Unit - I

Plant-Water relations: Importance of w a t e r; diffusion and osmosis; absorption; Transport of water, ascent of sap. Transpiration. Physiology of stomatal movement; Passive and active solute transport; source –sink relationship; factors affecting translocation.

IMPORTANCE OF WATER FOR PLANTS

Water is important for plants because of the following reasons:

(i) Water helps in the germination of seeds.

(ii) Water helps in the process of photosynthesis by which plants prepare their food.

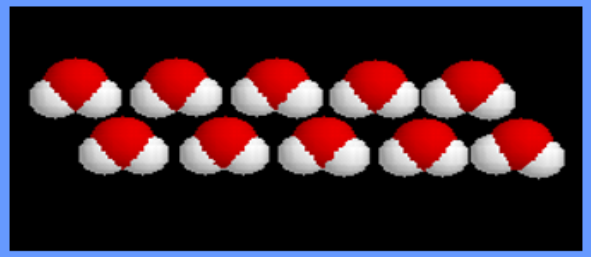
(iii) Water helps in the transport of nutrients and minerals from the soil to the plants.

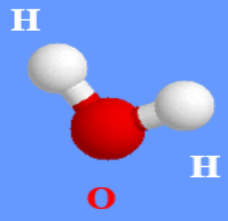
(iv) Water helps in the maintenance of the plant structure by providing the appropriate pressure to the plant tissues.

(v) Water provides habitat in the form of ponds, rivers, lakes and sea for a large number of plants.

Water

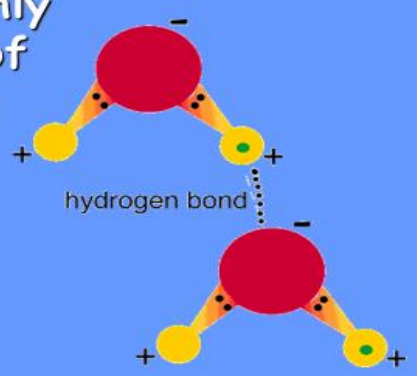
- A water molecule (H_2O), is made up of three atoms --- one oxygen and two hydrogen.





Hydrogen Bonds Exist Between Water Molecules

- Formed between a highly Electronegative atom of a polar molecule and a Hydrogen
- One hydrogen bond is weak , but many hydrogen bonds are strong

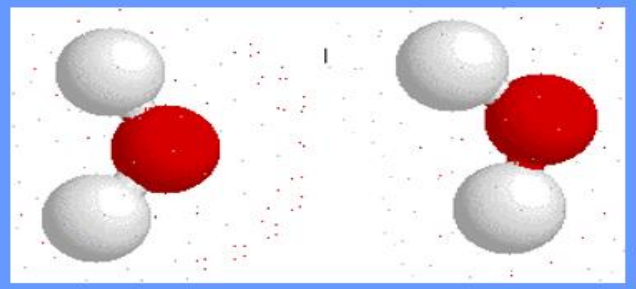


Water is Polar

- In each water molecule, the oxygen atom attracts more than its "fair share" of electrons
- The oxygen end "acts" negative
- The hydrogen end "acts" positive
- Causes the water to be POLAR
- However, Water is neutral (equal number of e- and p+) --- Zero Net Charge

Interaction Between Water Molecules

Negative Oxygen end of one water molecule is attracted to the Positive Hydrogen end of another water molecule to form a HYDROGEN BOND



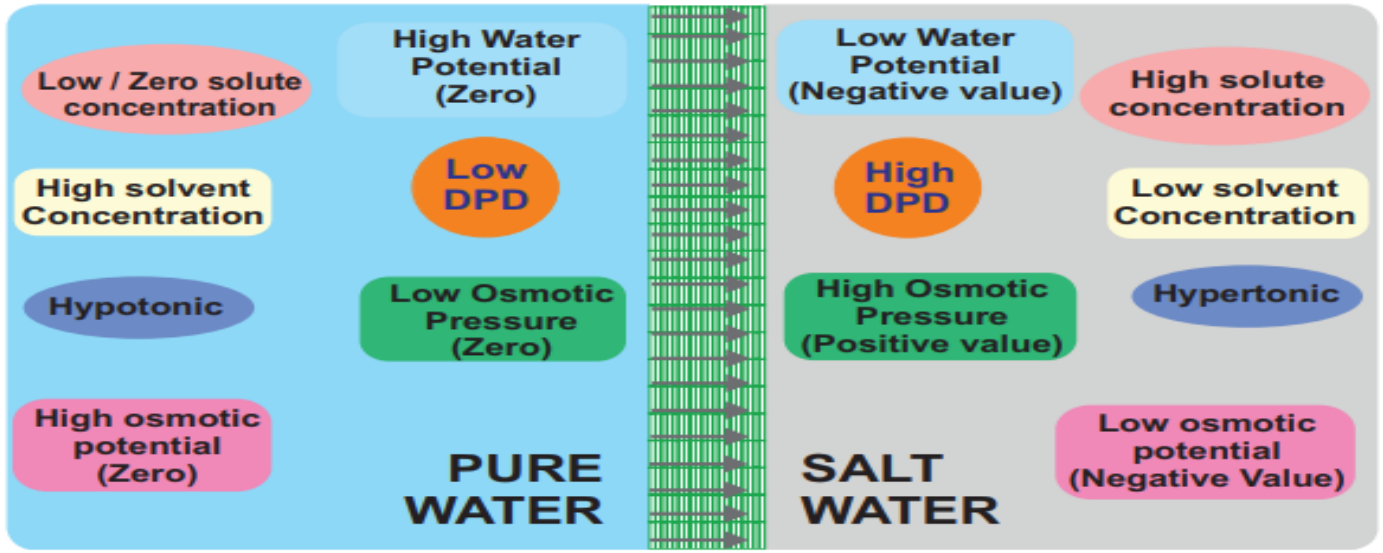
Covalent bonds are the bonds between the atoms within the same water **molecule**.
Hydrogen bonds are the bonds between two water molecules.

