act as if they are specialized organs, these structures are known as **organelles,** literally "little organs."

Cell biologists divide the eukaryotic cell into two major parts: the nucleus and the cytoplasm. The **cytoplasm** is the portion of the cell outside the nucleus. As you will see, the nucleus and cytoplasm work together in the business of life.



(magnification: 1500×)

▶ **Figure 7–5** This electron micrograph of a plant cell shows many of the different types of structures that are found in eukaryotic cells. The cell has been artificially colored so that you can distinguish one structure from another.

PLANT AND ANIMAL CELLS

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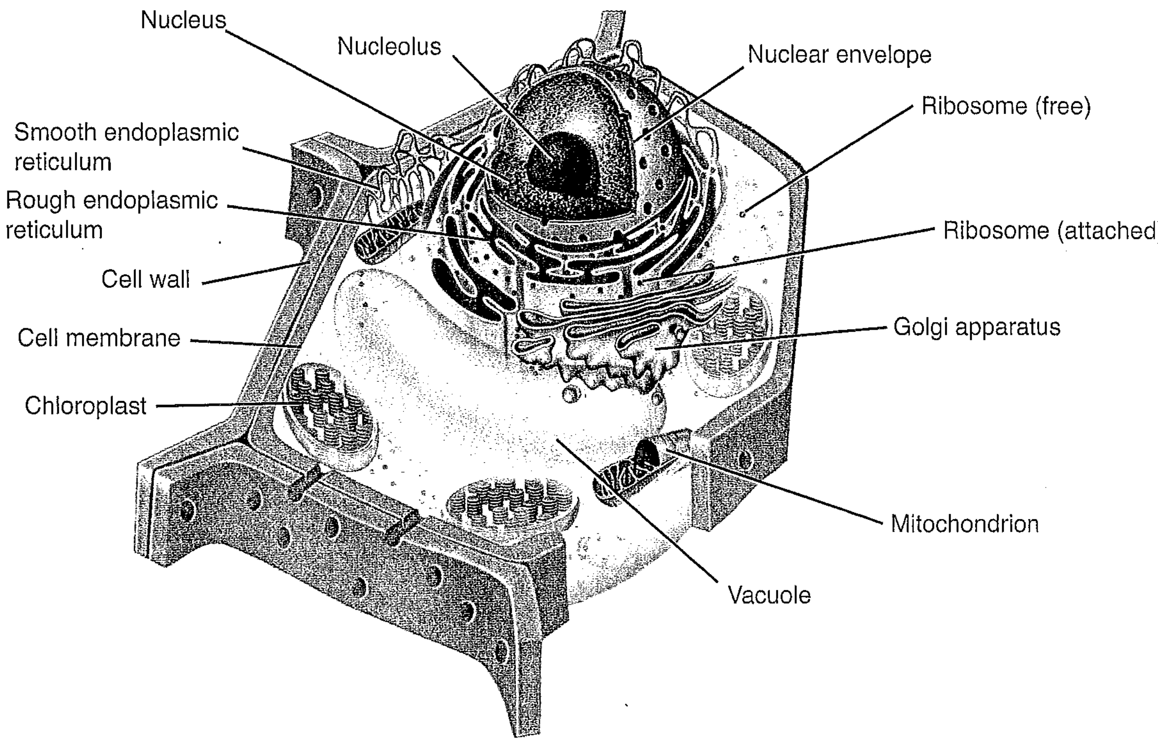
Figure 7–6 Both plant and animal cells contain a variety of organelles. Some structures are specific to either plant cells or animal cells only. **Interpreting Graphics** *What structures do plant cells have that animal cells do not?*

Plant Cell



Animal Cell

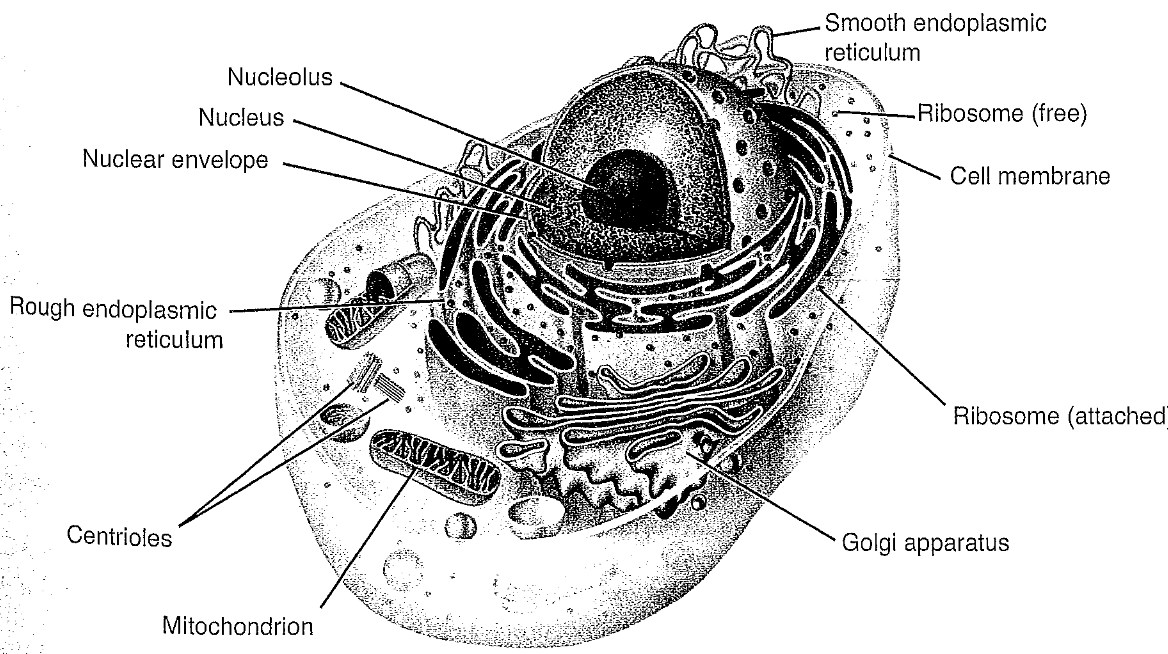
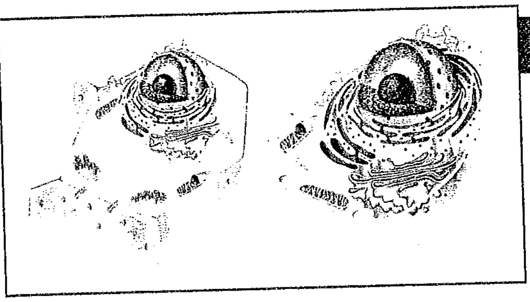
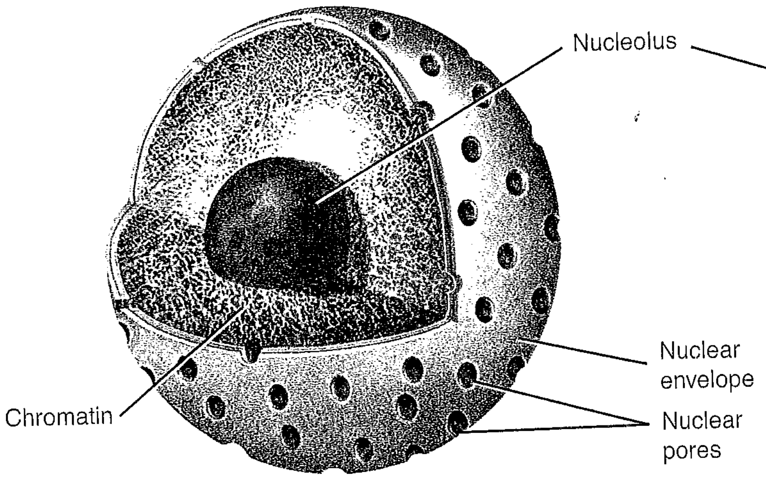
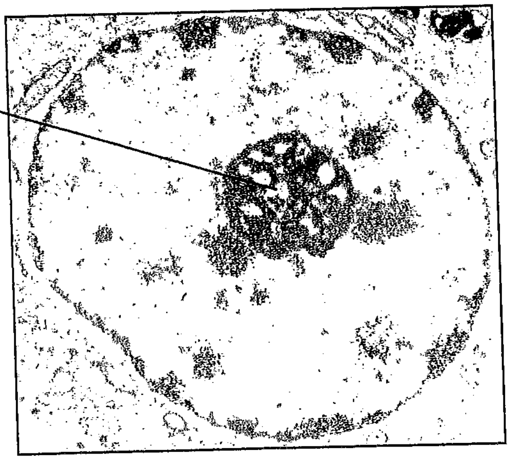


Figure 7–7 The Nucleus



The nucleus controls most cell processes and contains the hereditary information of DNA. The DNA combines with protein to form chromatin, which is found throughout the nucleus. The small, dense region in the nucleus is the nucleolus.





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.** The structure of the nucleus is shown in **Figure 7–7.**

The nucleus 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 main office, a steady stream of proteins, RNA, and other molecules move through the nuclear pores to and from the rest of the cell.

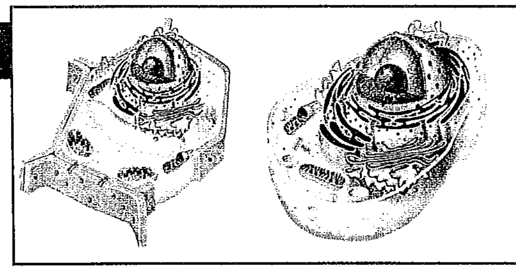
The granular material you can see in the nucleus is called **chromatin.** Chromatin consists of DNA bound to protein. Most of the time, chromatin is spread throughout the nucleus. When a cell divides, however, chromatin condenses to form **chromosomes** (KROH-muh-sohms). These distinct, threadlike structures contain the genetic information that is passed from one generation of cells to the next. You will learn more about chromosomes in later chapters.

