# NEET- 2020- 45 Days Crash Course

Date : 31st Aug 2020

Chapter Name : TRANSPORT IN PLANTS

Lecture Outline :

DIFFUSION , OSMOSIS, WATER POTENTIAL

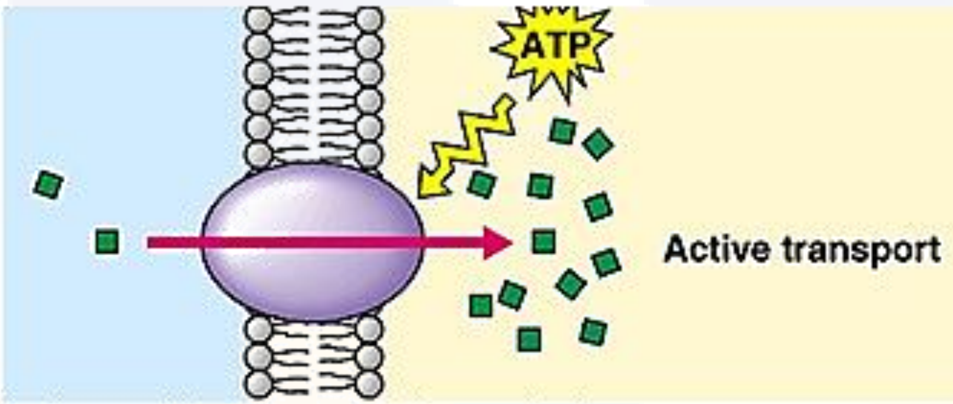
ABSORPTION OF WATER AND MINERALS

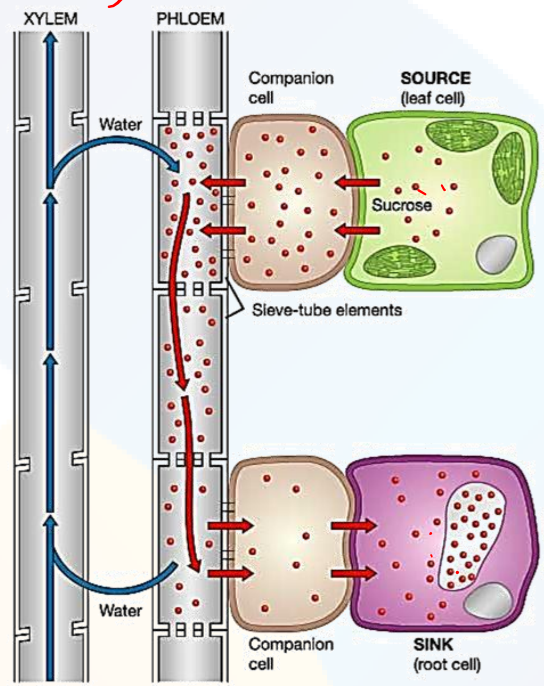
# Plant physiology

- Stephan hales (1727) is known as ‘Father of plant physiology’
- Plant physiology is a branch of science which deals with the study of all biological activities of plants. ( P, R, T, Growth )
- Plants absorb water and minerals from land.
- 80-90% part of plant is made up of water.

# TRANSPORT IN PLANTS

- Over small distances substances move by diffusion and by cytoplasmic streaming supplemented by active transport.




- Transport over long distances proceeds through the vascular system (the xylem and the phloem) and is called translocation.

## Diffusion

- The movement of molecules of gases, Liquid solid from the region of higher concentration to the region of lower concentration is called **diffusion.** passive

- The molecules move from the higher concentration to lower concentration due to kinetic energy until an equilibrium is obtained. along the conc gradient; dynamic equilibrium

- **Ex:** Diffusion of copper sulphate particles in water, Diffusion of Ammonia in air.

- The potential ability of a substance to diffuse from an area of its greater concentration to an area of its lower concentration is called **diffusion pressure.** → exerted by diffusing molecules, ions on the medium

Diffusion Rate → Gas > Liq > Solid

Diffusion Pressure of pure solvent is greater than its soln (solute added)

Rate of Diffusion decrease with ↑ size.

# Factors affecting rate Of Diffusion

- **Temperature** increases than the rate of diffusion is increased.

  Rate of diffusion ∝ Temperature

- **Density:** Rate of Diffusion is maximum in Gases

  Gases > Liquid > Solid

- **Diffusion pressure gradient (DPG)**

$$D \propto \frac{1}{\sqrt{d}}$$

$$DPG = \frac{\text{Differences between diffusion pressure at two places}}{\text{Distance of diffusion}} = \frac{DP_1 - DP_2}{D}$$

- **Pressure:** Rate of Diffusion ∝ Pressure

## Significance of Diffusion

- The exchange of gases ($O_2$ & $CO_2$) takes place through diffusion.
- Passive absorption of ions of mineral substances in plants.
- Evaporation of water from intercellular spaces during transpiration through diffusion.
- Distribution of hormones in plants through diffusion.
- Osmosis is a special type of diffusion.

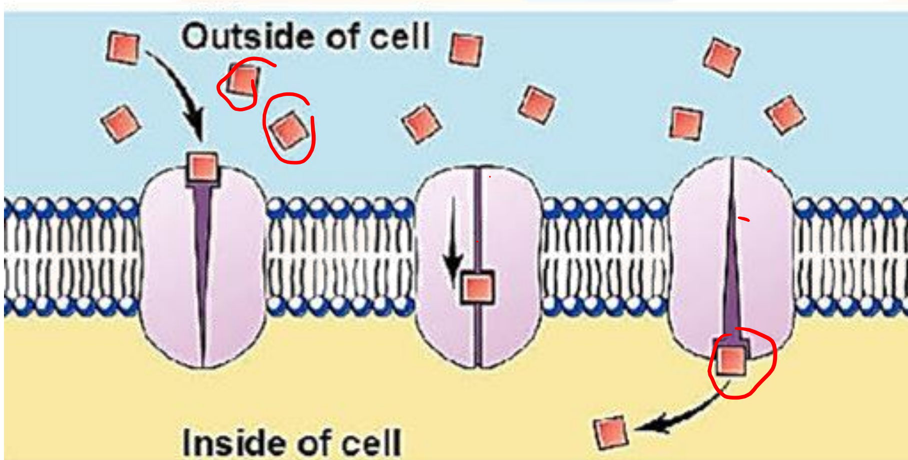
# FACILITATED DIFFUSION

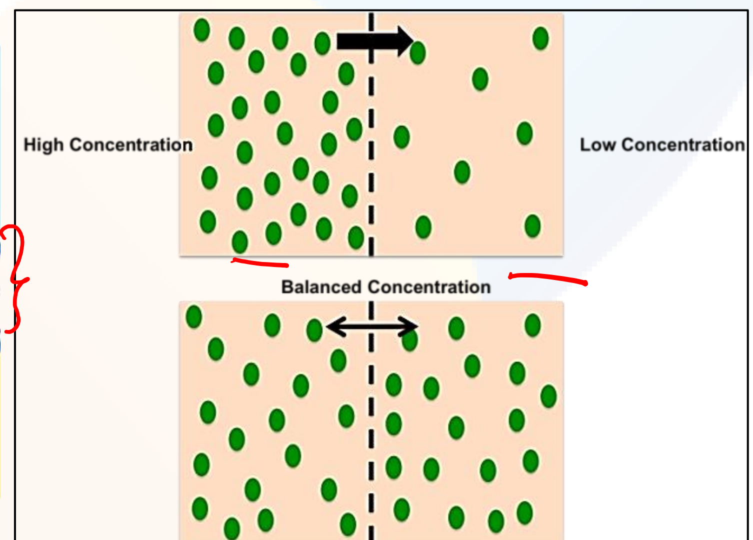
Carrier proteins involved

- ❖ The movement of molecules from higher concentration to lower concentration with the help of certain proteins present in the plasma membrane is called facilitated diffusion.

In facilitated diffusion, special proteins help to move substances across membranes without expenditure of ATP energy.

protein required, But no ATP

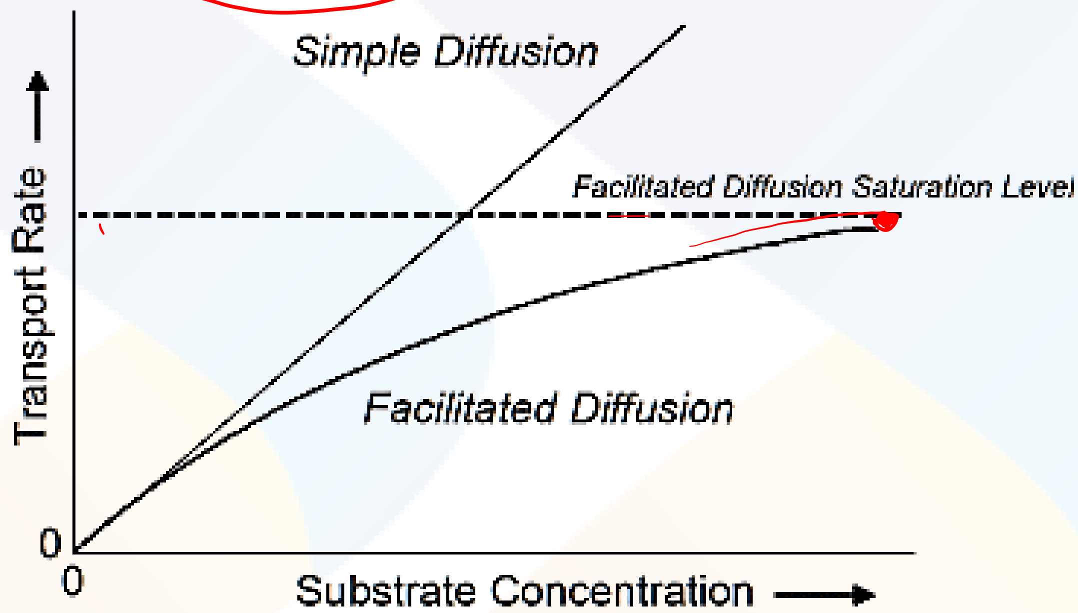


# FACILITATED DIFUSSION

- ❖ Transport rate reaches maximum when all of the protein transporters are being used.

This is called transport saturation.




→ when all carrier proteins are used up

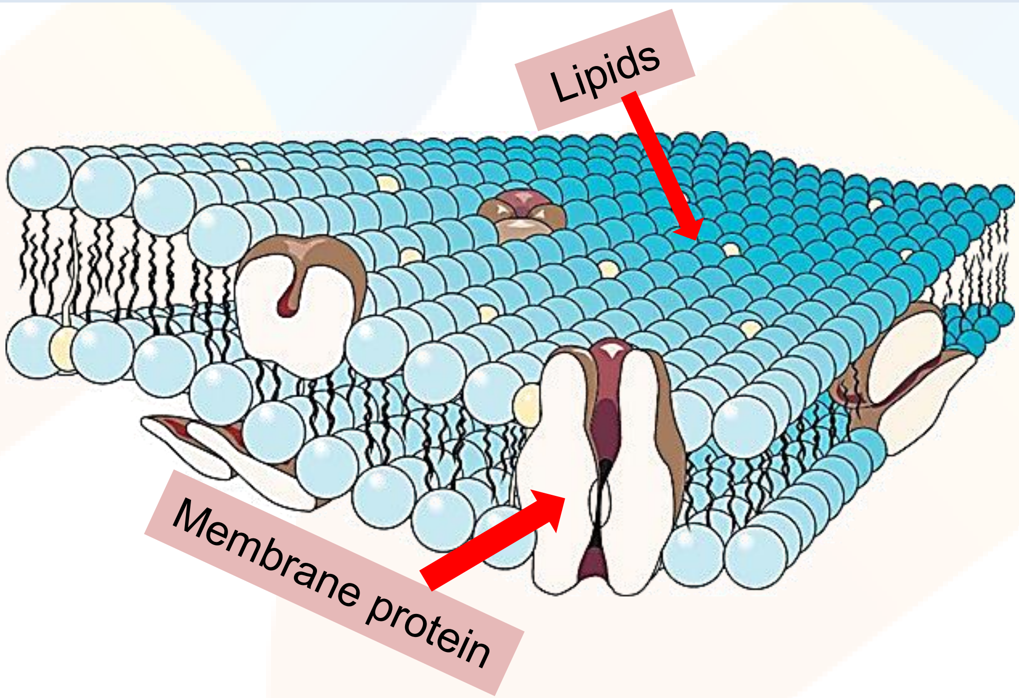
- ❖ Facilitated diffusion is very specific. due to carrier proteins
- ❖ Specific molecules are only carried by specific proteins.
- ❖ Facilitated diffusion is sensitive to inhibitors which react with protein side chains.