- Water potential is calculated using the following formula:
- Water potential = pressure potential + solute potential

$$\psi = \psi_p + \psi_S$$

$$\text{Water Potential} = \text{Pressure Potential} + \text{Solute Potential}$$

Concept Map - Movement of water in an osmotic system based on various parameters



Plants & water potential

- The combined effects of
  1.) solute concentration
  2.) physical pressure (cell wall)

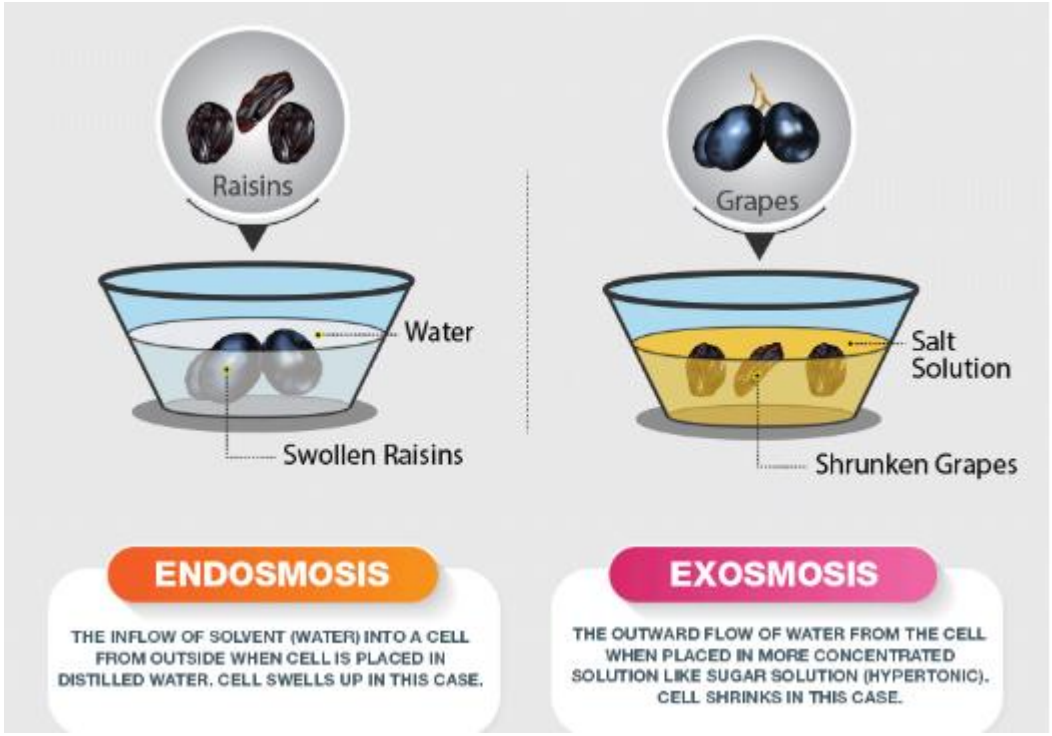
  can be measured as Water Potential Ψ
- Ψ = psi
- Ψ is measured in either kilopascals (KPa) or megapascals (MPa)
- *1 Mpa = 10 atmospheres of pressure

