

7.3

Cell Transport

Key Questions

 **What is passive transport?**

 **What is active transport?**

Vocabulary

diffusion • facilitated diffusion •
aquaporin • osmosis •
isotonic • hypertonic •
hypotonic •
osmotic pressure

Taking Notes

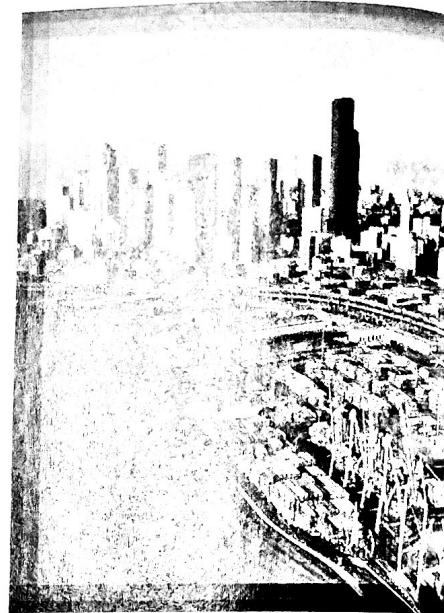
Compare/Contrast Table As you read, create a compare/contrast table for passive and active transport.

MYSTERY CLUE

As Michelle ran, she perspired, losing salts from her bloodstream. And as she drank more and more water during the race, the concentration of dissolved salts and minerals in her bloodstream decreased. How do you think these phenomena contributed to Michelle's condition?



THINK ABOUT IT In the previous lesson, cell walls and cell membranes were compared to the roof and walls of a factory. When you think about how cells move materials in and out, it can be helpful to think of a cell as a nation. Before you can learn anything about a nation, it's important to understand where it begins and where it ends. The boundaries of a nation are its borders, and nearly every country tries to regulate and control the goods that move across those borders, like the shipping containers seen here entering and leaving the port of Seattle. Each cell has its own border, which separates the cell from its surroundings and also determines what comes in and what goes out. How can a cell separate itself from its environment and still allow material to enter and leave? That's where transport across its border, the cell membrane, comes in.



Passive Transport

 **What is passive transport?**

Every living cell exists in a liquid environment. One of the most important functions of the cell membrane is to keep the cell's internal conditions relatively constant. It does this by regulating the movement of molecules from one side of the membrane to the other.

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

What does diffusion have to do with the cell membrane? Suppose a substance is present in unequal concentrations on either side of a cell membrane, as shown in **Figure 7-15**. If the substance can cross the cell membrane, its particles will tend to move toward the area where it is less concentrated until it is evenly distributed. Once the concentration of the substance on both sides of the cell membrane is the same, equilibrium is reached.

Even when equilibrium is reached, particles of a solution continue to move across the membrane in both directions. However, because almost equal numbers of particles move in each direction, there is no further net change in the concentration on either side.


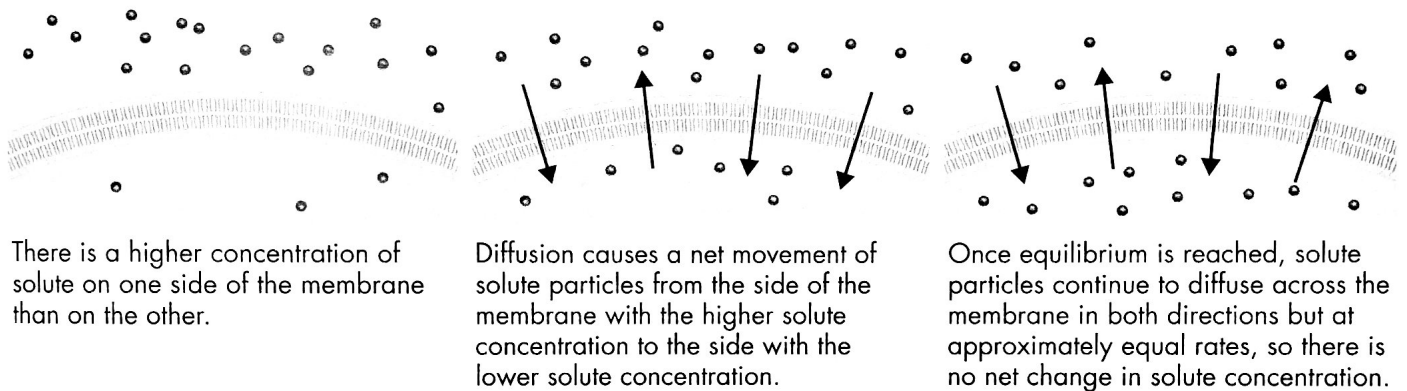

Diffusion depends on random particle movements. Therefore, substances diffuse across membranes without requiring the cell to use additional energy.  **The movement of materials across the cell membrane without using cellular energy is called passive transport.**

FIGURE 7-15 Diffusion Diffusion is the process by which molecules of a substance move from an area of higher concentration to an area of lower concentration. It does not require the cell to use energy. **Predict** How would the movement of solute particles seen here be different if the initial area of high concentration had been on the inside of the cell instead of the outside?



