

3.4

Diffusion and Osmosis

KEY CONCEPT Materials move across membranes because of concentration differences.

▶ MAIN IDEAS

- Diffusion and osmosis are types of passive transport.
- Some molecules diffuse through transport proteins.

VOCABULARY

passive transport, p. 85

diffusion, p. 85

concentration gradient, p. 85

osmosis, p. 86

isotonic, p. 86

hypertonic, p. 86

hypotonic, p. 87

facilitated diffusion, p. 87



MICHIGAN STANDARDS

B2.5h Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport).

Connect If you have ever been stuck in traffic behind a truck full of pigs, you know that “unpleasant” fails to fully describe the situation. That is because molecules travel from the pigs to receptors in your nose, which your brain interprets as a really bad odor. Or perhaps you have tie-dyed a T-shirt and have seen dye molecules spread throughout the pot of water, turning it neon green or electric blue. Why does that happen? Why don’t the molecules stay in one place?

▶ MAIN IDEA

Diffusion and osmosis are types of passive transport.

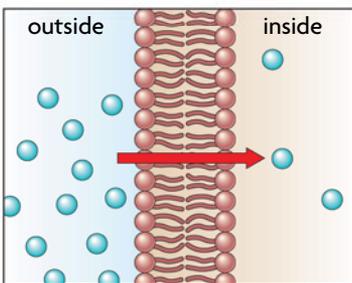


FIGURE 3.21 Passive transport is the movement of molecules across the membrane from areas of higher concentration to areas of lower concentration. It does not require energy input from the cell.

Cells almost continually import and export substances. If they had to expend energy to move every molecule, cells would require an enormous amount of energy to stay alive. Fortunately, some molecules enter and exit a cell without requiring the cell to work. As **FIGURE 3.21** shows, **passive transport** is the movement of molecules across a cell membrane without energy input from the cell. It may also be described as the diffusion of molecules across a membrane.

Diffusion

Diffusion is the movement of molecules in a fluid or gas from a region of higher concentration to a region of lower concentration. It results from the natural motion of particles, which causes molecules to collide and scatter. Concentration is the number of molecules of a substance in a given volume, and it can vary from one region to another. A **concentration gradient** is the difference in the concentration of a substance from one location to another. Molecules diffuse down their concentration gradient—that is, from a region of higher concentration to a region of lower concentration.

In the tie-dye example, dye molecules are initially at a high concentration in the area where they are added to the water. Random movements of the dye and water molecules cause them to bump into each other and mix. Thus, the dye molecules move from an area of higher concentration to an area of lower concentration. Eventually, they are evenly spread throughout the solution. This means the molecules have reached a dynamic equilibrium. The concentration of dye molecules is the same throughout the solution (equilibrium), but the molecules continue to move (dynamic).

Connecting CONCEPTS

Human Biology As you will learn in **Chapter 30**, diffusion plays a key role in gas exchange in the lungs and other body tissues.



FIGURE 3.22 Diffusion results from the natural motion of particles.

In cells, diffusion plays an important role in moving substances across the membrane. Small lipids and other nonpolar molecules, such as carbon dioxide and oxygen, easily diffuse across the membrane. For example, most of your cells continually consume oxygen, which means that the oxygen concentration is almost always higher outside a cell than it is inside a cell. As a result, oxygen generally diffuses into a cell, without the cell's expending any energy.

Osmosis

Water molecules, of course, also diffuse. They move across a semipermeable membrane from an area of higher water concentration to an area of lower water concentration. This process is called **osmosis**. It is important to recognize that the higher the concentration of dissolved particles in a solution, the lower the concentration of water molecules in the same solution. So if you put 1 teaspoon of salt in a cup of water and 10 teaspoons of salt in a different cup of water, the first cup would have the higher water concentration.