# LIPID SOLUBLE SUBSTANCES

The diffusion of any substance across a membrane also depends on its solubility in lipids.

Substances soluble in lipids diffuse through the membrane faster. as PM has phospholipid Bilayer

- ❖ Substances that have a hydrophilic moiety find it difficult to pass through the membrane.
- ❖ So their movement has to be facilitated. they are carrier proteins
- ❖ Membrane proteins provide sites at which such molecules cross the membrane.



# Facilitated Diffusion

- Lipid soluble substances diffuse faster through the membrane, but hydrophilic solutes, difficult to pass through the membrane, their movement has to be facilitated.
- Special proteins are helpful in the movement of substances across membranes without expenditure of ATP energy. E.g. aquaporin and ion channels.
- Carrier proteins allow transport only if two types of molecules move together. It is called **cotransport.**

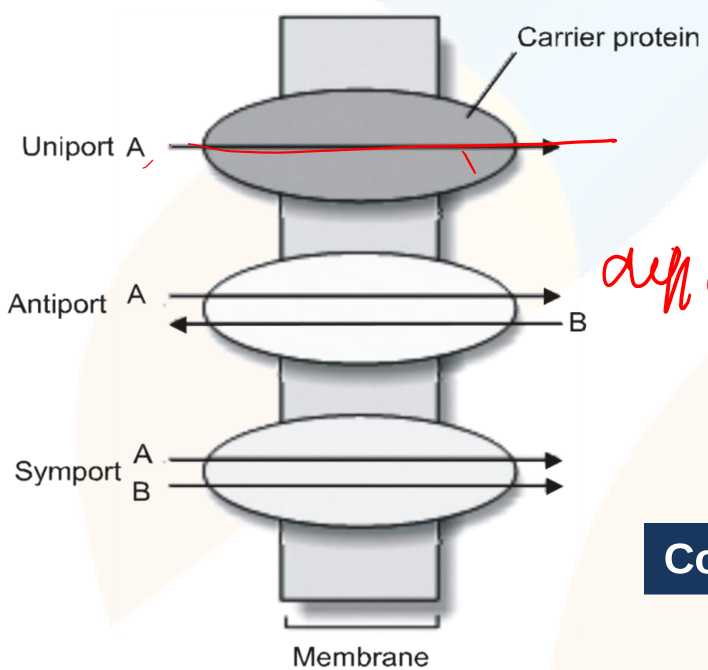



Fig : Facilitated diffusion

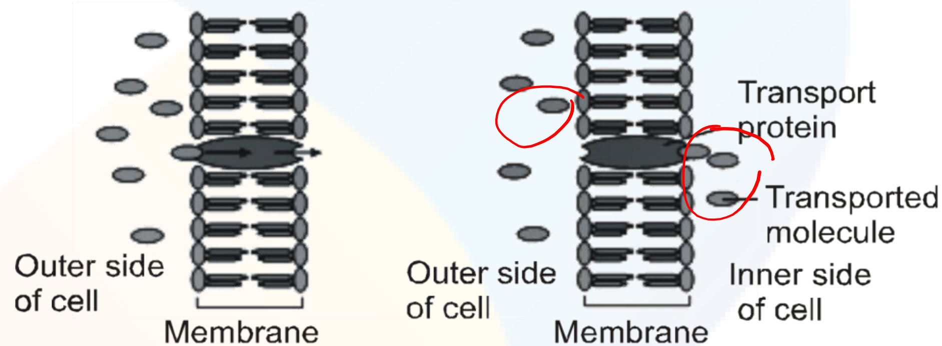



Fig : Facilitated diffusion

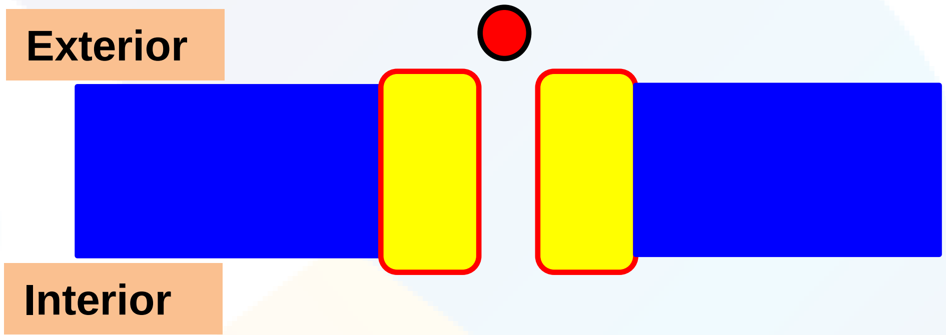
**Cotransport**
- **Uniport** → One protein
- **Antiport** → Opposite side
- **Symport** → Same side

# SYMPORT AND ANTIPORT

❖ Transport proteins can move molecule by

**1.Uniport**

If a molecule moves across a membrane independent of other molecules, the process is called uniport.




**2. Co-transport**

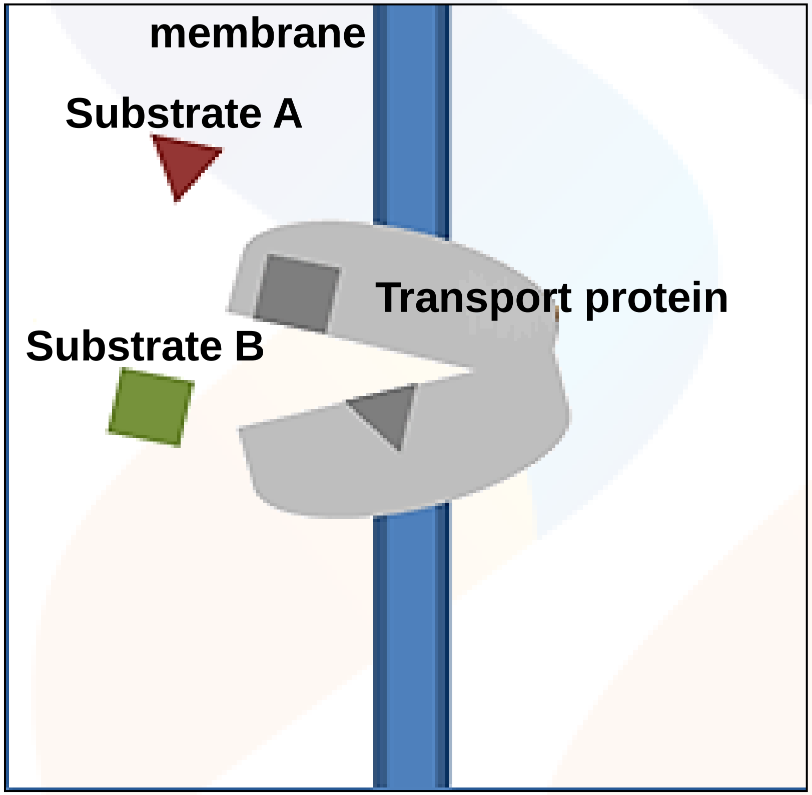
❖ Some carrier or transport proteins allow diffusion only if two types of molecules move together.

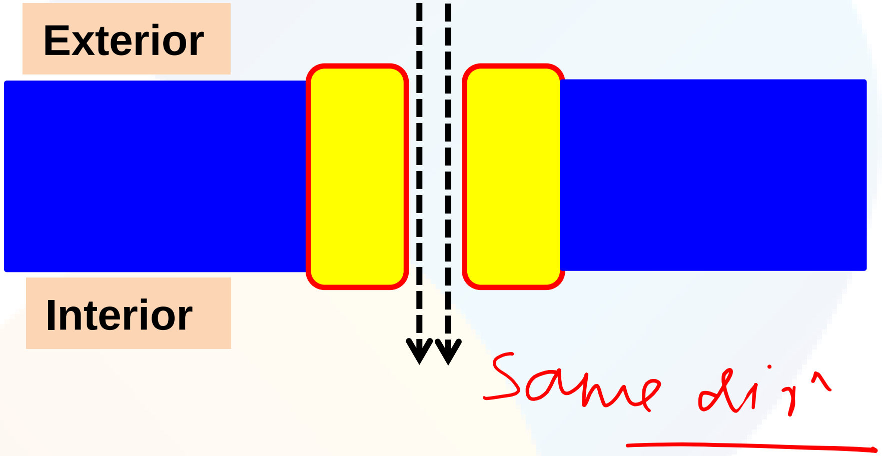
❖ Co-transport is two types:

- **Symport**
- **Antiport**

# SYMPORT

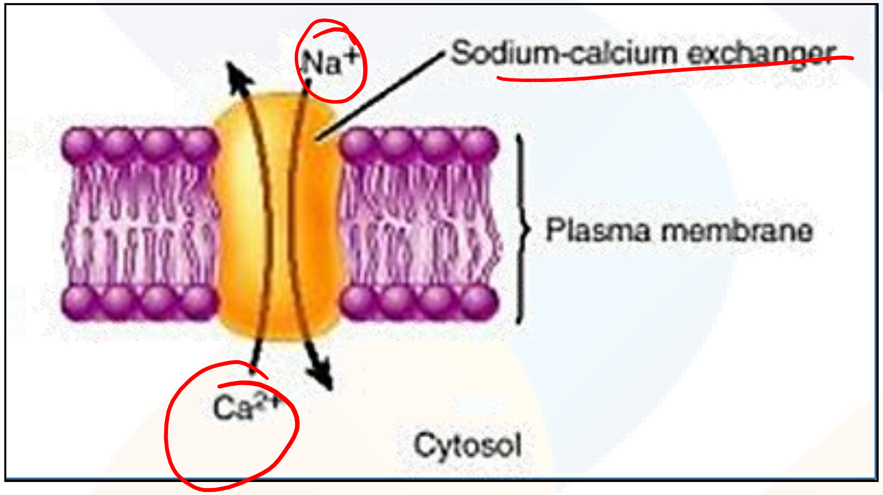
- ❖ In a symport, both molecules cross the membrane in the same direction.

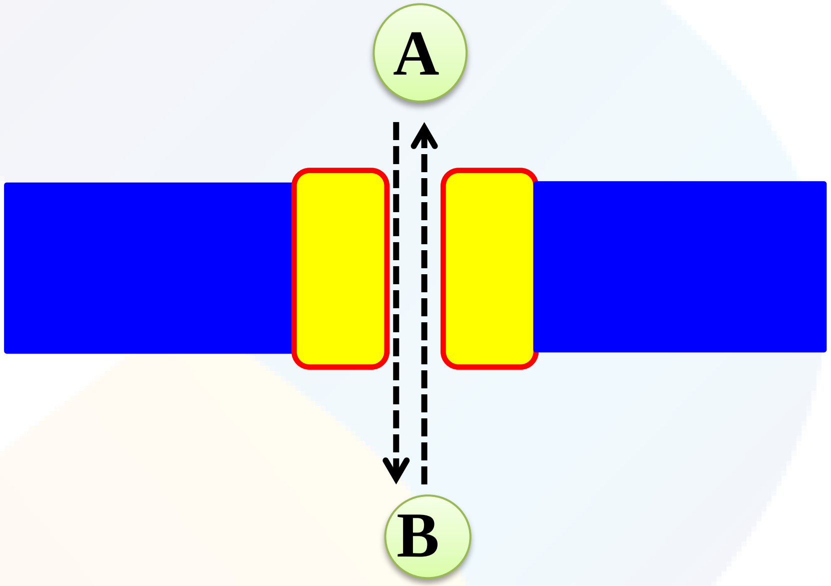


# ANTIPORT

❖ In an antiport, they move in opposite directions.