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

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

 **In Your Notebook** Explain how you can demonstrate diffusion by spraying air freshener in a large room.

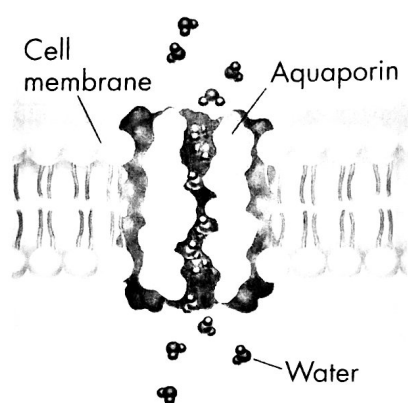


FIGURE 7-16 An Aquaporin

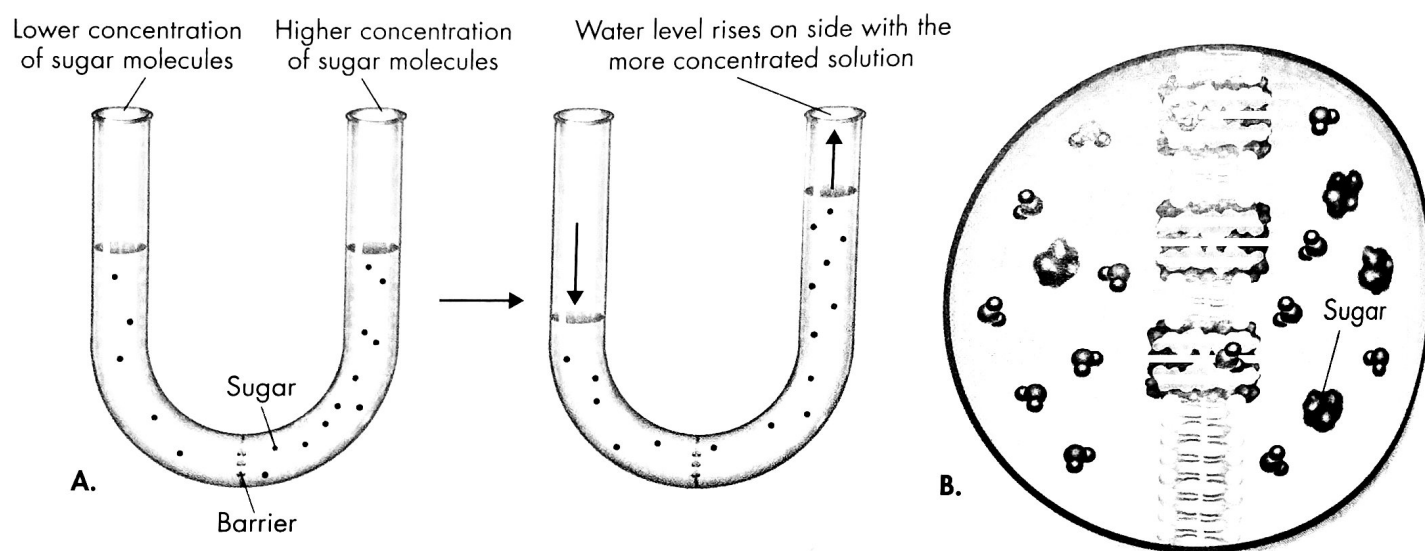
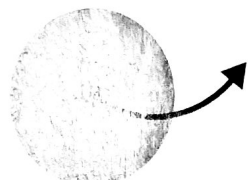
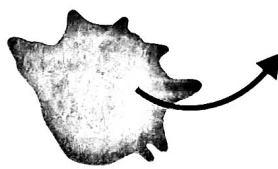
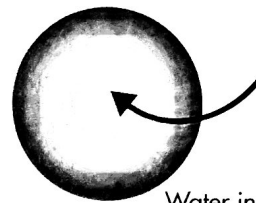
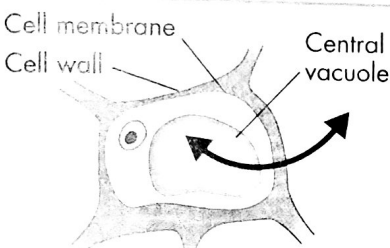
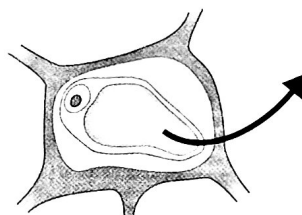
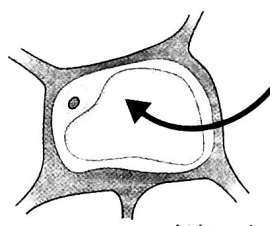


