The membrane potential:

Membrane potential (also **transmembrane potential** or **membrane voltage**) is the difference in electric potential between the interior and the exterior of a biological cell, it refers to a potential gradient that forces ions to passively move in one direction: positive ions are attracted by the 'negative' side of the membrane and negative ions by the 'positive' one. The typical values of membrane potential range from –40 mV to –80 mV.

Membrane potential is generated by a cell to facilitate the transmembrane transport of ions, nutrients, etc. Several indications exist that the presence of membrane potential across the biological membrane significantly influences the membrane structure.

Ion concentrations are determined by:

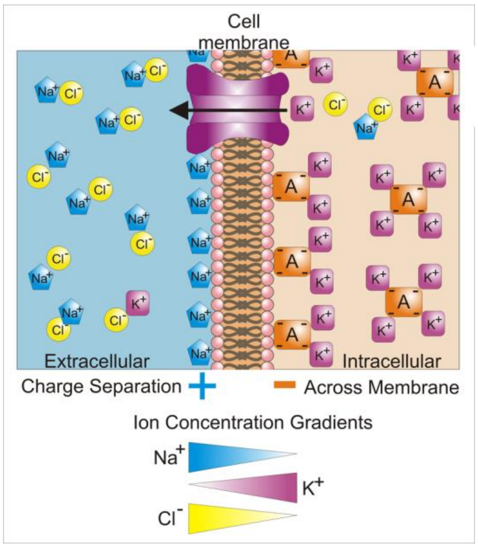
Ion transporter/pump proteins is a transmembrane protein that moves ions across a plasma membrane against their concentration gradient through active transport. These primary transporters are enzymes that convert energy from various sources—including Adenosine triphosphate (ATP), sunlight, and other redox reactions—to potential energy stored in an electrochemical gradient. This potential energy is then used by secondary transporters, including ion carriers and ion channels to drive vital cellular processes, such as ATP synthesis.

Ion pumps actively push ions across the membrane using energy to active transport ions and establish concentration gradients across the membrane.

Ion channels allow ions to move across the membrane down those concentration gradients. Transport through the channels is rapid and highly selective because of narrow pores in the channel.

The flow of ions through channels is dependent on ion gradients (deference in concentration between outside and inside of the plasma membrane.

Ion pumps and ion channels are electrically equivalent to a set of batteries and resistors inserted in the membrane, and therefore create a voltage between the two sides of the membrane.



Many ions have a concentration gradient across the membrane, including potassium (K^+), which is at a high concentration inside and a low concentration outside the membrane. Sodium (Na^+) and chloride (Cl^-) ions are at high concentrations in the extracellular region, and low concentrations in the intracellular regions. These concentration gradients provide the potential energy to drive the formation of the membrane potential.

The membrane potential has two basic functions:

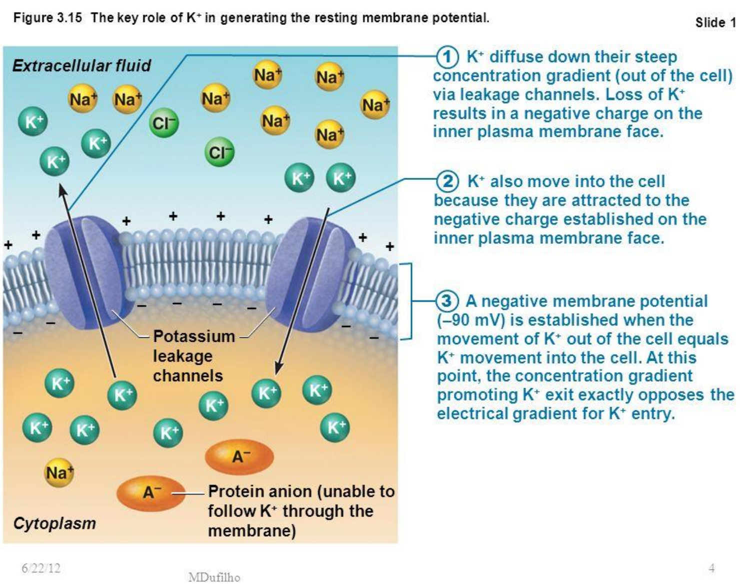
First, it allows a cell to function as a battery, providing power to operate a variety of "molecular devices" embedded in the membrane, for example in mitochondria, it is used to generate ATP.

Second, in electrically excitable cells such as neurons and muscle cells, it is used for transmitting signals between different parts of a cell.