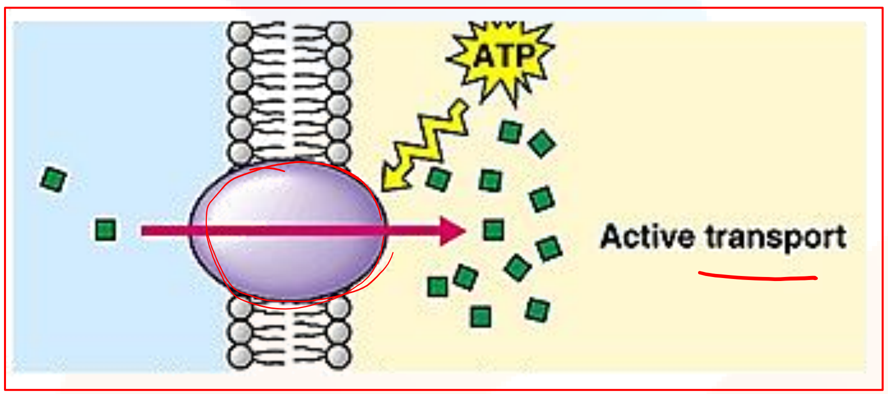


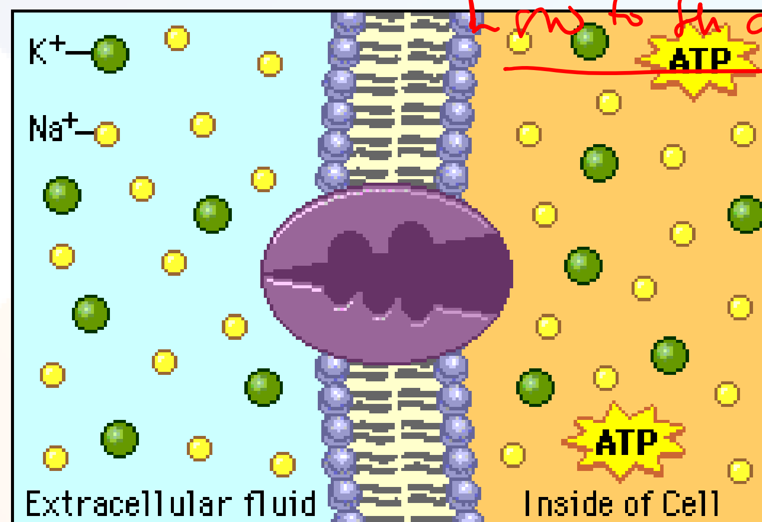



# ACTIVE TRANSPORT

Active transport is also carried out by membrane –proteins.

- ❖ Active transport uses energy to pump molecules against a concentration gradient.

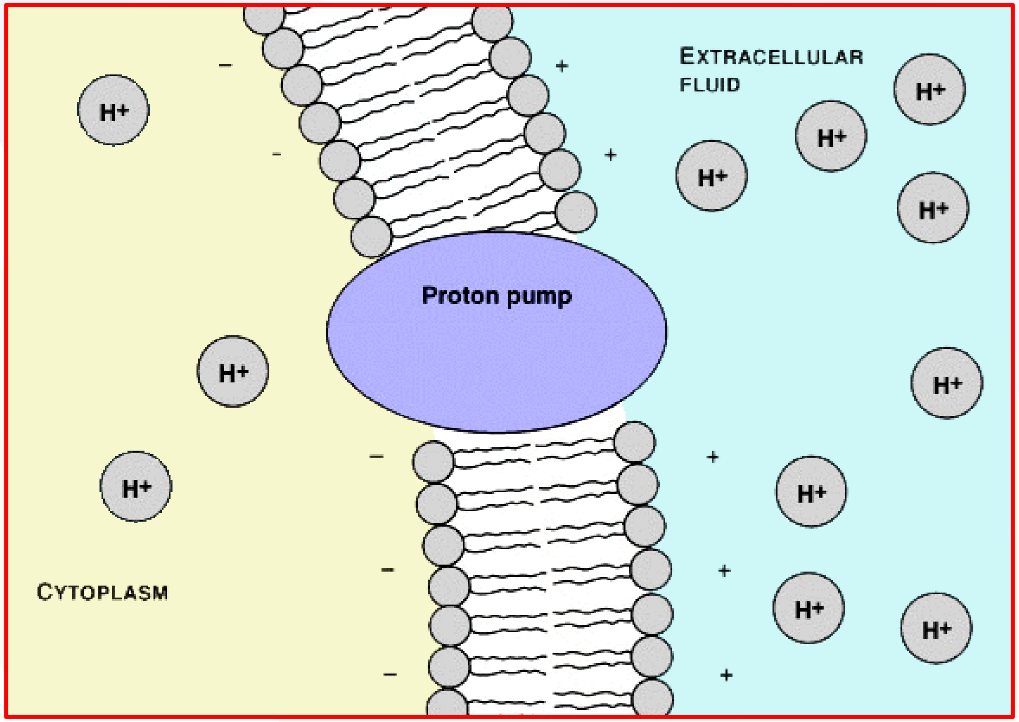


# PUMPS

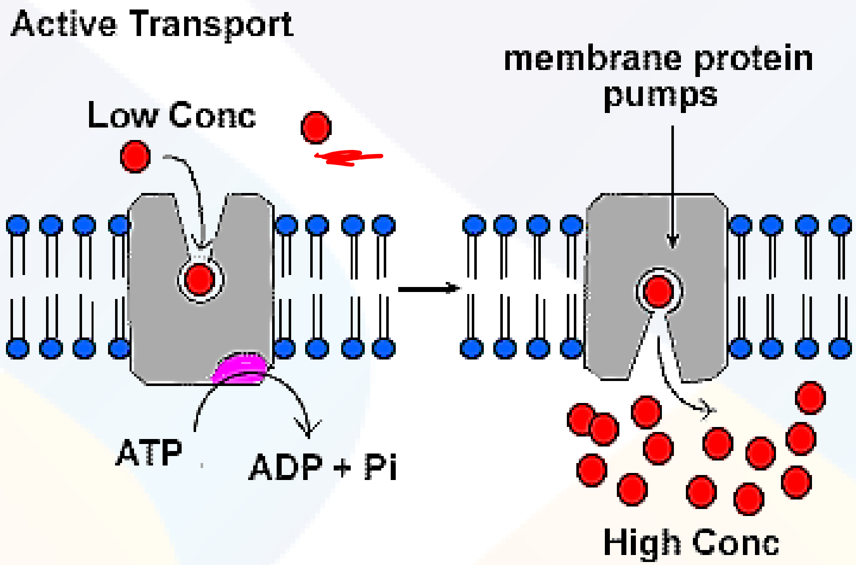
- Different proteins in the membrane play a major role in both active as well as passive transport.

- Pumps are proteins that use energy to carry substances across the cell membrane.



# MEMBRANE PROTEIN PUMPS

- These pumps can transport substances from low concentration to high concentration ('uphill' transport).



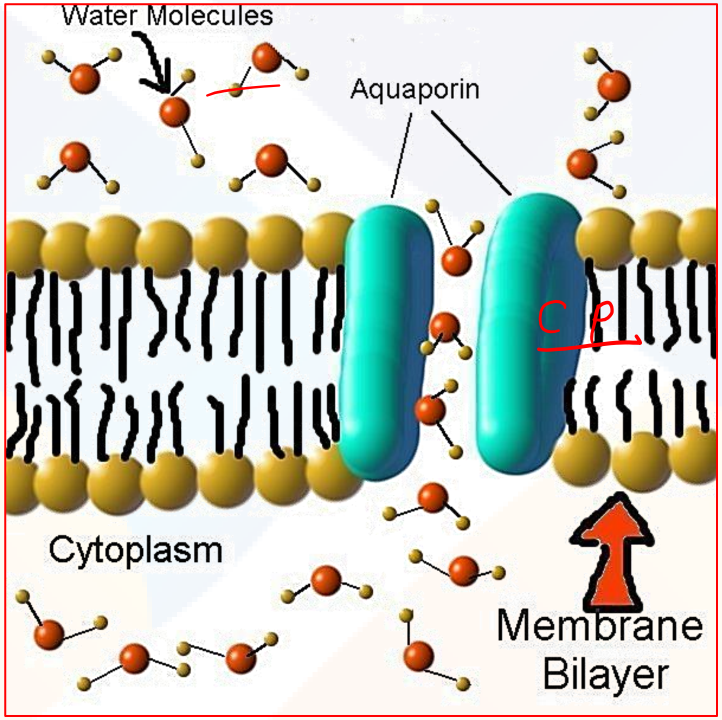

- Transport rate reaches maximum when all the protein transporters are being used or are saturated.

- Like enzymes the carrier protein is very specific in what it carries across the membrane.

- These proteins are sensitive to inhibitors that react with protein side chains.

# AQUAPORINS

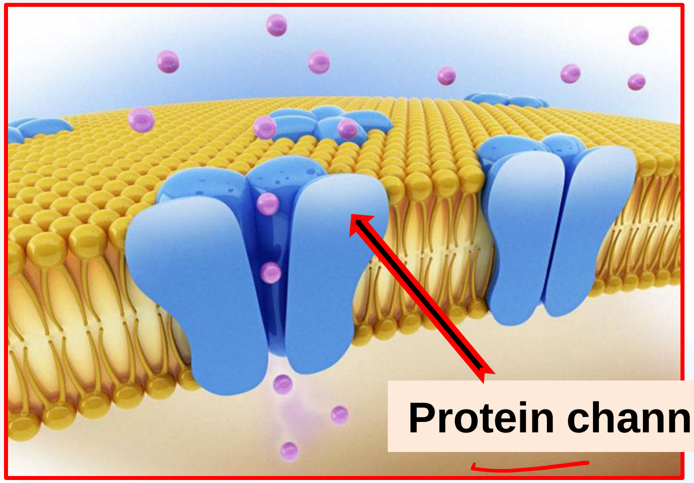
- One of the examples for porins is water channel made up of eight different types of aquaporins.




- Extra cellular molecule bound to the transport protein: the transport protein then rotates and releases the molecules inside the cell.

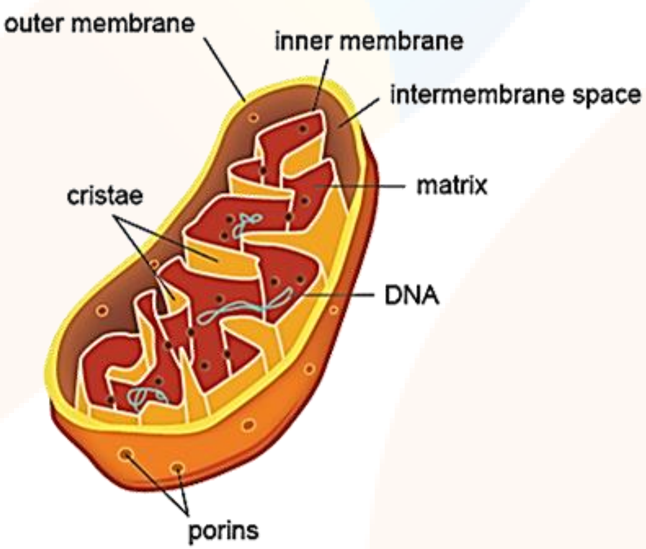
# CHANNEL PROTEINS – PORINS

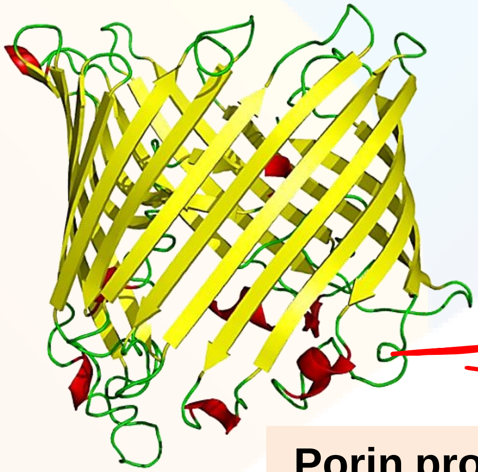
- The proteins form channels in the membrane for molecules to pass through.
- Some channels are always open; others can be controlled.
- Porins are proteins that form huge pores in the outer membranes of the plastids, mitochondria and some bacteria.



