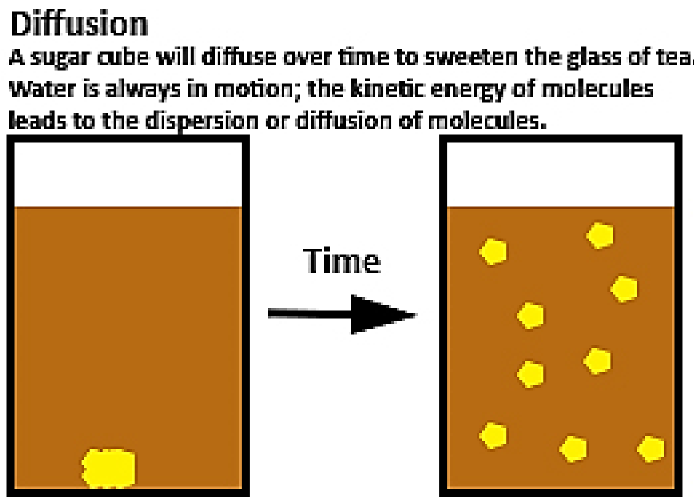
Cell Structure: Membranes Permeability, Diffusion and Osmosis

Diffusion

Movement across the plasma membrane for lipid soluble molecules or molecules transported by some types of channel proteins can be driven by diffusion. Diffusion is the process where molecules move from a region of higher concentration to a region of lower concentration. You can always find the food court at the mall because you can smell the food cooking. As you get closer and closer to the food court the odors become stronger and stronger. That is an example of diffusion. As food is cooking aromatic odors are released. They are at their highest concentration at the source, in the food. With time kinetic motion moves the 'food aroma molecules' further and further from the source.



Diffusion is a very important process. Carbon dioxide, a metabolic waste product, diffuses from the blood stream across the membranes of the lungs. Similarly, oxygen an essential nutrient, naturally diffuses from the atmosphere in the lung alveoli across the membranes of the lung and into the bloodstream. In both of these examples the molecules are diffusing from a region of high concentration to a region of lower concentration. Most of the compounds that diffuse into or out of cells are either lipid soluble (non-polar), very small or have a protein that permits the specific molecule to diffuse. When molecules diffuse across membranes through protein channels the process is called facilitated diffusion. Diffusion is considered a passive process, meaning cells do not have to expend any energy (ATP) to move molecules across the membrane.

Although diffusion does not require the cell to expend energy to move molecules across its membrane it does have some drawbacks. Molecules will only diffuse until the concentration of molecules inside the cell equals the concentration outside the cell. Cells cannot concentrate or hoard desirable molecules in their cytoplasm by diffusion. Cells also cannot control diffusion. Diffusion will occur.

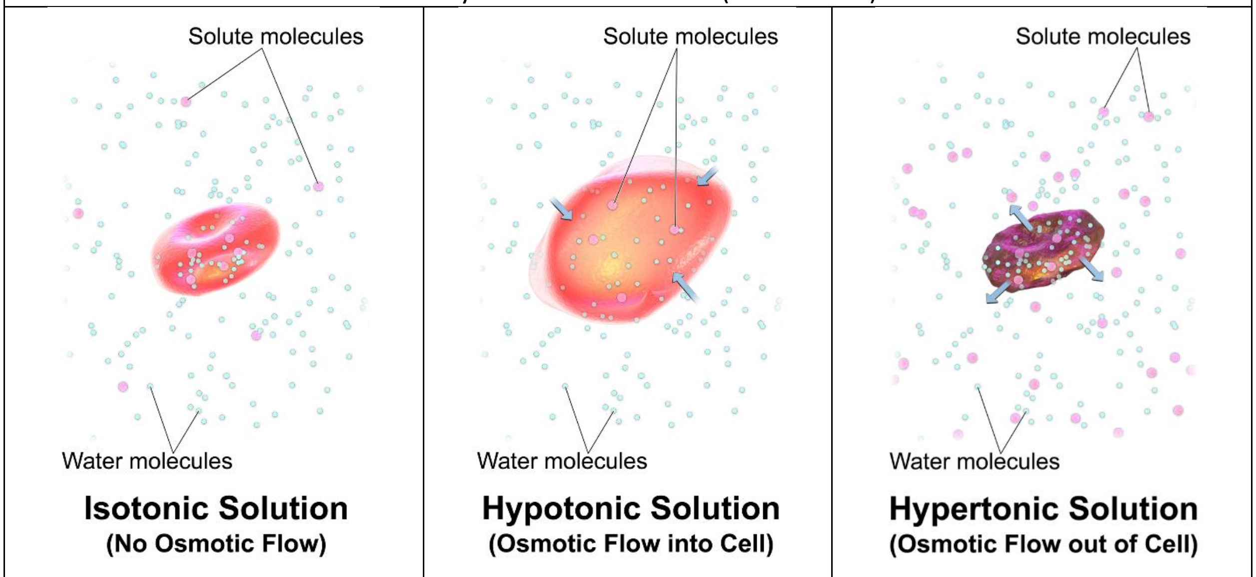
The major determinants for how fast molecules diffuse are temperature and molecular size. The larger the molecule, the slower it diffuses. Since diffusion is driven by the kinetic collisions of molecules, the warmer the temperature the faster diffusion occurs.

