Physiology | Lecture 2 / B

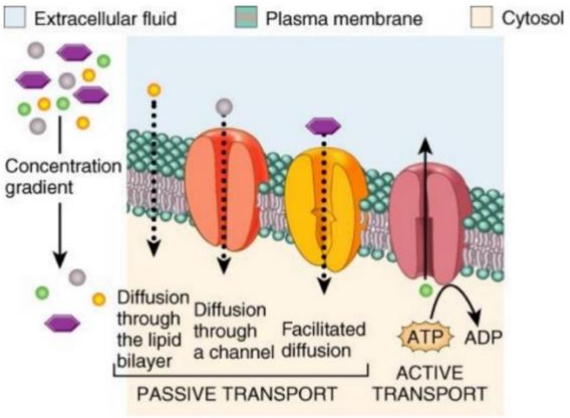
Transport across the plasma membrane

Reviewed by : Heba Salah

Nadeen Alrawajfeh

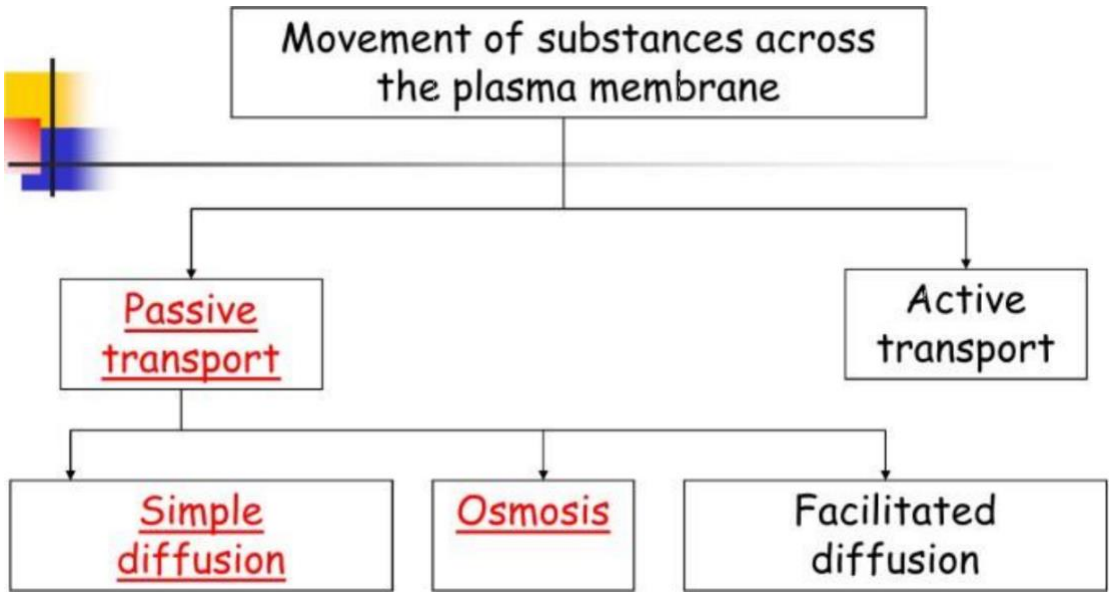
Transport across Plasma Membrane

In this lectureg we will talk about transport modalities across the plasma membranes.
To understand the general idea of the transportation, you can follow the link below:



https://www.youtube.com/watch?v=A9ihz5gYxU4

We talked previously about the plasma membranes , and that we have proteins impeded in them . These proteins help with transportation across the membrane ,for example using carriers or channels.
But besides that, we can have some particles passing through the Lipid bilayer structure(its simply transported that way) .
Also ,we have some carriers that consumes energy to transport particles from law to high concentration (we call it active transport modalities) .
Passive = without consuming macro-energetic molecules (ATP).
*Active= there is consumption of macro-energetic molecules (ATP).



Diffusion :

Generally, dissolved particles found in solution are in
Constant movement. This random motion is due to thermal energy
In particles that found themselves at a temperature above the
Absolute zero (in living systems about 310 degrees K). The random
Motion in liquids and gases will result in a random collision of
Particles with each other and with the wall. These haphazard
Collisions will cause a transfer of kinetic energy from one particle
To another and change in the direction of motion. This continuous
Movement in liquids and gases is known as **diffusion.**

- Random motion: Each molecule moves in unpredictable directions due to collisions, but without a specific purpose. This motion never stops as long as the temperature is above absolute zero

- Diffusion: the overall movement of molecules from a high concentration area to a low concentration area. It results from many random movement but only happens when there is a concentration difference
- Reminder: More kinetic energy means higher concentration.For example,If you have high concentration in a compartment, you have high kinetic energy in that compartment, and so on.
- The reason why diffusion doesn't need to consume macro-energetic