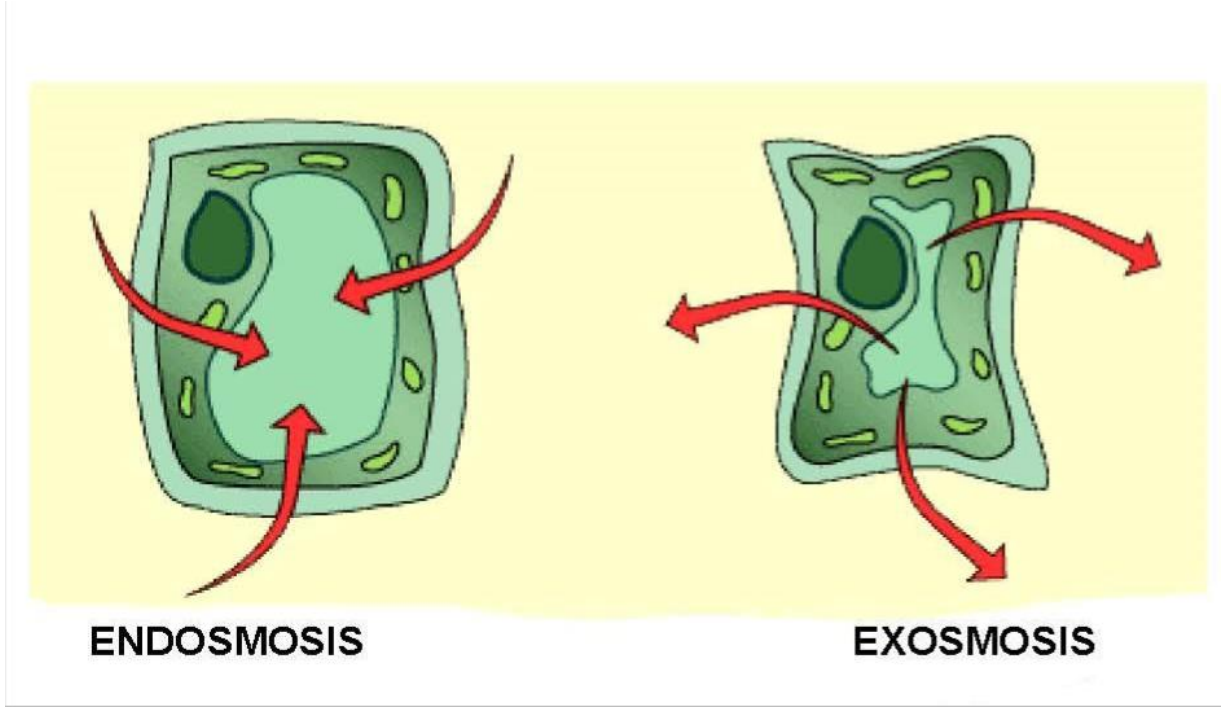
Osmosis

Osmosis is the movement of water across a semi-permeable membrane. Water moves from a region of its higher concentration to the region of its lower concentration till equilibrium is reached.

In this again there are two processes- Endosmosis and Exosmosis.

Endosmosis is a process in which inward diffusion of water through a semipermeable membrane occurs when the surrounding solution is less concentrated while exosmosis is a process in which the outward diffusion of water through a semipermeable membrane occurs when the surrounding medium is more concentrated.



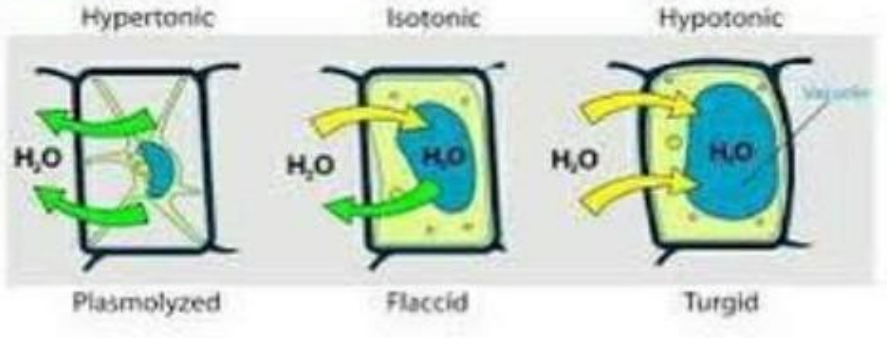


Plasmolysis

Plasmolysis is a process that occurs when water moves out of the cell and the cell membrane shrinks away from the cell wall. This occurs when the cell is placed in a hypertonic solution (which has more solutes). Water is lost from the cytoplasm and then from the vacuole. When the cell is placed in an isotonic solution, no net movement of water occurs and when it is placed in a hypotonic solution, water moves into the cell and exerts a pressure on its walls known as turgor pressure.

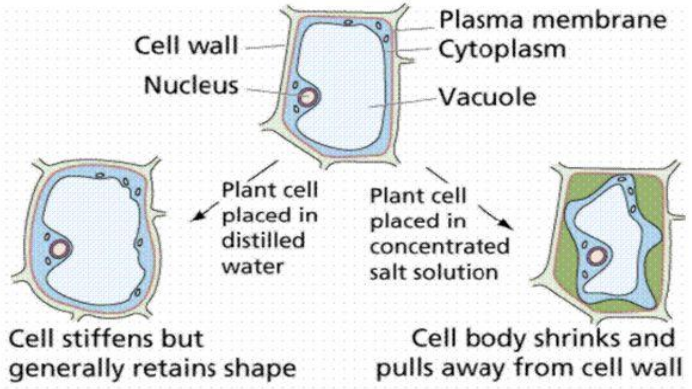
PLASMOLYSIS

Plasmolysis is the process in plant cells where the plasma membrane pulls away from the cell wall due to the loss of water through osmosis.