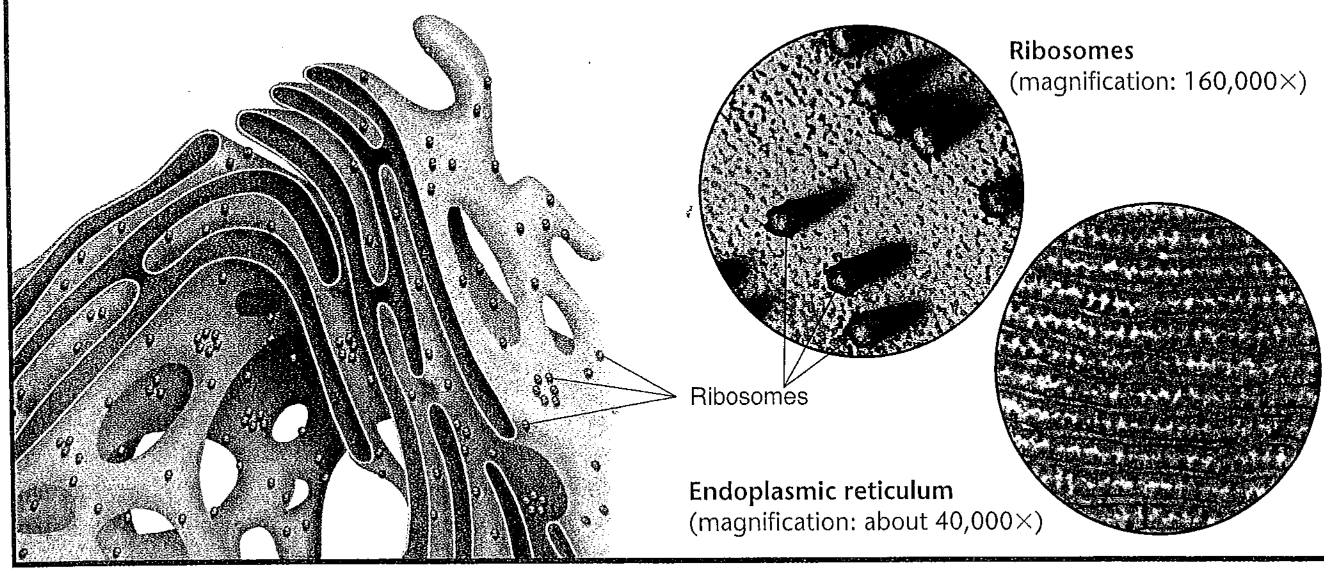
Most nuclei also contain a small, dense region known as the **nucleolus** (noo-KLEE-uh-lus). The nucleolus is where the assembly of ribosomes begins.

✓CHECKPOINT *What kind of information is contained in chromosomes?*

FIGURE 7–8 ENDOPLASMIC RETICULUM

The endoplasmic reticulum synthesizes proteins for export from the cell. The rough endoplasmic reticulum, shown here, gets its name from the "rough" appearance of the ribosomes on its surface.





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. They produce proteins by following coded instructions that come from the nucleus. Each ribosome, in its own way, is like a small machine in a factory, turning out proteins on orders that come from its "boss"—the cell nucleus. Cells that are active in protein synthesis are often packed with ribosomes.

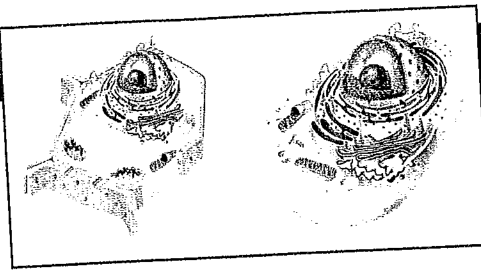
Endoplasmic Reticulum

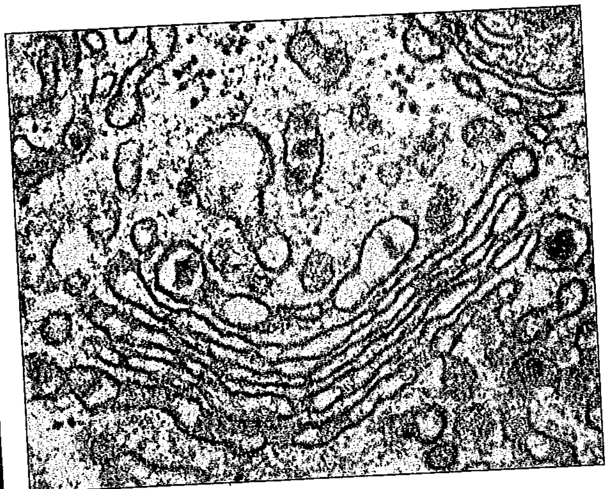
Eukaryotic cells also contain an internal membrane system known as the **endoplasmic reticulum** (en-doh-PLAZ-mik rih-TIK-yuh-lum), or ER. **The endoplasmic reticulum is the site where lipid components of the cell membrane are assembled, along with proteins and other materials that are exported from 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 are inserted into the rough ER, where they may be chemically modified.

FIGURE 7–9 GOLGI APPARATUS

The Golgi apparatus modifies, sorts, and packages proteins. Notice the stacklike membranes that make up the Golgi apparatus in this transmission electron micrograph.





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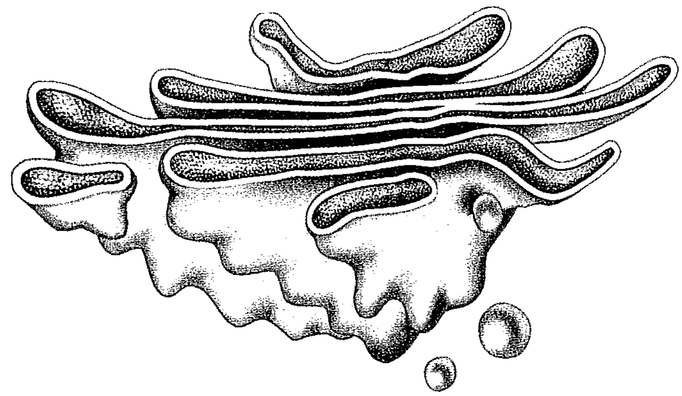


Proteins that are released, or exported, from the cell are synthesized on the rough ER, as are many membrane proteins. Rough ER is abundant in cells that produce large amounts of protein for export. Other cellular proteins are made on "free" ribosomes, which are not attached to membranes.

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 membrane lipids and the detoxification of drugs. Liver cells, which play a key role in detoxifying drugs, often contain large amounts of smooth ER.

Golgi Apparatus

Proteins produced in the rough ER move next into an organelle called the **Golgi apparatus,** discovered by the Italian scientist Camillo Golgi. As you can see in **Figure 7–9**, Golgi appears as a stack of closely apposed membranes. **The function of the Golgi apparatus is to modify, sort, and package proteins and other materials from the endoplasmic reticulum for storage in the cell or secretion outside 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 then "shipped" to their final destinations throughout the cell or outside of the cell.

Lysosomes

Even the neatest, cleanest factory needs a cleanup crew, and that's what lysosomes (LY-suh-sohmz) are. **Lysosomes** are small organelles filled with enzymes. One function of lysosomes is the digestion, or breakdown, of lipids, carbohydrates, and proteins into small molecules that can be used by the rest of the cell.

Lysosomes 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 serious human diseases, including Tay-Sachs disease, can be traced to lysosomes that fail to function properly.

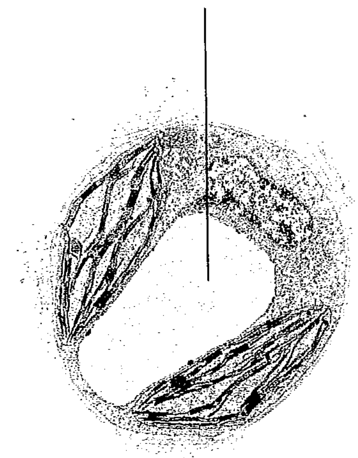
CHECKPOINT *What is the role of lysosomes?*

Vacuoles

Every factory needs a place to store things, and cells contain places for storage as well. Some kinds of cells contain saclike structures called **vacuoles** (VAK-yoo-ohlz) that store materials such as 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 makes it possible for plants to support heavy structures such as leaves and flowers.

Vacuoles are also found in some unicellular organisms and in some animals. The paramecium in **Figure 7–10** contains a vacuole called a contractile vacuole. By contracting rhythmically, this specialized vacuole pumps excess water out of the cell. The control of water content within the cell is just one example of an important process known as homeostasis. Homeostasis is the maintenance of a controlled internal environment.

Figure 7–10 Vacuoles have a variety of functions. In the *Coleus* plant cell (top), the large blue structure is the central vacuole that stores salts, proteins, and carbohydrates. The paramecium (bottom) contains contractile vacuoles that fill with water and then pump the water out of the cell. **Applying Concepts** *How do vacuoles help support plant structures?*



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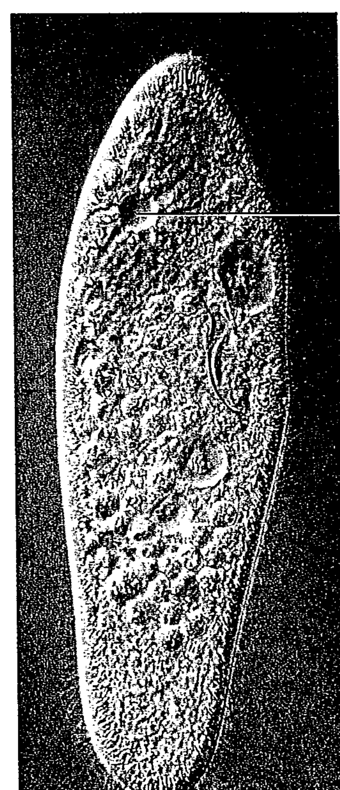


Mitochondria and Chloroplasts

All living things require a source of energy. Factories are hooked up to the local power company, but what about cells? Most cells get energy in one of two ways—from food molecules or from the sun.

Mitochondria Nearly all eukaryotic cells, including plants, contain **mitochondria** (myt-oh-KAHN-dree-uh; singular: mitochondrion). **Mitochondria are organelles that convert the chemical energy stored in food into compounds that are more convenient for the cell to use.** Mitochondria are enclosed by two membranes—an outer membrane and an inner membrane. The inner membrane is folded up inside the organelle.

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 come 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!

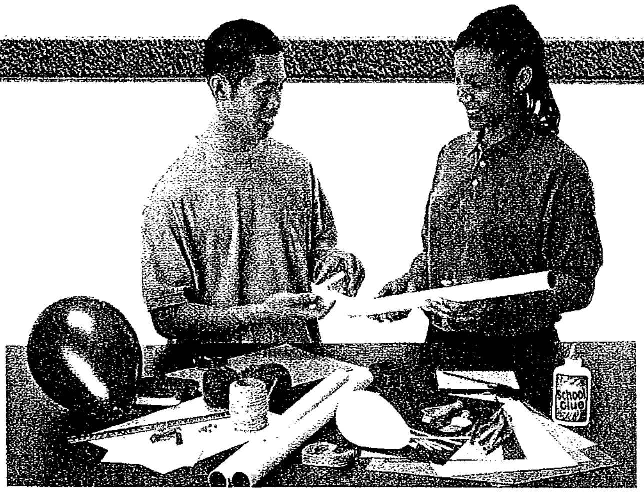
Quick Lab

How can you make a model of a cell?