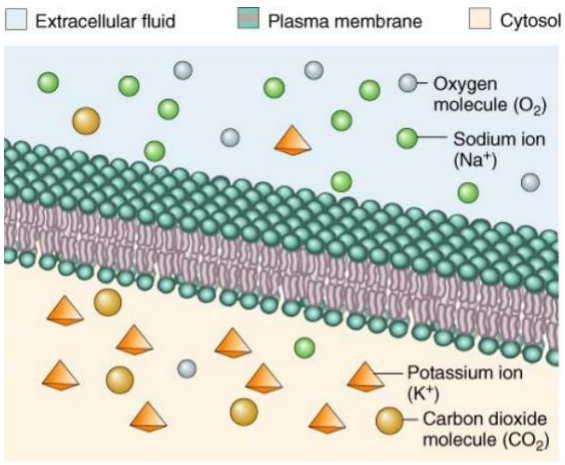
Particles can move across membrane by diffusion. This type of transport does not need consumption of energetic compounds ATP(Passive)

Diffusion through lipid Bilayer

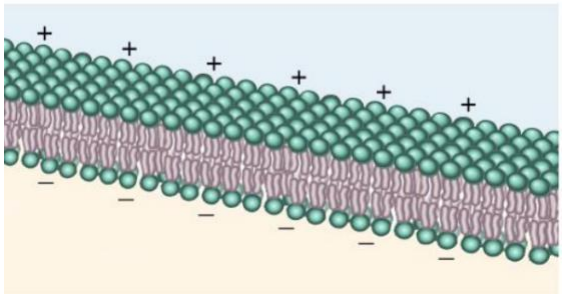
● We have some particles (lipid soluble substances):

- *CO2*
- *O2*
- *NO*
- *Steroid Hormones*
- *Monoglycerides*

These can move through the Lipid bilayer structure (Their diffusion depends on the solubility of particles in the lipid bilayer.)



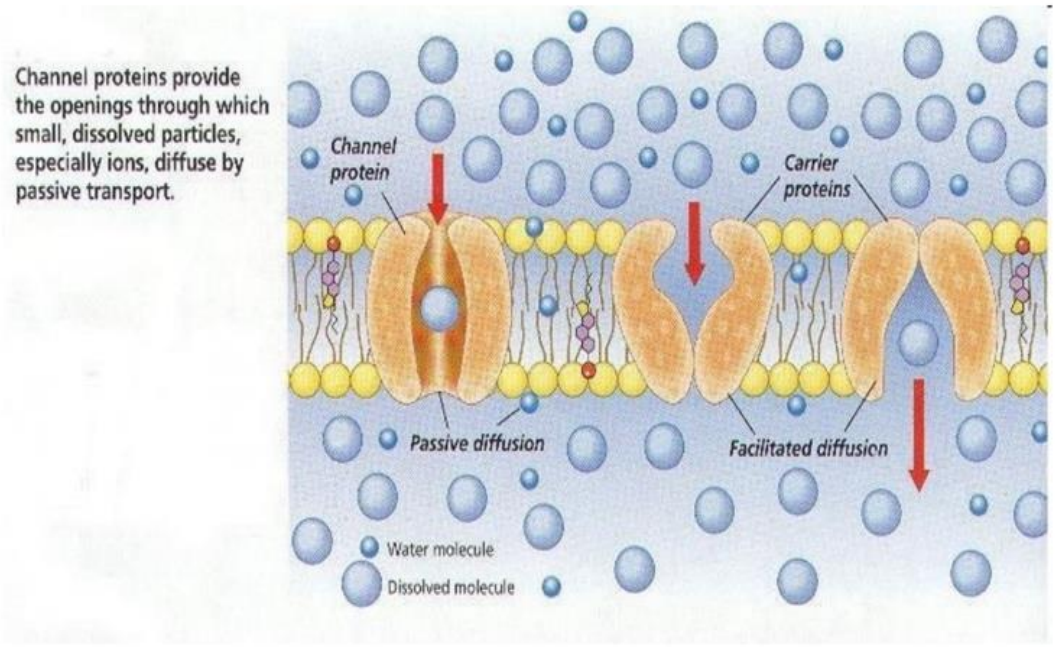
(a) Concentration gradients



(b) Electrical gradient

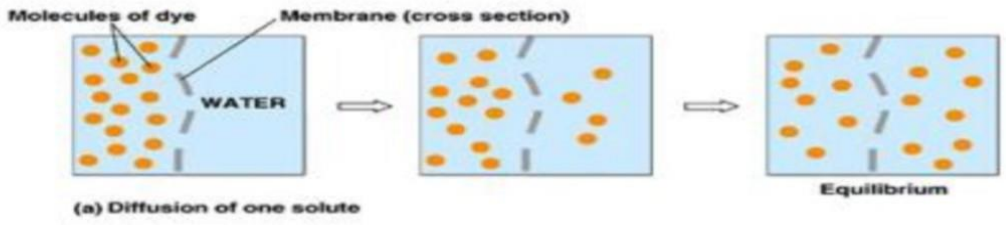
Diffusion through channels

Other particles (charged particles for example or bigger particles) , we need protein structures that can help them to move across the membrane.



