Tonicity

Tonicity describes the amount of solute in a solution. The measure of the tonicity of a solution is called its **osmolarity**. Three terms, hypotonic, isotonic, and hypertonic, are used to relate the osmolarity of a cell to the osmolarity of the extracellular fluid that surrounds the cell.

In a **hypotonic solution**, such as distilled water, the extracellular fluid has a lower concentration of solutes than the fluid inside the cell. As a result, water enters the cell. In living systems, the cytoplasm is always used as the point of comparison, so the prefix *hypo-* means that the extracellular fluid has a lower concentration of solutes, or a lower osmolarity when compared to the cell cytoplasm. It also means that the extracellular fluid has a higher concentration of free water when compared to the cell's cytoplasm. In this situation, water will move down its concentration gradient and enter the cell. This may cause an animal cell to burst or lyse.

In a **hypertonic solution,** the prefix *hyper-* refers to the extracellular fluid having a higher concentration of solutes than the cell's cytoplasm. Imagine putting an animal cell into a glass of seawater. Because the cell has a lower concentration of solutes when compared to the fluid surrounding the cell, water will leave the cell. This may cause an animal cell to shrivel, or crenate.

In an **isotonic solution**, the extracellular fluid has the same osmolarity as the cell. If the concentration of solutes in a cell is approximately equal to that of the extracellular fluid, there will be no net movement of water into or out of the cell. Figure 5.11 shows what will happen if you put red blood cells in hypertonic, isotonic, and hypotonic solutions.

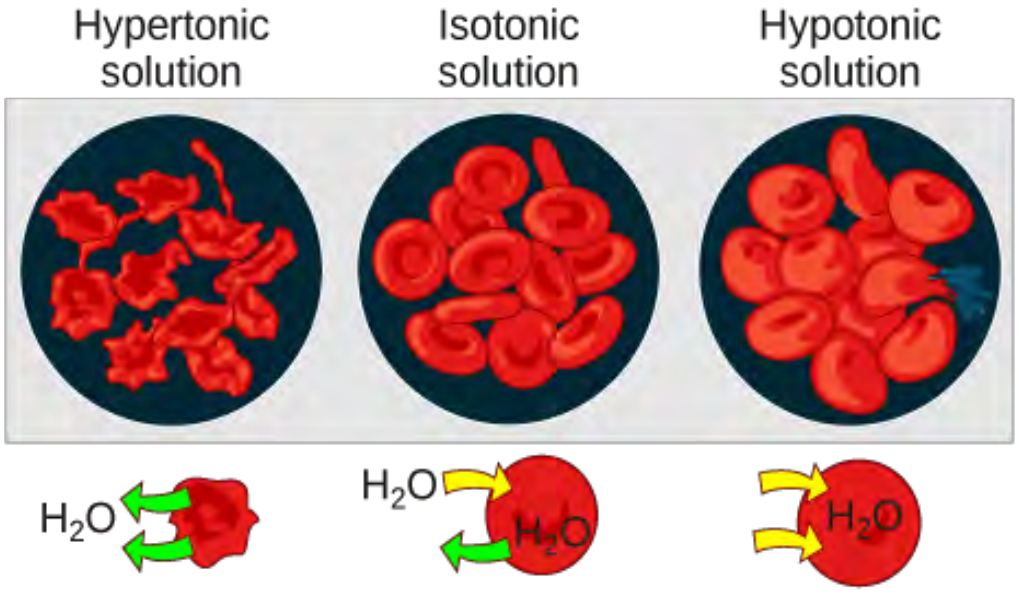

Figure 5.11 Osmotic pressure changes the shape of red blood cells in hypertonic, isotonic, and hypotonic solutions. (credit: modification of work by Mariana Ruiz Villarreal / Concepts of Biology OpenStax)

Check your knowledge

A doctor injects a patient with what the doctor thinks is an isotonic saline solution. The patient dies, and the autopsy reveals that many neurons (brain cells) have burst. Do you think the solution the doctor injected was isotonic? If not, what type of solution do you think was injected?

No, the solution injected was most likely a hypotonic solution, such as distilled water. This resulted in the blood being hypotonic when compared to the cytoplasm of the cells. Water moved into the cells from an area of low solutes in the blood to an area of high solutes in the cytoplasm resulting in the cells bursting.