Signals are generated by opening or closing of ion channels at one point in the membrane, producing a local change in the membrane potential. This change in the electric field can be quickly affected by either adjacent or more distant ion channels in the membrane. Those ion channels can then open or close as a result of the potential change, reproducing the signal.

In a **resting state**, the inside of the membrane is negative by about (70) mV as compared to the outside. This electric charge can provide power, much like a battery, for driving membrane functions.

Change in the potential can also be used to transmit signals from one part of the membrane to another, as it does in nerve cells. A reversal of the potential at one point creates a reversal of charge along the membrane (outside more negative; inside more positive), much like an electric current. Such reversals can be initiated by several forces, including chemicals, electric energy (voltage), and various other physical stimuli, such as light and pressure.



Movement of substances across the plasma membrane

In order for the cell cytoplasm to communicate with the external environment, materials must be able to move through the plasma membrane, which is act as semi – permeable barrier that allow some substances to pass the membrane but not others.

Substances can pass across the membrane depends not only on the particles of substances themselves but also on additional consideration like how much of substance is already on each side of the membrane (concentration gradient), or on the availability of energy to support the process because some transport mechanism require energy to be provided by the cell in order for certain types of substances to be moved from one side of the membrane to the other.

There are two types of transport mechanism by which molecules traverse membrane:

1-**passive transport** is the movement of molecules or ions from an area of higher to lower concentration , mechanism does not require energy from cells (metabolic energy). The rate of passive transport depends on the permeability of the cell membrane, which, in turn, depends on the organization and characteristics of the membrane lipids and proteins. The four main kinds of passive transport are like simple diffusion, facilitated diffusion, filtration and osmosis. Passive transports can happen through three different channels:

a- lipid bilayer

b- pore/channel protein

c- carrier protein

2-Other **transport mechanism** that require energy from cells like active transport and bulk transport mechanisms.

Types of movement across membrane:

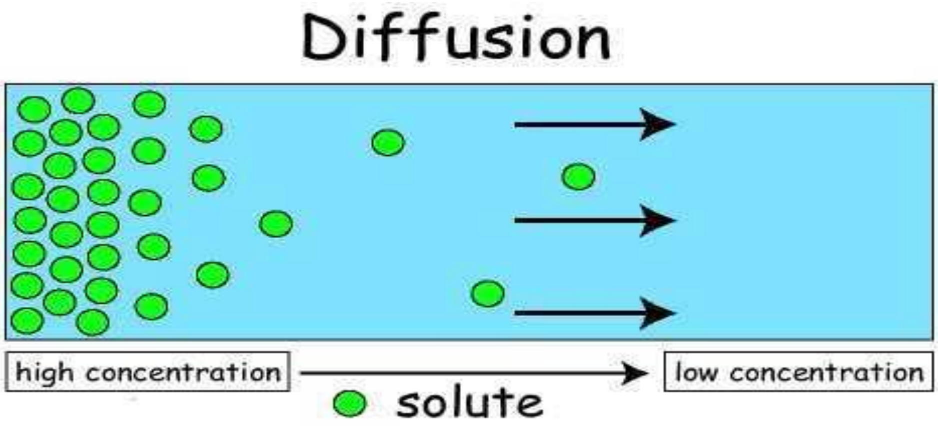
passive transport mechanism

A-Diffusion :is the net movement of material from an area of high concentration to an area with lower concentration and no membrane proteins are involved. The difference of concentration between the two areas is often termed as the concentration gradient, and diffusion will continue until this gradient has been eliminated. Since diffusion moves materials from an area of higher concentration to an area of lower concentration, it is described as moving solutes "down the concentration gradient" (compared with active transport, which often moves material from area of low concentration to area of higher concentration, and therefore referred to as moving the material "against the concentration gradient"). The energy used in the process of diffusion is supplied by the particles themselves for example the rate of diffusion increase with increase in temperature.

Particles that Move through the Plasma Membrane through Diffusion

Substances soluble in fat: fatty acid, glycerol, some vitamins (A ,D ,E ,K)

Neutral particles: water, oxygen, carbon dioxide



Factors that affect the RATE of diffusion

1. Difference in concentration between the inside and outside of the cell. The bigger the difference between concentrations, the diffusion will be faster.

2. The size of the chemical substance. O_2 is two atoms. Glucose is 24 atoms big. Protein is massive. Oxygen can easily diffuse across a cell membrane. Sugar can kind of, that's why it's assisted by a transporter protein to facilitate it. The proteins don't move at all.

3. Temperature. Higher temps = molecules move faster.

4. Whether the chemical substance is water-soluble or lipid soluble. The lipid soluble goes through faster because the cell membrane is phospholipids and can easily diffuse through a fatty membrane.