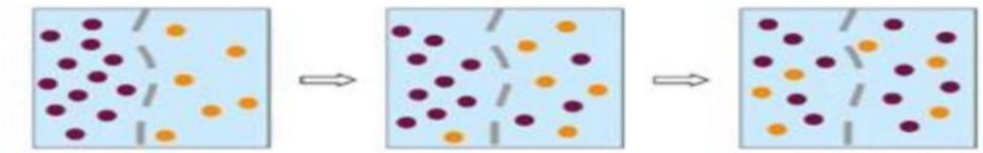
The Concept of Simple Diffusion

In this example, we have a membrane that separate two compartments, one contains number of dies and the other is empty. The dies start to move (**downhill**) from the higher concentration to the lower concentration until it reaches a state of **Equilibrium** where the **net diffusion is zero**. Equilibrium doesn't mean that there are no diffusion between the two compartments, it means that **the rate of diffusion to the right is the same rate of diffusion to the left**.(net diffusion=zero



(a) Diffusion of one solute

This example is the same as above, but notice that there are **two different dies** (**red** and yellow), the movement of each particle depends on it **its own concentration** gradient throw the membrane,not the number of all particles in each compartment.(the yellow dies move according to the number of only yellow dies in each section, not the number of red and yellow dies).



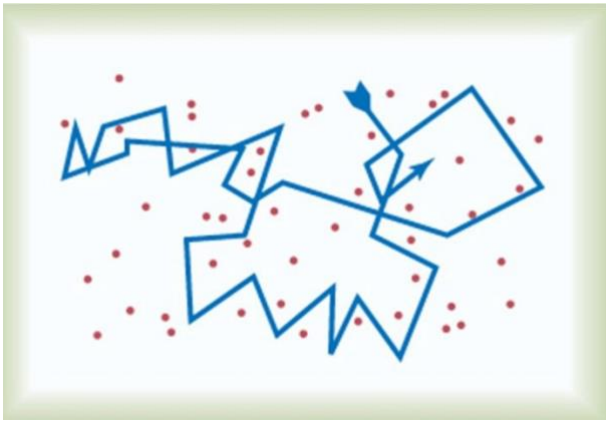
(b) Diffusion of two solutes

Note that simple diffusion doesn't consume ATP as a source of energy, but what is moving these particles is the kinetic energy.

So , For simple diffusion we need :

- the membrane to be semi-permeable for the substance/both substances.
- to have low concentration in one compartment and high concentration in the other one .
- we don’t need to consume Macro-energetic molecules (ATP)

❖ <u>The energy is held in the particle, its called ***KINETIC ENERGY***</u>

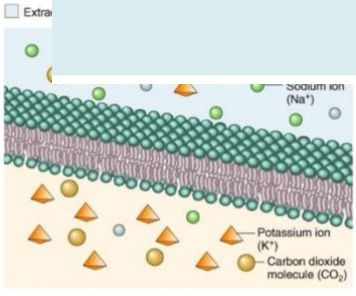


(If you have high concentration in a compartment, you have high kinetic energy in that compartment, and so on).

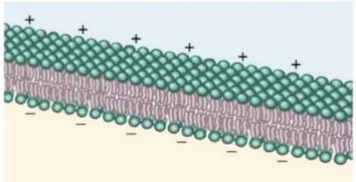
Simple diffusion

Diffusion through lipid bilayer

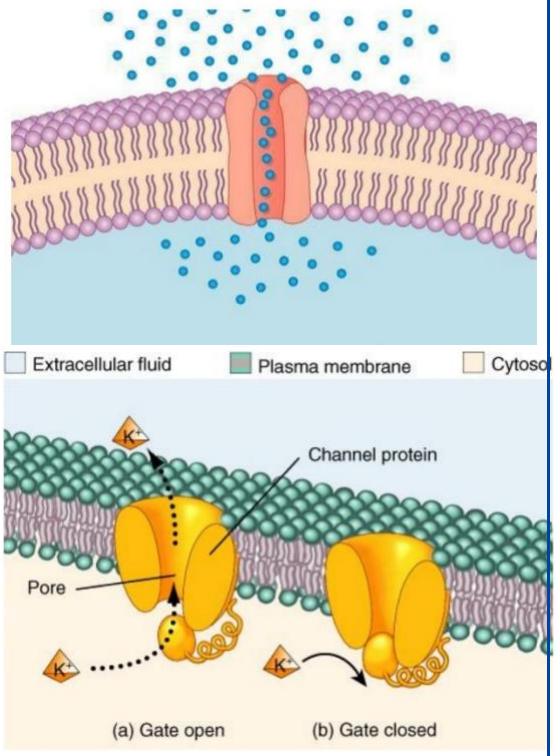
- CO2
- O2
- NO
- Steroid Hormones
- Monoglycerides



(a) Concentration gradients



Diffusion through Channels



* changing the permeablity *

■As we said , diffusion depends on the permeability of the membrane and the concentration gradient.

