11.1.1

Osmosis

By definition, osmosis is the diffusion of water through a **selectively permeable** membrane from an area of high-water potential (low solute concentration) to and area of low water potential (high solute concentration). Therefore, for osmosis to occur the membrane must be permeable to water but impermeable to the solute, and the concentration of the solute must be different on the two sides of the membrane. Water will move from the side with lower solute concentration to the side with higher solute concentration until the concentrations are equal or until some external force prevents further movement of water. This is a passive process, in that no energy expenditure is required for the movement of water. If the solute concentration in the extracellular fluid is lower than the solute concentration in the cell, water moves into the cell, and the cell will swell.

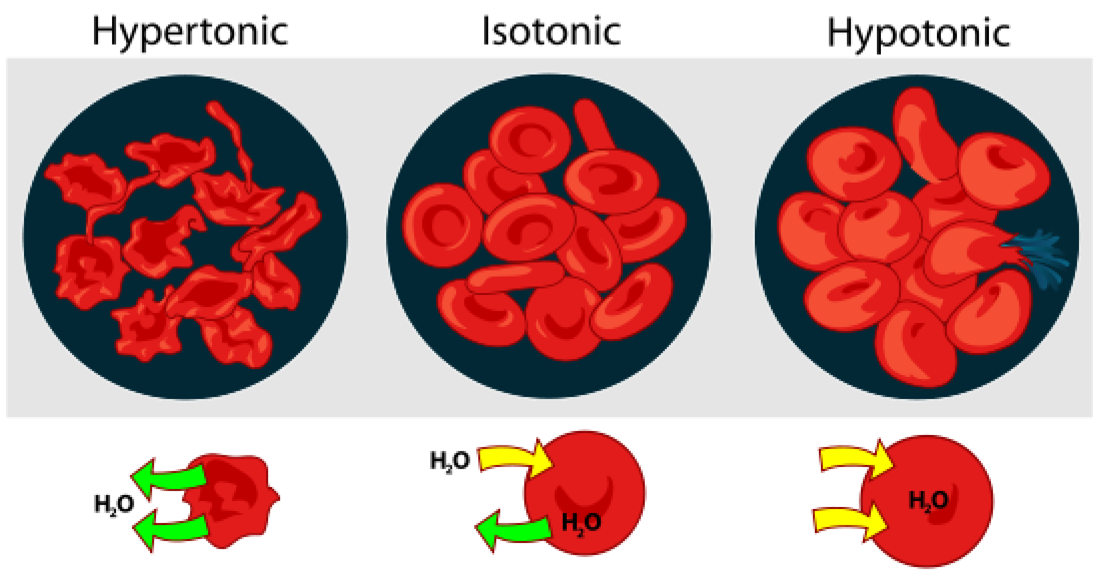
Before we can explain why cells shrink or expand when placed in a certain kind of solution, we first need to discuss the difference between osmolarity and tonicity. Osmolarity represents the number of moles of *particles* per liter of solution, while molarity represents the number of moles of *molecules* per liter of solution. Why do we have these different ways of expressing concentration? We have to change the units because different substances behave differently in solution. For example, when NaCl is dissolved in water it breaks apart into Na^+ and Cl^- ions (this is a characteristic of substances held together by ionic bonds). Thus, the number of particles double when NaCl is added to water when compared to dry NaCl. Consequently, a *1 molar* solution of NaCl (molecules) would be a *2 osmolar* solution (particles) (*technically it would be a 1.6 osmolar solution as there is not complete dissociation of the two atoms*). Glucose is different. Glucose does not break apart in water because the atoms are covalently bonded. Therefore, a 1 molar solution of glucose will also be a 1 osmolar solution. Osmolarity is a useful term because now we can use words to describe solutions: such as *isosmotic*, which means, "two solutions have the same number of particles;" *hyperosmotic*, which means, "one solution is more concentrated than the other;" or *hyposmotic*, which means, "One solution is less concentrated than the other." Notice how we use three different prefixes to help us describe the nature of the solution: *iso* means "same," *hyper* means "more," and *hypo* means "less." (Note: Osmolarity takes into account all of the particles in the solution. Therefore, if you have a liter of solution containing one mole of glucose and one mole of NaCl, you will have a *three osmolar* solution.)