Materials variety of craft supplies, index cards

Procedure

1. Your class is going to make a model of a plant cell using the whole classroom. Work with a partner or in a small group to decide what cell part or organelle you would like to model. (Use **Figure 7–6** as a starting point. It will give you an idea of the relative sizes of various cell parts and their possible positions. **Figures 7–7** through **7–10** can provide additional information.)
2. Using materials of your choice, make a three-dimensional model of the cell part or organelle you chose. Make the model as complete and as accurate as you can.
3. Label an index card with the name of your cell part or organelle and list its main features and functions. 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. **Inferring** What are the functions of the different organelles in plant cells?
2. **Calculating** Assume that a typical plant cell is 50 micrometers wide. 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.)
3. **Comparing and Contrasting** How is your model cell part or organelle similar to the real cell part or organelle? How is it different?
4. **Evaluating** Based on your work with this model, describe how you could make a better model. Specify what new information the improved model would demonstrate.

Chloroplasts Plants and some other organisms contain **chloroplasts. Chloroplasts are organelles that capture the energy from sunlight and convert it into chemical energy in a process called photosynthesis.** Chloroplasts are the biological equivalents of solar power plants. Like mitochondria, chloroplasts are surrounded by two membranes. Inside the organelle are large stacks of other membranes, which contain the green pigment chlorophyll. Interestingly, chloroplasts and mitochondria contain their own genetic information in the form of small DNA molecules. This has led to the idea that they may have descended from independent microorganisms. This idea, called the endosymbiotic theory, will be discussed in Chapter 17.

Cytoskeleton

A supporting structure and a transportation system complete our picture of the cell as a factory. As you know, a factory building is supported by steel or cement beams and by columns that support its walls and roof. Eukaryotic cells are given their shape and internal organization by a supporting structure known as the **cytoskeleton.**

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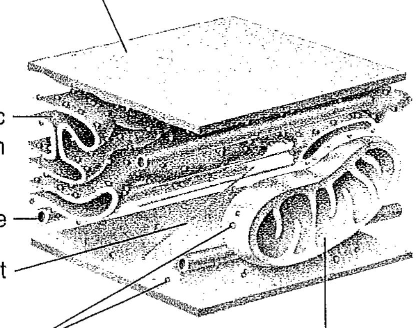
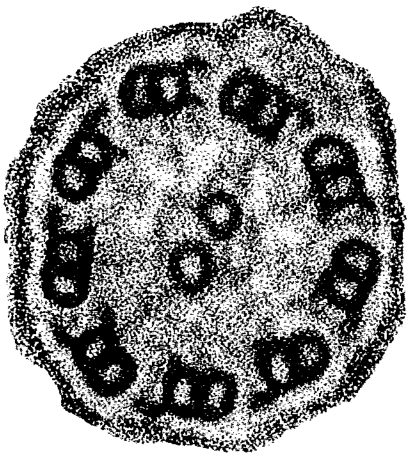
The cytoskeleton is a network of protein filaments that helps the cell to maintain its shape. The cytoskeleton is also involved in movement. Microfilaments and microtubules are two of the principal protein filaments that make up the cytoskeleton.

Microfilaments Microfilaments are threadlike structures made 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 is responsible for the cytoplasmic movements that allow cells, such as amoebas, 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, structures known as centrioles are also formed from tubulin. **Centrioles** are located near the nucleus and help to organize cell division. Centrioles are not found in plant cells.

Microtubules also help to build projections from the cell surface, which are known as cilia (singular: cilium) and flagella (singular: flagellum), that enable cells to swim rapidly through liquids. As you can see in **Figure 7–11**, the microtubules are arranged in a "9 + 2" pattern. Small cross-bridges between the microtubules in these organelles use chemical energy to generate force, allowing cells to produce controlled movements using the cytoskeleton.





▲ **Figure 7–11** **The cytoskeleton is a network of protein filaments that helps the cell to maintain its shape and is involved in many forms of cell movement.** The micrograph shows a cross section of an epithelial cell cilia. You can see the nine pairs of microtubules surrounding the two single microtubules, hence the "9 + 2" pattern.

7–2 Section Assessment

1. **Key Concept** Describe the functions of the endoplasmic reticulum, Golgi apparatus, chloroplast, and mitochondrion.
2. Describe the role of the nucleus in the cell.
3. What are two functions of the cytoskeleton?
4. How is a cell like a factory?
5. **Critical Thinking Inferring** You examine an unknown cell under the microscope and discover that the cell contains chloroplasts. What type of organism could you infer that the cell came from?

Thinking Visually

Creating Artwork
Create a work of art—such as a painting or sculpture—depicting a cross section of a plant cell or an animal cell. Include all the different organelles described in this section that would be found in that type of cell. Label each organelle in your artwork.

7–3 Cell Boundaries

Guide for Reading

Key Concepts
- What are the main functions of the cell membrane and the cell wall?
- What happens during diffusion?
- What is osmosis?

Vocabulary
cell membrane • cell wall
lipid bilayer • concentration
diffusion • equilibrium
osmosis • isotonic
hypertonic • hypotonic
facilitated diffusion
active transport • endocytosis
phagocytosis • pinocytosis
exocytosis

Reading Strategy: Summarizing As you read, make a list of the ways in which substances can move through the cell membrane. Write one sentence describing each process.

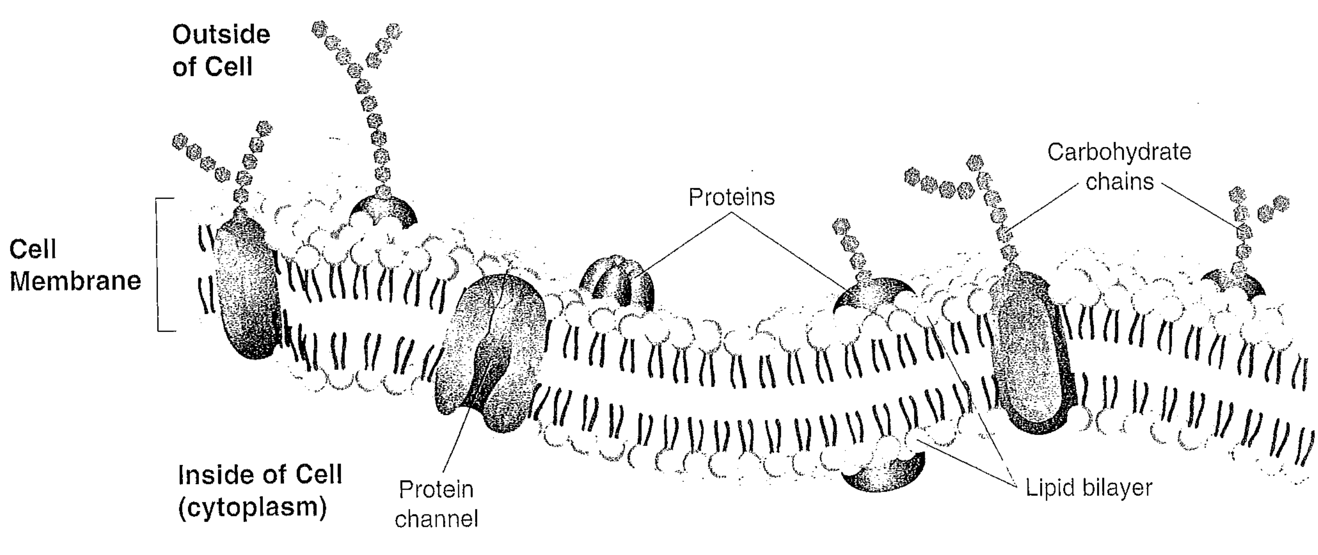
When you first study a country, you may begin by examining a map of the country's borders. Before you can learn anything about a nation, it's important to understand where it begins and where it ends. The same principle applies to cells. Among the most important parts of a cell are its borders, which separate the cell from its surroundings. All cells are surrounded by a thin, flexible barrier known as the **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. Many cells also produce a strong supporting layer around the membrane known as a **cell wall.**

Cell Membrane

The cell membrane regulates what enters and leaves the cell and also provides protection and support. The composition of nearly all cell membranes is a double-layered sheet called a **lipid bilayer.** As you can see in **Figure 7–12,** there are two layers of lipids, hence the name bilayer. The lipid bilayer gives cell membranes a flexible structure that forms a strong barrier between the cell and its surroundings.

In addition to lipids, most cell membranes contain protein molecules that are embedded in the lipid bilayer. Carbohydrate molecules are attached to many of these proteins. In fact, there are so many kinds of molecules in cell membranes that scientists describe their understanding of the membrane as the "fluid mosaic model" of membrane structure. As you will see, some of the proteins form channels and pumps that help to move material across the cell membrane. Many of the carbohydrates act like chemical identification cards, allowing individual cells to identify one another.

▼ Figure 7–12 The cell membrane regulates what enters and leaves the cell. This cell membrane is made up of a lipid bilayer in which proteins are embedded.



Cell Walls

Cell walls are present in many organisms, including plants, algae, fungi, and many prokaryotes. Cell walls lie outside the cell membrane. Most cell walls are porous enough to allow water, oxygen, carbon dioxide, and certain other substances to pass through easily. **The main function of the cell wall is to provide support and protection for the cell.**

Most cell walls are made from fibers of carbohydrate and protein. These substances are produced within the cell and then released at the surface of the cell membrane where they are assembled to form the wall. Plant cell walls are composed mostly of cellulose, a tough carbohydrate fiber. Cellulose is the principal component of both wood and paper, so every time you pick up a sheet of paper, you are holding the stuff of cell walls in your hand.

Diffusion Through Cell Boundaries

Every living cell exists in a liquid environment that it needs to survive. It may not always seem that way; yet even in the dust and heat of a desert like the one in **Figure 7–13,** the cells of cactus plants, scorpions, and vultures are bathed in liquid. One of the most important functions of the cell membrane is to regulate the movement of dissolved molecules from the liquid on one side of the membrane to the liquid on the other side.

Measuring Concentration The cytoplasm of a cell contains a solution of many different substances in water. Recall that a solution is a mixture of two or more substances. The substances dissolved in the solution are called solutes. The **concentration** of a solution is the mass of solute in a given volume of solution, or mass/volume. For example, if you dissolved 12 grams of salt in 3 liters of water, the concentration of the solution would be 12 g/3 L, or 4 g/L (grams per liter). If you had 12 grams of salt in 6 liters of water, the concentration would be 12 g/6 L, or 2 g/L. The first solution is twice as concentrated as the second solution.