Fick's Law

- $J = P.\Delta C$
- $P = D.A/\Delta X$
- $J = D.A.\Delta C/\Delta X$

J = Flux (Rate of diffusion)
P = Permeability
D = Diffusion Coefficient
A = Surface area
C = Concentration
X = Membrane thickness

This law combines these parameters to **calculate the rate of diffusion**

■ Diffusion net rate:

the number of particles that moves from one side to another (more precisely : [from **high** to **low** - from **low** to **high**])

▪ One of the **factors** that influence the Rate of net diffusion is **concentration gradient** (ΔC= CA-CB), which represents the Chemical Potential for movement of particles across membranes.

▪ In addition to concentration gradient, net rate of diffusion (Q)
Depends also on:

- ❖ **Permeability** of the membrane to a given substance (P): the

Higher the permeability for a substance the greater the diffusion rate is
Through membrane.

- ❖ **Surface area** of transport (A): diffusion increases by increasing

(A). The increase in surface area in biological membranes will result in
More protein channels that can be used for diffusion from one
Compartment to another.

- ❖ **Molecular weight** (MW): lighter molecules move more quickly

Than heavier.

- ❖ **Membrane thickness** (X) (distance of movement): the greater the

Distance the slower the rate of diffusion.

All these **factors** form the Ficks' law of diffusion:

- J = P.ΔC.....(J = Flux, P=Permeability, ΔC = Concentration gradient)

- P = D.A/ΔX ..... (, A: surface Area, ΔX = membrane Thickness)

- J = D.A.ΔC/ΔX..... (D=Diffusion Coefficient)

In addition to all these factors, diffusion can also be *influenced* by:

- Effect of membrane electrical potential: mainly influences

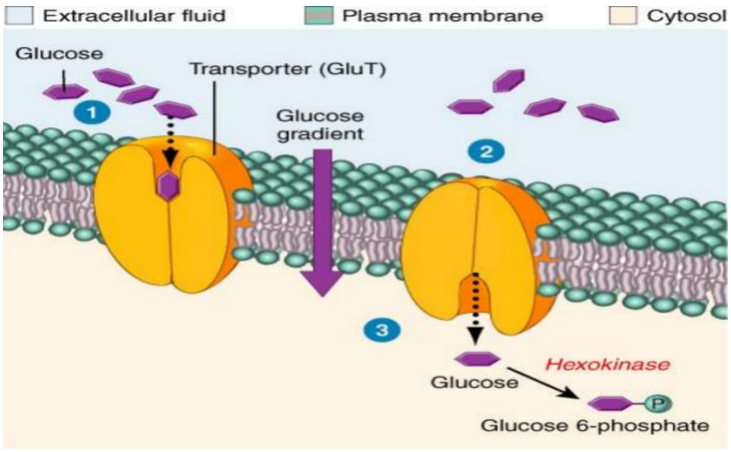
Electrically charged particles.
The presence of a negative potential inside the cell prevents movement of negative (-) charged particles from the extracellular
Compartment to the intracellular compartment and the positive charged particles from the intracellular to the extracellular compartment.

So, movement of charged particles is governed by an electrochemical
Potential. This will be discussed in more details later.

➢ Effect of pressure:

The presence of pressure difference between two compartments
will cause more kinetic energy in particles in the compartment with
Higher pressure. This will cause movement of more particles from the
High pressure side to the low pressure side.

