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

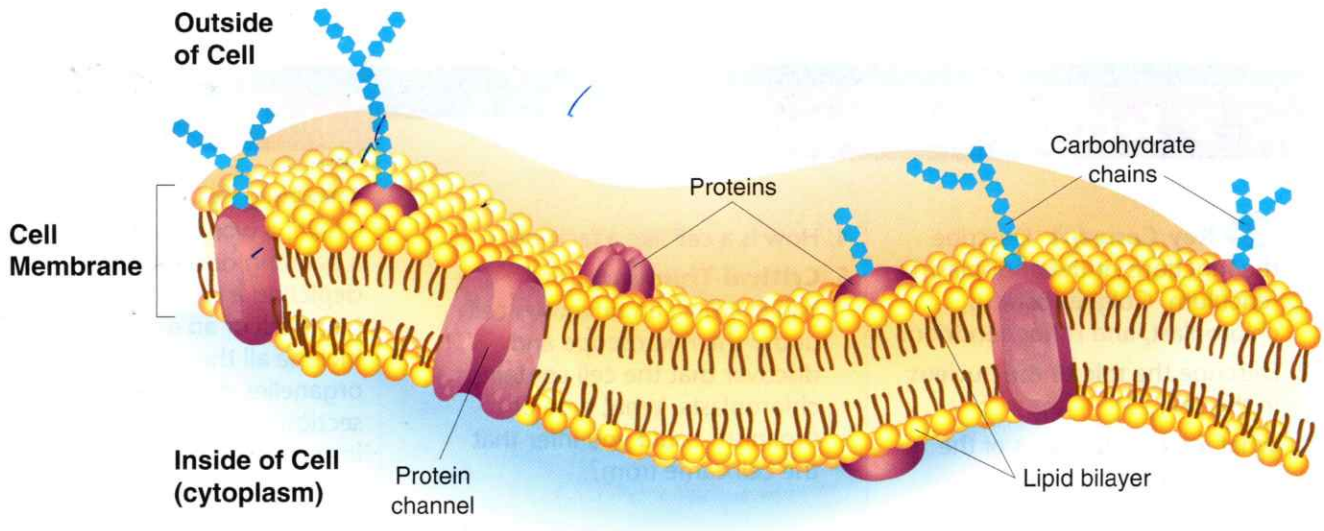
As you read, make a list of the ways in which substances can move through the cell membrane. Write one sentence describing each process.