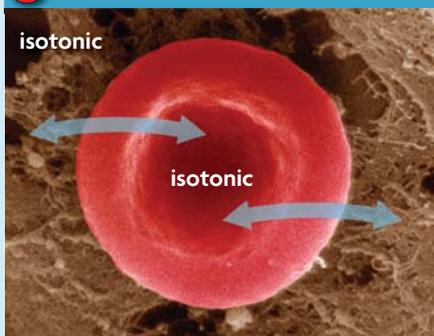
A solution may be described as isotonic, hypertonic, or hypotonic relative to another solution. Note that these terms are comparisons; they require a point of reference, as shown in **FIGURE 3.23**. For example, you may be taller than your coach or taller than you were two years ago, but you are never just taller. Likewise, a solution may be described as isotonic only in comparison with another solution. To describe it as isotonic by itself would be meaningless.

- 1 A solution is **isotonic** to a cell if it has the same concentration of dissolved particles as the cell. Water molecules move into and out of the cell at an equal rate, so the cell's size remains constant.
- 2 A **hypertonic** solution has a higher concentration of dissolved particles than a cell. This means water concentration is higher inside the cell than outside. Thus, water flows out of the cell, causing it to shrivel or even die.

FIGURE 3.23 Effects of Osmosis

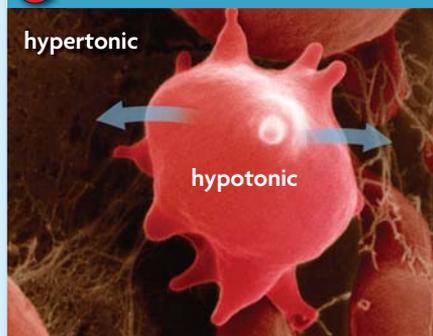
Osmosis is the diffusion of water across a semipermeable membrane from an area of higher water concentration to an area of lower water concentration.

1 ISOTONIC SOLUTION



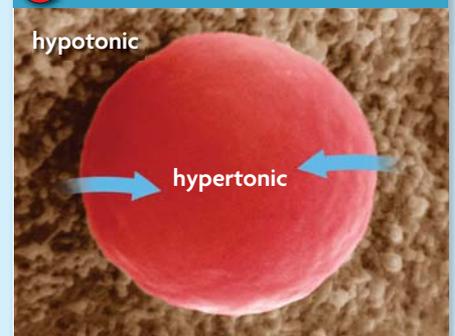
A solution is isotonic to a cell if it has the same concentration of solutes as the cell. Equal amounts of water enter and exit the cell, so its size stays constant.

2 HYPERTONIC SOLUTION



A hypertonic solution has more solutes than a cell. Overall, more water exits a cell in hypertonic solution, causing the cell to shrivel or even die.

3 HYPOTONIC SOLUTION



A hypotonic solution has fewer solutes than a cell. Overall, more water enters a cell in hypotonic solution, causing the cell to expand or even burst.

Apply How would adding salt to the isotonic solution above affect the cell?

colored SEMs; magnification 4500×

3 A **hypotonic** solution has a lower concentration of dissolved particles than a cell. This means water molecules are more concentrated outside the cell than inside. Water diffuses into the cell. If too much water enters a cell, the cell membrane could potentially expand until it bursts.

Some animals and single-celled organisms can survive in hypotonic environments. Their cells have adaptations for removing excess water. In plants, the rigid cell wall prevents the membrane from expanding too much. Remember from Section 3.2 that pressure exerted on the cell wall by fluid inside the central vacuole provides structural support for each cell and for the plant as a whole.

Apply What will happen to a houseplant if you water it with salt water (a hypertonic solution)?

▶ MAIN IDEA

Some molecules diffuse through transport proteins.

Some molecules cannot easily diffuse across a membrane. They may cross more easily through transport proteins—openings formed by proteins that pierce the cell membrane. **Facilitated diffusion** is the diffusion of molecules across a membrane through transport proteins. The word *facilitate* means “to make easier.” Transport proteins make it easier for molecules to enter or exit a cell. But the process is still a form of passive transport. The molecules move down a concentration gradient, requiring no energy expenditure by the cell.

There are many types of transport proteins. Most types allow only certain ions or molecules to pass. As **FIGURE 3.24** shows, some transport proteins are simple channels, or tunnels, through which particles such as ions can pass. Others act more like enzymes. When bound, the protein changes shape, allowing the molecule to travel the rest of the way into the cell.