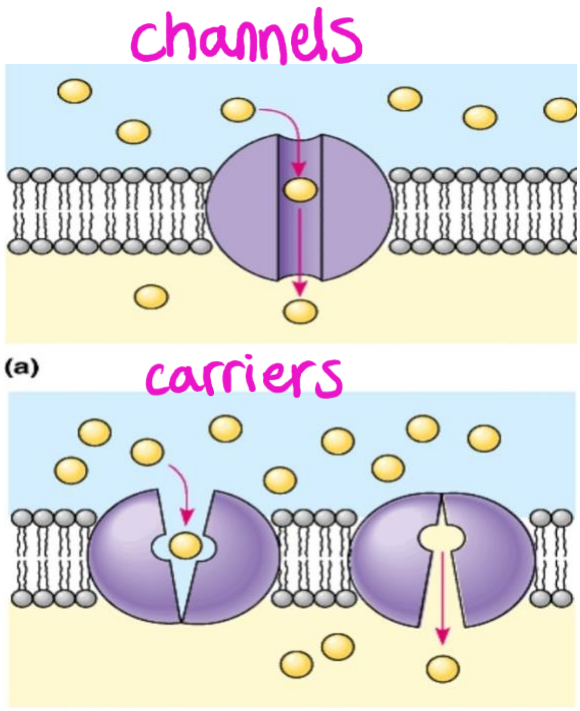
Facilitated Diffusion

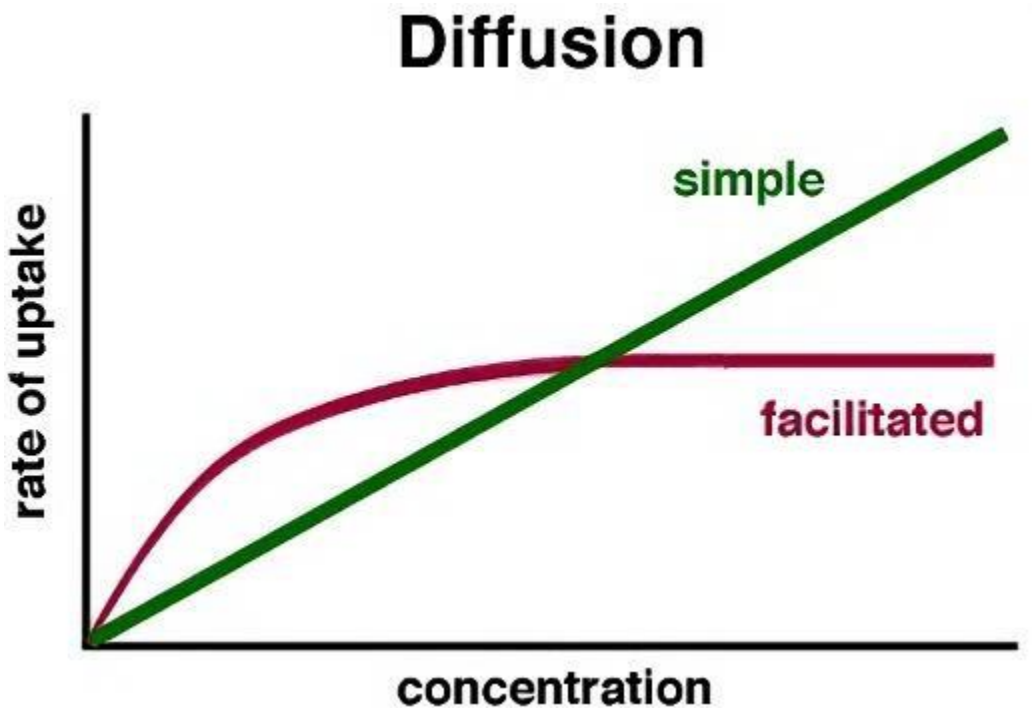


Sometimes, we need to transport bigger molecules .For these particles, we don't have channels , instead we have carriers that can help these particles to transport across the plasma membrane.
These carriers are specific,
(for example, we have specific carriers for glucose different from the carriers of galactos, and so on).
These carriers have binding sites for these particles, it an get some changes in the protein structure so it can move the particles **from high concentration to low concentration**.

- Examples on **big molecules**:

  - Aminoacids
  - Glucose
  - Galactose
  - Fructose



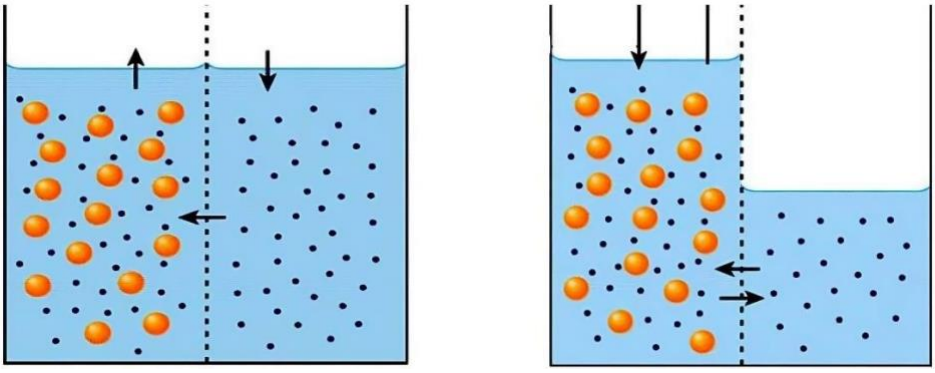


As you can see, the simple diffusion curve is linear and always **increasing**, but the facilitated one is increasing at the beginning, and after one point it will stop increasing, this is the **limitation point** and at this point it have the maximum velocity of transport (Vmax), why this happens? Because we have a **limited number of carriers**, when all these carriers are busy in transporting (they are all under using) even if we increased the concentration of specific particle on one side, these carriers won't be able to transport these particles to the other side, **so the curve will stop increasing**.
Now we should go back to the channels, channels follow simple diffusion curve, so at this point they are considered as simple diffusion, but as we mentioned before, channels are protein structures, and for that they should be considered as facilitated diffusion, from our doctor perspective they are just "**diffusion**", neither simple nor facilitated.