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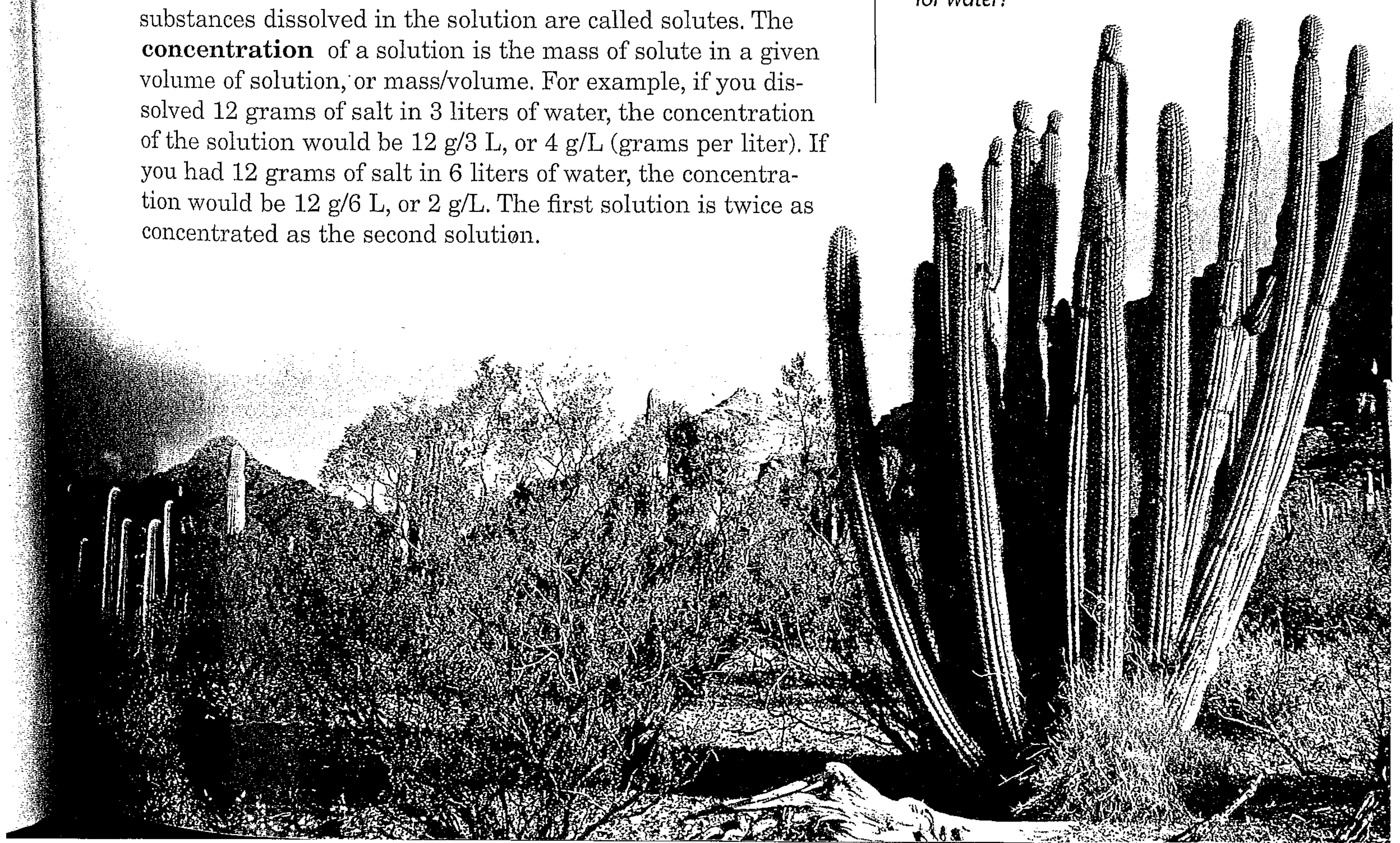
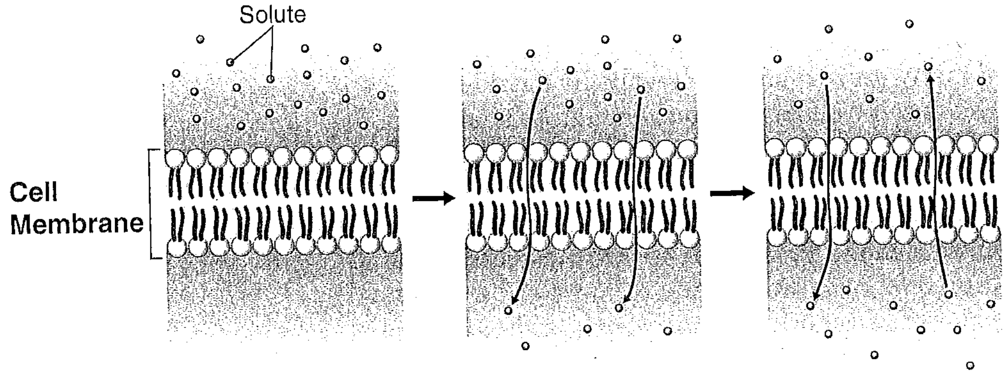
Figure 7–13 The cells of living things are bathed in liquid even in dry environments. When it rains, these cactus plants store the water in their stems. **Applying Concepts** *Which cell structure could serve as a storage location for water?*



DIFFUSION



A There is a higher concentration of solute on one side of the membrane as compared to the other side of the membrane.

B Solute particles move from the side of the membrane with a higher concentration of solute to the side of the membrane with a lower concentration of solute. The solute particles will continue to diffuse across the membrane until equilibrium is reached.

C When equilibrium is reached, solute particles continue to diffuse across the membrane in both directions.

▲ **Figure 7–14** Diffusion is the process by which molecules of a substance move from areas of higher concentration to areas of lower concentration. **Diffusion does not require the cell to use energy.**

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Diffusion In a solution, 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, a process known as **diffusion** (dih-FYOO-zhun). When the concentration of the solute is the same throughout a system, the system has reached **equilibrium.**

What do diffusion and equilibrium have to do with cell membranes? Suppose a substance is present in unequal concentrations on either side of a cell membrane, as shown in **Figure 7–14.** If the substance can cross the cell membrane, its particles will tend to move toward the area where it is less concentrated until equilibrium is reached. At that point, the concentration of the substance on both sides of the cell membrane will be the same. **Because diffusion depends upon random particle movements, substances diffuse across membranes without requiring the cell to use energy.** Even when equilibrium is reached, particles of a solution will continue to move across the membrane in both directions. However, because almost equal numbers of particles move in each direction, there is no further change in concentration.

✓CHECKPOINT *What conditions are present when equilibrium is reached in a solution?*

Osmosis

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

Water passes quite easily across most membranes, even though many solute molecules cannot. An important process known as **osmosis** is the result. **Osmosis is the diffusion of water through a selectively permeable membrane.**

How Osmosis Works Look at the beaker on the left in **Figure 7–15.** There are more sugar molecules on the left side of the membrane than on the right side. That means that the concentration of water is lower on the left than it is on the right. The membrane is permeable to water but not to sugar. This means that water can cross the membrane in both directions, but sugar cannot. As a result, there is a net movement of water from the area of high concentration to the area of low concentration.

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." When the experiment began, the more concentrated sugar solution was **hypertonic,** which means "above strength," as compared to the dilute sugar solution. The dilute sugar solution was **hypotonic,** or "below strength."

Word Origins

Hypotonic comes from the Greek word *hupo,* meaning "under," and the New Latin word *tonicus,* meaning "tension" or "strength." So a hypotonic solution is less strong, or less concentrated, than another solution of the same type. **If *derma* means "skin," how would you describe a hypodermic injection?**

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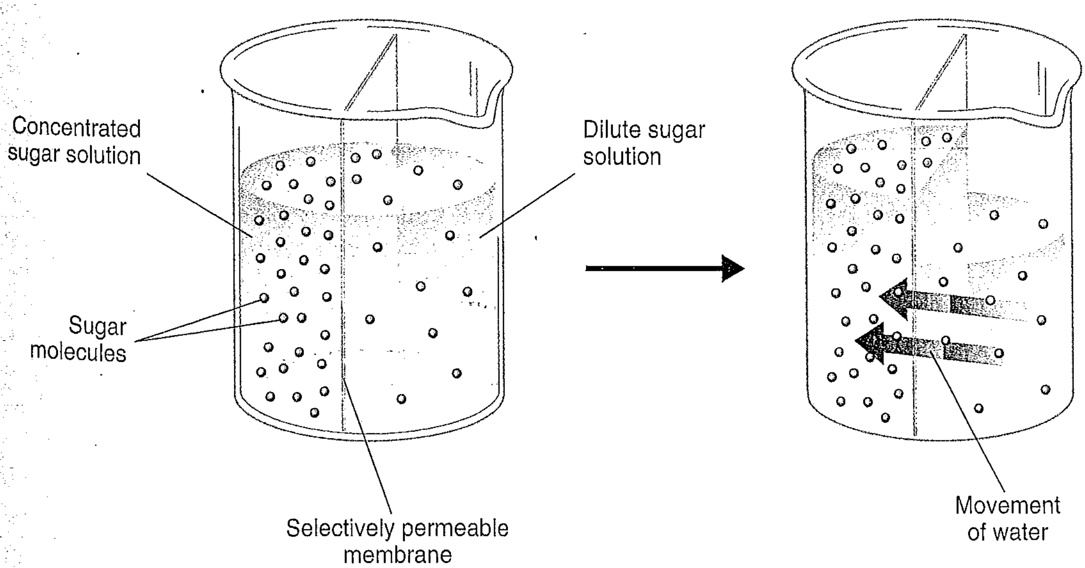
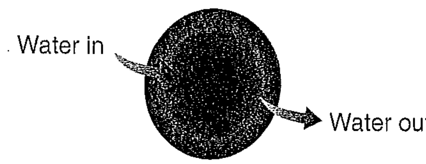
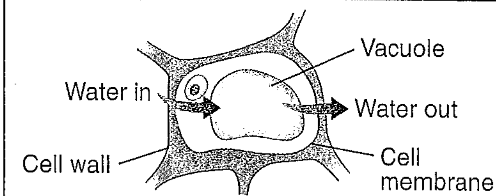
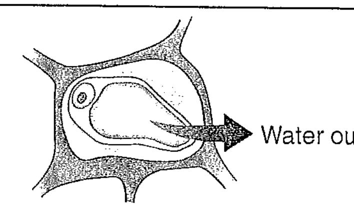
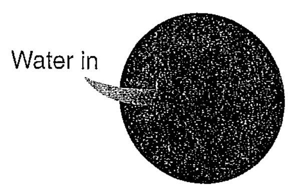
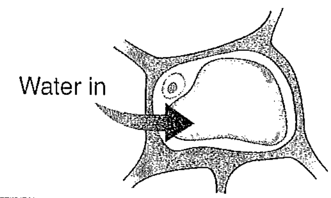
Figure 7–15 **Osmosis is the diffusion of water through a selectively permeable membrane.** In the first beaker, water is more concentrated on the right side of the membrane. As a result, the water diffuses (as shown in the second beaker) to the area of lower concentration.