Protein channels

- These proteins allow molecules upto the size of small proteins to pass through.



Porin protein

# PORINS AND AQUAPORINS

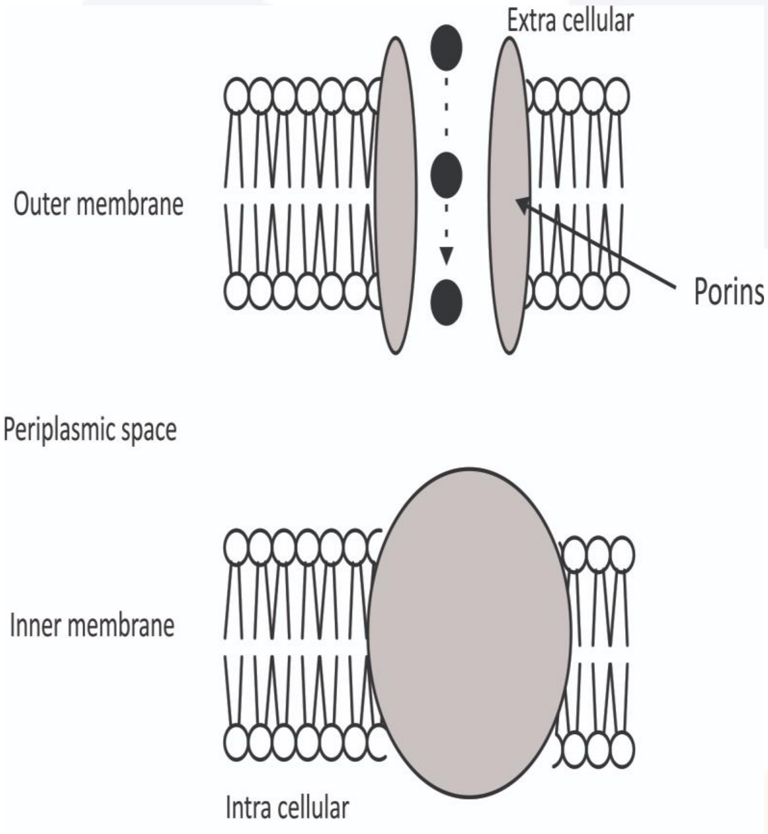
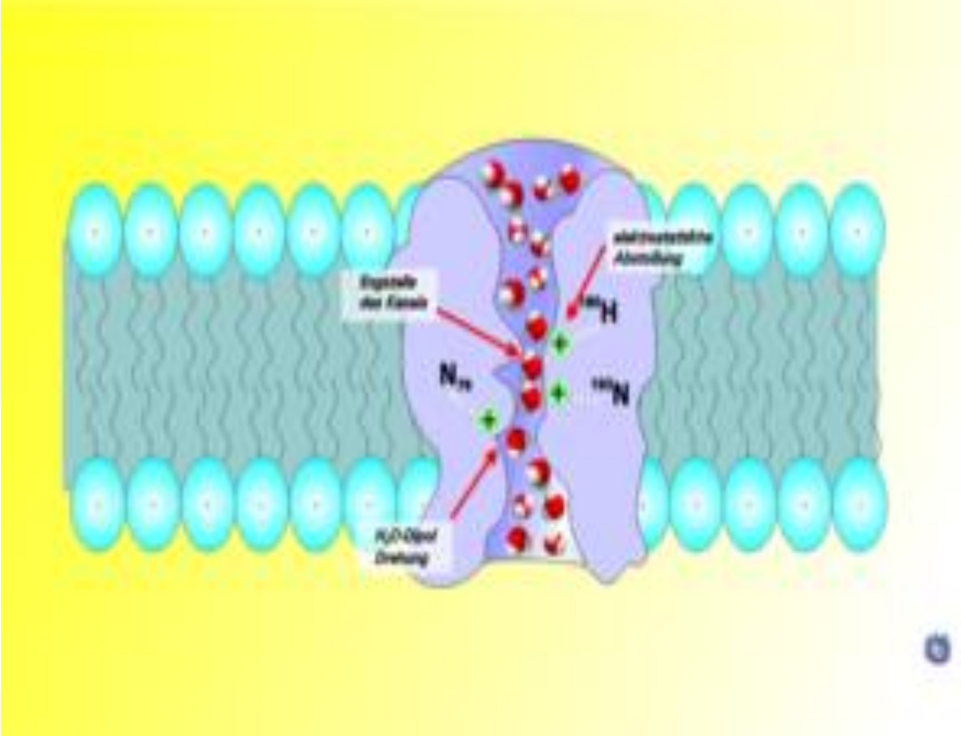



Fig. : Porins



# COMPARISON OF TRANSPORT PROCESSES

NCERT → **

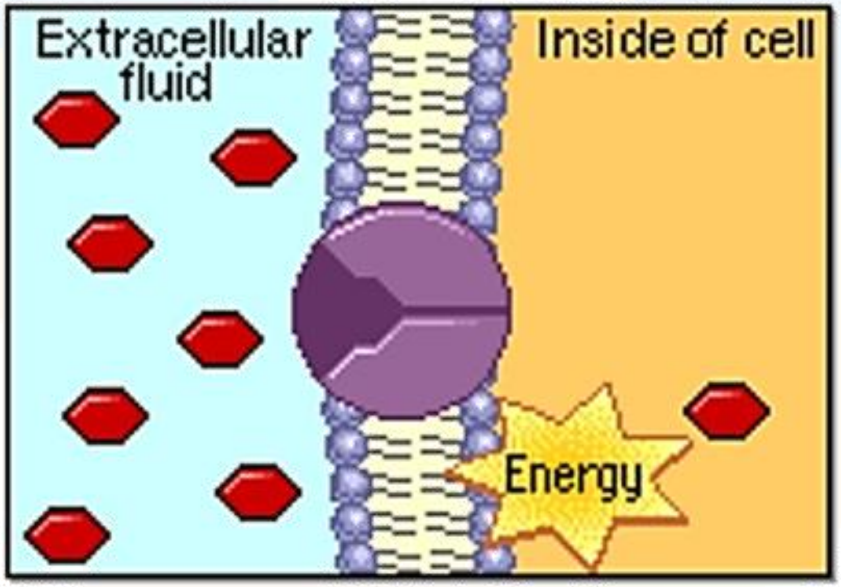
| Property | Simple diffusion | Facilitated transport | Active transport |
|---|---|---|---|
| Requires special membrane proteins | No | Yes | Yes |
| Highly selective | No | Yes | Yes |
| Transport saturates | No | Yes | Yes |
| Uphill transport | No along | No along | Yes low to high |
| Requires ATP energy | No | No | Yes |

# Active Transport

- Active transport use energy in the form of **ATP** in the process of pumping molecules against the concentration gradient.

- The **ATP** donates a phosphate to a particular gateway molecule which then pumps the desired molecule across membrane, even if goes opposite concentration gradient.

- Thus, the energy of **ATP** is used to drive the pump.




This transport requires energy in the form of ATP

# Permeability

- Exchange of different substances from plasma membrane is called **permeability**.

## On the basis of permeability

### Permeable membrane

Permeable for the both solute and solvent

**Ex: cellulosic cell wall**

### Impermeable membranes

Inhibit the diffusion of both solute & solvent particles

**Ex: cutinised or suberized cell walls**

*impervious*

### Semi-permeable membrane

Impermeable for solute and permeable for solvent

**Ex: Copper ferrocyanide membrane, Cellophane**

*cellophane, parchment paper, goat bladder*

### Selectively permeable membrane or differential permeable membrane

Permeable for some solute along with solvents

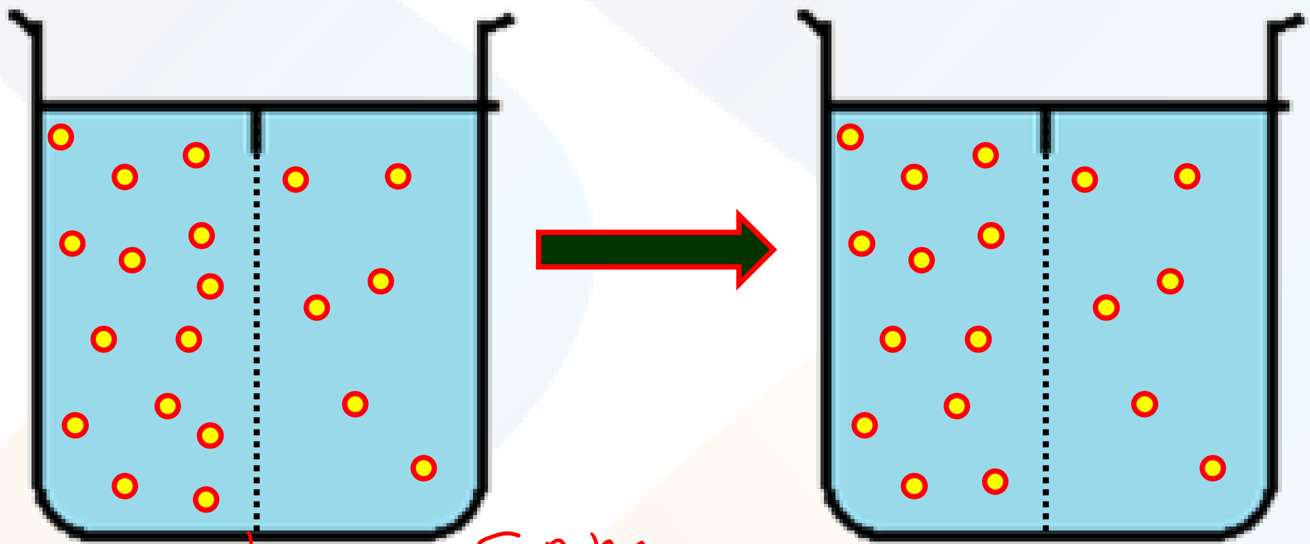
**Ex: Plasma membrane**

*tonoplast, organelle membranes*

# OSMOSIS

- Osmosis is the term used to refer specifically to the diffusion of water across a semi-permeable membrane.

- Osmosis occurs spontaneously in response to a driving force.



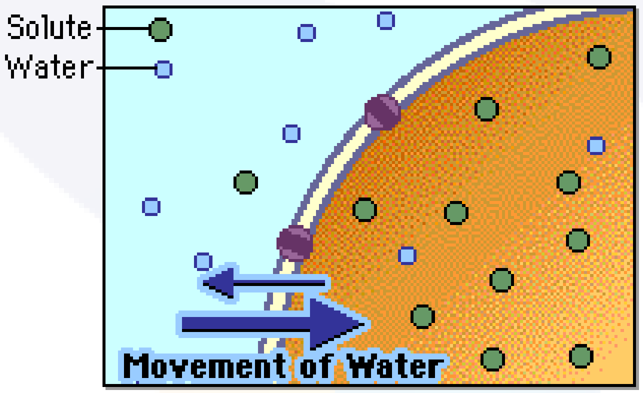
- The net direction and rate of osmosis depends on

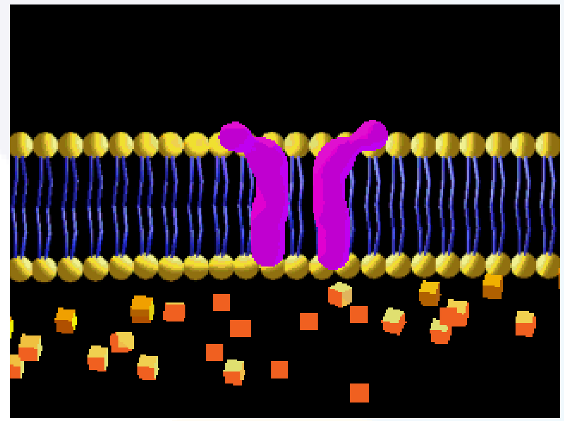
**Pressure gradient.**

**Concentration gradient.**

# MECHANISM OF OSMOSIS

- Most of the water is absorbed by plants through osmotic mode that occurs due to concentration gradient and does not require any metabolic energy (passive absorption).