At this point you should ask: The number of carriers is limited, and the channels number too, so why there is limitation point in the curve of facilitated diffusion (carriers) and not in channels (as we mentioned above, they follow simple diffusion curve)?

Osmosis

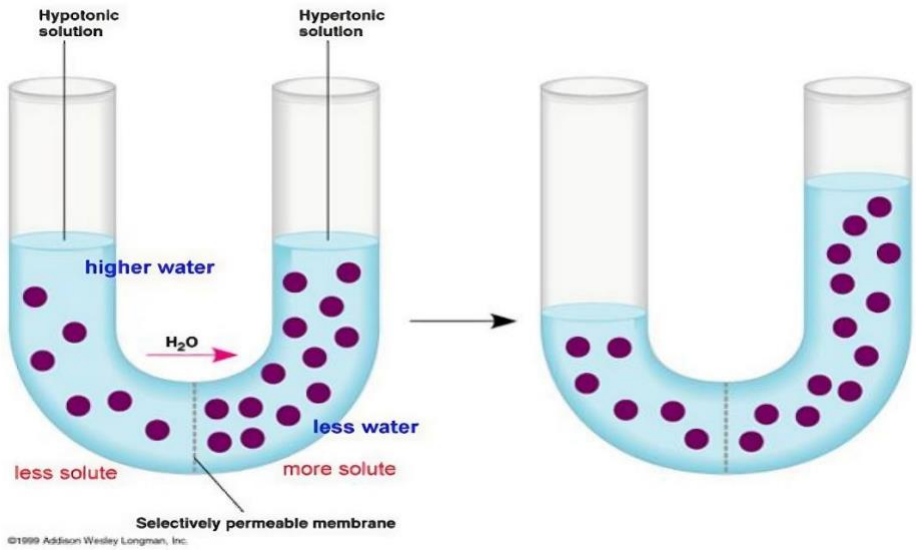
If we assume that there is a membrane that it's not permeable for particles, and permeable for water, what will happen? The water will move from the compartment that has a **high** concentration of **water** to the **low** one, in other words: from **low** concentration of **particles** to **high** concentration of **particles**, this is **Osmosis**.



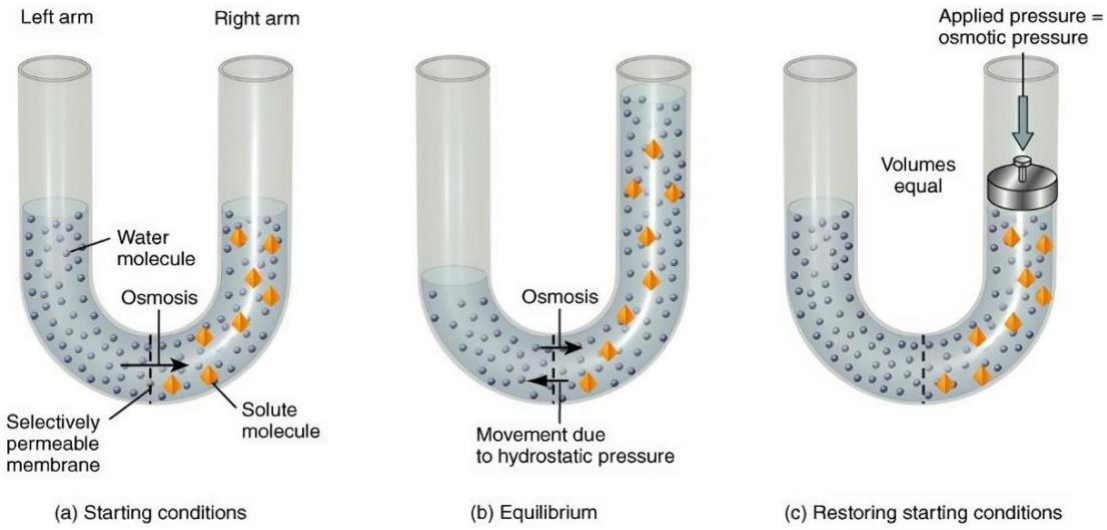
We can reach equilibrium in osmosis.

We reach equilibrium in osmosis when hydrostatic pressure is created.

