GENERAL PHYSIOLOGY
LECTURE (5)

OSMOSIS

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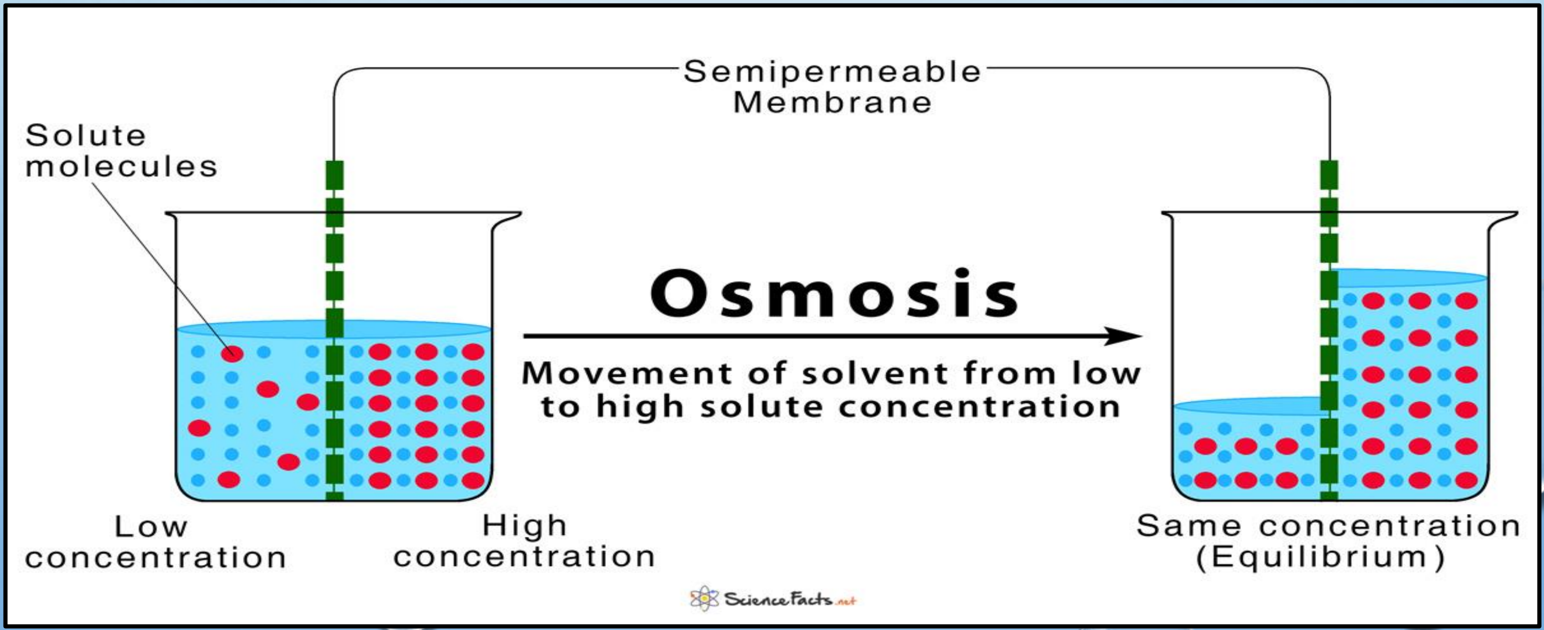