The Effects of Osmosis on Cells

Solution	Animal Cell	Plant Cell
Isotonic: The concentration of solutes is the same inside and outside the cell.		
Hypertonic: Solution has a higher solute concentration than the cell.		
Hypotonic: Solution has a lower solute concentration than the cell.		

▲ **Figure 7–16** Cells placed in an isotonic solution neither gain nor lose water. In a hypertonic solution, animal cells shrink, and plant cell vacuoles collapse. In a hypotonic solution, animal cells swell and burst. The vacuoles of plant cells swell, pushing the cell contents out against the cell wall. **Predicting** *What would happen to the animal cell in the isotonic solution if it were placed in pure water?*

Osmotic Pressure For organisms to survive, they must have a way to balance the intake and loss of water. Osmosis exerts a pressure known as osmotic pressure on the hypertonic side of a selectively permeable membrane. Osmotic pressure can cause serious problems for a cell. Because the cell is filled with salts, sugars, proteins, and other molecules, it will almost always be hypertonic to fresh water. This means that osmotic pressure should produce a net movement of water into a typical cell that is surrounded by fresh water. If that happens, the volume of a cell will increase until the cell becomes swollen. Eventually, the cell may burst like an overinflated balloon.

Fortunately, cells in large organisms are not in danger of bursting. Most cells in such organisms do not come in contact with fresh water. Instead, the cells are bathed in fluids, such as blood, that are isotonic. These isotonic fluids have concentrations of dissolved materials roughly equal to those in the cells themselves.

Other cells, such as plant cells and bacteria, which do come into contact with fresh water, are surrounded by tough cell walls. The cell walls prevent the cells from expanding, even under tremendous osmotic pressure. However, the increased osmotic pressure makes the cells extremely vulnerable to injuries to their cell walls.

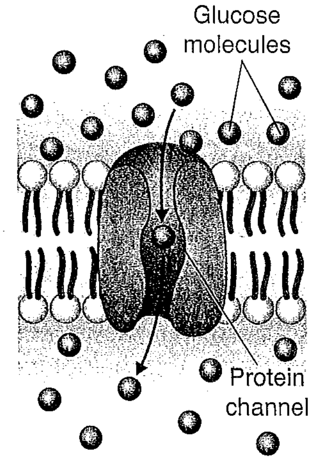
✓CHECKPOINT *What structures protect plant and bacterial cells from potential damage resulting from osmotic pressure?*

Facilitated Diffusion

A few molecules, such as the sugar glucose, seem to pass through the cell membrane much more quickly than they should. One might think that these molecules are too large or too strongly charged to cross the membrane, and yet they diffuse across quite easily.

How does this happen? Cell membranes have protein channels that act as carriers, making it easy for certain molecules to cross. Red blood cells, for example, have membrane proteins with carrier channels that allow glucose to pass through them. Only glucose can pass through this protein carrier, and it can move through in either direction. This is sometimes known as carrier-facilitated diffusion. These cell membrane channels are also said to facilitate, or help, the diffusion of glucose across the membrane. The process, shown in **Figure 7–17**, is known as **facilitated** (fuh-SIL-uh-tayt-ud) **diffusion.** Hundreds of different protein channels have been found that allow particular substances to cross different membranes.

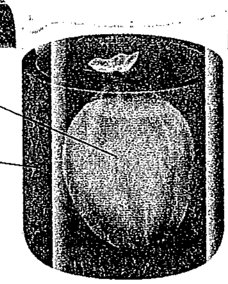
Although facilitated diffusion is fast and specific, it is still diffusion. Therefore, a net movement of molecules across a cell membrane will occur only if there is a higher concentration of the particular molecules on one side than on the other side. This movement does not require the use of the cell's energy.



▲ **Figure 7–17** During facilitated diffusion, molecules, such as glucose, that cannot diffuse across the cell membrane's lipid bilayer on their own move through protein channels instead. **Applying Concepts** *Does facilitated diffusion require the cell to use energy?*

Quick Lab

How can you model permeability in cells?



Materials graduated cylinder, plastic sandwich bag, starch, twist tie, 500-mL beaker, iodine solution

Procedure

1. Pour about 50 mL of water into a plastic sandwich bag. Add 10 mL of starch. Secure the bag with a twist tie, and shake it gently to mix in the starch.
2. Put on your goggles, plastic gloves, and apron.
3. Pour 250 mL of water into a 500-mL beaker. **CAUTION:** *Handle the beaker carefully.* Add 15 drops of iodine. **CAUTION:** *Iodine is corrosive and irritating to the skin and can stain skin and clothing. Be careful not to spill it on yourself.*
4. Place the sandwich bag of water and starch into the beaker of water and iodine.
5. After 20 minutes, look at the sandwich bag in the beaker. Observe and record any changes that occurred.

Analyze and Conclude

1. **Using Models** What cell structure does the sandwich bag represent?
2. **Observing** What did you see inside the sandwich bag? Outside the sandwich bag?
3. **Inferring** Iodine turns blue-black in the presence of starch. What process do you think occurred that caused the results you observed? Explain.

Analyzing Data

Crossing the Cell Membrane

The cell membrane regulates what enters and leaves the cell and also provides protection and support. The core of nearly all cell membranes is a double-layered sheet called a lipid bilayer. Most materials entering the cell pass across this membrane by diffusion. The graph shows the sizes of several molecules that can diffuse across a lipid bilayer.

1. **Predicting** Which substances do you think will diffuse across the lipid bilayer most quickly? Most slowly? Explain your answers.
2. **Formulating Hypotheses** Formulate a hypothesis about the relationship between molecule size and rate of diffusion.
3. **Designing Experiments** Design an experiment to test your hypothesis.

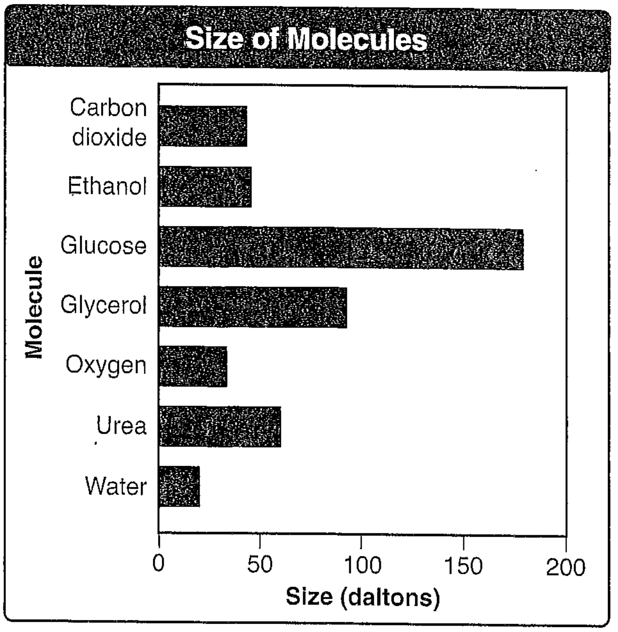
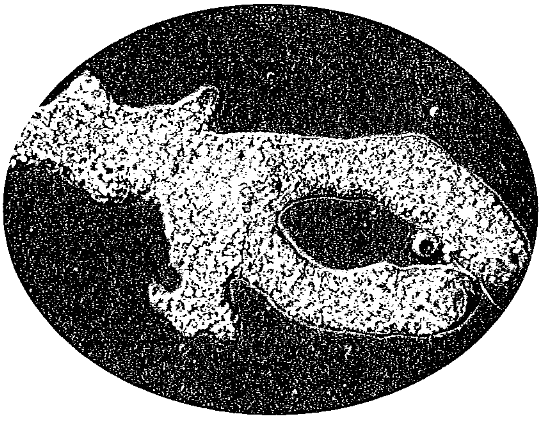


Figure 7–18 Phagocytosis is one form of active transport. During phagocytosis, extensions of cytoplasm surround and engulf large particles. Amoebas are one type of organism that uses this process to take in food and other materials.



Active Transport

As powerful as diffusion is, cells sometimes must move materials in the opposite direction—against a concentration difference. This is accomplished by a process known as **active transport.** As its name implies, active transport requires energy. The active transport of small molecules or ions across a cell membrane is generally carried out by transport proteins or "pumps" that are found in the membrane itself. 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.

Molecular Transport Small molecules and ions are carried across membranes by proteins in the membrane that act like energy-requiring pumps. Many cells use such proteins to move calcium, potassium, and sodium ions across cell membranes. Changes in protein shape, as shown in **Figure 7–19**, seem to play an important role in the pumping process. A considerable portion of the energy used by cells in their daily activities is devoted to providing the energy to keep this form of active transport working. 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.

Endocytosis and Exocytosis Larger molecules and even solid clumps of material may be transported by movements of the cell membrane. One of these movements is called endocytosis (en-doh-sy-TOH-sis). **Endocytosis** is the process of taking material into the cell by means of infoldings, or pockets, of the cell membrane. The pocket that results breaks loose from the outer portion of the cell membrane and forms a vacuole within the cytoplasm. Large molecules, clumps of food, and even whole cells can be taken up in this way. Two examples of endocytosis are phagocytosis (fag-oh-sy-TOH-sis) and pinocytosis (py-nuh-sy-TOH-sis).

Phagocytosis means "cell eating." In **phagocytosis,** extensions of cytoplasm surround a particle and package it within a food vacuole. The cell then engulfs it. Amoebas use this method of taking in food. Engulfing material in this way requires a considerable amount of energy and, therefore, is correctly considered a form of active transport.

In a process similar to endocytosis, many cells take up liquid from the surrounding environment. Tiny pockets form along the cell membrane, fill with liquid, and pinch off to form vacuoles within the cell. This process is known as **pinocytosis.**

Many cells also release large amounts of material from the cell, a process known as exocytosis (ek-soh-sy-TOH-sis). During **exocytosis,** the membrane of the 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.

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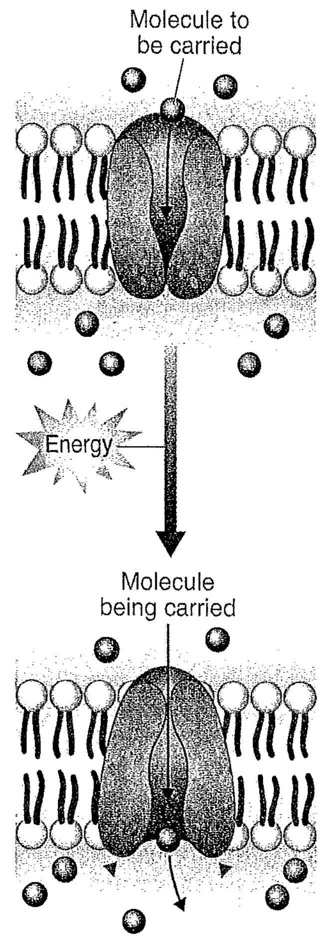


Figure 7–19 Active transport of particles against a concentration difference requires transport proteins and energy. **Interpreting Graphics** *What is happening in the illustration?*

7–3 Section Assessment

1. **Key Concept** Describe the functions of the cell membrane and cell wall.
2. **Key Concept** What happens during diffusion?
3. **Key Concept** Describe how water moves during osmosis.
4. What is the basic structure of a cell membrane?
5. What is the difference between phagocytosis and pinocytosis?
6. **Critical Thinking Comparing and Contrasting** What is the main way that active transport differs from diffusion?