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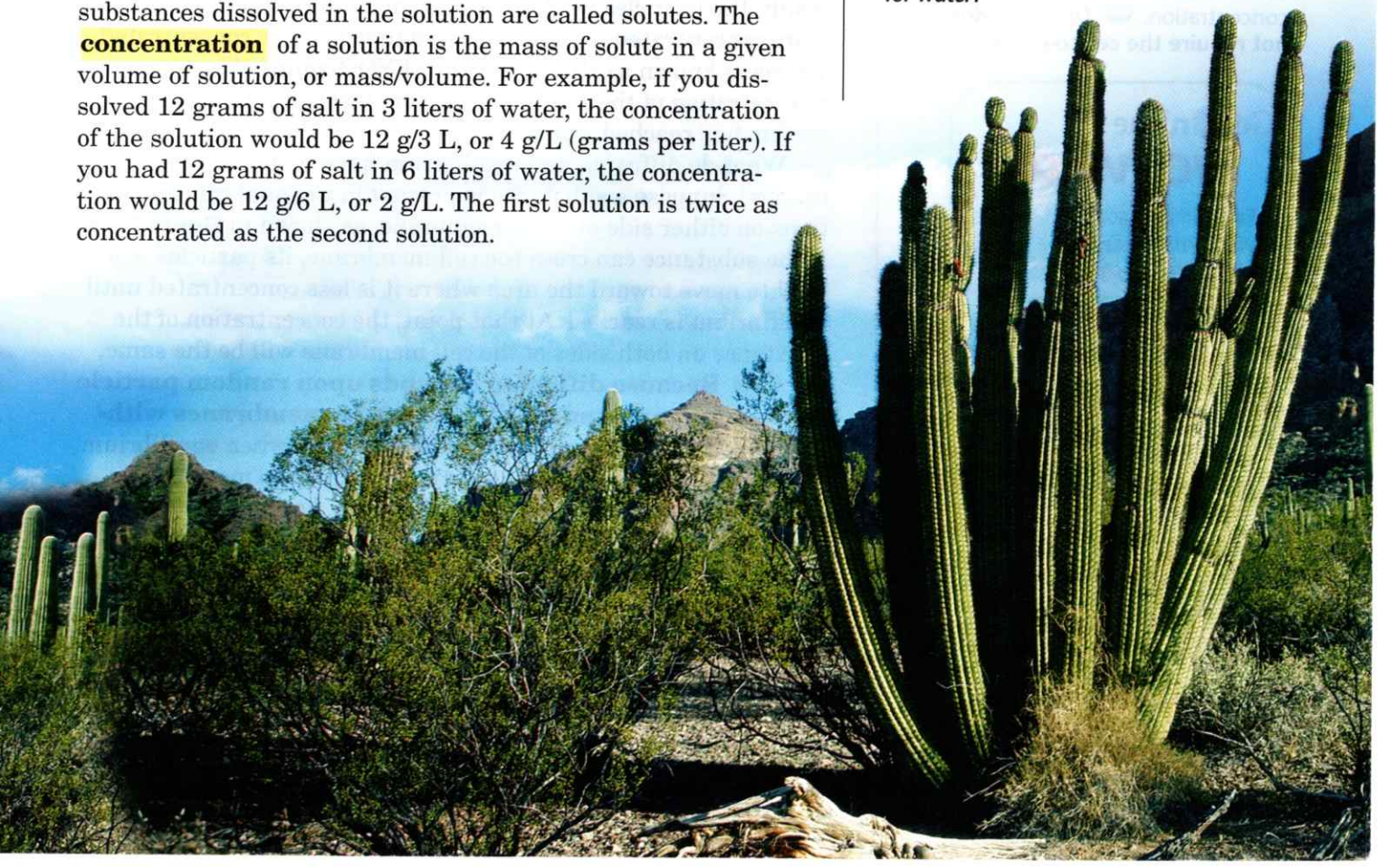
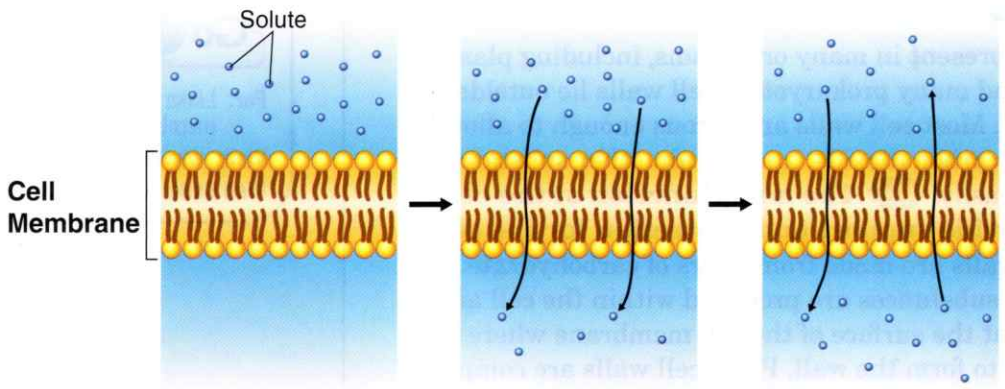
▼ **Figure 7–13** The cells of living things are bathed in liquid even in dry environments. When it rains, these cactus plants store the water in their stems. **Applying Concepts** *Which cell structure could serve as a storage location for water?*