FIGURE 7-17 Osmosis Osmosis is a form of facilitated diffusion. **A.** In a laboratory experiment, water moves through a selectively permeable barrier from an area of lower to higher solute concentration. **B.** In the cell, water passes in through aquaporins embedded in the cell membrane. Although water moves in both directions through aquaporins, there is a net movement of water from an area of lower to higher sugar concentration. **Apply Concepts Does osmosis require the cell to use energy?**

► **How Osmosis Works** Look at the experimental setup in Figure 7-17A. The barrier is permeable to water but not to sugar. This means that water can cross the barrier in both directions, but sugar cannot. To start, there are more sugar molecules on the right side of the barrier than on the left. Therefore, the concentration of water is lower on the right, where more of the solution is made of sugar. Although water molecules move in both directions across the membrane, there is a net movement of water toward the concentrated sugar solution.

Water will tend to move across the membrane until equilibrium is reached. At that point, the concentrations of water and sugar will be the same on both sides of the membrane. When this happens, the two solutions will be **isotonic**, which means “same strength.” Note that “strength” refers to the amount of solute, not water. When the experiment began, the more concentrated sugar solution (right side of the tube) was **hypertonic**, or “above strength,” compared to the left side. So the dilute sugar solution (left side of the tube) was **hypotonic**, or “below strength,” compared to the right side. Figure 7-17B shows how osmosis works across a cell membrane.

The Effects of Osmosis on Cells

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

► **Osmotic Pressure** Driven by differences in solute concentration, the net movement of water out of or into a cell produces a force known as **osmotic pressure**. As shown in **Figure 7-18**, osmotic pressure can cause an animal cell in a hypertonic solution to shrink, and one in a hypotonic solution to swell. Because cells contain salts, sugars, proteins, and other dissolved molecules, they are almost always hypertonic to fresh water. As a result, water tends to move quickly into a cell surrounded by fresh water, causing it to swell. Eventually, the cell may burst like an overinflated balloon. In plant cells, osmotic pressure can cause changes in the size of the central vacuole, which shrinks or swells as water moves into or out of the cell.

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

What happens when cells do come in contact with fresh water? Some, like the eggs laid in fresh water by fish and frogs, lack water channels. As a result, water moves into them so slowly that osmotic pressure is not a problem. Others, including bacteria and plant cells, are surrounded by tough walls. The cell walls prevent the cells from expanding, even under tremendous osmotic pressure. Notice how the plant cell in **Figure 7-18** holds its shape in both hypertonic and hypotonic solutions while the animal red blood cell does not. However, increased osmotic pressure makes plant cells extremely vulnerable to cell wall injuries.

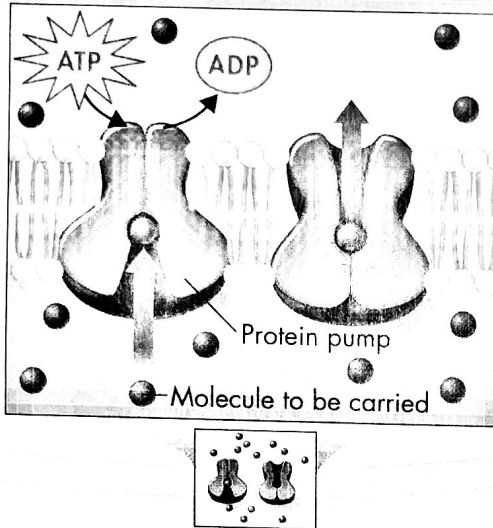
FIGURE 7-18 Osmotic Pressure

Water molecules move equally into and out of cells placed in an isotonic solution. In a hypertonic solution, animal cells, like the red blood cell shown, shrink, and plant cell central vacuoles collapse. In a hypotonic solution, animal cells swell and burst. The central vacuoles of plant cells also swell, pushing the cell contents out against the cell wall. **Predict** What would happen to the cells of a saltwater plant if the plant were placed in fresh water?

In Your Notebook In your own words, explain why osmosis is really just a special case of facilitated diffusion.

Protein Pumps

Energy from ATP is used to pump small molecules and ions across the cell membrane. Active transport proteins change shape during the process, binding substances on one side of the membrane, and releasing them on the other.