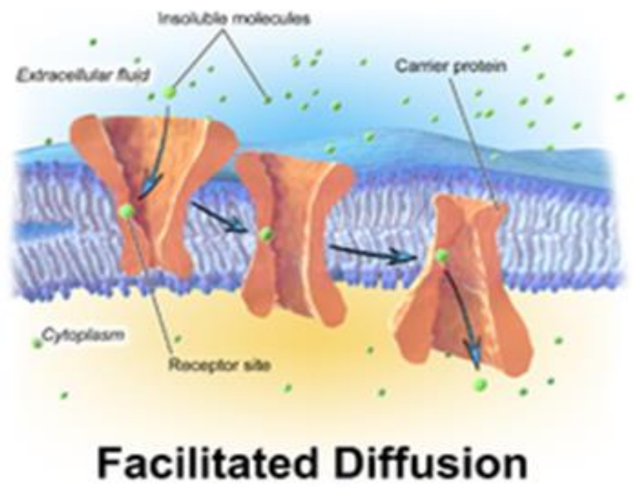
b- Facilitated diffusion: Some larger molecules, such as glucose, need help by way of a transport protein to help carry glucose (very essential elements for life and it represents the main source of energy for cells) into a cell and this requires no energy.

Most cells use facilitated transport for taking glucose in the way of uniport .

Facilitated diffusion, also called carrier-mediated osmosis, is the movement of molecules across the cell membrane via special transport proteins that are embedded within the cellular membrane so it differs from passive diffusion in that molecules do not dissolve in phospholipids bilayer but their passage is mediated by proteins.

Large, insoluble molecules, such as glucose, vesicles and proteins require a carrier molecule to move through the plasma membrane. Therefore, it will bind with its specific carrier proteins, and the complex will then be bonded to a receptor site and moved through the cellular membrane.

Facilitated diffusion is a passive process: the solutes move down their concentration gradient and do not require the expenditure of cellular energy for this process.



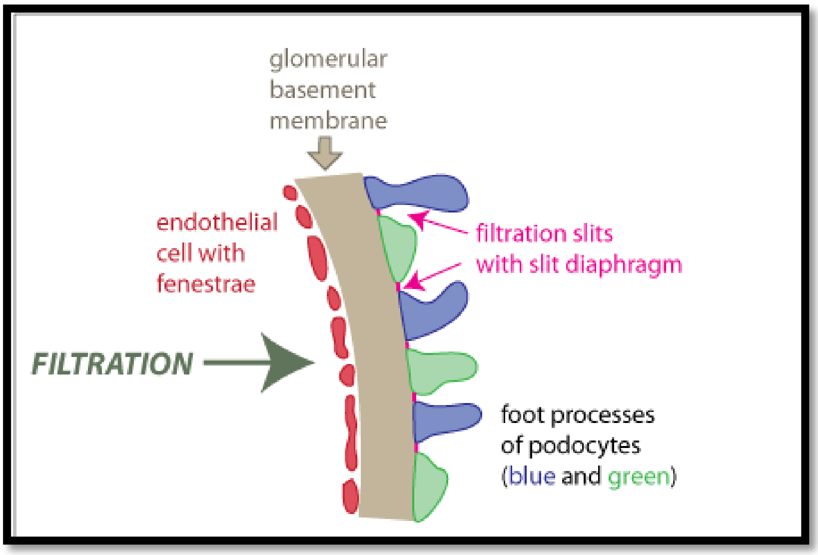
Two classes of proteins mediate facilitated diffusion

Carrier proteins and channel proteins allow for the diffusion of molecules across the cell membrane. Carrier proteins undergo conformational alterations to allow molecules to pass, while channel proteins form unblocked pores. These carrier proteins are specific, each can transport with only a certain type of molecule or ion, which is then transported through the membrane. For example, various sugar molecules of identical size might be present inside or outside the cell, but glucose can cross the membrane hundreds times faster than the other sugars. For that reason the membrane can be called differentially permeable.

c- filtration

Filtration is movement of water and solute molecules across the cell membrane due to hydrostatic pressure or filtration is the passage of water and dissolved materials through a membrane as a result of a mechanical ("pushing") force on one side. Depending on the size of the membrane pores, only solutes of a certain size may pass through it. For example, the membrane pores of the Bowman's capsule in the kidneys are very small, and only albumins, the smallest of the proteins, have any chance of being filtered through.