Summarize Explain why transport proteins are needed in the cell membrane.

VOCABULARY

The words *isotonic*, *hypertonic*, and *hypotonic* share the root word *tonic*, which means “pressure.” Their prefixes give them different comparative meanings.

iso- = equal, same

hyper- = over, above

hypo- = under, below

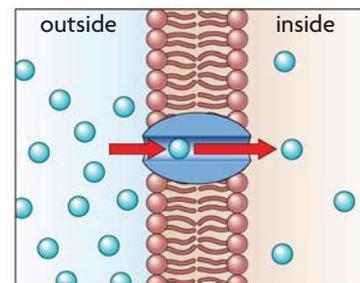


FIGURE 3.24 Facilitated diffusion enables molecules that cannot directly cross the phospholipid bilayer to diffuse through transport proteins in the membrane.

3.4 ASSESSMENT



REVIEWING ▶ MAIN IDEAS

1. Explain what a **concentration gradient** is and what it means for a molecule to diffuse down its concentration gradient.
2. Explain why **facilitated diffusion** does not require energy from a cell.

CRITICAL THINKING

3. **Apply** A cell is bathed in fluid. However, you notice that water is flowing out of the cell. In what kind of solution is this cell immersed: **isotonic**, **hypotonic**, or **hypertonic**?
4. **Compare** How are receptors and transport proteins similar?

Connecting CONCEPTS

5. **Health** When a person becomes dehydrated due to the loss of fluids and solutes, saline solution (water and salts) is infused into the bloodstream by medical personnel. Why is saline solution used instead of pure water?

MATERIALS

- 2 vinegar-soaked chicken eggs
- water
- balance
- 2 disposable plastic cups
- distilled water
- 5% NaCl solution
- 20% NaCl solution
- 50% glucose solution
- 10 cm masking tape
- marker
- 500-mL beaker
- 20 cm piece of plastic wrap
- 2 rubber bands



PROCESS SKILL

- **Designing Experiments**
- **Analyzing Data**



B1.C Conduct scientific investigations using appropriate tools and techniques (e.g., selecting an instrument that measures the desired quantity—length, volume, weight, time interval, temperature—with the appropriate level of precision).

B2.5h Explain the role of cell membranes as a highly selective barrier (diffusion, osmosis, and active transport).

Diffusion Across a Membrane

In this investigation, you will determine whether different solutions are hypotonic, isotonic, or hypertonic relative to the inside of a chicken egg. Your teacher has already soaked the eggs in vinegar, which removes calcium from the shell. This allows the egg to act as a single cell encased in a selectively permeable membrane.

PROBLEM Are the tested solutions hypotonic, isotonic, or hypertonic to the egg?

PROCEDURE

1. Choose two solutions you want to test in your experiment to determine whether they are hypotonic, isotonic, or hypertonic relative to the chicken egg. Select from distilled water, 5% NaCl, 20% NaCl, and 50% glucose solutions.
2. Identify the variables you will measure and the constants you will maintain during the investigation. Examples of constants include the amount of solution used for each egg.
3. Design a data table, such as the example shown below, to organize your results.
4. Thoroughly rinse each egg and find its mass. Place each egg in a separate plastic cup.
5. Cover each egg with one of the solutions you are testing. Label the cups with the solution names.
6. Cover each cup with plastic wrap, securing it with a rubber band. Soak the eggs overnight.
7. The next day, find the mass of each egg and note any changes in appearance.



TABLE 1. CHANGES IN EGG MASS

	Name of Solution 1	Name of Solution 2
Initial mass of egg (g)		
Mass of egg after soaking in solution (g)		

ANALYZE AND CONCLUDE

1. **Apply** What is the operational definition of the dependent variable in this lab?
2. **Analyze** How did you conclude whether the solutions you tested were hypotonic, isotonic, or hypertonic?
3. **Identify** What were the independent and dependent variables in your experiment? What was held constant?
4. **Calculate** Calculate the change in the mass of the eggs. Explain how this may relate to your findings.
5. **Predict** What effect would eating too much salt have on the human body?
6. **Experimental Design** List possible reasons for any inconsistent results you may have observed.