Cellular Transport

Cellular transport moves substances within the cell and moves substances into and out of the cell.

Real-World Reading Link Imagine studying in your room while cookies are baking in the kitchen. You probably did not notice when the cookies were put into the oven because you could not smell them. But, as the cookies baked, the movement of the aroma from the kitchen to your room happened through a process called diffusion.

Diffusion

As the aroma of baking cookies makes its way to you, the particles are moving and colliding with each other in the air. This happens because the particles in gases, liquids, and solids are in random motion. Similarly, substances dissolved in water move constantly in random motion called Brownian motion. This random motion causes diffusion, which is the net movement of particles from an area where there are many particles of the substance to an area where there are fewer particles of the substance. The amount of a substance in a particular area is called concentration. Therefore, substances diffuse from areas of high concentration to low concentration. Figure 1 illustrates the process of diffusion. Additional energy input is not required for diffusion because the particles already are in motion.

For example, if you drop red and blue ink into a container of water at opposite ends of the container, which is similar to the watery environment of a cell, the process of diffusion begins, as shown in Figure 1(A). In a short period of time, the ink particles have mixed as a result of diffusion to the point where a purple-colored blended area is visible. Figure 1(B) shows the initial result of this diffusion.

Given more time, the ink particles continue to mix and, in this case, continue to form the uniform purple mixture shown in Figure 1(C). Mixing continues until the concentrations of red ink and blue ink are the same in all areas. The final result is the purple solution. After this point, the particles continue to move randomly, but no further change in concentration will occur. This condition, in which there is continuous movement but no overall change, is called dynamic equilibrium.

![Figure 1](image)

Diffusion causes the inks to move from high-ink concentration to low-ink concentration until the colors become evenly blended in the water.

One of the key characteristics of diffusion is the rate at which diffusion takes place. Three main factors affect the rate of diffusion: concentration, temperature, and pressure. When concentration is high, diffusion occurs more quickly because there are more particles that collide. Similarly, when temperature or pressure increases, the number of collisions increases, thus increasing the rate of diffusion. Recall that at higher temperatures particles move faster, and at higher pressure the particles are closer together. In both cases, more collisions occur and diffusion is faster. The size and charge of a substance also affects the rate of diffusion.

Diffusion across the plasma membrane

In addition to water, cells need certain ions and small molecules, such as chloride ions and sugars, to perform cellular functions. Water can diffuse across the plasma membrane, as shown in Figure 2(A), but most other substances cannot. Another form of transport, called facilitated diffusion, uses transport proteins to move other ions and small molecules across the plasma membrane. By this method, substances move into the cell through a water-filled transport protein, called a channel protein, that opens and closes to allow the substance to diffuse through the plasma membrane, as shown in Figure 2(B). Another type of transport protein, called a carrier protein, also can help substances diffuse across the
Carrier proteins change shape as the diffusion process continues to help move the particle through the membrane, as illustrated in Figure 2(C).

Figure 2: Although water moves freely through the plasma membrane, other substances cannot pass through the phospholipid bilayer on their own. Such substances enter the cell by facilitated transport.

Diffusion of water and facilitated diffusion of other substances require no additional input of energy because the particles are moving from an area of high concentration to an area of lower concentration. This is also known as passive transport. You will learn later in this lesson about a form of cellular transport that does require energy input.

**Reading Check** Describe how sodium (Na⁺) ions get into cells.

### VOCABULARY

**ACADEMIC VOCABULARY**

- **Concentration**: the amount of a component in a given area or volume

  The concentration of salt in the aquarium was too high, causing the fishes to die.

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**Osmosis: Diffusion of Water**

Water is a substance that passes freely into and out of a cell through the plasma membrane. The diffusion of water across a selectively permeable membrane is called osmosis (ahs MOH sus). Regulating the movement of water across the plasma membrane is an important factor in maintaining homeostasis within the cell.

**How osmosis works**

Recall that in a solution, a substance called the solute is dissolved in a solvent. Water is the solvent in a cell and its environment. Concentration is a measure of the amount of solute dissolved in a solvent. The concentration of a solution decreases when the amount of solvent increases.

Examine Figure 3, showing a U-shaped tube containing solutions with different sugar concentrations separated by a selectively permeable membrane. What will happen if the solvent (water) can pass through the membrane but the solute (sugar) cannot?
Before osmosis, the sugar concentration is greater on the right side. After osmosis, the concentrations are the same on both sides.