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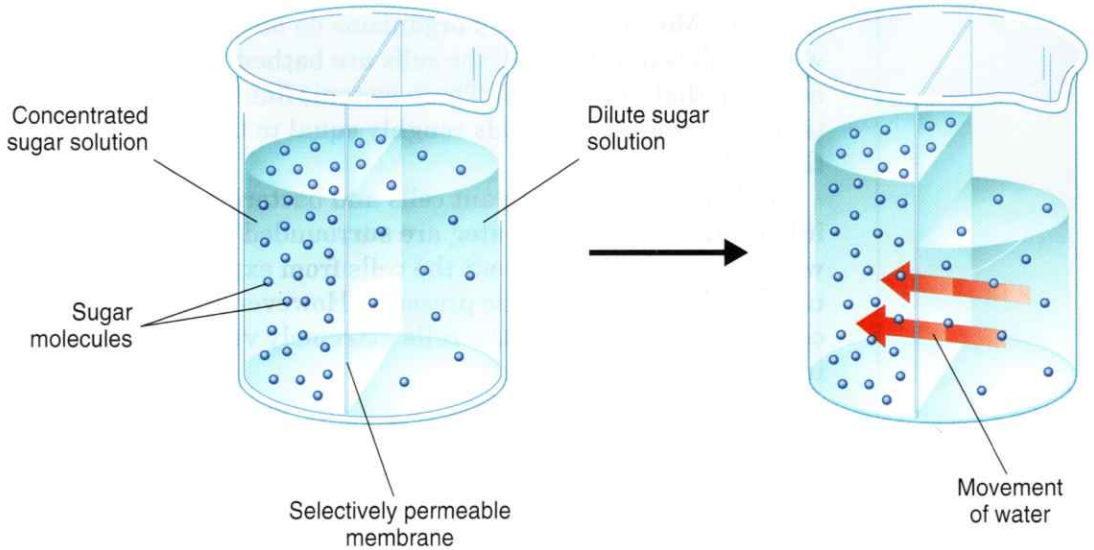
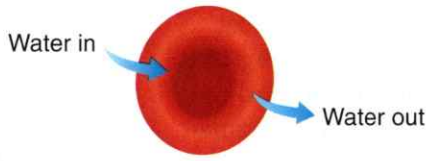
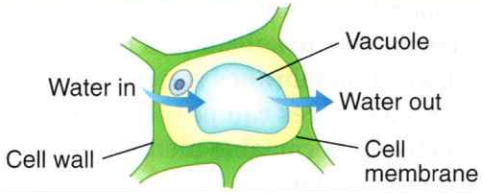
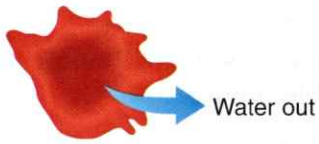
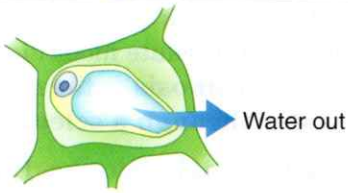
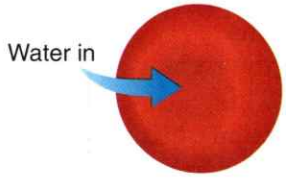
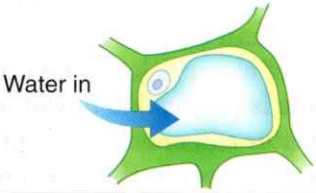
Figure 7–15 **Osmosis is the diffusion of water through a selectively permeable membrane.** In the first beaker, water is more concentrated on the right side of the membrane. As a result, the water diffuses (as shown in the second beaker) to the area of lower concentration.



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.

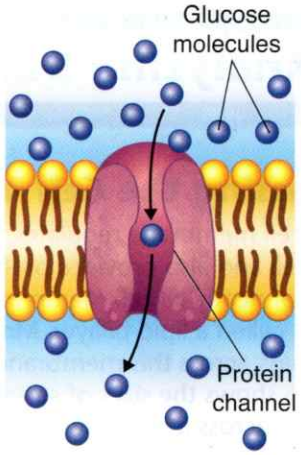
CHECKPOINT *What structures protect plant and bacterial cells from potential damage resulting from osmotic pressure?*

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.