OSMOSIS

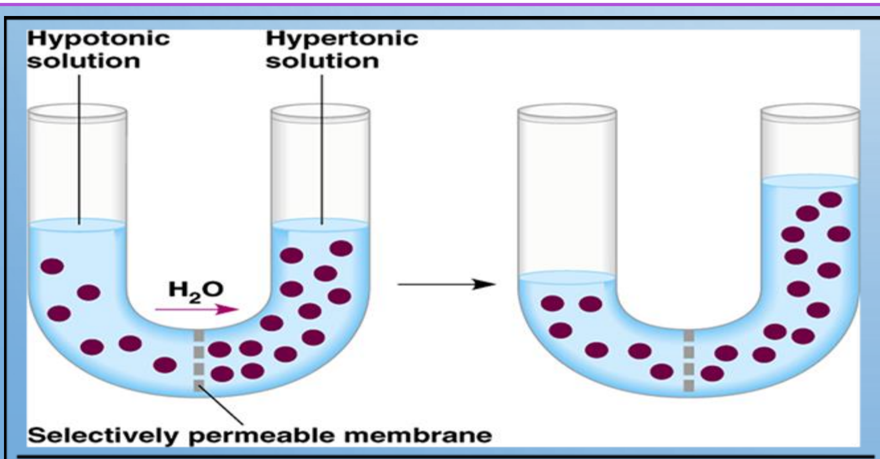
✓ **Definition:**

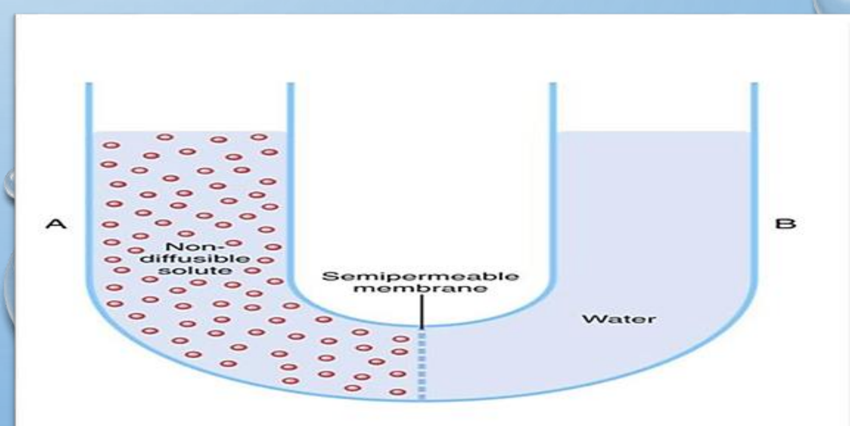
- It's the diffusion of the solvent molecules through a semipermeable membrane from the compartment of lower concentration to the compartment of higher concentration of the solute.

- Or it's the movement of water through a semi- permeable membrane from an area of high concentration of water (diluted solution of a solute) to an area of low concentration of water (higher concentration of solute).

✓ It is a passive mechanism (no energy needed). It occurs according to concentration (chemical) gradient of water molecules.

✓ Osmosis results in changes in volume on either side of the membrane.