**Name the term for this phenomenon.**

Water molecules diffuse toward the side with the greater sugar concentration—the right side. As water moves to the right, the concentration of the sugar solution decreases. The water continues to diffuse until dynamic equilibrium occurs—the concentration of the solutions is the same on both sides. Notice in Figure 3 that the result is an increase in solution level on the right side. During dynamic equilibrium, water molecules continue to diffuse back and forth across the membrane. But, the concentrations on each side no longer change.

**Reading Check** Compare and contrast diffusion and osmosis.

**Cells in an isotonic solution**

When a cell is in a solution that has the same concentration of water and solutes—ions, sugars, proteins, and other substances—as its cytoplasm, the cell is said to be in an isotonic solution. Iso- comes from the Greek word meaning equal. Water still moves through the plasma membrane, but water enters and leaves the cell at the same rate. The cell is at equilibrium with the solution, and there is no net movement of water. The cells retain their normal shape, as shown in Figure 4. Most cells in organisms are in isotonic solutions, such as blood.

**Cells in a hypotonic solution**

If a cell is in a solution that has a lower concentration of solute, the cell is said to be in a hypotonic solution. Hypo- comes from the Greek word meaning under. There is more water outside of the cell than inside. As a result of osmosis, the net movement of water through the plasma membrane is into the cell, as illustrated in Figure 5. Pressure generated as water flows through the plasma membrane is called osmotic pressure. In an animal cell, as water moves into the cell, the pressure increases and the plasma membrane swells. If the solution is extremely hypotonic, the plasma membrane might be unable to withstand this pressure and the cell might burst.

Because they have a rigid cell wall that supports them, plant cells do not burst when in a hypotonic solution. As the pressure inside a cell increases, the plant’s central vacuole fills with water, pushing the plasma membrane against the cell wall, shown in the plant cells in Figure 5. Instead of bursting, the plant cell becomes firmer. Grocers use this process to keep produce looking fresh by misting fruits and vegetables with water.
Cells in a hypertonic solution

When a cell is placed in a hypertonic solution, the concentration of the solute outside of the cell is higher than it is inside. Hyper- comes from the Greek word meaning above. During osmosis, the net movement of water is out of the cell, as illustrated in Figure 6. Animal cells in a hypertonic solution shrivel because of decreased pressure in the cells. Plant cells in a hypertonic solution lose water, mainly from the central vacuole. The plasma membrane shrinks away from the cell wall. Loss of water in a plant cell causes wilting.

Reading Check Compare and contrast the three types of solutions.

MiniLab: Investigate Osmosis

What will happen to cells placed in a strong salt solution? Regulating the flow and amount of water into and out of a cell is critical to the survival of that cell. Osmosis is one method used to regulate a cell’s water content.

Procedure

1. Read and complete the lab safety form.

2. Prepare a control slide using onion epidermis, water, and iodine stain as directed by your teacher.

3. Prepare a test slide using onion epidermis, salt water, and iodine stain as directed by your teacher.

4. Predict the effect, if any, that the salt solution will have on the onion cells in the test slides.

5. View the control slide using a compound microscope under low power and sketch several onion cells.

6. View the test slide under the same magnification and sketch your observations.

Analysis

1. Analyze and conclude whether your prediction was correct or incorrect. Explain.

2. Explain Use the process of osmosis to explain what you observe.

Active Transport

Sometimes substances must move from a region of lower concentration to a region of higher concentration against the passive movement from higher to lower concentration. This movement of substances across the plasma membrane against a concentration gradient requires energy; therefore, it is called
active transport. Figure 7 illustrates how active transport occurs with the aid of carrier proteins, commonly called pumps. Some pumps move one type of substance in only one direction, while others move two substances either across the membrane in the same direction or in opposite directions. Because of active transport, the cell maintains the proper balance of substances it needs. Active transport helps maintain homeostasis.

![Figure 7](image)

**Figure 7** Carrier proteins pick up and move substances across the plasma membrane against the concentration gradient and into the cell.

**Explain why active transport requires energy.**

**Na⁺/K⁺ ATPase pump**

One common active transport pump is called the sodium-potassium ATPase pump. This pump is found in the plasma membrane of animal cells. The pump maintains the level of sodium ions (Na⁺) and potassium ions (K⁺) inside and outside the cell. This protein pump is an enzyme that catalyzes the breakdown of an energy-storing molecule. The pump uses the energy to transport three sodium ions out of the cell while moving two potassium ions into the cell. The high level of sodium on the outside of the cell creates a concentration gradient. Follow the steps in Figure 8 to see the action of the Na⁺/K⁺ ATPase pump.

![Figure 8](image)

**Figure 8** Some cells use elaborate pumping systems, such as the Na⁺/K⁺ ATPase pump shown here, to help move substances through the plasma membrane.