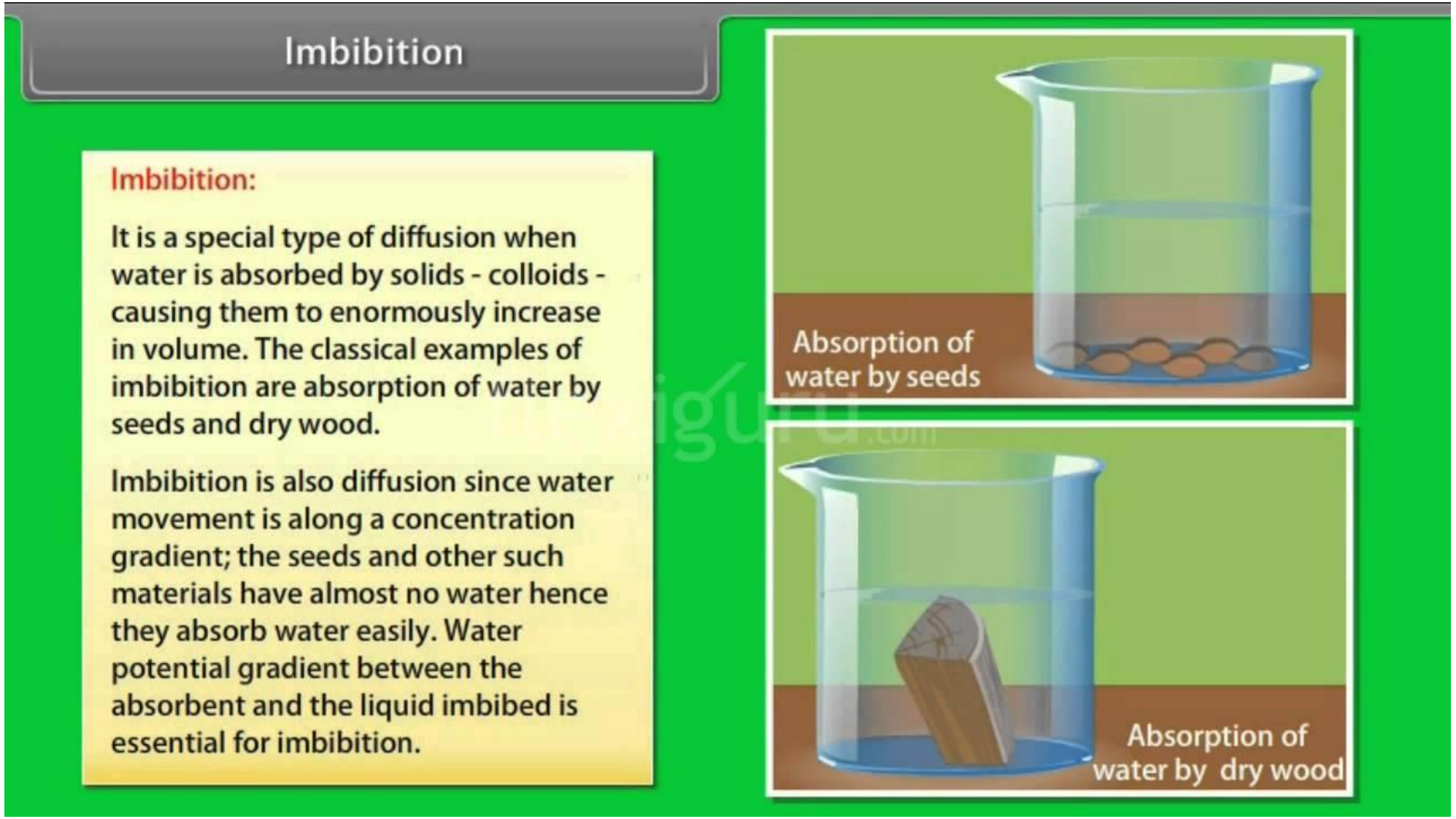
Plasmolysis

- Loss in pressure between the CW and CM in a plant cell.
  - When plants are in a hypertonic environment, the water will diffuse out of the cell, and the CM will pull away from the CW.