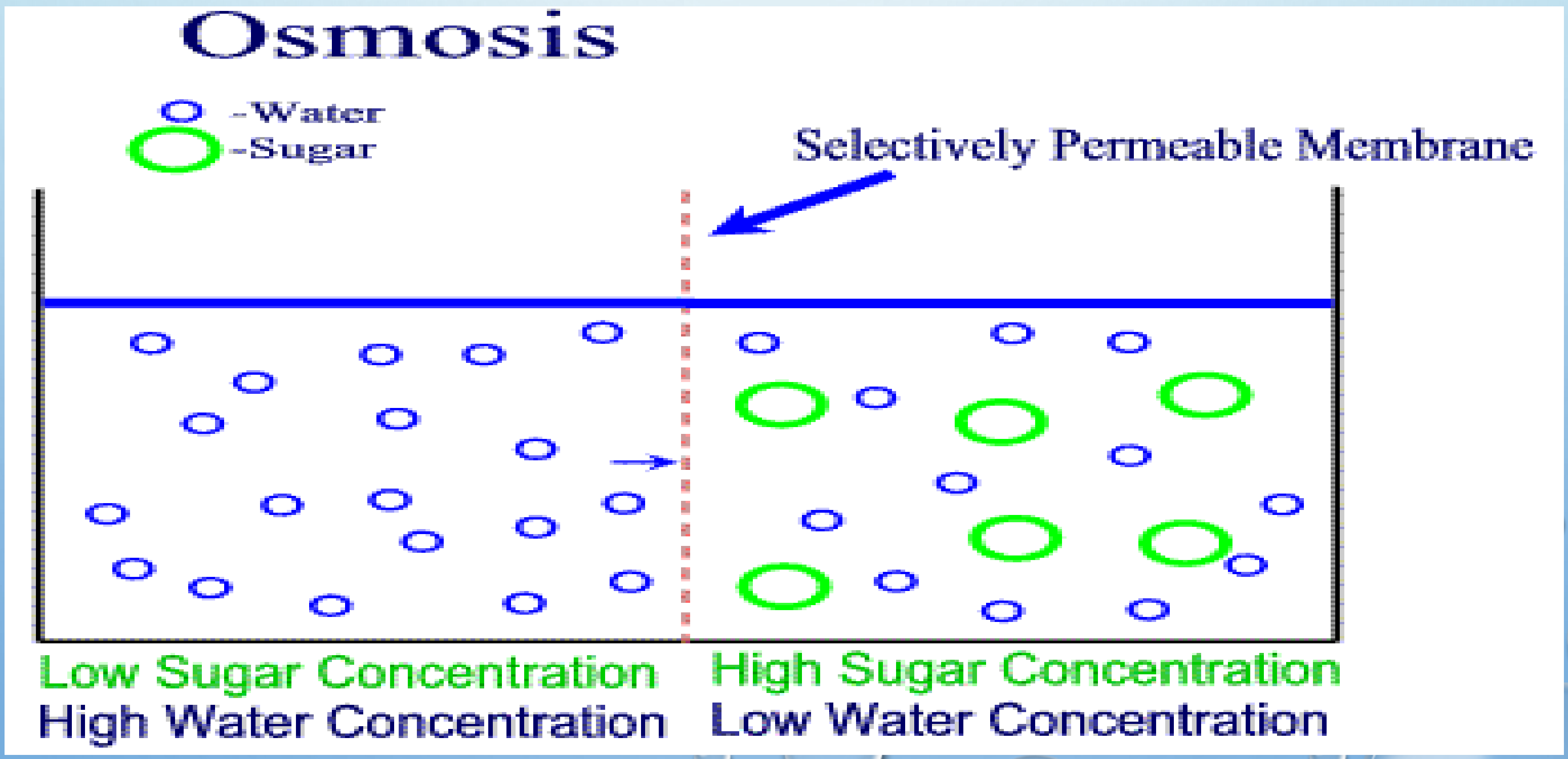




For osmosis to occur:

1.The membrane must be permeable to water and impermeable to the solutes in the solution (i.e. **semipermeable**)

2.There must be a difference in solute concentration between the two sides of the membrane.



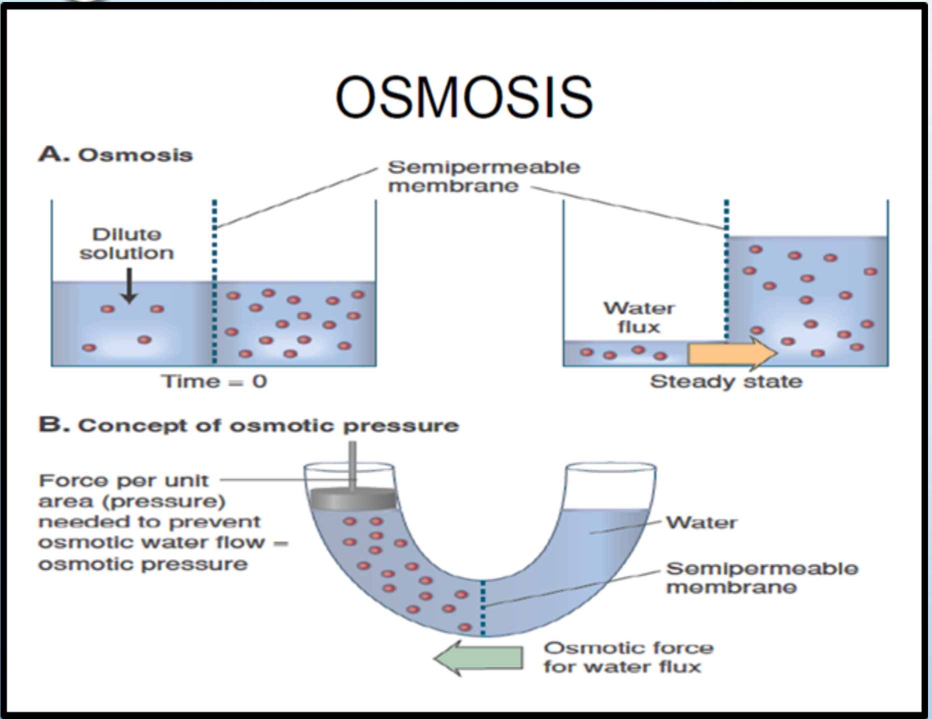
The osmotic pressure:

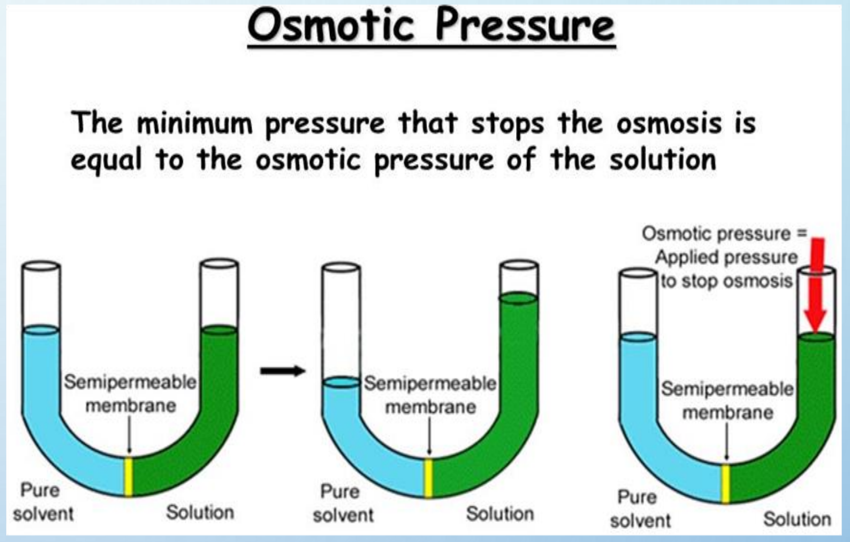
- It is the **pressure required to stop osmosis (measured in mmHg). The pressure necessary to prevent solvent migration.**
- It **depends on number of particles** (whether they are molecules or ions) **of solutes/unit volume of solution and not on their mass**.
- The reason for this is that each particle in a solution, regardless of its mass, exerts, on average, the same amount of pressure against the membrane. That is, large particles, which have greater mass (m) than small particles, move at slower velocities (v). The small particles move at higher velocities in such a way that their average **kinetic energies (k)**, determined by the equation:

$$k = \frac{mv^2}{2}$$

- are the **same for each small particle as for each large particle**. Consequently, the **factor that determines the osmotic pressure of a solution** is the concentration of the solution in terms of **number of particles** (which is the same as its molar concentration if it is a non-dissociated molecule), **not in terms of mass of the solute**.

- So, ionizing salts (e.g. NaCl) are more osmotically active (because each ion is active by itself) than non-ionizing salts (e.g. glucose).





OSMOTIC PRESSURE

Mole: is the molecular weight of a substance in grams.

To express **the concentration of a solution in terms of number of particles, the unit called the Osmole is used in place of grams**.

Osmole: is the number of osmotically active particles in solution.

Osmole = 1000 mosmole

So, for any substance:

(if not dissociated; non-ionized);

1 Osmole = 1 Mole

If dissociated;

No of osmoles = 1 mole of substance X number of particles in the solution

Example:

1 mole of glucose (1 particle) = 1 osmole

But, 1 mole of NaCl = 1 x 2 particles = 2 osmoles

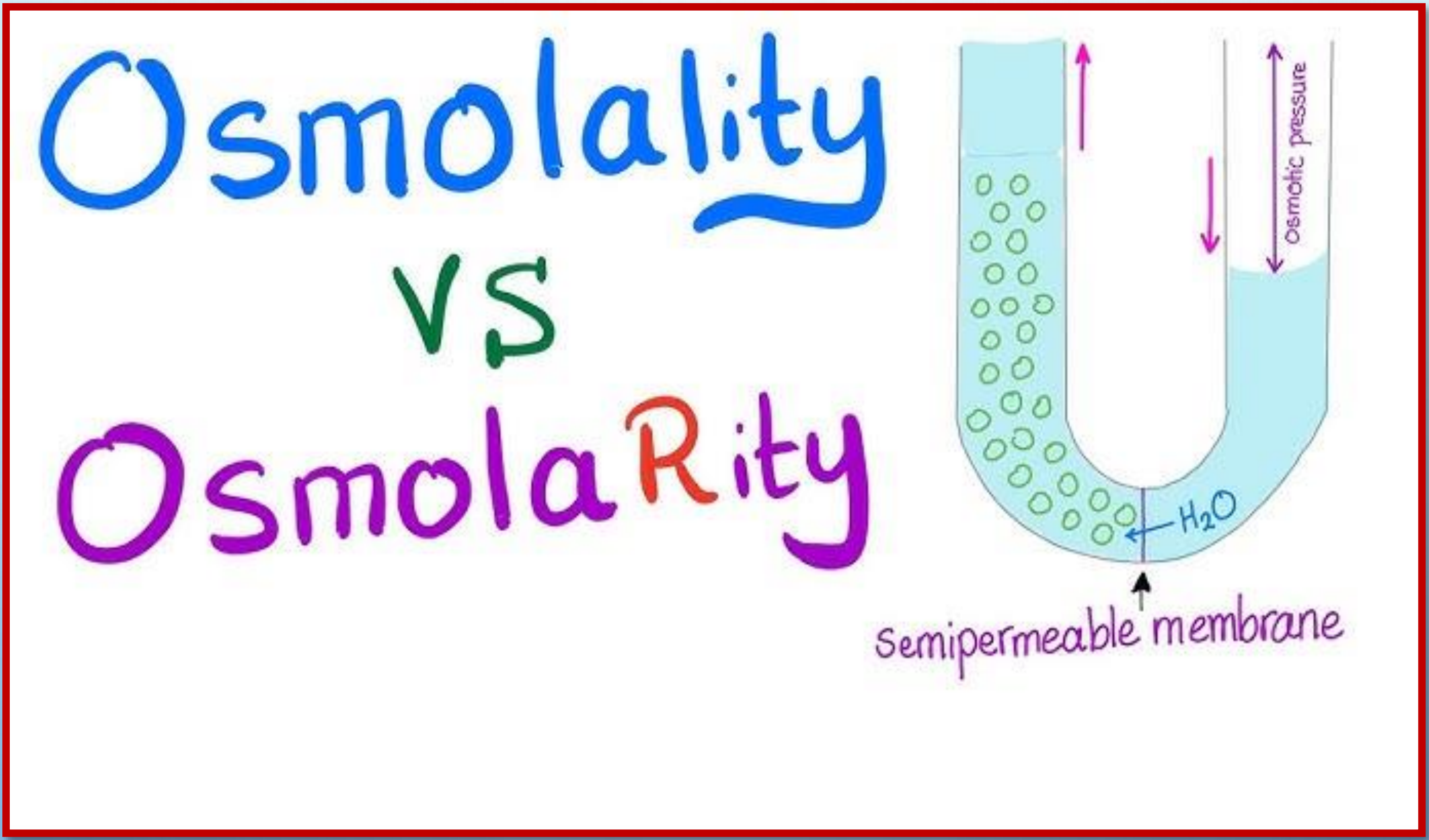
Na^+ Cl^-

(2 particles)

1 Mole of $CaCl_2$ → 3 osmoles.

1 Mole of Na_2SO4→ 3 Osmoles.

Osmotic pressure for 1 mosmole= 19.3 mmHg.


Osmolality
vs
OsmolaRity
osmotic pressure