The activity of the Na⁺/K⁺ ATPase pump can result in yet another form of cellular transport. Substances, such as sugar molecules, must come into the cell from the outside, where the concentration of the substance is lower than it is inside. This requires energy. Recall, however, that the Na⁺/K⁺ ATPase pump moves Na⁺ out of the cell, which creates a low concentration of Na⁺ inside the cell. In a process called coupled transport, the Na⁺ ions that have been pumped out of the cell can couple with sugar molecules and be transported into the cell through a membrane protein called a coupled channel. The sugar molecule, coupled to a Na⁺ ion, enters the cell by facilitated diffusion of the sodium, as shown in Figure 9. As a result, sugar enters the cell without spending any additional cellular energy.
2.3.e  Transport of Large Particles

Some substances are too large to move through the plasma membrane by diffusion or transport proteins and must get inside the cell by a different process. Endocytosis is the process by which a cell surrounds a substance in the outside environment, enclosing the substance in a portion of the plasma membrane. The membrane then pinches off and leaves the substance inside the cell. The substance shown on the left in Figure 10 is engulfed and enclosed by a portion of the cell’s plasma membrane. The membrane then pinches off inside of the cell, and the resulting vacuole, with its contents, moves to the inside of the cell.

Exocytosis is the secretion of materials at the plasma membrane. The illustration in Figure 10 shows that exocytosis is the reverse of endocytosis. Cells use exocytosis to expel wastes and to secrete substances, such as hormones, produced by the cell. Both endocytosis and exocytosis require the input of energy. Cells maintain homeostasis by moving substances into and out of the cell. Some transport processes require additional energy input, while others do not. Together, the different types of transport allow a cell to interact with its environment while maintaining homeostasis.

**Review**

**Lesson Summary**

- Cells maintain homeostasis using passive and active transport.
- Concentration, temperature, and pressure affect the rate of diffusion.
- Cells must maintain homeostasis in all types of solutions, including isotonic, hypotonic, and hypertonic.
Some large molecules are moved into and out of the cell using endocytosis and exocytosis.

**Vocabulary Review**

*Explain the difference in the terms in each pair below. Then explain how the terms are related.*

1. active transport, facilitated diffusion
2. endocytosis, exocytosis
3. hypertonic solution, hypotonic solution

**Understand Main Ideas**

4. **MAIN IDEA** List and describe the types of cellular transport.
5. **Describe** how the plasma membrane controls what goes into and comes out of a cell.
6. **Sketch** a before and an after diagram of an animal cell placed in a hypotonic solution.
7. **Contrast** how facilitated diffusion is different from active transport.
8. Which is not a factor that affects the rate of diffusion?
   A. conductivity  
   B. concentration  
   C. pressure  
   D. temperature
9. Which type of transport requires energy input from the cell?
   A. active transport  
   B. facilitated diffusion  
   C. osmosis  
   D. simple diffusion

**Constructed Response**

10. **Short Answer** Why is active transport an energy-utilizing process?

11. **Short Answer** Some protists that live in a hypotonic pond environment have cell membrane adaptations that slow water uptake. What adaptations might this protist, shown above, living in the hypertonic Great Salt Lake have?

12. **MAIN IDEA** Summarize how cellular transport helps maintain homeostasis within a cell.

**Think Critically**

13. **Describe** Some organisms that normally live in pond water contain water pumps. These pumps continually pump water out of the cell. Describe a scenario that might reverse the action of the pump.

14. **Summarize** the role of the phospholipid bilayer in cellular in cellular transport in living cells.

15. **Hypothesize** how oxygen crosses the plasma membrane if the concentration of oxygen is lower inside the cell than it is outside the cell.
16. **Analyze**  Farming and watering that are done in very dry regions of the world leave salts that accumulate in the soil as water evaporates. Based on what you know about concentration gradients, why does increasing soil salinity have adverse effects on plant cells?

**Summative Assessment**

17. **Big Idea**  Cells are the structural and functional units of living things. Create an analogy where “smaller parts” provide structure and function for a “whole.” Relate it to cells and living things by giving specific examples.

18. Use what you have learned about osmosis and cellular transport to design an apparatus that would enable a freshwater fish to survive in a saltwater habitat.

19. **Writing in Biology**  Create a poem that describes the functions of at least five cell organelles.

**Document-Based Questions**

The graph below describes the relationship between the amount of glucose entering a cell and the rate at which the glucose enters the cell with the help of carrier proteins. Use this graph to answer questions 20 and 21.


20. Summarize the relationship between the amount of glucose and the rate of diffusion.

21. Infer why the rate of diffusion tapers off with higher amounts of glucose. Make an illustration to explain your answer.