Focus on the BIG Idea

Homeostasis
What is the relationship between active transport and homeostasis? Give one example of active transport in an organism, and explain how the organism uses energy to maintain homeostasis.

7–4 The Diversity of Cellular Life

Guide for Reading

Key Concepts
- What is cell specialization?
- What are the four levels of organization in multicellular organisms?

Vocabulary
cell specialization
tissue
organ
organ system

Reading Strategy: Using Visuals Before you read, preview **Figure 7–22.** As you read, note the different levels of organization in the body.

Earth is sometimes called a living planet, and for good reason. From its simple beginnings, life has spread to every corner of the globe, penetrating deep into the earth 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, use the same basic chemistry, follow the same genetic code, and even contain the same kinds of organelles. This does not mean that all living things are the same. It does mean that their differences arise from the ways in which cells are specialized to perform certain tasks and the ways in which cells associate with one another to form multicellular organisms.

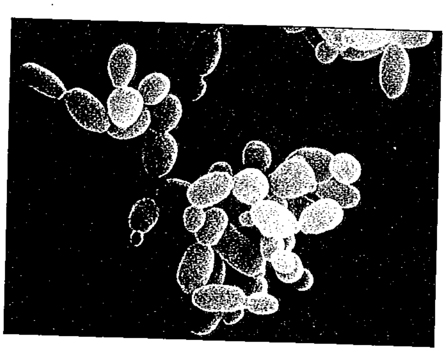
Unicellular Organisms

Cells are the basic living units of all organisms, but sometimes a single cell is a little more than that. Sometimes, a cell *is* the organism. A single-celled organism is also called a unicellular organism. Unicellular organisms do everything that you would expect a living thing to do. They grow, respond to the environment, transform energy, and reproduce. In terms of their numbers, unicellular organisms dominate life on Earth. Some examples of unicellular organisms are shown in **Figure 7–20.**

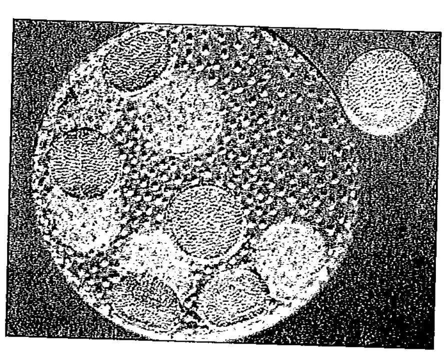
Multicellular Organisms

Organisms that are made up of many cells are called multicellular. There is a great variety among multicellular organisms. However, all multicellular organisms depend on communication and cooperation among specialized cells. **Cells throughout an organism can develop in different ways to perform different tasks.** This process is called **cell specialization.** Some examples of specialized cells are shown in **Figure 7–21.**

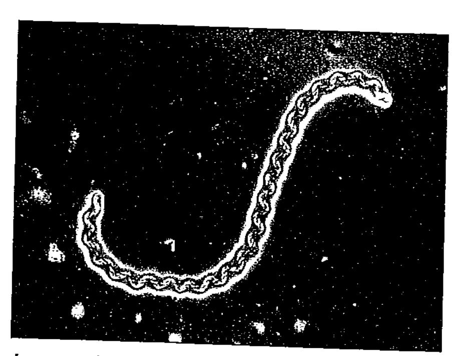
Figure 7–20 Yeasts, which are often used in bread making, are unicellular fungi. The *Volvox aureus* cells shown are actually individual alga cells that live together in a colony. The unicellular spiral-shaped bacterium *Leptospira interrogans* causes a serious disease in humans.



Yeast (magnification: 3400×)



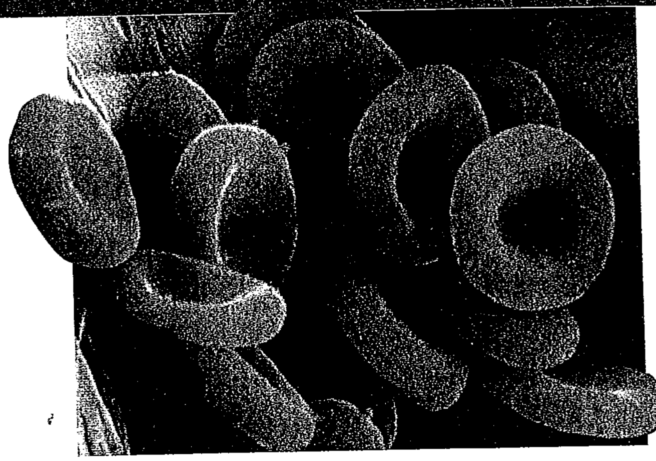
Volvox aureus (magnification: 250×)



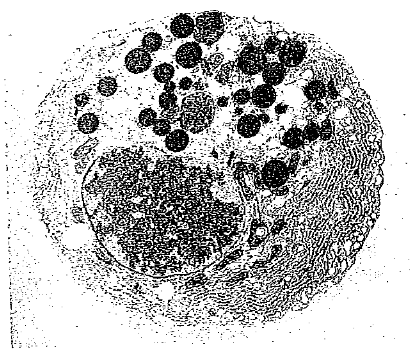
Leptospira interrogans (magnification: 27,000×)

FIGURE 7–21 CELL SPECIALIZATION

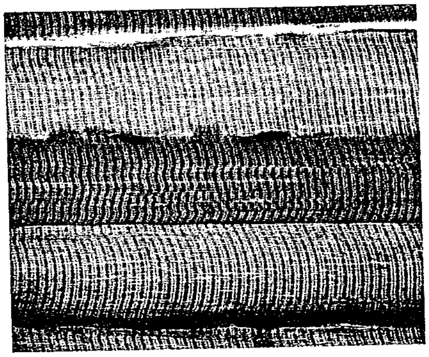
Cells in multicellular organisms are specialized to perform particular functions within the organism. Red blood cells transport oxygen throughout the body. Pancreatic cells produce compounds such as insulin that the body needs. Muscle cells contract and relax to move parts of the body. Guard cells control the opening and closing of stomata on the undersides of leaves.



Red Blood Cells (magnification: 13,000×)



Pancreatic Cell (magnification: 4000×)



Muscle Cell (magnification: 350×)

Stomata (magnification: 510×)

Specialized Animal Cells Animal cells are specialized in many ways. Red blood cells are specialized to transport oxygen. Red blood cells contain a protein that binds to oxygen in the lungs and transports the oxygen throughout the body where it is released. Cells specialized to produce proteins, for example, are found in the pancreas. The pancreas is a gland that produces enzymes that make it possible to digest food. As you might expect, pancreatic cells are packed with ribosomes and rough ER, which are where proteins are produced. Pancreatic cells also possess large amounts of other organelles needed for protein export, including a well-developed Golgi apparatus and clusters of storage vacuoles loaded with enzymes.

The human ability to move is result of the specialized structures of muscle cells. These cells generate force by using a dramatically overdeveloped cytoskeleton. Skeletal muscle cells are packed with fibers arranged in a tight, regular pattern. Those fibers are actin microfilaments and a cytoskeletal protein called myosin. When they contract, muscle cells use chemical energy to pull these fibers past each other, generating force. Whether your muscles are large or small, your muscle cells themselves are "bulked up" with these specialized cytoskeletal proteins to a degree that makes them the body's undisputed heavy-lifting champions.

Careers in Biology

Histotechnologist

Job Description: work in a hospital laboratory, research institution, industrial laboratory, or government agency to prepare slides of body tissues for microscopic examination using special dyes and more advanced techniques, such as electron microscopy

Education: a bachelor's degree from a certified histotechnology program or a bachelor's degree with emphasis in biology and chemistry and one year's experience under a board-certified pathologist to become eligible for national certification exam, leading to a histotechnologist (HTL) certification

Skills: background in biology, anatomy, pathology, and/or chemistry; manual dexterity; attention to detail; good organizational skills; strong writing skills; computer literacy

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Specialized Plant Cells A plant basking in the sunlight may seem quiet and passive, but it is actually interacting with the environment at every moment. It rapidly exchanges carbon dioxide, oxygen, water vapor, and other gases through tiny openings called stomata on the undersides of leaves. Highly specialized cells, known as guard cells, regulate this exchange. Guard cells monitor the plant's internal conditions, changing their shape according to those conditions. For example, when the plant can benefit from gas exchange, the stomata open. The stomata close tightly when the plant's internal conditions change.

Levels of Organization

Biologists have identified levels of organization that make it easier to describe the cells within a multicellular organism. **The levels of organization in a multicellular organism are individual cells, tissues, organs, and organ systems.** These levels of organization are shown in **Figure 7–22.**

Tissues In multicellular organisms, cells are the first level of organization. Similar cells are grouped into units called tissues. A **tissue** is a group of similar cells that perform a particular function. The collection of cells that produce digestive enzymes in the pancreas makes up one kind of tissue. Most animals have four main types of tissue: muscle, epithelial, nervous, and connective tissue. You will read about these tissues in later chapters.

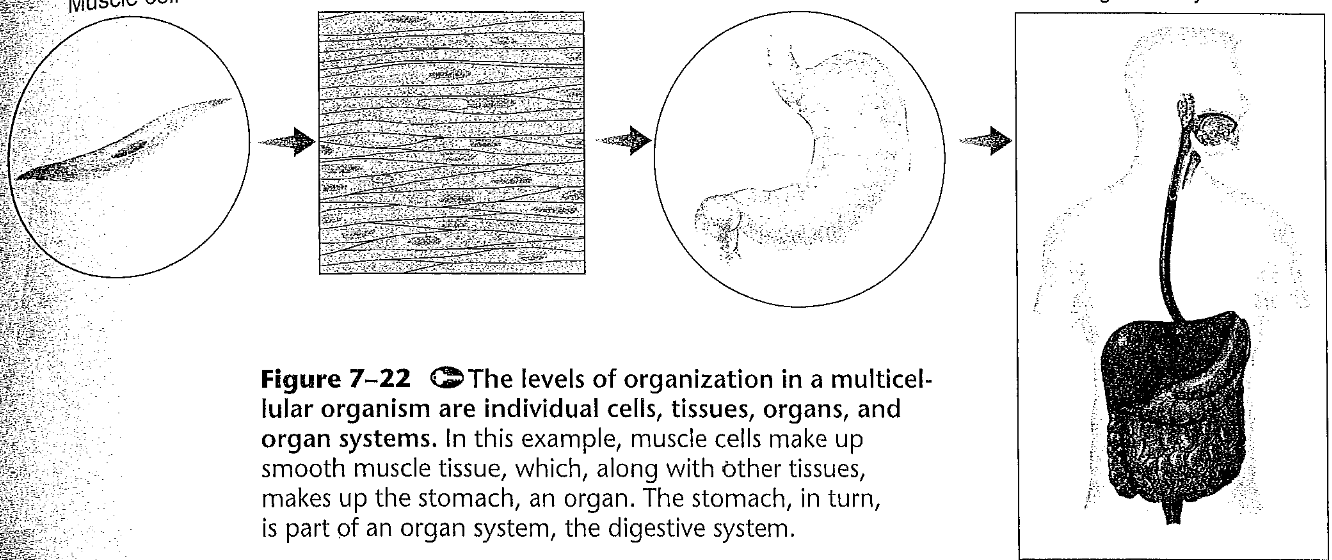


Figure 7–22 **The levels of organization in a multicellular organism are individual cells, tissues, organs, and organ systems.** In this example, muscle cells make up smooth muscle tissue, which, along with other tissues, makes up the stomach, an organ. The stomach, in turn, is part of an organ system, the digestive system.