H_2O
Semipermeable membrane

Osmotic concentration of a solution can be expressed by

Two ways

I. <u>Osmolarity</u>
(No. of osmoles / unit volume)
(i.e. **<u>osmoles / Liter</u>**)

II. <u>Osmolality</u>
(No. of osmoles / unit weight)
(i.e. **<u>osmoles / Kg</u>**)

<u>Variable</u>
Because, **volume** is affected by **Temperature**

But

constant
Because, **weight** is constant, **<u>not</u> <u>affected</u>** by **Temperature**

<u>So, Osmolality is MORE accurate than osmolarity.</u>

N.B.

For Water,

1 L of water = 1 Kg (Specific gravity of water is one). So, osmolarity = osmolality.

Thus, **a solution that has 1 osmole of solute dissolved in each kilogram of water** is said to have an **osmolality of 1 osmole/kg**, and a solution that has **1/1000 osmole dissolved per kilogram** has an **osmolality of 1 mosmole/Kg**.

Osmolarity of ICF = ECF = 290-300 mosmole/L (about 5500 mmHg).

Normal plasma osmolarity = 290-300 mosmole/L.

Factors affecting plasma osmolarity:

1. Plasma Na^+ and its accompanying anions, Cl^- and HCO_3^-.

2. The major nonelectrolytes of plasma; Plasma glucose and urea.

3. Plasma proteins.

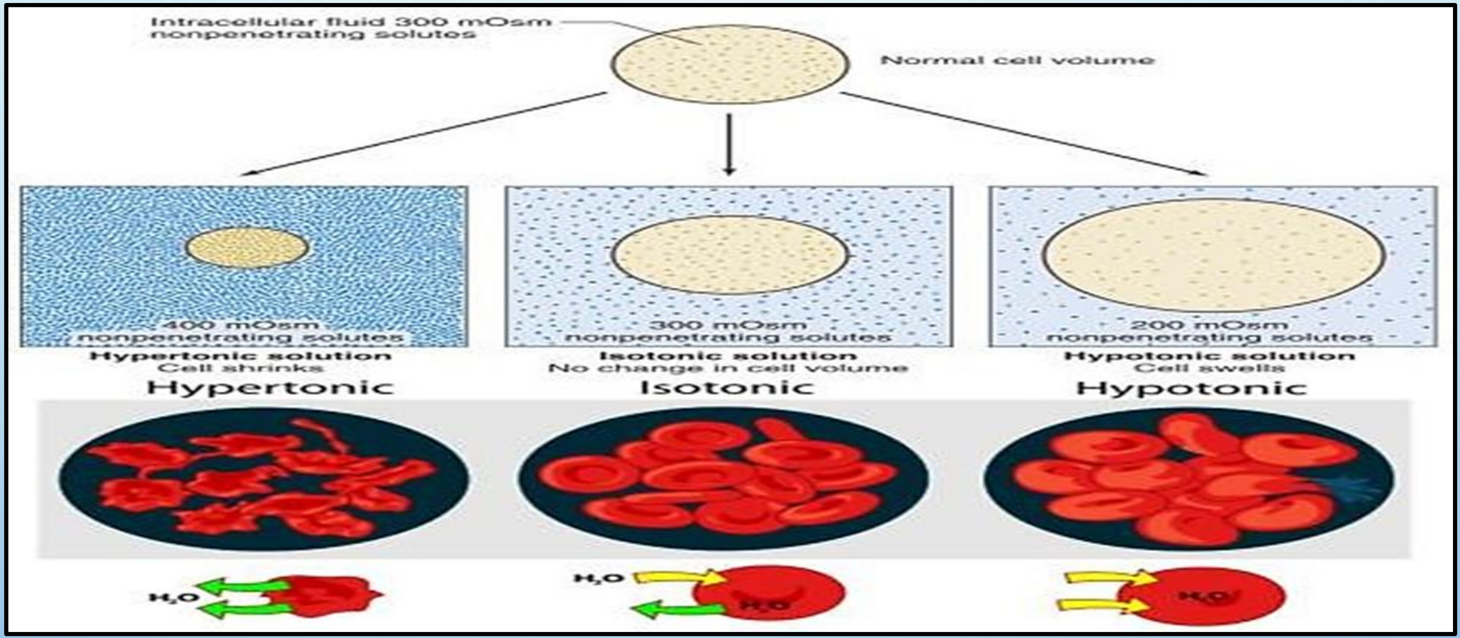
The total plasma osmolarity is important in assessing dehydration, over hydration and other fluid and electrolyte abnormalities.