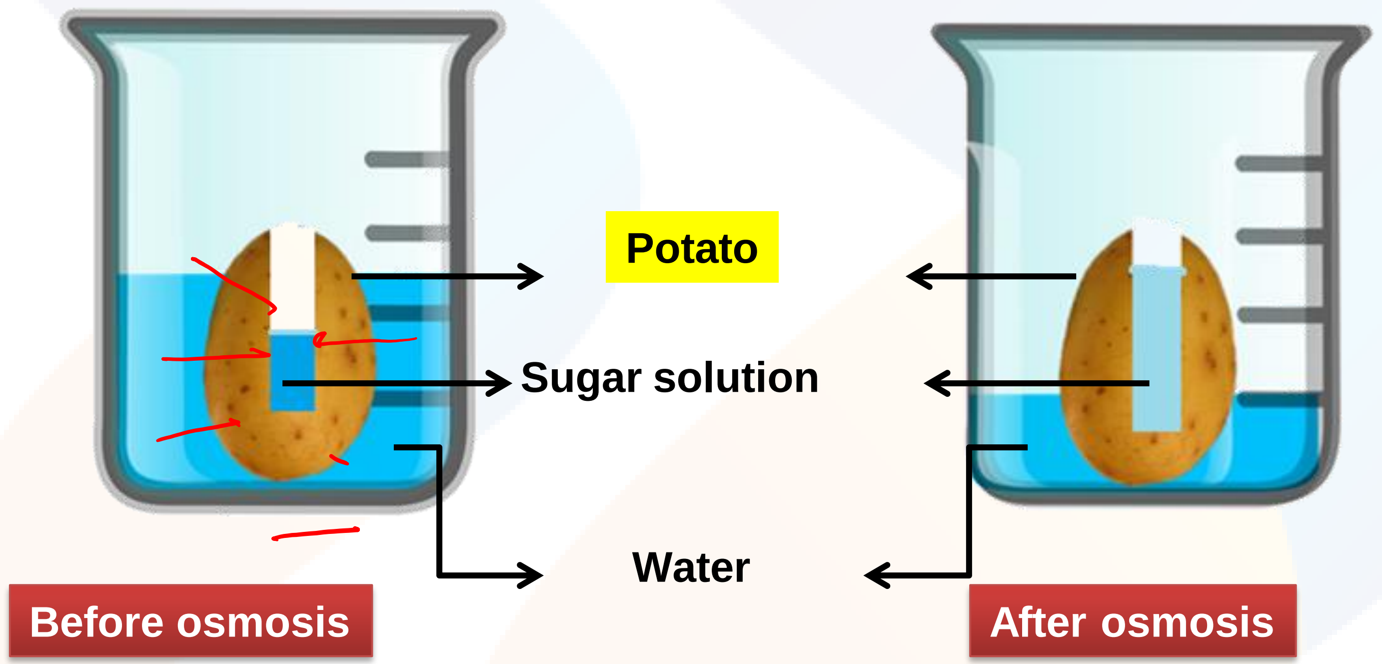



- Water moves from its region of higher chemical potential (or concentration) to its region of lower chemical potential until equilibrium is reached.

- At equilibrium the two chambers will have the same water potential.

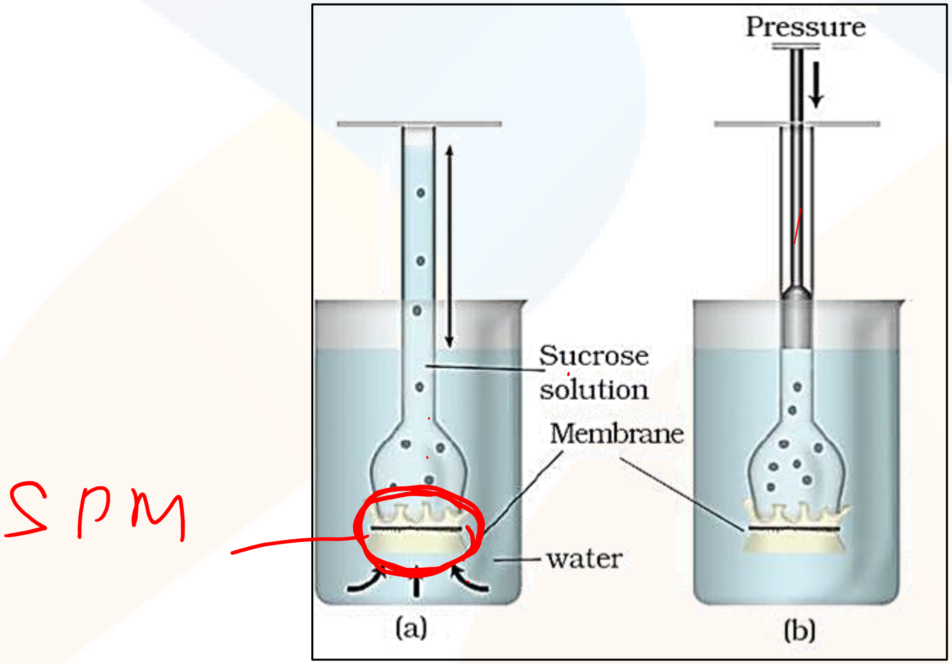
# POTATO OSMOSCOPE EXPERIMENT

- If the potato tuber containing a concentrated solution of sugar is placed in a beaker containing normal water, the cavity in the potato tuber collects water due to osmosis.



# THISTLE FUNNEL EXPERIMENT

- ❖ This experiment is also used to demonstrate osmosis.
- ❖ In this experiment, a solution of sucrose is taken in a thistle funnel which is separated from pure water in a beaker through a semi-permeable membrane.

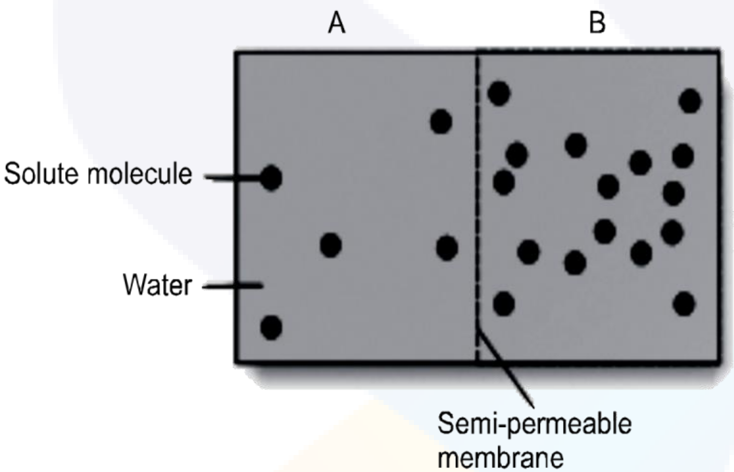


# THISTLE FUNNEL EXPERIMENT – 2

- ❖ Water will move into the funnel resulting in increasing the level of the solution in the funnel.
- ❖ This will continue till the equilibrium is reached.
- ❖ External pressure can be applied from the upper part of the funnel such that no water diffuses into the funnel through the membrane.
- ❖ This pressure required to prevent water from diffusing is, in fact the osmotic pressure and this is the function of solute concentration.
- ❖ The more the solute, the greater will be the pressure required to prevent water from diffusing in.
- ❖ Numerically osmotic pressure is equivalent to the osmotic potential, but the sign is opposite.
- ❖ Osmotic pressure is the positive pressure applied while osmotic potential is negative.

# Osmosis

- Type of diffusion higher concentration to lower concentration through semi permeable membrane.



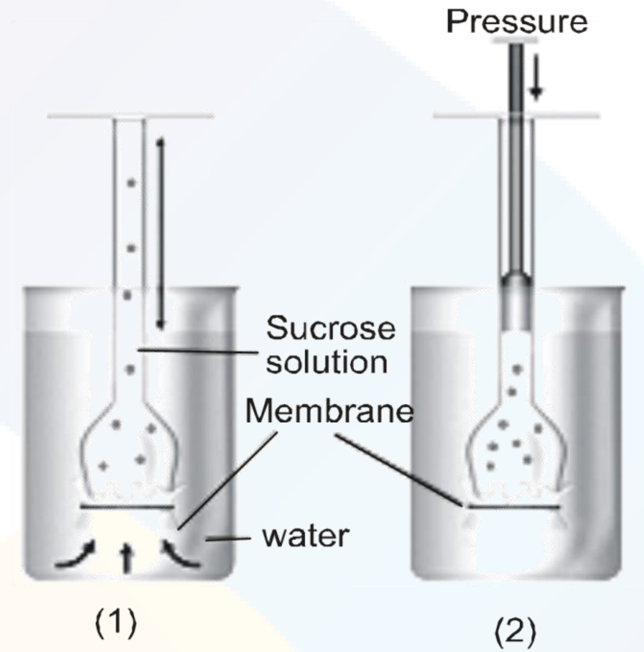




**Fig : A demonstration of osmosis.**
**A thistle funnel is filled with sucrose solution and kept inverted in a beaker containing water. (1) water will diffuse across the membrane (as shown by arrows) to raise the level of the solution in the funnel (2) pressure can be applied as shown to stop the water movement into the funnel**

## ❖ Types of osmosis

- **Endosmosis:** Intake of water molecules into the cell sap through osmosis.

- **Exosmosis:** Exit of water molecules from cell.

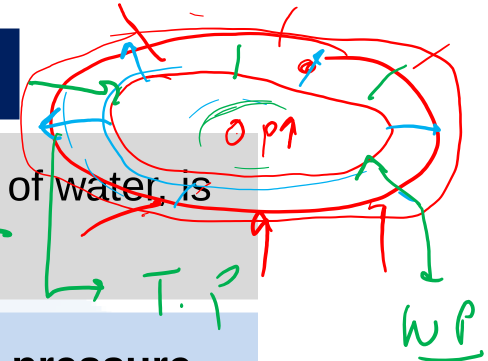
# Osmotic Pressure (OP)

- The pressure needed to prevent the passage of water into the solution through semipermeable membrane is called osmotic pressure.
- Osmotic pressure of pure water is zero.
- OP is measured by osmometer which was firstly made by Pfeffer.
- **OP = CRT** (for nonelectrolyte solutions)
- O.P. ∝ Temperature
- $\Psi_s = -\mathbf{p}$

## ❖ Significance of Osmosis

- Root hairs absorb water from soil through osmosis.
- Exchange of soluble substances & water from one cell to another cell by osmosis.
- Osmosis cause turgidity in plants which is helpful to maintain the definite shape of leaves, stem & flowers. It also provides mechanical support to the plant.
- Opening and closing of stomata, germination of seeds, dehiscence of sporangium. Seismonasty in Mimosa pudica occurs due to osmosis
- The resistance of plants to drought and frost increases with increase in osmotic pressure of their cells.

# Turgor Pressure (TP) And Wall Pressure (WP)



- The pressure created by cytoplasm upon the cell wall due to intake of water, is called **turgor pressure (TP)**
- The pressure created by cell wall upon the cytoplasm is called **wall pressure (WP).** Usually TP & WP are equal and opposite in direction.
- **Turgor pressure in flaccid cell is zero**
- Turgor pressure is maximum in turgid cell and equal to the osmotic pressure (OP).