Organs Many tasks within 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, each muscle in your body is an individual organ. Within a muscle, however, there is much more than muscle tissue. There are nervous tissues and connective tissues. Each type of tissue performs an essential task to help the organ function.

Organ Systems 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.**

The organization of the body's cells into tissues, organs, and organ systems creates a division of labor among those cells that makes multicellular life possible. Specialized cells such as nerve and muscle cells are able to function precisely because other cells are specialized to obtain the food and oxygen needed by those cells. This overall specialization and interdependence is one of the remarkable attributes of living things. Appreciating this characteristic is an important step in understanding the nature of living things.

7–4 Section Assessment

1. **Key Concept** In what kinds of organisms is cell specialization a characteristic?
2. **Key Concept** List the levels of biological organization in multicellular organisms from most simple to most complex.
3. How are unicellular organisms similar to multicellular organisms?
4. **Critical Thinking Predicting** Using what you know about the ways muscle moves, predict which organelles would be most common in muscle cells.

Writing in Science

Using Analogies
Use an organized area in your life—such as school, sports, or extracurricular activities—to construct an analogy to explain how the levels of organization in that chosen area can be compared with those of living organisms.

Exploration

Investigating Cell Structures and Processes

A cell's structures affect how it responds to changes in its environment. In this investigation, you will observe the differences between plant and animal cells. You will then determine how plant and animal cells are affected by hypertonic and hypotonic solutions and relate those effects to the cells' structures.

Problem How do the differences in structure between plant and animal cells influence how they are affected by hypertonic and hypotonic solutions?

Materials

- forceps
- piece of red onion
- scalpel
- 4 glass slides
- dropper pipette
- 4 coverslips
- iodine solution
- paper towel
- microscope
- prepared slide of human cheek cells
- concentrated salt solution
- distilled water
- treated animal blood

Skills Observing, Comparing and Contrasting, Drawing Conclusions

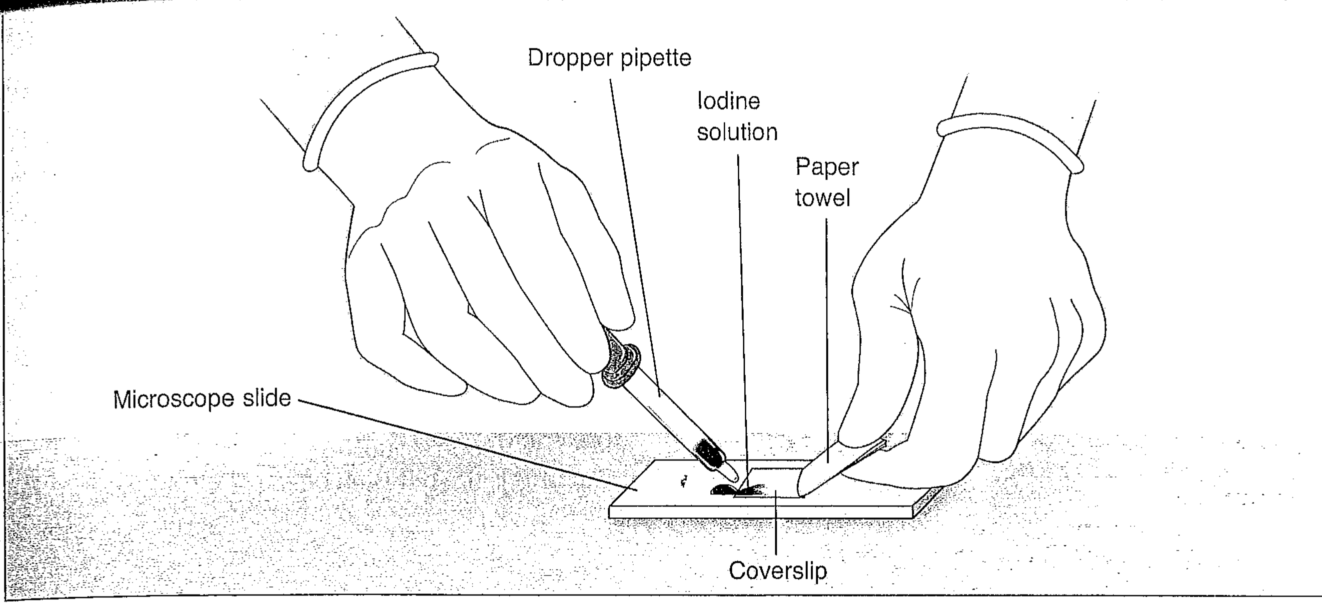
Procedure

Part A: Plant and Animal Cell Structures

1. Put on safety goggles and a lab apron. Using forceps, peel a thin layer from the inner surface of a piece of a red onion, as shown in the photograph.
2. Use a scalpel to cut a small piece out of the layer you removed. **CAUTION:** *The scalpel is very sharp. Handle it carefully, and make sure to cut away from yourself.*
3. Place the piece of onion in the center of a glass slide. Add a drop of distilled water to the piece of onion, and cover it with a coverslip.
4. Put on your plastic gloves. Use a dropper pipette to place a drop of iodine solution at one end of the coverslip. **CAUTION:** *Iodine can stain skin and clothing. Be careful not to spill it on yourself.* Hold a piece of paper towel near the opposite edge of the coverslip, as shown in the diagram on page 195. This will draw the iodine under the coverslip, where it will stain the onion cells.
5. Examine your slide under the low-power objective of the microscope. **CAUTION:** *Microscopes and slides are fragile. Handle them carefully.* Sketch one cell, and label any structures you recognize.
6. Carefully switch to high power, and observe the cell again. Try to identify other cell structures, and add them to your sketch with appropriate labels.
7. Repeat steps 5 and 6 using a prepared slide of human cheek cells.

Part B: Effects of Hypertonic and Hypotonic Solutions

8. Repeat steps 1 to 3 to prepare another onion cell wet mount. Using the same method as in step 4, add a drop of concentrated salt solution to the slide, and use a paper towel to draw it under the coverslip.



9. Observe the onion cells under the microscope under both low power and high power. Record your observations.
10. Prepare a wet-mount slide using treated animal blood. **CAUTION:** *Use only blood samples provided by your teacher.* Do not add water as you did with the onion cells.
11. Observe the blood cells under the microscope under both low power and high power. Sketch one cell, and label any structures you recognize.
12. Using the same method as in step 4, add a drop of concentrated salt solution to the slide, and use a paper towel to draw it under the coverslip.
13. Observe the blood cells under the microscope under both low power and high power. Record your observations. Rinse out the dropper pipette with distilled water.
14. Prepare another wet-mount slide of blood cells. This time, add a drop of distilled water to the slide and draw it under the coverslip.
15. Observe the blood cells under the microscope under both low power and high power. Record your observations.
16. Remove the plastic gloves and discard them according to your teacher's instructions. Wash your hands thoroughly with warm water and soap.

Analyze and Conclude

1. **Applying Concepts** Describe the shapes of the onion cells and the cheek cells you observed in Part A. What structures did you see in the onion cells? The cheek cells? Describe the functions of each of the structures you saw.
2. **Comparing and Contrasting** How are plant and animal cells similar in structure? How are they different?
3. **Drawing Conclusions** Explain your observations in step 9 of Part B in terms of osmosis and permeability.
4. **Drawing Conclusions** Explain your observations in steps 13 and 15 in terms of osmosis and permeability.
5. **Applying Concepts** What part of the cell is involved in the processes you observed in steps 9, 13, and 15? Explain your answer.
6. **Comparing and Contrasting** Why didn't the onion cells burst when they are in distilled water as in step 3? Relate your answer to the

Go Further

Designing Experiments Design one or more experiments to test the effects of hypotonic and hypertonic solutions on other cells. Write a hypothesis for each experiment and control all variables. Get your teacher's permission before carrying out your experiments.

Chapter 7 Study Guide

7–1 Life Is Cellular

Key Concepts

- The cell theory states that all living things are composed of cells, cells are the basic units of structure and function in living things, and new cells are produced from existing cells.
- Prokaryotic cells have genetic material that is not contained in a nucleus. Eukaryotic cells contain a nucleus in which their genetic material is separated from the rest of the cell.

Vocabulary
cell, p. 170 • cell theory, p. 170
nucleus, p. 173 • eukaryote, p. 173
prokaryote, p. 173

7–2 Eukaryotic Cell Structure

Key Concepts

- The nucleus contains nearly all the cell's DNA and the coded instructions for making proteins and other important molecules.
- Proteins are assembled on ribosomes.
- One type of endoplasmic reticulum makes membranes and secretory proteins. The other type of ER makes lipids and helps to detoxify, or remove harmful substances.
- The Golgi apparatus modifies, sorts, and packages proteins and other materials from the endoplasmic reticulum for storage or secretion outside the cell.
- Mitochondria convert the chemical energy stored in food into compounds that are more convenient for the cell to use.
- Chloroplasts capture the energy from sunlight and convert it into chemical energy.
- The cytoskeleton is a network of protein filaments that helps the cell to maintain its shape. The cytoskeleton is also involved in movement of materials within and outside the cell.

Vocabulary
organelle, p. 174 • cytoplasm, p. 174
nuclear envelope, p. 176
chromatin, p. 176 • chromosome, p. 176
nucleolus, p. 176 • ribosome, p. 177
endoplasmic reticulum, p. 177
Golgi apparatus, p. 178
lysosome, p. 179 • vacuole, p. 179
mitochondrion, p. 179 • chloroplast, p. 180
cytoskeleton, p. 181 • centriole, p. 181

7–3 Cell Boundaries

Key Concepts

- All cells have a cell membrane. The cell membrane regulates what enters and leaves the cell and also provides protection and support. Some cells also have cell walls. Cell walls provide additional support and protection.
- Diffusion causes many substances to move across a cell membrane but does not require the cell to use energy.
- Osmosis is the diffusion of water through a selectively permeable membrane.