SOLUTIONS COMPARED TO PLASMA OSMOLARITY ARE 3 TYPES

Tonicity.

Describe the osmolarity of a solution relative to that of plasma.

Isotonic	Hypertonic	Hypotonic
Tonicity is equal to that of plasma osmolarity.	Tonicity is more than that of plasma osmolarity.	Tonicity is less than that of plasma osmolarity.
They are the only solutions allowed to be given to the patient parenterally (i.v.)	If given i.v. -------- it causes Shift of water from cells into the blood leading to Cell shrinkage.	If given i.v. ------ it causes Shift of water into the cells…..leading to Cell swelling or edema…..Cell rupture.
Ex. 0.9 % NaCl = **(saline)** 5 % Glucose	Used for treatment of cell edema	Used to treat cell dehydration



TYPES OF SOLUTIONS RELATIVE TO PLASMA OSMOLARITY

Cell volume regulation:

- All fluid compartments of the body (ICF&ECF) are in isosmotic equilibrium.
- The cell membranes are highly permeable to water. Whenever, the osmolality of either compartment is changed, water moves from less concentrated fluid to the more concentrated one. Cell **swells** if exposed to **extracellular hypotonicity** (↓ osmotic pressure) and cell **shrinks** if exposed to **extracellular hypertonicity** (↑ osmotic pressure).

APPLIED PHYSIOLOGY
DONNAN'S EFFECT (EQUILIBRIUM)

Donnan's Effect:

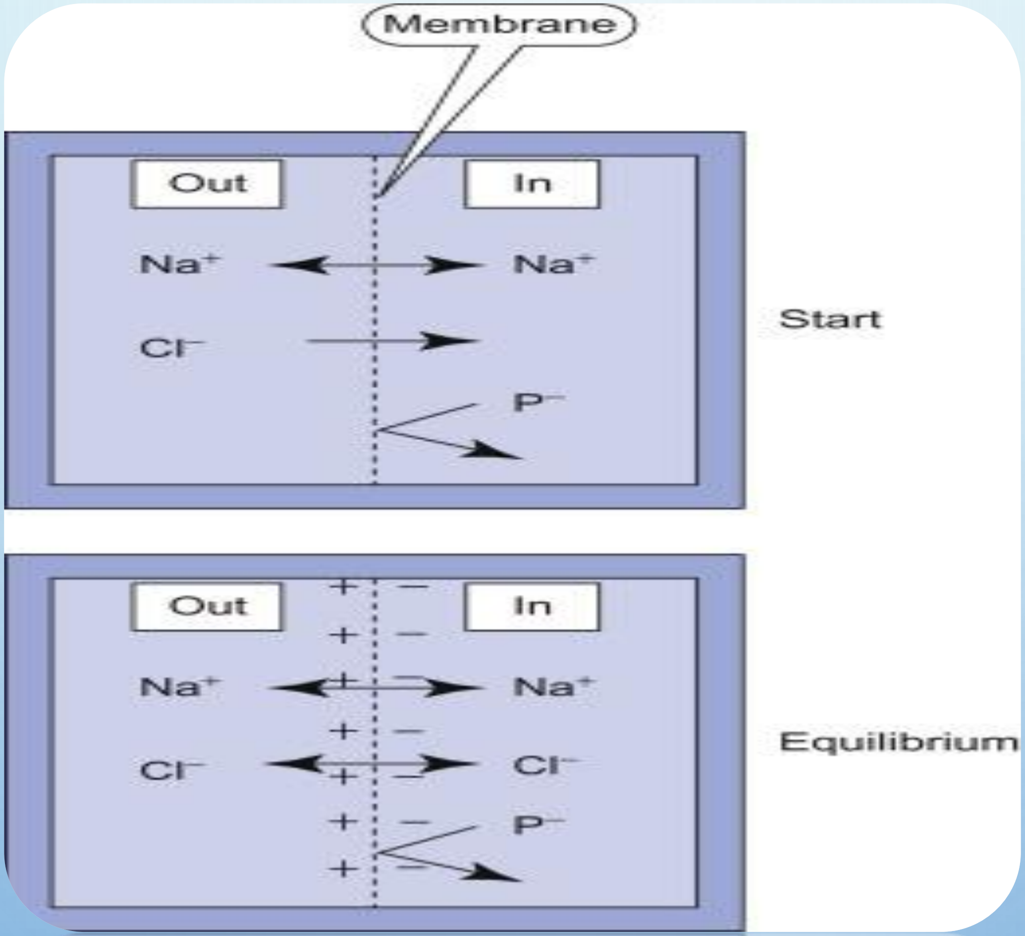
Definition:

The presence of non-diffusible ion (pr-) on one side of a semipermeable membrane affects the diffusion and distribution of other diffusible ions (e.g. NaCl) on both sides of the membrane------ leading to increased concentration of diffusible ions and water in the side where there is the non- diffusible ion.

Significance:

A. Inside the cells:

There are non-diffusible protein anions (Pr^-) ------------- exert Donnan's effect ------ shift of diffusible ions (as Na^+) followed by water into the cells → cell swelling → malfunction.


Membrane
Out
In
Na+
Na+
Cl−
P−
Start
Out
In
Na+
Na+
Cl−
Cl−
P−
Equilibrium

- Normally, this Donnan’s effect is antagonized by an active pump (needs energy from ATP) called (Na^+-K^+) pump ------- repulsion of any Na^+ molecules from entering the cells and subsequently water ---------- So, prevent Donnan’s effect and keep normal function of cells.

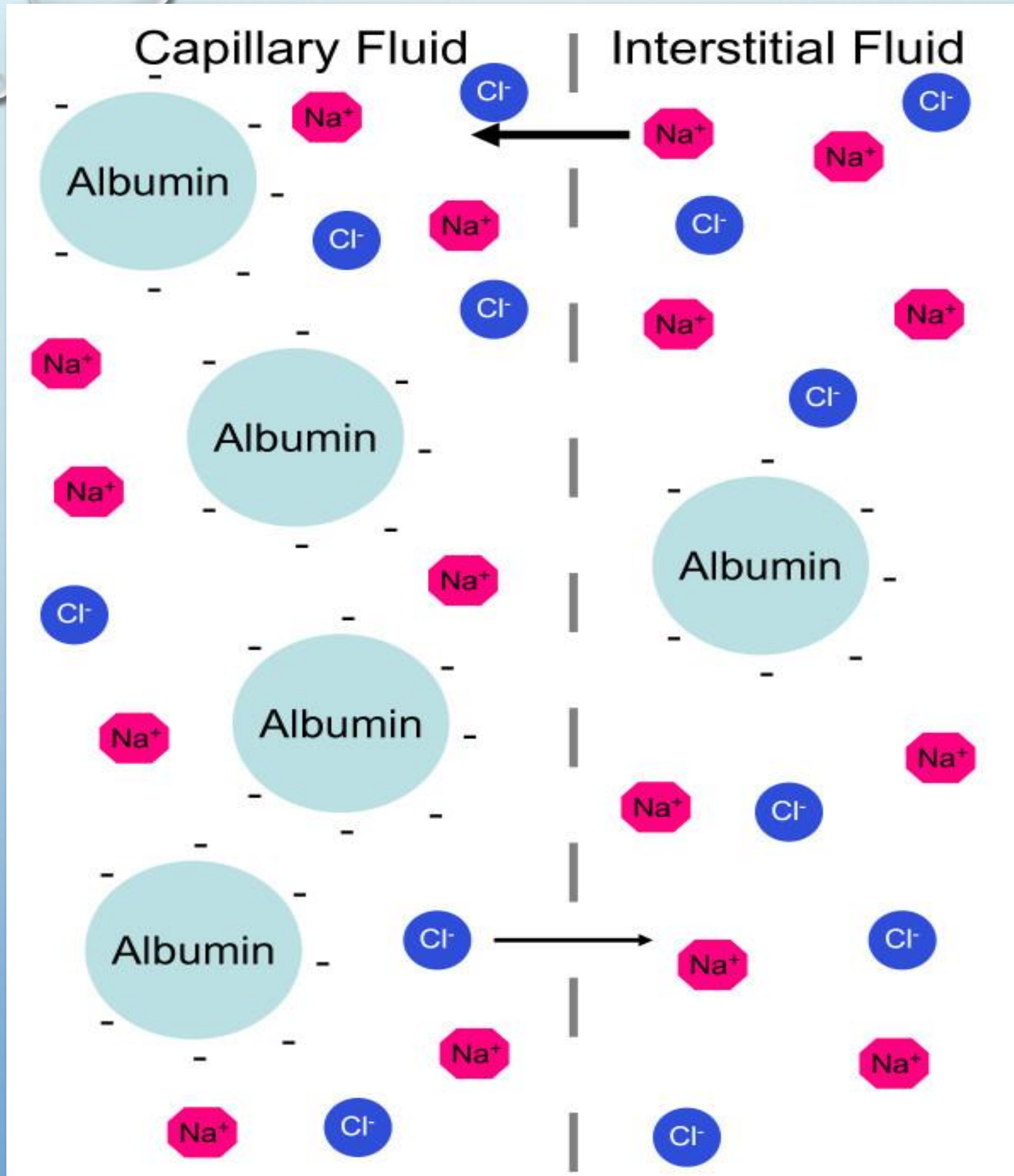
- In case of ATP depletion ------ Donnan’s effect is not antagonized by the Na^+-K^+ pump → cell swelling and malfunction.