Some organisms, such as plants, fungi, bacteria, and some protists, have cell walls that surround the plasma membrane and prevent cell lysis. The plasma membrane can only expand to the limit of the cell wall. The cytoplasm in plants is always slightly hypertonic compared to the cellular environment. Water will always enter a cell if water is available. This influx of water produces turgor pressure, which stiffens the cell walls of the plant (Figure 5.12). In nonwoody plants, turgor pressure supports the plant. If the plant cells become hypotonic, which can occur during a drought or if a plant is not watered adequately, water will leave the cell, a process called crenation. Plants lose turgor pressure in this condition and wilt.

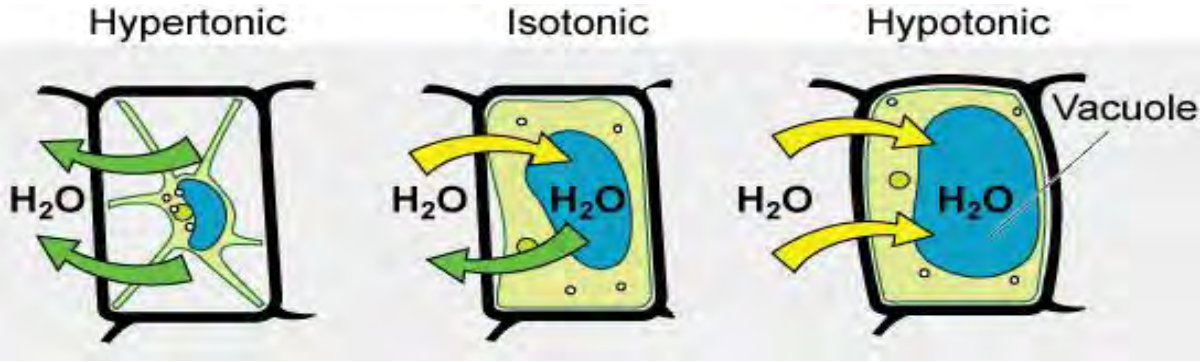

Figure 5.12 The turgor pressure within a plant cell depends on the tonicity of the solution that it is bathed in. (credit: modification of work by Mariana Ruiz Villarreal/ Concepts of Biology OpenStax)

CONCEPTS IN ACTION - For an animation of the diffusion process in action, view this short video on cell membrane transport. https://www.youtube.com/watch?v=JShwXBWGMyY

Section Summary

In living systems, diffusion of substances into and out of cells is mediated by the plasma membrane. Some materials diffuse readily through the membrane, but others are hindered, and their passage is only made possible by protein channels and carriers.

Passive forms of transport, such as diffusion and osmosis, move materials without expending energy. Substances diffuse from areas of high concentration to areas of low concentration. This process continues until the substance is evenly distributed in a system. In solutions of more than one substance, each type of molecule diffuses according to its own concentration gradient. Many factors can affect the rate of diffusion, including concentration gradient, the sizes of the particles that are diffusing, and the temperature of the system.

Water also can move freely across the cell membrane of all cells, either through protein channels or by slipping between the lipid tails of the membrane itself. Osmosis is the movement of water molecules through a semipermeable membrane from an area of low solute concentration to an area of high solute concentration.

Two solutions that have the same concentration of solutes are said to be isotonic. Osmosis occurs when there is an imbalance of solutes outside of a cell versus inside the cell. A solution that has a higher concentration of solutes than another solution is said to be hypertonic, and water molecules tend to diffuse into a hypertonic solution. In contrast, a solution that has a lower concentration of solutes than another solution is said to be hypotonic, and water molecules tend to diffuse out of a hypotonic solution.

Exercises

1. A plant cell is submerged in an unknown solution. When you look at the plant cell using a microscope, the cells appear to be bulging and swelling. What type of solution do you think this plant cell was placed in: hypotonic, hypertonic or isotonic? Explain.

2. Which statement below best describes the process of diffusion?
    a. Solutes move throughout the cytoplasm from one organelle to another.
    b. Solutes move from an area with a higher solute concentration to an area of lower solute concentration.
    c. Solutes move from an area with a lower solute concentration to an area of higher solute concentration.
    d. Solutes cannot move from one area to another.

3. For molecules to move during passive transport a _____ is required.
    a. cool temperature
    b. large particle size
    c. concentration gradient
    d. transport protein

4. Why does osmosis occur in cells?