## ❖ Diffusion Pressure Deficit (DPD)

- The amount by which the diffusion pressure of a solution is lower than that of its solvent is called DPD. It is also called **Suction pressure (SP).**
- Osmosis occurs from a region of lower DPD (SP) to region of higher DPD (SP).
- On full turgidity of cell DPD will be zero. So water does not enter in cell.
- In plasmolysed cell DPD is maximum because TP is negative.

# Water Potential

- The difference between the free energy of water molecules in pure water and the energy of water in any system is called **water potential**.
- Water potential (Ψ) of protoplasm is equal to DPD but opposite in sign.
- **Taylor & Slatyer** gave the term water potential.
- Water potential of pure water is maximum and zero.
- Water potential is denoted by **Psi (Ψ)** letter. It is measured in **Bar**.
- Movement of water occurs from region of higher water potential to region of lower water potential.

**Water potential = Matric potential + Osmotic or Solute potential + Pressure Potential**

$$\Psi_W = \Psi_m + \Psi_s + \Psi_P$$

# EFFECT OF SOLUTE ON WATER POTENTIAL

❖ If some solute is dissolved in pure water, the solution has fewer free water molecules and the concentration of water decreases, reducing its water potential.

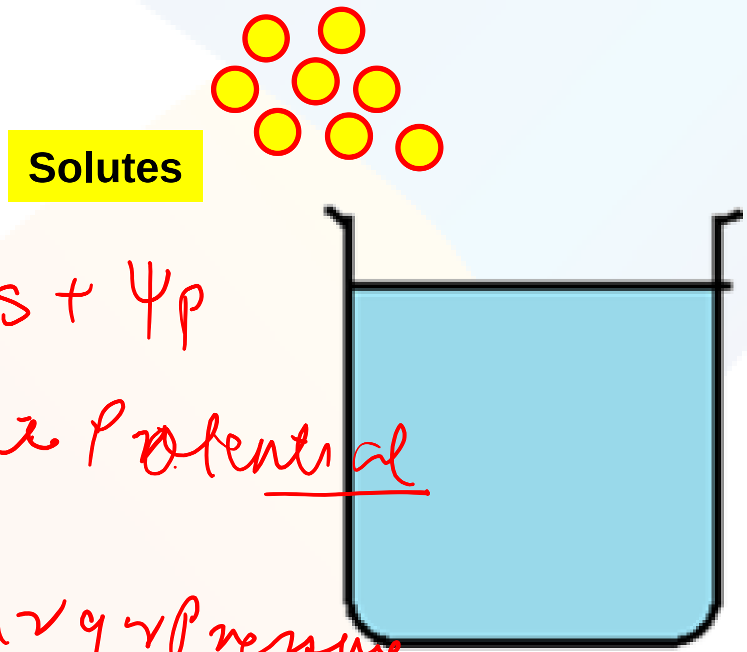
Hence all solutions have a lower water potential than pure water.

The magnitude of this lowering due to dissolution of a solute is called solute potential or $\Psi_S$.

$\Psi_S$ is always negative

Concentration of water ↓

Water potential ↓




$\Psi_w = \Psi_s + \Psi_p$

$\Psi_s$ = Osmotic P / Solute Potential

$\Psi_p$ = Pressure P / Turgor Pressure

# SOLUTE POTENTIAL

- For a solution at atmospheric pressure

The more the solute molecules, the lower (more negative) is $\Psi_S$.

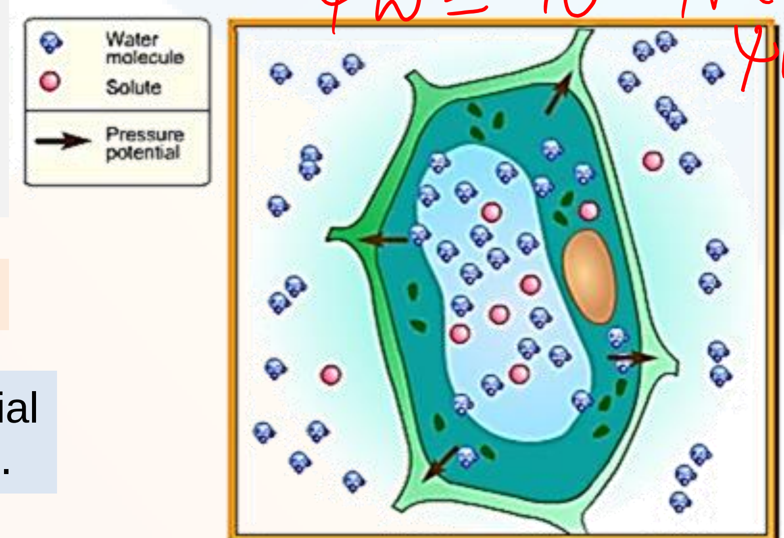
(Water potential) $\Psi_W$ = (solute potential)$\Psi_S$.

Fully turgid cell
OP = -10, PP = +10
$\Psi_W = -10 + 10 = 0$

❖ If a pressure greater than atmospheric pressure is applied to pure water or a solution, its water potential increases.

Flaccid cell
$\Psi_W = -10$ $\Psi_P = 0$
$\Psi_W = \Psi_S$

❖ Pressure can build up in a plant system when water enters a plant cell due to diffusion, causing a pressure to build-up against the cell wall.




This makes the cell turgid .

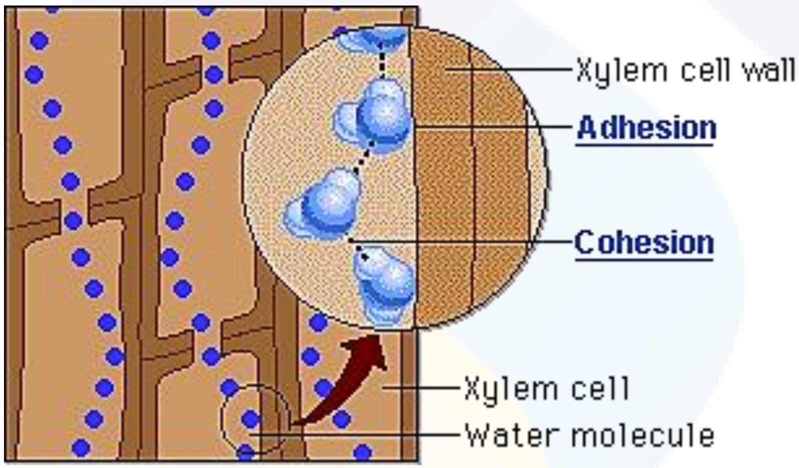
The magnitude of increment in water potential in such turgid cell is called Pressure potential..

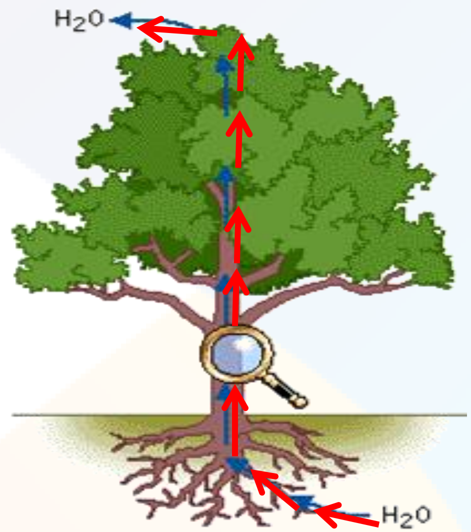
In plasmolysed cell
eg $\Psi_W = -10 + (-2) = -12$ bars.

# EXPRESSION OF WATER POTENTIAL

- It is usually positive.

- In plants negative potential or tension in the water column in the xylem plays a major role in water transport up a stem.




- Water potential of cell is affected by both solute and pressure potential.

- The relationship between them is as follows:

Pressure potential is denoted as $\Psi_P$.

$$\Psi_W = \Psi_S + \Psi_P$$

# Plasmolysis and Deplasmolysis

- **Limiting plasmolysis:** If the plant cell is placed in a hypertonic solution water comes out from the cell sap into the outer solution due to exosmosis and the protoplast becomes reduced. So cell wall contracts which result in reduction in cell size.

- **Incipient plasmolysis:** Further loss of water from cell causes contraction of protoplast which withdraws from corner of cell.

- **Evident plasmolysis:** Ultimately the protoplasm separates from the cell wall and assumes a spherical form.

## ❖ Deplasmolysis

- When a plasmolysed cell is placed in water or hypotonic solution endosmosis takes place and cell become turgid and protoplasm again assumes its normal shape and position.

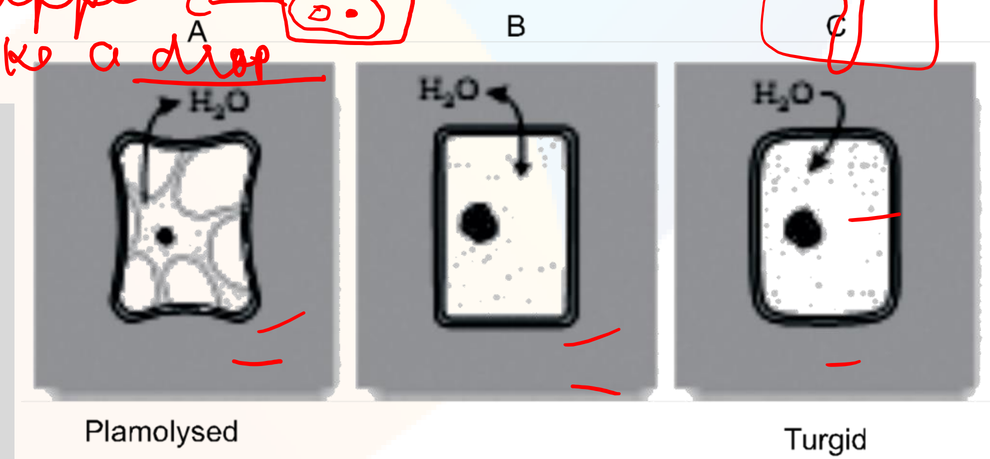
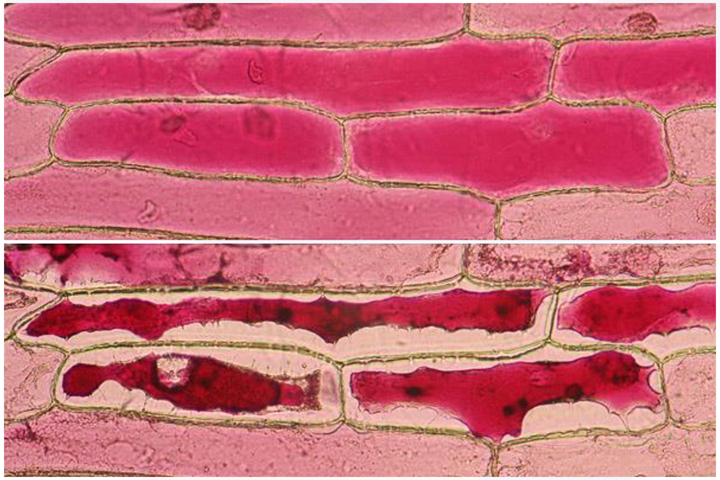


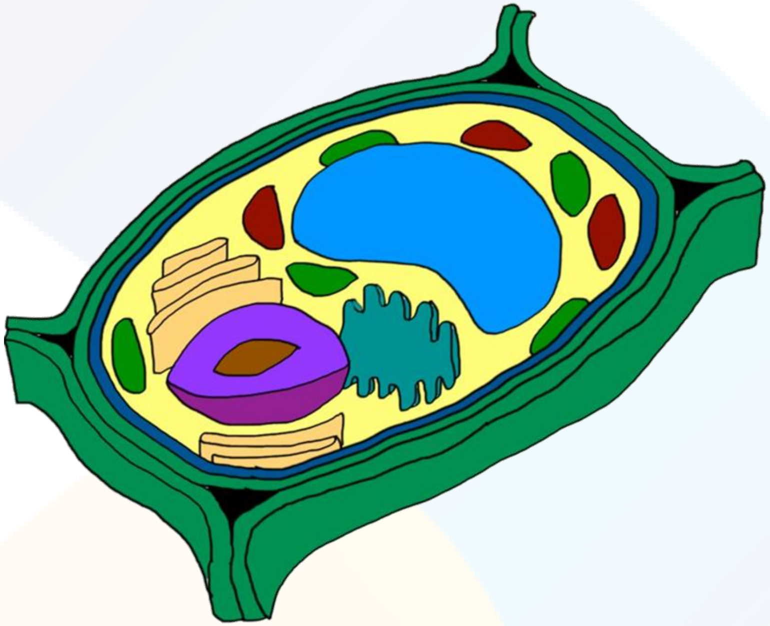

**Fig Plant cell plasmolysis**

# PLASMOLYSIS

- Plasmolysis occurs when water moves out of the cell and cell membrane of a plant cell shrinks away from its cell wall.