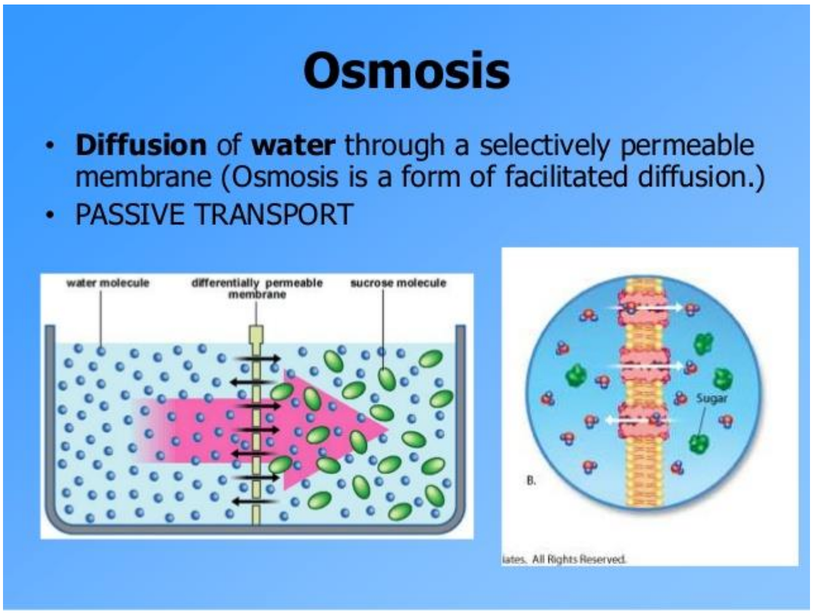
On the other hand, the membrane pores of liver cells are extremely large, but not forgetting cells are extremely small to allow a variety of solutes to pass through and be metabolized.



Filtration process in kidney glomeruli.

d- Osmosis: is the movement of water molecules across a selectively permeable membrane. The net movement of water molecules through a partially permeable membrane from a solution of high water potential to an area of low water potential.

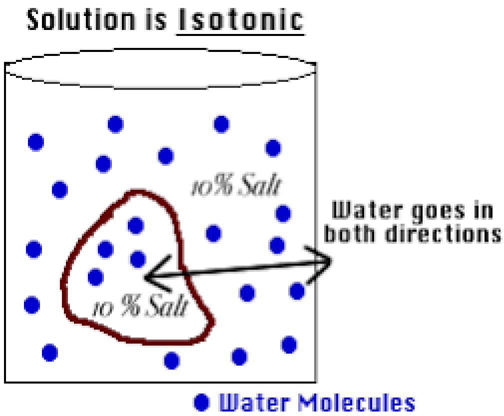
Water can pass through phospholipid bilayers by simple diffusion or by facilitated diffusion through special channel proteins called **aquaporins**.



There are three types of Osmosis solutions:

1-Isotonic solution

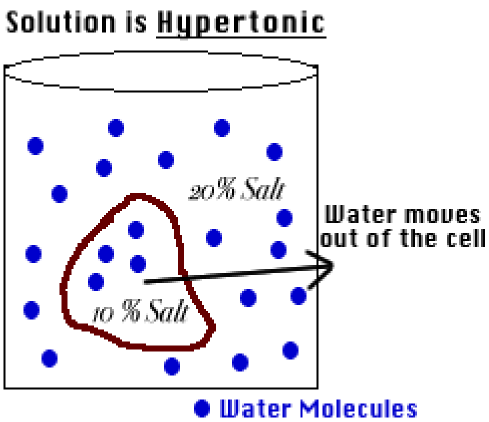
Isotonic solution is when the extracellular solute concentration is balanced with the concentration inside the cell. In the Isotonic solution, the water molecules still moves between the solutions, but the rates are the same from both directions, thus the water movement is balanced between the inside of the cell as well as the outside of the cell. Tissue fluids and blood plasma are isotonic for body cells.



2- Hypotonic solution

Hyper tonic solution is when the solute concentration outside the cell is lower than the concentration inside the cell.

In hypertonic solutions, water diffuses out of the cell due to osmosis and the cell shrinks. Thus, the animal cell has always to be surrounded by an isotonic solution. In the human body, the kidneys provide the necessary regulatory mechanism for the blood plasma and the concentration of water and salt removed from the blood by the kidneys is controlled by a part of the brain called the hypothalamus.



3- Hypotonic solutions

The water **moves into** the cell, down its concentration gradient (from higher to lower water concentrations). That can cause the cell to swell up and explode as they cannot become turgid because there is no cell wall to prevent the cell from bursting. When the cell is in danger of bursting, organelles called contractile vacuoles will pump water out of the cell to prevent this.