Perhaps the most important concept when talking about solutions and how they affect cells is **tonicity**. "Tone" means "firmness or stretch", so the term Tonicity is a term used to describe how a solution affects the firmness or stretching of a cell when it is placed into a solution. Why are cells affected by different solutions? The answer lies in the behavior of particles with regard to diffusion. Particles will tend to diffuse from areas of high concentration to areas of lower concentration to reach equilibrium (diffusion). However, if the membrane is not permeable to the particles, then instead of particles diffusing, water will move through aquaporins in the cell membrane to reach equilibrium. Additionally, at equilibrium, the osmolarities of the two solutions will be the same. When water moves out of a cell, the cell shrinks; likewise, when water moves into a cell, the cell swells. Thus, if we place a cell into an isotonic solution, the cell shape will not change because the solutions are already in equilibrium, so there will be no net movement of water or solutes across the membrane. In other words, isotonic solutions have the same concentration of osmotically active particles (osmotically active particles are non-permeable particles) as are found in the cell. If the cell swells, we say that the solution was hypotonic, and if the cell shrinks (crenates), we say the solution was hypertonic.

Remember, fluids and ions inside the cell (intracellular fluid) and fluids and ions outside the cell (extracellular fluid) will always move to equilibrium, either by movement of solutes (ions) if they can cross the membrane or by the movement of water if the solutes cannot cross

Here is another way to think of osmolarity and tonicity. Osmolarity can be used to compare the concentration of solutes in two solutions. It can also be used to compare the concentration of the solutes in a solution with those in the cell before equilibrium is achieved. Tonicity is used to describe what effect the solution has on the cell. Osmolarity does not take into account the nature of the solutes, while tonicity is dependent upon the concentration of the *nonpermeable* solutes.

The figure below shows what happens to red blood cells when they are placed into hypertonic, isotonic, or hypotonic solutions.



Osmotic Pressure on Blood Cells Diagram. Title: File: Osmotic pressure on blood cells diagram.svg; Author: LadyofHats; Site: https://commons.wikimedia.org/wiki/File:Osmotic_pressure_on_blood_cells_diagram.svg; License: Public Domain

When placed in a hypertonic solution, red blood cells will shrink or crenate. When placed in an isotonic solution, there will be no change in volume, and when placed in a hypotonic solution, red blood cells will swell. If the concentration of the solution is great enough inside the cell, the cells will swell and even burst (lyse).

The link below shows what happens to a wilted plant when it is placed into a hypotonic solution.

https://books.byui.edu/-vip

Let's try one more example. Consider a solution that is composed of a 0.9% NaCl solution mixed with a 5% dextrose solution. Both solutions are considered isosmotic to the cell, but when added together, they become double the concentration of the cell. Thus, this solution would be considered hyperosmotic. If we place a cell into this solution, what will happen? To answer this question, let's talk about tonicity. Now, when talking about tonicity we need to consider the nature of the particles. NaCl is considered nonpenetrating (nonpermeable), while dextrose is considered penetrating (permeable). Once a cell is added to the solution, the dextrose will immediately move down its concentration gradient into the cell and "disappear" until all that is left will be the 0.9% NaCl. Thus, even though this solution was hyperosmotic to begin with, it becomes isotonic with respect to its interactions with the cell. At equilibrium, the cell will not change shape.

To check understanding, complete the table below by filling in the missing column items with regard to osmolarity and tonicity. Use the terms *iso*, *hypo*, and *hyper* to complete the table.

SOLUTION	OSMOLARITY	TONICITY
0.9 % saline		
5% dextrose		
5% dextrose + 0.9% saline		
0.45% saline		
5% dextrose + 0.45% saline		

Here are the answers for the table above. Be sure you understand why the answers are what they are.

SOLUTION	**OSMOLARITY**	**TONICITY**
0.9% saline	Isosmotic	Isotonic
5% dextrose	Isosmotic	Hypotonic
5% dextrose + 0.9% saline	Hyperosmotic	Isotonic
0.45% saline	Hyposmotic	Hypotonic
5% dextrose + 0.45% saline	Hyperosmotic	Hypotonic