**Onion Plasmolysis**

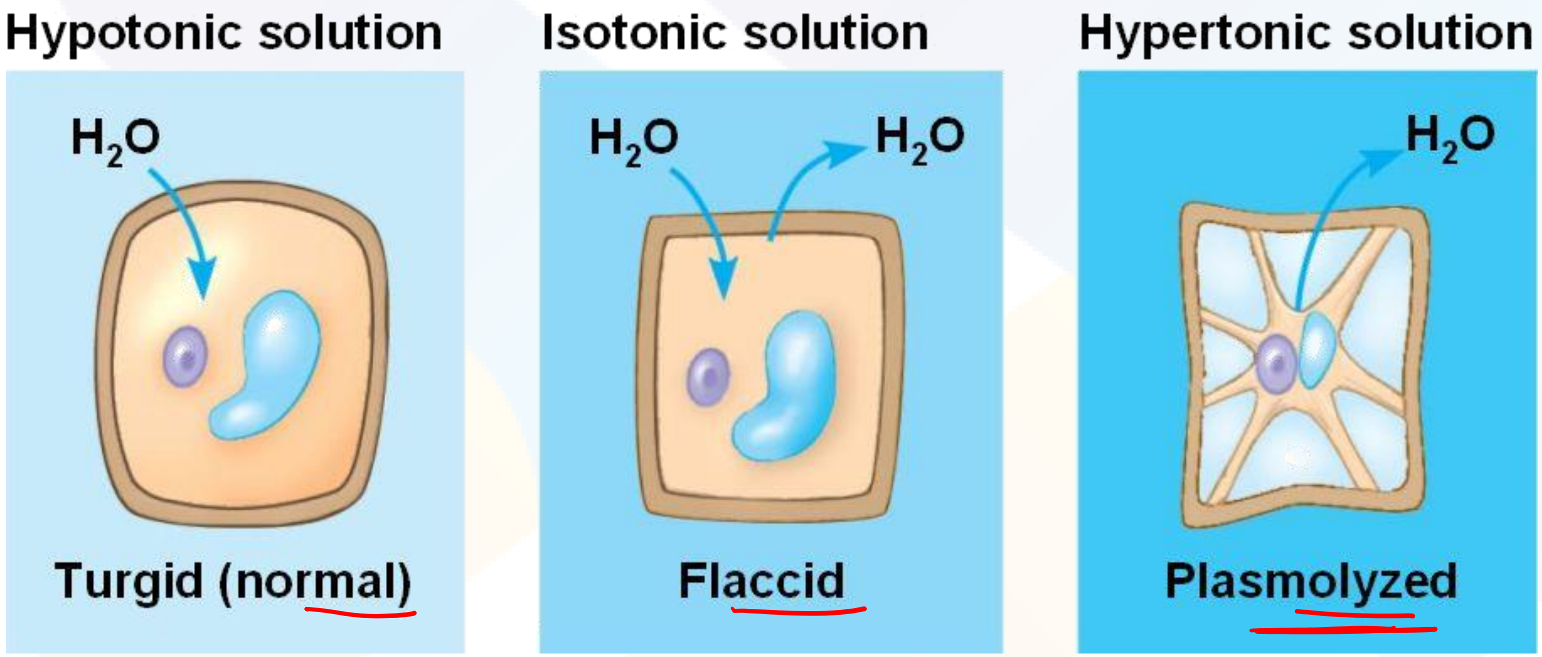


- This occurs when the cell (or tissue) is placed in a solution that is hypertonic (has more solutes) to the protoplasm.

# INCIPIENT PLASMOLYSIS

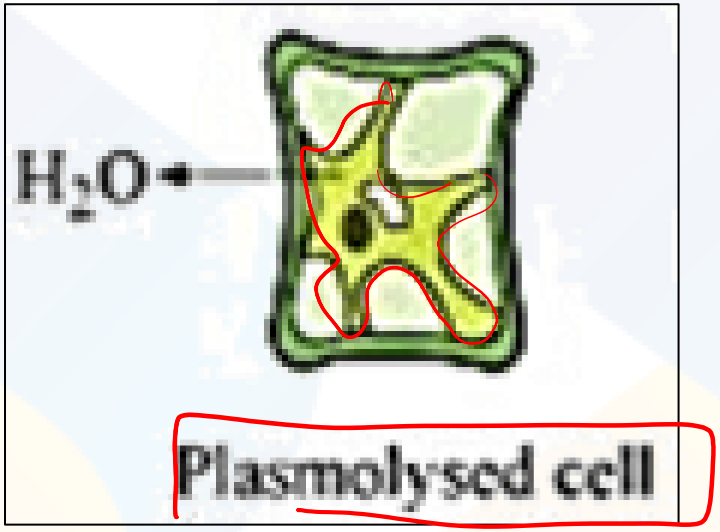
❖ Initially, this phenomenon is indicated by shrinkage of protoplast, leading to the separation of plasma membrane from the cell wall in the corners.

This stage is called incipient plasmolysis.



# PLASMOLYSED CELL

❖ When the cell is left in the hypertonic solution for more time, the protoplasm completely shrinks, now the cell is said to be plasmolysed.




❖ The movement of water occurs across the membrane, moving from an area of higher water potential (from the cell) to an area of lower water potential (out side the cell).

# FLACCID CELL

- In flaccid cells the pressure potential becomes zero, hence the water potential becomes equal to the solute potential.

$$\Psi_W = \Psi_S$$

- Plasmolysis does not normally occur in nature–with the possible exception of extreme water stress or saline environments.

$\psi_p = 0$

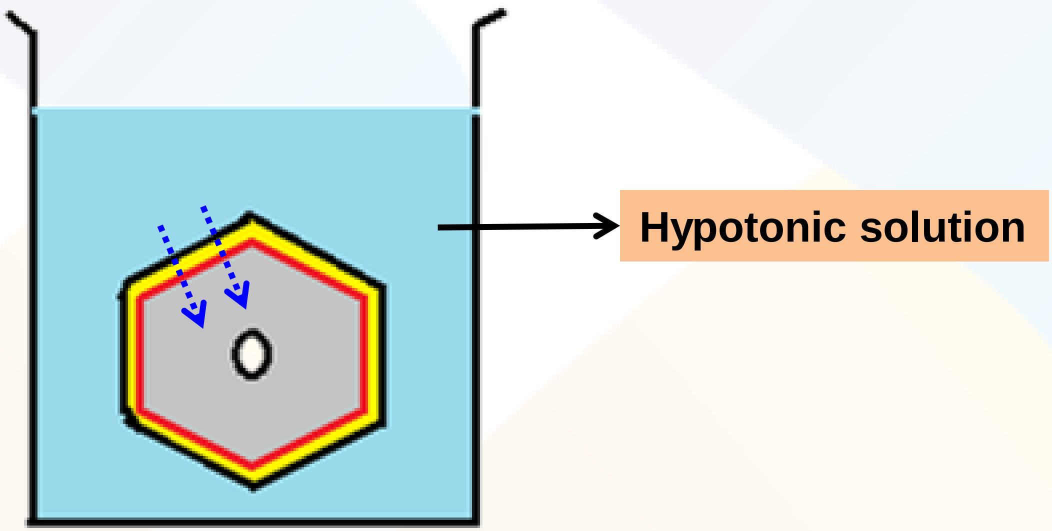
Thus normal living cells when kept in hypertonic solution become flaccid.

# TURGOR PRESSURE

- ❖ When the cells are placed in a hypotonic solution, water diffuses into the cell causing the cytoplasm to build up pressure against the wall.

This is called turgor pressure.

The process of plasmolysis is usually reversible.




The pressure exerted by the protoplasts due to entry of water against the rigid walls is called pressure potential $\Psi_P$.

# Types of solution

- Plasmolysis depends on the three type of solution

**Solution**

| Hypertonic solution | Hypotonic solution | Isotonic solution |
|---|---|---|
| Concentration of solution is higher than protoplasm **It shows exosmosis or plasmolysis** | Concentration of solution is less than protoplasm **It shows endosmosis** | Concentration of a specific solution and the protoplasm is same |

## ❖ Significance of plasmolysis

- Plasmolysis can be used to detect dead cell and living cell.
- Plasmolysis is utilized in salting of meat and fishes and addition of concentrate sugar solution in jams and jellies to check the growth of fungi and bacteria which becomes plasmolysed in concentrate solution.
- Common salt kills weeds by plasmolysis.
- Osmotic pressure of a cell can be known by plasmolysis.

# Imbibition

- It is a physical process in which adsorption of water by hydrophilic protoplasmic substances and cell wall constituents specially polysaccharides and proteins without forming a solution.

- **Example of Imbibition:** Absorption of water by dry wood and seeds.

## ❖ Significance of Imbibition

- Young cells absorb water through imbibition.
- Absorption of water during seed germination through Imbibition.
- Bursting of seed coat during seed germination due to imbibition.
- Wood absorbs water and swell up in rainy season.

# Effects of Imbibition

- **Swelling:** Volume of substances increase due to imbibition but the total volume is less than sum of both volume.
- **Liberation of Heat:** Usually water molecules are situated on the surface of the imbibing they lose some of their kinetic energy due to imbibition which appear as heat in system, that is called **Heat of wetting**
- **Imbibition pressure (I.P.):** It is a maximum pressure that is produced after complete absorption of pure water by imbibants.
- **Suction capacity – Agar – Agar > Protein > Pectin > Starch > cellulose**

# Absorption Of Water By Plants

## ❖ Soil water relation

- Study of soil is called **Pedology or Edaphology**
- Development of soil is called **Pedogenesis**
- **Loam soil** is suitable for healthy growth of plants

## ❖ Soil water

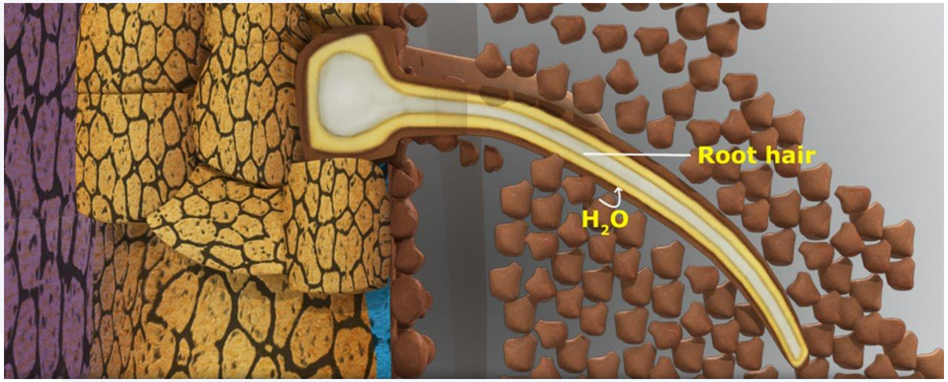
- **Run way water :** After heavy rain fall or irrigation some of the water drains away along the slopes and is not available to plant.
- **Gravitational water :** Due to gravitational force water sweeps down to water table and is not available to plant.
- **Hygroscopic water :** This thin film of water is tightly held by the soil particles and cannot be absorbed by the plants
- **Capillary water :** It occurs as a thin film around soil-particles in the capillary space and is available to the plants
- **Chemical water :** Some of the water molecules are chemically combined with soil minerals. It is not available to plants

## Regions in a root

- Root hairs of root absorbs water from soil.
- In lower plants like Bryophytes, rhizoids perform absorption of water from soil while in Pteridophytes and spermatophytes roots absorb water from soil.
- **Root cap :** It is lowest apex part of root. It functions as protective tissue
- **Region of cell formation :** It is a meristematic zone and show active cell division
- **Region of cell elongation :** The cells of this region grow in length
- **Region of cell maturation :** In this zone, cells are matured and differentiated to perform different functions
- The outer wall is of pectin which dissolve in water, so that root hair surface become sticky. The inner wall is made up of cellulose.
- Each root hair has a central vacuole filled with osmotically active cell sap its OP is about 3 Atm.