Hydrostatic pressure opposing more movement of the water is called **the osmotic pressure of that solution**, here is another example:

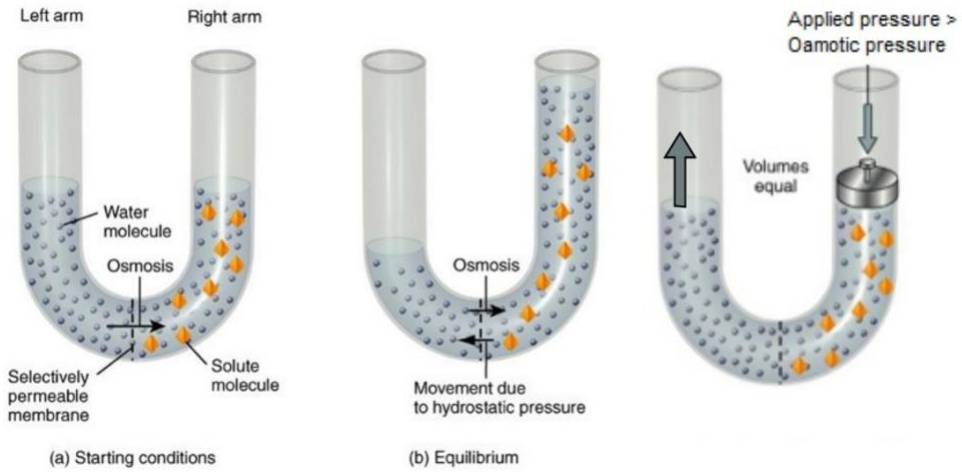


What if we applied external pressure that is opposite to osmotic pressure and equal to it? Look at the next page.



Simply, if we applied an external pressure that is opposite and equal to the osmotic pressure, we will go back to the starting condition.

Did you think about applying an external pressure that is more than the osmotic pressure and opposite to it? The water will move from the lower to the higher concentration of it, this is called **filtration**.



Van't Hoff's Law

$$\pi = RTC$$

π = osmotic pressure

R = Gas constant

T = Absolute temperature

C = Concentration

-Osmatic pressure depends mainly on the molar concentration or

-**Important note:** the equations are for understanding the correlation between the elements (positive/negative), solving

Osmole, Osmolality and Osmolarity

We know that if we get a specific grams of particle that is equal to its molecular weight, then we have 1 gram molecular weight of it, as an example: glucose molecular weight is 180 grams, so if we have 180 g of glucose, then we have 1 gram molecular weight.

Osmole: A unit used to express the concentration of a solution in terms of numbers of particles in place of grams.

Based on that, if we have 180 grams of glucose, then we have 1 osmole of glucose.

In glucose situation, the glucose doesn't dissociate into ions in water, so we said **1 osmole**, but what if we are dealing with something that dissociate into ions in water?

Let's take sodium chloride as an example, if we have 58.8 grams of it (equal to its molecular weight) then we have 1 gram molecular weight of sodium and 1 gram molecular weight of chlore, if we are talking in terms of osmosis, that's **2 osmoles**.

If we take a solution that has 1 osmole of solute dissolved in each kilogram of water is said to have **Osmolality** of 1 osmole per kilogram.

If we take a solution that has 1 osmole of solute dissolved in each liter of water is said to have **Osmolarity** of 1 osmole per liter.

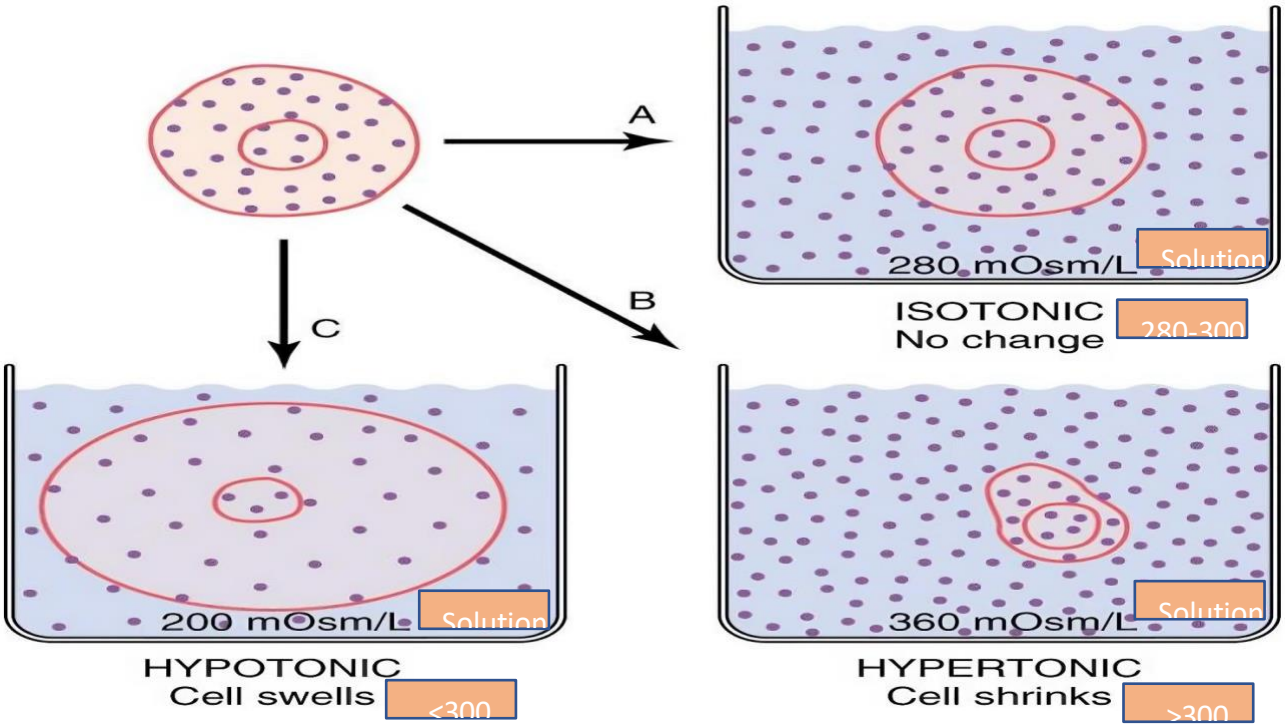
To sum up:

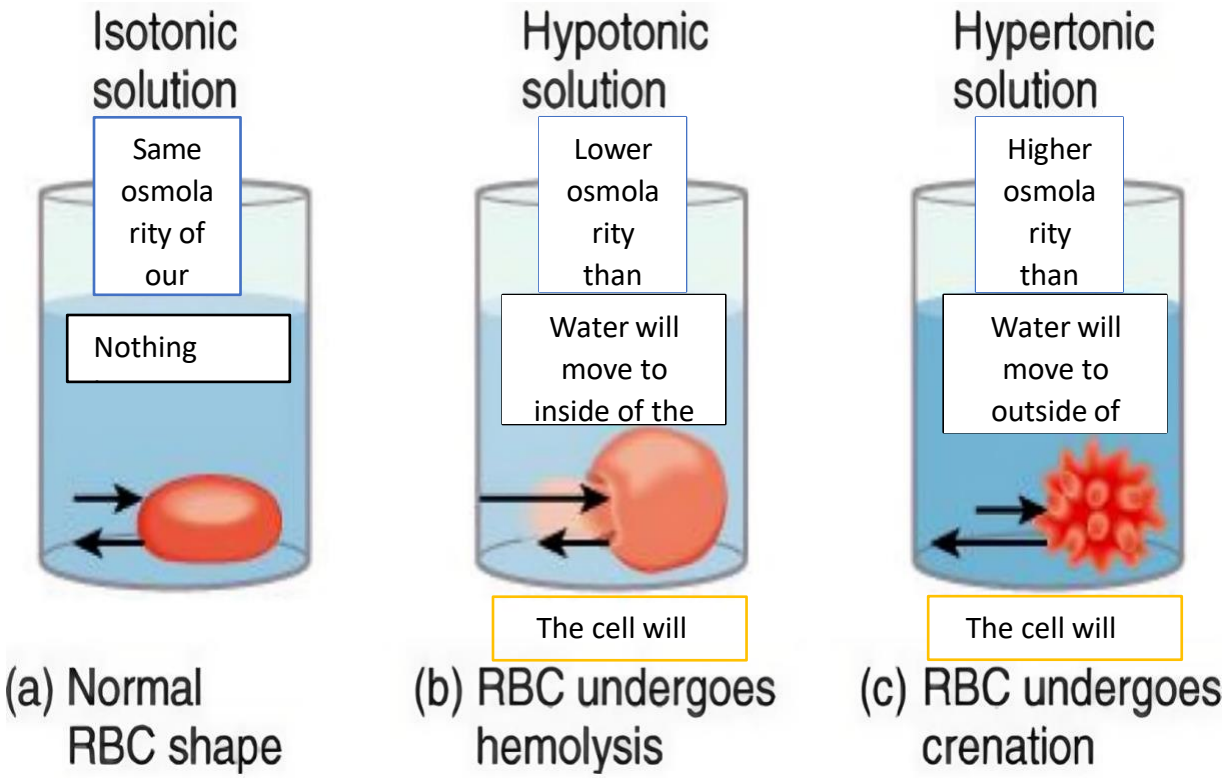
1 gram molecular weight -> 1 osmole

Osmolality -> osmole per kilogram

Osmolarity -> osmole per liter

Our cells contain a fluid, that is in composition has differences with extracellular fluid, but they must be similar in osmolarity, why? Let's find out on the next page.


A
B
C
280 mOsm/L
Solution
ISOTONIC
No change
280-300
200 mOsm/L
Solution
HYPOTONIC
Cell swells
<300
360 mOsm/L
Solution
HYPERTONIC
Cell shrinks
>300


Isotonic solution
Same osmolarity of our
Nothing
(a) Normal RBC shape
Hypotonic solution
Lower osmolarity than
Water will move to inside of the
The cell will
(b) RBC undergoes hemolysis
Hypertonic solution
Higher osmolarity than
Water will move to outside of
The cell will
(c) RBC undergoes crenation

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