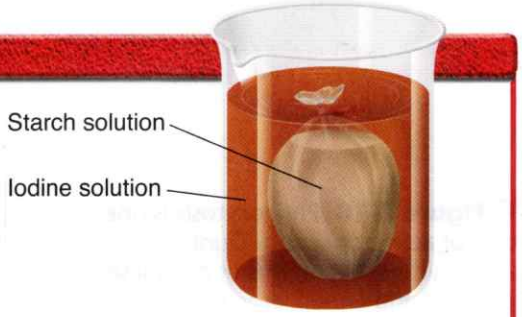
Although facilitated diffusion is fast and specific, it is still diffusion. Therefore, a net movement of molecules across a cell membrane will occur only if there is a higher concentration of the particular molecules on one side than on the other side. This movement does not require the use of the cell's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

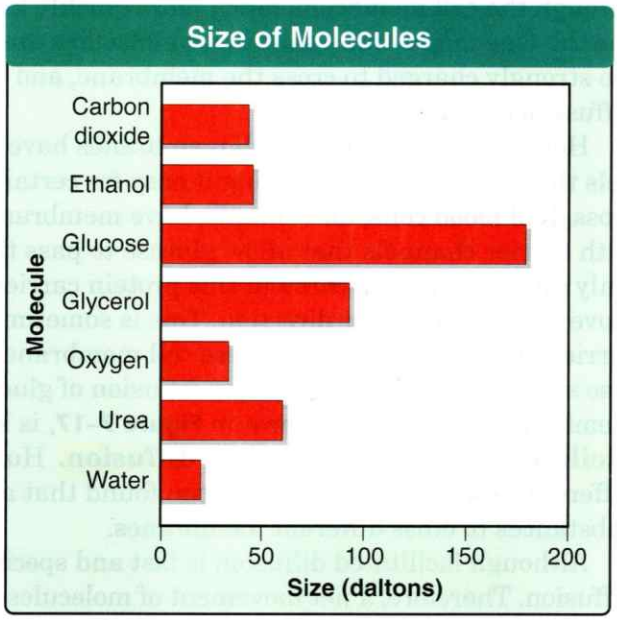
1. **Using Models** What cell structure does the sandwich bag represent?
2. **Observing** What did you see inside the sandwich bag? Outside the sandwich bag?
3. **Inferring** Iodine turns blue-black in the presence of starch. What process do you think occurred that caused the results you observed? Explain.

Analyzing Data

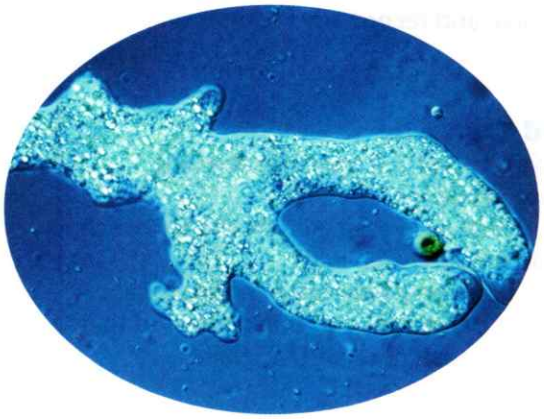
Crossing the Cell Membrane

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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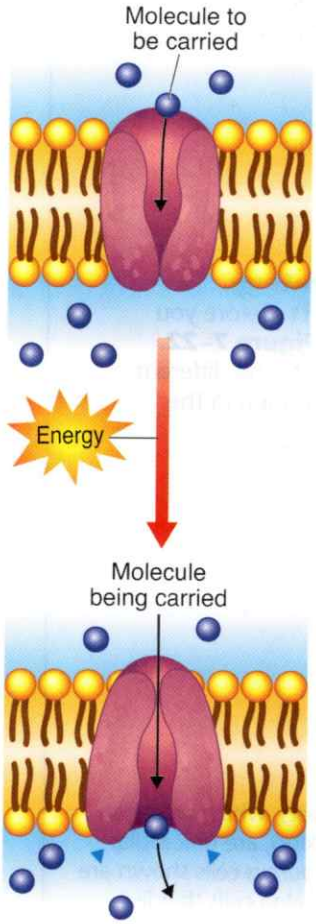

▶ **Figure 7–19** Active transport of particles against a concentration difference requires transport proteins and energy. **Interpreting Graphics** *What is happening in the illustration?*

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.