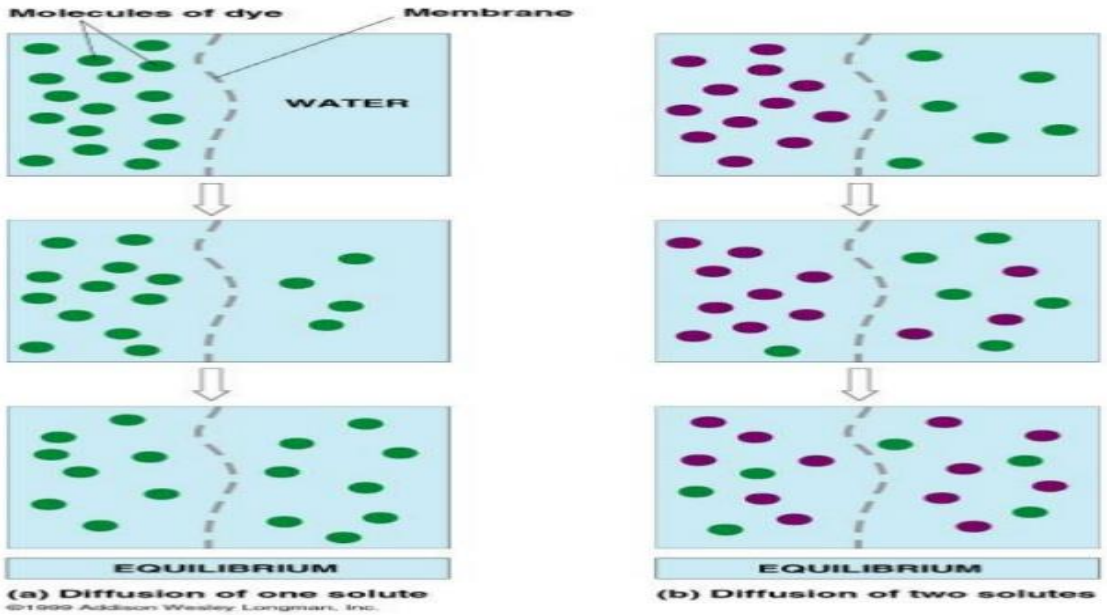
Imbibition

It is a process in which water is absorbed by solids and their volume increases. An example of this can be- absorption of water by seeds and dry wood. In this, the movement of water is along the concentration gradient.



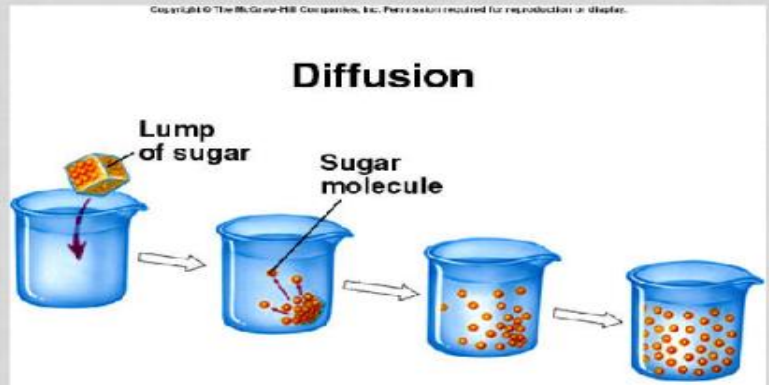
Diffusion

- Movement of molecules from a region of higher concentration to a region of lower concentration down a concentration gradient
- Form of passive transport
- Diffusion stops when the concentration gradient is zero that is state of equilibrium is reached



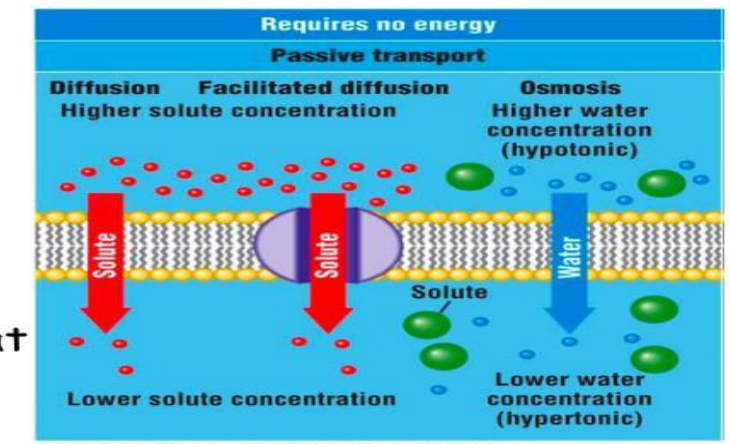
MOVEMENT OF MATERIALS THROUGH THE CELL MEMBRANE: DIFFUSION

diffusion – process by which molecules of a substance move from areas of higher concentration of that substance to areas of lower concentration



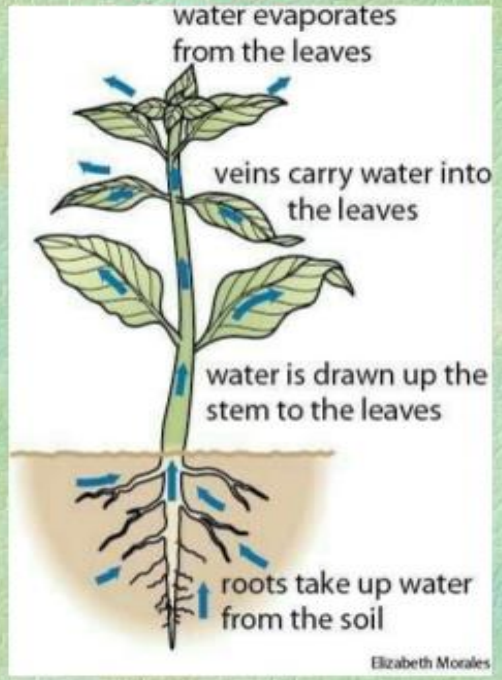
FACILITATED DIFFUSION

- A type of passive transport that does not require energy to move molecules down their concentration gradient
- uses membrane proteins to move molecules across the membrane that are large or charged (ions)