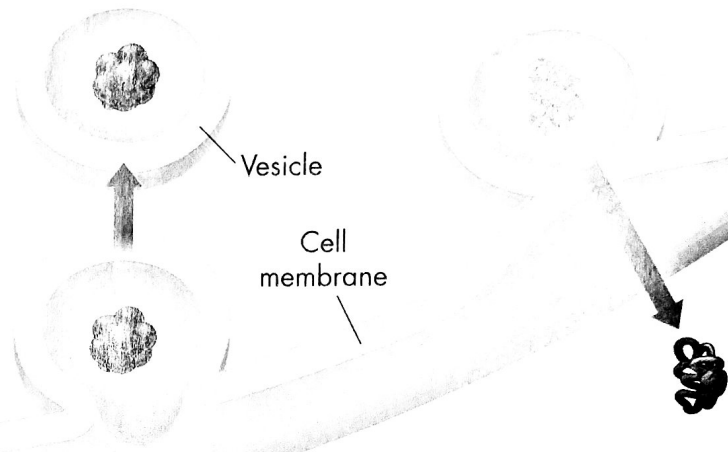


Endocytosis

The membrane forms a pocket around a particle. The pocket then breaks loose from the outer portion of the cell membrane and forms a vesicle within the cytoplasm.

Exocytosis

The membrane of a vesicle surrounds the material then fuses with the cell membrane. The contents are forced out of the cell.



VISUAL SUMMARY

ACTIVE TRANSPORT

FIGURE 7-19 Energy from the cell is required to move particles against a concentration gradient.

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

Active Transport

What is active transport?

As powerful as diffusion is, cells sometimes must move materials against a concentration difference. **The movement of materials against a concentration difference is known as active transport. Active transport requires energy.** The active transport of small molecules or ions across a cell membrane is generally carried out by transport proteins—protein pumps—that are found in the membrane 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. The major types of active transport are shown in **Figure 7-19**.

Molecular Transport Small molecules and ions are carried across membranes by proteins in the membrane that act like pumps. Many cells use protein pumps to move calcium, potassium, and sodium ions across cell membranes. Changes in protein shape seem to play an important role in the pumping process. A considerable portion of the energy used by cells in their daily activities is spent 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.

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

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

Phagocytosis (fag oh sy TOH sis) is a type of endocytosis, in which extensions of cytoplasm surround a particle and package it within a food vacuole. The cell then engulfs it. Amoebas use this method for taking in food, and white blood cells use phagocytosis to “eat” damaged cells, as shown in **Figure 7–20**. Engulfing material in this way requires a considerable amount of energy and is considered a form of active transport.

In a process similar to phagocytosis, 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 type of endocytosis is known as pinocytosis (py nuh sy TOH sis).

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

BUILD Vocabulary

PREFIXES The prefix *endo-* in *endocytosis* comes from a Greek word meaning “inside” or “within.” The prefix *exo-* in *exocytosis* means “outside.”

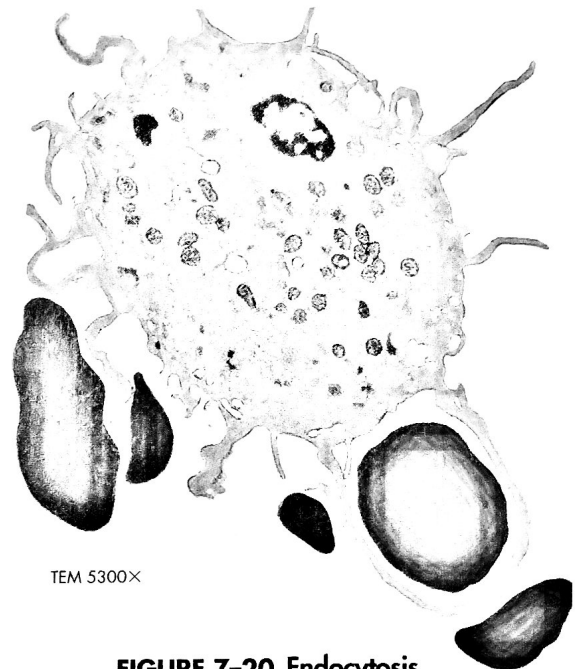


FIGURE 7–20 Endocytosis

The white blood cell seen here is engulfing a damaged red blood cell by phagocytosis—a form of endocytosis. Extensions, or “arms,” of the white blood cell’s cell membrane have completely surrounded the red blood cell.

7.3 Assessment

Review Key Concepts

- Review** What happens during diffusion?
 - Explain** Describe the process of osmosis.
 - Compare and Contrast** What is the difference between diffusion and facilitated diffusion?
- Review** How is active transport different from passive transport?
 - Explain** Describe the two major types of active transport.
 - Compare and Contrast** How is endocytosis different from exocytosis?

BUILD VOCABULARY

- Based on the meanings of *isotonic*, *hypertonic*, and *hypotonic*, write definitions for the prefixes *iso-*, *hyper-*, and *hypo-*. Then come up with another set of words that uses these prefixes (the words do not need to have the same suffixes).
- The prefix *phago-* means “to eat.” The prefix *pino-* means “to drink.” Look up the definition of *-cytosis*, and write definitions for *phagocytosis* and *pinocytosis*.