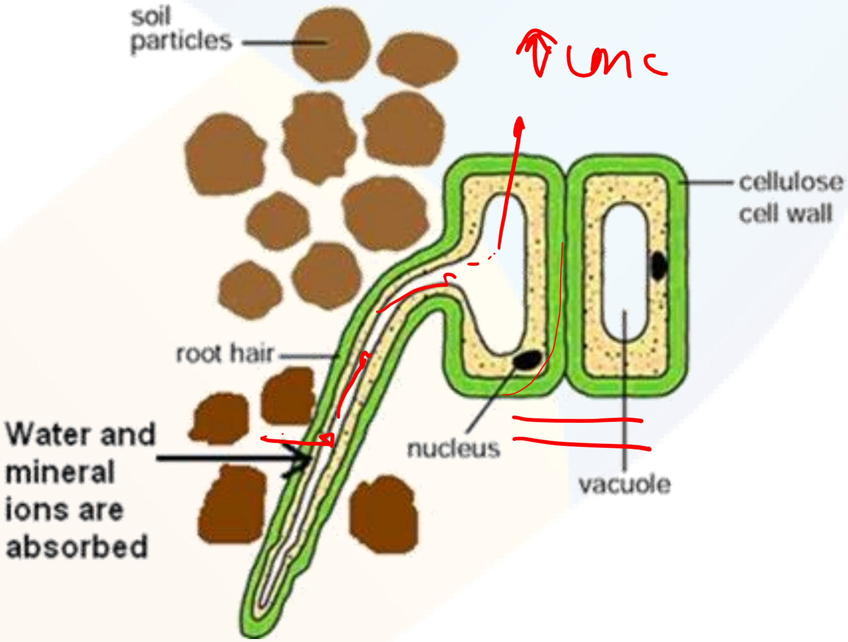
# ABSORPTION BY ROOT HAIRS

❖ Root hairs are thin-walled slender extensions of root epidermal cells that greatly increase the surface area for absorption.




use ATP absorbed actively

❖ Water is absorbed along with mineral solutes, by the root hairs, purely by diffusion.



# Mechanism of Water Absorption

## Processes of water absorption

### Active water absorption

- Absorption of water due to forces present in the root. It is 2-4% of the total water absorption

### Passive water absorption

- In rapid transpiring plants the force for water absorption develops in shoot or aerial parts it is called Transpiration pull.
- In passive water absorption water is just pulled through the root and not by the roots

#### Osmotic active water absorption

- Cell wall functions as permeable membrane.
- When the osmotic concentration of vascular sap of root hairs is higher than soil solution, direct expenditure of ATP is not found & absorption of water takes place.
- At this time the D.P.D. of soil solution is less than root hairs. Therefore, water moves from soil solution to the roots across differential permeable membrane.

#### Non-osmotic active water absorption

- Water absorption take place against a concentration gradient (lower D.P.D. to higher D.P.D.) and it also requires energy (ATP)

Lower DPD to ↑ DPD
↑ WP → ↓ WP

# Pathways of Water Movements In Roots - I

## ❖ Symplast pathway

- ➢ Water passes from cell to cell by their protoplasm. It involves living continue **cytoplasm & Plasmodesmata.**

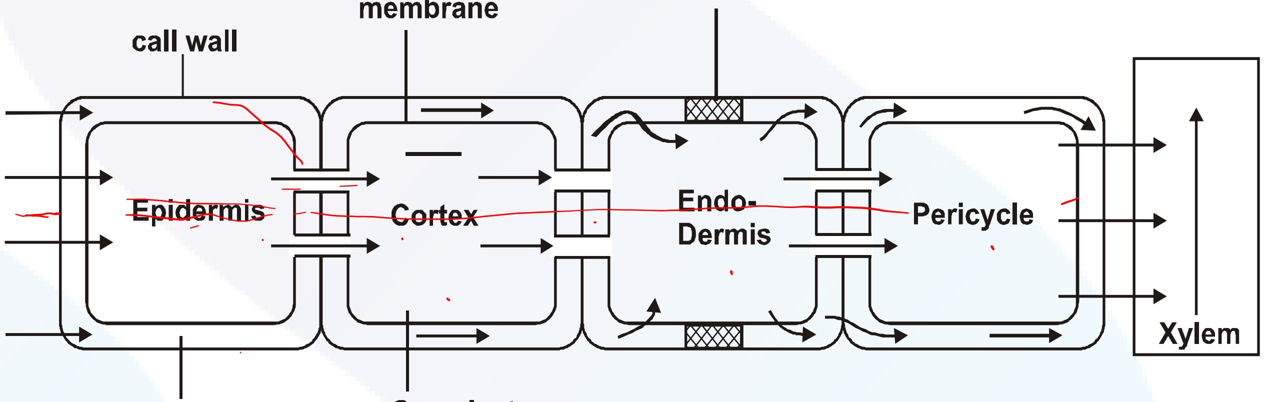



Fig:- Pathways of water movement inside the root

- ➢ For entering into Symplast, water has to pass through Plasmalemma (cell membrane) at least at one place. It is also called **Transmembrane pathway.**

**1. Non Vacuolar Symplast pathway:** Water passes between adjacent cells by Plasmodesmata.

**2. Vacuolar Symplast pathway:** Water passes from the tonoplast surrounding vacuole

# APOPLAST AND SYMPLAST PATHWAYS

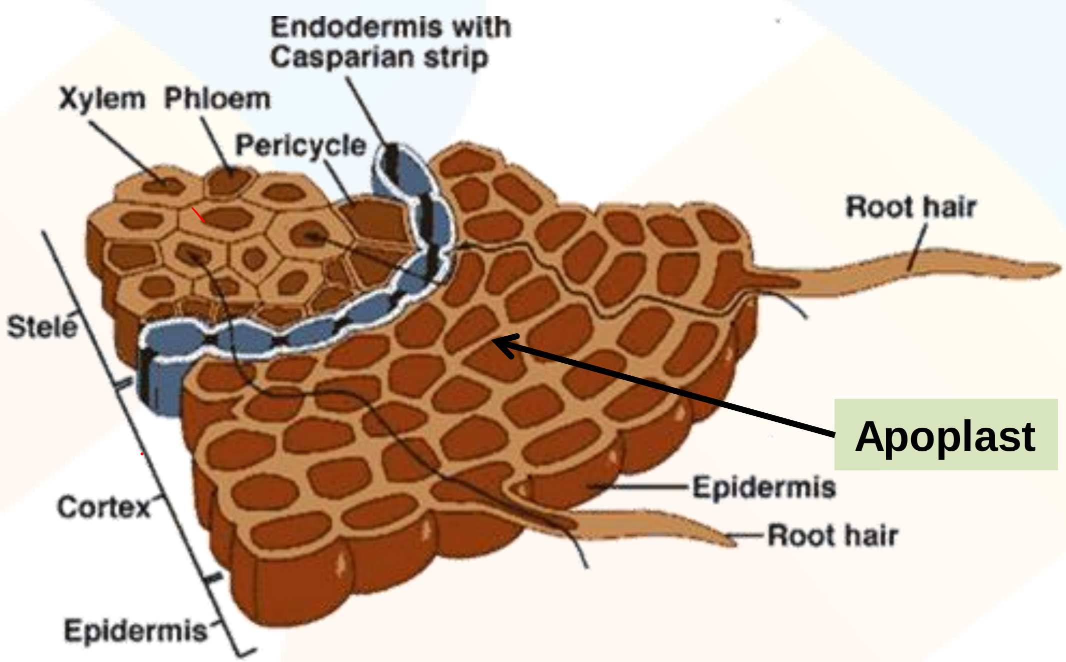
❖ Once water is absorbed by the root hairs, it can move deeper into root layers by two distinct pathways:

- **Apoplast pathway**
- **Symplast pathway**

## ❖ Apoplast pathway

→ Through intercellular spaces

- The apoplast is the system of adjacent cell walls that is continuous throughout the plant, except at the casparian strips of the endodermis in the roots.



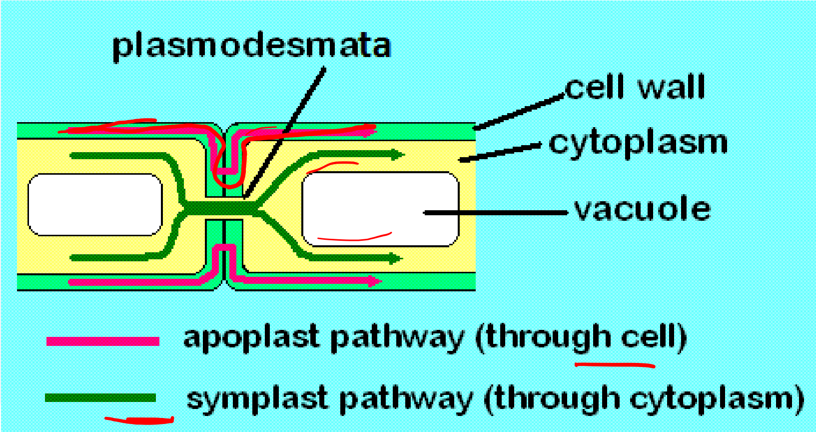
# APOPLAST PATHWAY

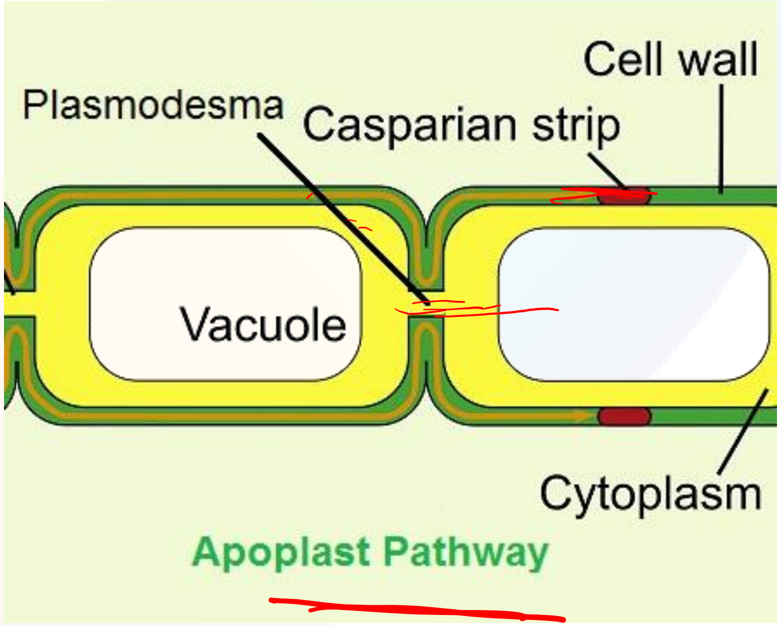
❖ The apoplastic movement of water occurs exclusively through the intercellular spaces and the walls of the cells .

This movement is dependent on the gradient.

❖ Movement through the apoplast does not involve crossing the cell membrane.

❖ The apoplast does not provide any barrier to the water movement and water movement is through mass flow.



# SYMPLAST PATHWAY

❖ Neighbouring cells are connected through cytoplasmic strands that extend through plasmodesmata.

The symplastic system is the system of interconnected protoplasts.