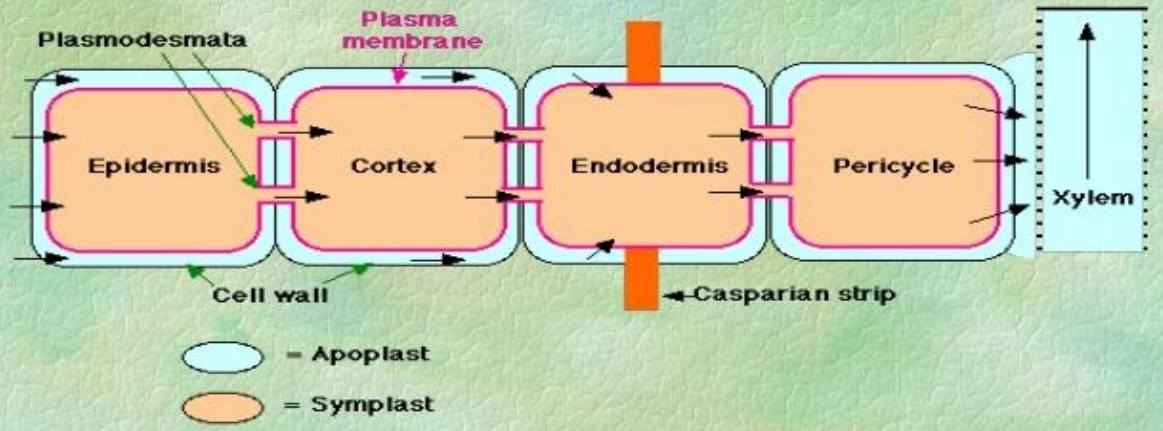
ABSORPTION OF WATER

- ✓ Uptake of water by plant is called absorption of water.
- Plant absorb water from the soil through the root hairs.
- Water is said to be the liquid gold of life.
- Plant are capable of absorbing water from soil solution.
- Mainly absorb capillary water.
- Plant also absorb dissolved nutrients along with water.