Vocabulary
cell membrane, p. 182 • cell wall, p. 182
lipid bilayer, p. 182 • concentration, p. 183
diffusion, p. 184 • equilibrium, p. 184
osmosis, p. 185 • isotonic, p. 185
hypertonic, p. 185 • hypotonic, p. 185
facilitated diffusion, p. 187
active transport, p. 188
endocytosis, p. 189 • phagocytosis, p. 189
pinocytosis, p. 189 • exocytosis, p. 189

7–4 The Diversity of Cellular Life

Key Concepts

- Cells in multicellular organisms develop in different ways to perform particular functions within the organism.
- The levels of organization in a multicellular organism are individual cells, tissues, organs, and organ systems.

Vocabulary
cell specialization, p. 190
tissue, p. 192
organ, p. 193
organ system, p. 193

Thinking Visually

Use the information in this chapter to create a concept map about the ways substances can move into and out of cells. Use the following terms in your concept map: *diffusion, osmosis, facilitated diffusion, active transport, phagocytosis, endocytosis, pinocytosis, exocytosis.*

Chapter 7 Assessment

Reviewing Content

Choose the letter that best answers the question or completes the statement.

1. In many cells, the structure that controls the cell's activities is the
   a. cell membrane. c. nucleolus.
   b. organelle. d. nucleus.

2. Despite differences in size and shape, all cells have cytoplasm and a
   a. cell wall. c. mitochondrion.
   b. cell membrane. d. nucleus.

3. If a cell of an organism contains a nucleus, the organism is a(an)
   a. plant. c. animal.
   b. eukaryote. d. prokaryote.

4. Distinct threadlike structures containing genetic information are called
   a. ribosomes. c. nuclei.
   b. chromosomes. d. mitochondria.

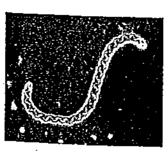
5. Which organelle converts the chemical energy in food into a form that cells can use?
   a. nucleolus c. mitochondrion
   b. chromosome d. chloroplast

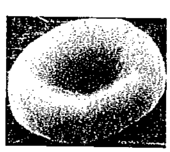
6. Cell membranes are constructed mainly of
   a. lipid bilayers. c. carbohydrate gates.
   b. protein pumps. d. free-moving proteins.

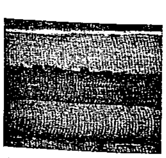
7. The movement of water molecules across a selectively permeable membrane is known as
   a. exocytosis. c. endocytosis.
   b. phagocytosis. d. osmosis.

8. A substance that moves across a cell membrane without using the cell's energy tends to move
   a. away from the area of equilibrium.
   b. away from the area where it is less concentrated.
   c. away from the area where it is more concentrated.
   d. toward the area where it is more concentrated.

9. Which cell helps in gas exchange in plants?

a. 

c. 

b. 

d. 

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10. A tissue is composed of a group of
    a. similar cells.
    b. related organelles.
    c. organ systems.
    d. related organs.

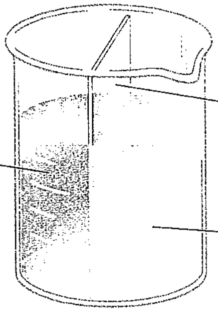
Understanding Concepts

11. Make a table to summarize the contributions made to the cell theory by Robert Hooke, Matthias Schleiden, Theodor Schwann, and Rudolf Virchow.
12. How are prokaryotic and eukaryotic cells alike? How do they differ?
13. Draw a cell nucleus. Label and give the function of the following structures: chromatin, nucleolus, and nuclear envelope.
14. What is the function of a ribosome?
15. What process takes place in the rough endoplasmic reticulum?
16. Describe the role of the Golgi apparatus.
17. Other than the nucleus, which two organelles contain their own DNA?
18. Name and describe the two types of structures that make up the cytoskeleton.
19. Briefly describe the structure of a cell membrane. How does the cell membrane affect the contents of a cell?
20. What is meant by the concentration of a solution? Give a specific example of concentration involving volume and mass.
21. Describe the process of diffusion. Name and describe the condition that exists when the diffusion of a particular substance is complete.
22. What is the relationship between osmosis and diffusion? By definition, what's the only substance that carries out osmosis?
23. Using the example of a cell in a sugar solution, explain what is meant by an isotonic solution.
24. Name and describe the cell structure that helps prevent damage to certain cells when they are subjected to high osmotic pressure.
25. Use an example to describe the relationship among cells, tissues, organs, and organ systems.

Chapter 7 Assessment

Critical Thinking

26. **Predicting** The beaker in the diagram has a selectively permeable membrane separating two solutions. Assume that the water molecules and salt can pass freely through the membrane. When equilibrium is reached, will the fluid levels be the same as they are now? Explain your answer.



27. **Calculating** Which salt solution is more concentrated, solution A, which contains 18 g of salt in 6 L of water, or solution B, which contains 24 g of salt in 12 L of water? Explain.

28. **Predicting** What would happen to a sample of your red blood cells if they were placed into a hypotonic solution? Explain your prediction.

29. **Inferring** Would you expect skin cells to contain more or fewer mitochondria than muscle cells? Explain your answer.

30. **Designing Experiments** You are given vegetable coloring and three beakers. The first beaker contains water at room temperature, the second beaker contains ice water, and the third beaker contains hot water. Design an experiment to determine the effects of temperature on the rate of diffusion. Be sure to state your hypothesis and to include a control.

31. **Inferring** The pancreas, an organ present in certain animals, produces enzymes used elsewhere in the animals' digestive systems. Which type of cell structure(s) might produce those enzymes? Explain your answer.

32. **Using Analogies** Compare a cell to a factory, as in the chapter, or to something else, such as a school. (For example, a cell has a nucleus, and a school has a principal.) Use that analogy to describe the function of different parts of the cell.

33. **Applying Concepts** As waste chemicals build up in a cell, homeostasis is threatened. State how diffusion helps cells maintain homeostasis.

34. **Comparing and Contrasting** Diffusion and active transport are processes that are important to the maintenance of homeostasis in organisms. Compare the two processes, including examples that describe how they are important to living organisms.

Focus on the BIG Idea

Cellular Basis of Life In Chapter 2, you learned about four categories of carbon compounds called the "molecules of life." Explain where some of those compounds are found in a typical cell.

Writing in Science

Different beverages have different concentrations of solutes. Some beverages have low solute concentrations and can be a source of water for body cells. Other beverages have high solute concentrations and can actually dehydrate your body cells. Should companies that market these high-solute beverages say that these drinks quench your thirst?

Performance-Based Assessment

Prepare to Debate One day, unicellular organisms got tired of being referred to as simple organisms by the multicellular organisms. They felt that they should be recognized as complex individuals and challenged the multicellular organisms to a debate. As a unicellular organism, what arguments would you use to defend your position?

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Test-Taking Tip When you answer a question based on experimental data, read the description of the experiment carefully to determine the steps followed. Then, try to see if there are any trends in the data. For example, "if x increases, what happens to y?"

Directions: Choose the letter that best answers the question or completes the statement.

1. Animals cells have all of the following EXCEPT
   (A) mitochondria.
   (B) chloroplasts.
   (C) a nucleus.
   (D) a cell membrane.
   (E) Golgi apparatus.

2. The nucleus includes all of the following structures EXCEPT
   (A) cytoplasm.
   (B) nuclear envelope.
   (C) DNA.
   (D) nucleolus.
   (E) chromatin.

3. Which statement best describes the expected result when a typical cell is placed into fresh water?
   (A) Active transport of water into the cell would begin.
   (B) There would be a net movement of water out of the cell.
   (C) There would be a net movement of water into the cell.
   (D) Protein synthesis would begin.
   (E) No change in the cell's water content would occur.

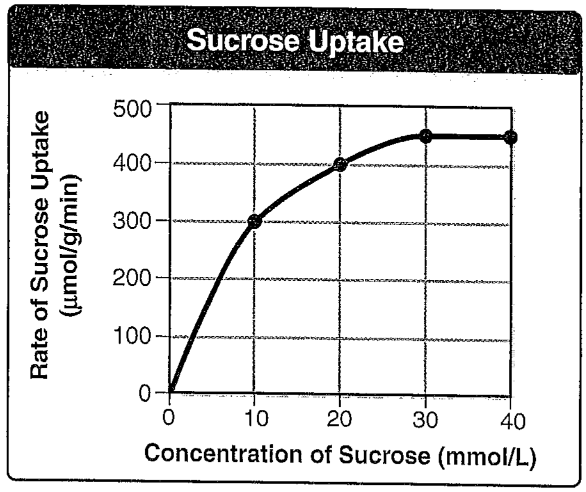
4. Which cell structures are sometimes found attached to the endoplasmic reticulum?
   (A) chloroplasts
   (B) mitochondria
   (C) vacuoles
   (D) nuclei
   (E) ribosomes

5. Which process always involves the movement of materials from inside the cell to outside the cell?
   (A) phagocytosis
   (B) endocytosis
   (C) diffusion
   (D) exocytosis
   (E) osmosis

6. Which of the following is NOT an example of active transport?
   I. Facilitated diffusion
   II. Osmosis
   III. Diffusion
   (A) I only
   (B) III only
   (C) I and II only
   (D) II and III only
   (E) I, II, and III

Questions 7–9

In an experiment, plant cells were placed in sucrose solutions of varying concentrations. The rate at which the plant cells absorbed sucrose from the solution was then measured for the different concentrations. The results are summarized in the graph below.



7. In this experiment, there was a positive sucrose uptake. Sucrose probably entered the cells by means of
   (A) endocytosis.
   (B) osmosis.
   (C) exocytosis.
   (D) phagocytosis.
   (E) active transport.

8. The graph shows that as the concentration of sucrose increases from 10 to 30 mmol/L, the plant cells
   (A) take in sucrose more slowly.
   (B) take in sucrose more quickly.
   (C) fail to take in more sucrose.
   (D) secrete sucrose more slowly.
   (E) secrete sucrose more quickly.

9. Which statement is best supported by information in the graph?
   (A) The rate of sucrose uptake increases at a constant rate from 0 to 30 mmol/L.
   (B) The rate of sucrose uptake decreases at a varying rate from 0 to 30 mmol/L.
   (C) The rate of sucrose uptake is less at 25 mmol/L than at 5 mmol/L.
   (D) The rate of sucrose uptake is constant between 30 and 40 mmol/L.
   (E) The rate of sucrose uptake declines between 30 and 40 mmol/L.