Osmosis

Osmosis is a special term that refers to the movement (diffusion) of water, and only water. Water as mentioned in the chemistry module is a solvent. Most biological molecules will dissolve in water. The molecules that dissolve in the solvent are called solutes. The cytoplasm of cells is a watery mix of proteins, carbohydrates, minerals, salts, nucleotides and other factors. The cell has a lot of stuff, solutes inside its plasma membrane. Water is attracted to solutes and forms a hydration sphere around these solutes. Where ever the solute concentration is highest, that is the direction in which water will move or osmose. Water moves toward the higher solute concentration.

Scientists describe the solute environment within which a cell is suspended using the following 3 terms, isotonic, hypotonic and hypertonic. An isotonic ("iso" literally means equal) environment is one in which the solute concentration of the environment is the same as the solute concentration of the cell. Water is constantly in motion. For each water molecule that moves into the cell, one water molecule will move out of the cell. There is no net flow of water in an isotonic environment. If you are ever hospitalized and need fluids, you will be prescribed isotonic saline. Isotonic saline is a salt water solution that has the same solute concentration as your blood. In a hypotonic (hypo – under, below) environment, the

Tonicity and Red Blood Cells (animal cells)



[Solute $_{\text{in environment}}$] = [Solute $_{\text{in cell}}$]	[Solute $_{\text{in environment}}$] < [Solute $_{\text{in cell}}$]	[Solute $_{\text{in environment}}$] > [Solute $_{\text{in cell}}$]
No net movement of water	Net movement of water into cell	Net movement of water out of cell

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concentration of

solutes in the environment are less concentrated than the solute concentration of the cell. As a result, water moves into the cell toward the region of higher solute concentration. While some animal cells can tolerate a slightly hypotonic environment, when too much water flows into a cell and the environment is too hypotonic the cell will swell and rupture. This is called cytolysis or in the case of red blood cells hemolysis. In rare cases, people can drink too much water and not urinate leading a potentially lethal condition called water intoxication. In water intoxication the blood becomes too dilute and cells within tissues rupture leading to the death of the individual. Another instance of lethal hypotonicity occurs when salt water fish are thrown into fresh water. The cells in the fish's gills will explode and the fish dies. Plant cells, because of their retaining cell wall tolerate hypotonic conditions better than animal cells. As water floods into the cell, the central vacuole swells pressing the plasma membrane against the cell wall. The cells become turgid. The pressure caused by water pushing on the cell wall is called turgor pressure. The final solute condition occurs when the solute concentration in the environment outside the cell is greater than the solute concentration inside the cell. This is a hypertonic (hyper- over) condition. Water in the cell will flow across the plasma membrane into the environment. The cell shrivels and the plasma membrane collapses around the remaining cytoplasm. In red blood cells, this leads to crenation, the cells have a bumpy appearance like the turrets in a castle. While this may not appear to be as devastating as hypotonic conditions, hypertonic conditions are still quite harmful. Solute conditions which crinkle the plasma membrane and shrivel the cell, cause membrane and membrane protein damage. Cells may die from damage inflicted by hypertonic conditions. In fact hypertonicity has been used for millennia as a means to kill spoilage organisms and preserve food. Salting food, meat in particular has been practiced by many cultures for years as a means to preserve food. Sugar can also be used. High sugar foods like jelly resist spoilage by bacteria.

A final few words on tonicity. The concentration of solutes that is isotonic for one organism is not isotonic for all organisms. Organisms have evolved under different conditions, saltwater fish for example survive in the ocean, but die when placed in freshwater. Organisms tolerate and compensate for osmotic conditions differently. Secondly, when discussing tonicity, we are discussing the movement of water. Water can move freely across the plasma membrane through the aquaporins. Salts, sugars or other solutes are not moving in these examples, only water.