Cell edema occurs in ATP deficiency.

Because depletion of ATP inside the cell stops Na^+-K^+ pump that leads to accumulation of active particles (Na^+) inside the cells because cells contain non diffusible anions (protein) that exert Donnan's equilibrium → ↑ number of osmotically active particles inside the cell → draw water into the cell → cell swelling (edema) and disturbed functions.

B. Inside the blood capillaries:

-There are non-diffusible protein anions (Pr^-) ------------- exert Donnan's effect -------- shift of diffusible ions (as Na^+) and water from tissue fluid into the blood -----↑ the blood volume ------ ↑ hydrostatic capillary pressure ------ ↑ filtration to oppose Donnan's effect to keep blood volume and pressure constant.



Capillary Fluid
Interstitial Fluid
Cl-
Na+
Albumin
Na+
Cl-
Na+
Cl-
Na+
Albumin
Na+
Na+
Cl-
Na+
Cl-
Albumin
Na+
Albumin
Na+
Cl-
Na+
Cl-
Na+
Albumin
Cl-
Na+
Cl-
Na+
Na+
Cl-
Na+
Cl-

Calculate the osmolarity of a solution containing: 1 mole of glucose and 2 moles of NaCl /Liter?

1 M glucose = 1 osmole

2 M NaCl (= 2x2) = 4 osmole

= 1 + 4=5 osmole/L

Calculate the osmolarity of a solution containing: 1 mole of glucose and 3 moles of NaCl /0.5 Liter?

1 M glucose= 1 osmole

3 M NaCl = 6 osmole

= 7 osmole/0.5 L

= 7 x2 = 14 osmole/L

- **PROBLEMS:**

180 gm glucose dissolved in 1 liter of distilled water, calculate the osmolarity of the solution? (MW for glucose = 180)

- Solution

- No of moles = $\frac{\text{Amount given}}{\text{MW}}$

$$= \frac{180}{180} = 1 \text{ MOLE}$$

SINCE, 1 MOLE OF GLUCOSE = 1 OSMOLE (NO. OF PARTICLES = 1)

SO, OSMOLARITY OF THE SOLUTION = NO. OF MOLES X NO. OF PARTICLES

= 1 X 1 = 1 OSMOLE / L

90 gm glucose dissolved in 1 liter distilled water, calculate the osmolarity of the solution? (MW of glucose = 180)

Solution:

- No of moles = $\frac{\text{Amount given}}{\text{MW}}$

$= \frac{90}{180} = 0.5$ MOLE

SINCE, 1 MOLE OF GLUCOSE……..1 OSMOLE (NO. OF PARTICLES = 1)

IF, 1/2 MOLE GLUCOSE ….. ?

SO, OSMOLARITY = NO. OF MOLES X NO. OF PARTICLES

= 0.5 X 1 = 0.5 OSMOLE/L

117 gm NaCl dissolved in 2 liter of distilled water, calculate the osmolarity of the solution? (MW of NaCl = 58.5 gm)

Solution:

First, adjust the volume

Amount given in 1 liter = 117 / 2 = 58.5 gm/L

- No of moles = $\frac{\text{Amount given}}{\text{MW}}$

$= \frac{58.5}{58.5} = 1$ MOLE

SINCE, 1 MOLE OF NACL → 2 OSMOLES (NO. OF PARTICLES = 2)

SO, OSMOLARITY OF THE SOLUTION = NO. OF MOLES X NO. OF PARTICLES

= 1 X 2 = 2 OSMOLES/L


THANK
YOU