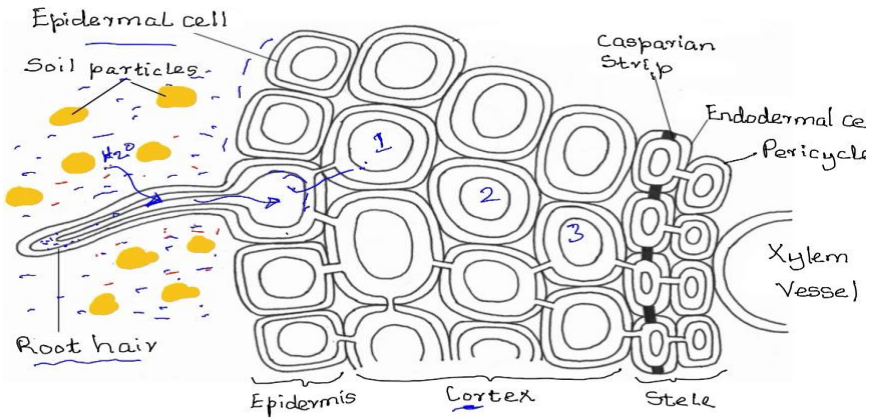


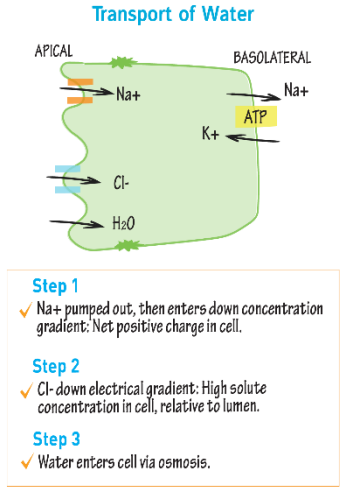
Apoplast and Symplast

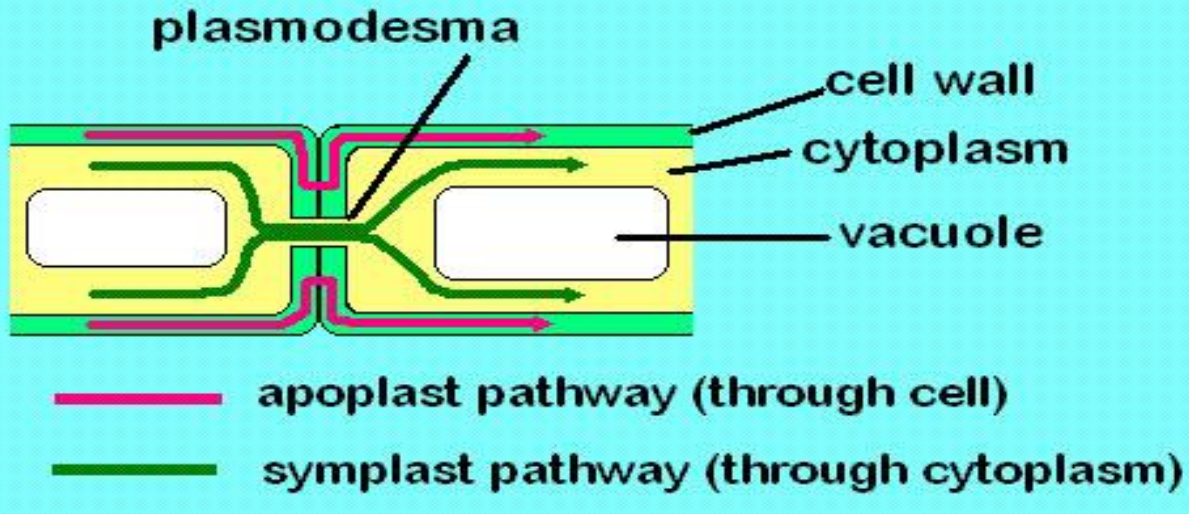
- ❑The water move through apoplastic pathway(Through intercellular pathway).
- ❑Symplast pathway through plasmadesmata.
- ❑Transmembrane pathway through aquaporins.



Site: The root :- Internal Structure







Transportation of Water

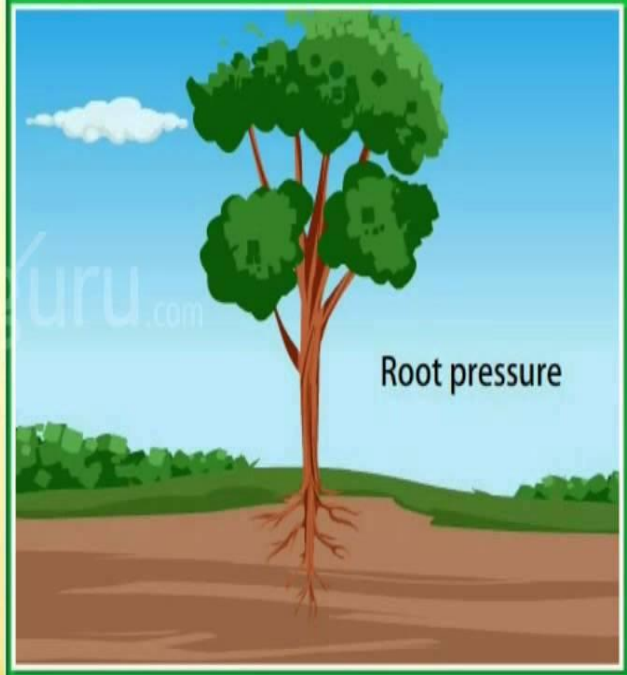
The large amount of water lost by transpiration must be replaced. (Evaporation from stems and leaves known as **transpiration**, is caused by drying power of air.)
Water in the soil is taken up by roots and transported upwards through the xylem of roots to stems and into the leaves.

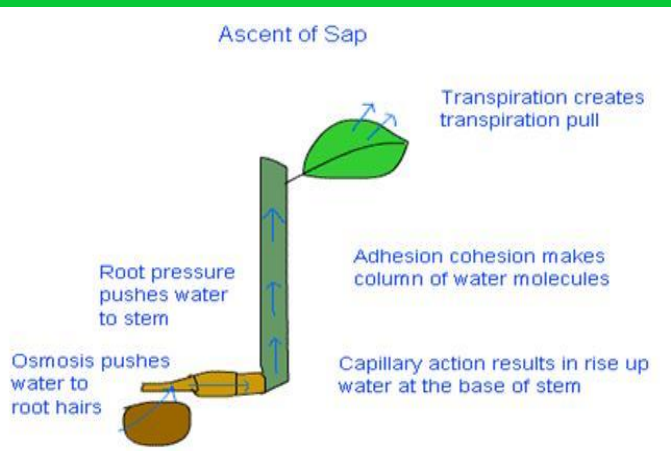
There are four main processes for the transport of water:

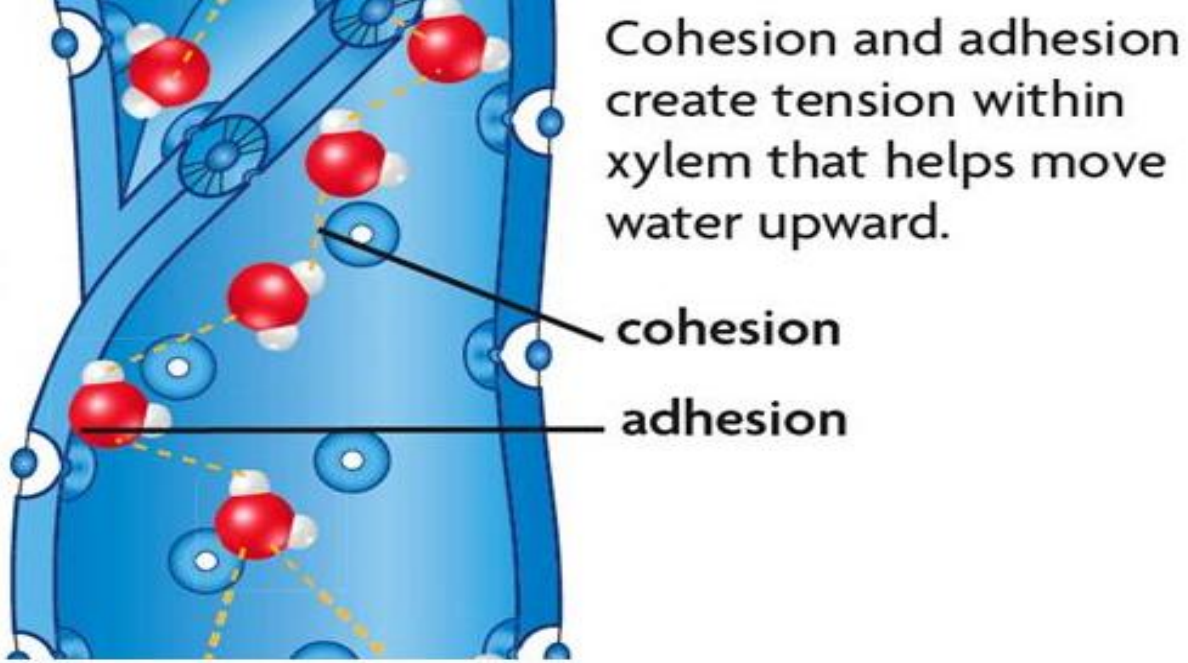
1. Root osmotic pressure
2. Cohesion- adhesion (Transpiration – Cohesion Theory)
3. Capillarity
4. Transpiration pull

Root Pressure Theory

- Various ions from the soil are actively transported into the vascular tissues of the roots, water follows (its potential gradient) and increases the pressure inside the xylem. This positive pressure is called root pressure, and can be responsible for pushing up water to small heights in the stem.
- Effects of root pressure is observable at night and early morning when evaporation is low, and excess water collects in the form of droplets around special openings of veins near the tip of grass blades, and leaves of many herbaceous parts. Such water loss in its liquid phase is known as guttation.



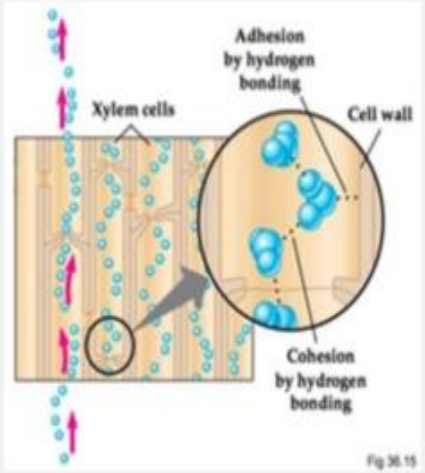




Cohesion and adhesion create tension within xylem that helps move water upward.

Capillary Action

- **Adhesion** occurs when water forms hydrogen bonds with xylem cell walls.
- **Cohesion** occurs when water molecules hydrogen bond with each other.
- Cohesion between water molecules creates a "water chain" effect.



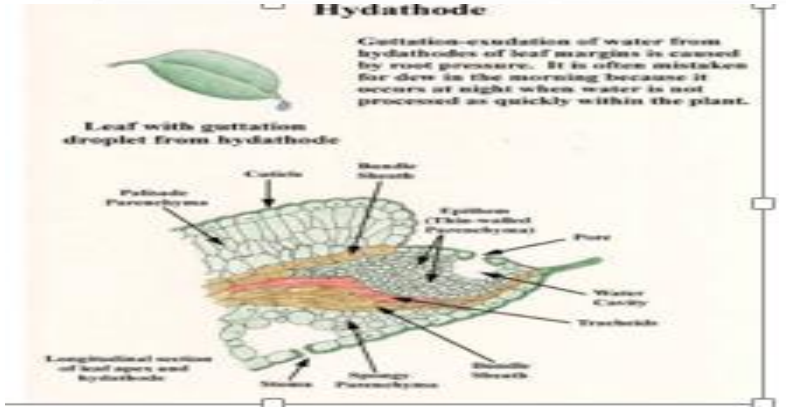
Gutation

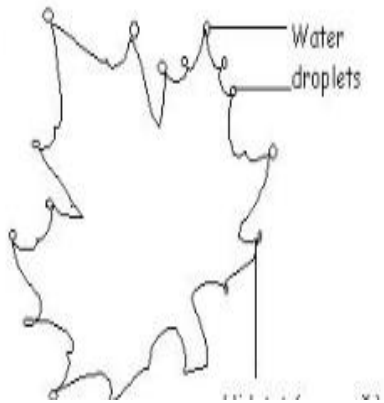
Gutation (yaşarma, damlama): It is the formation of water droplets at the edge of leaves as a result of root pressure.

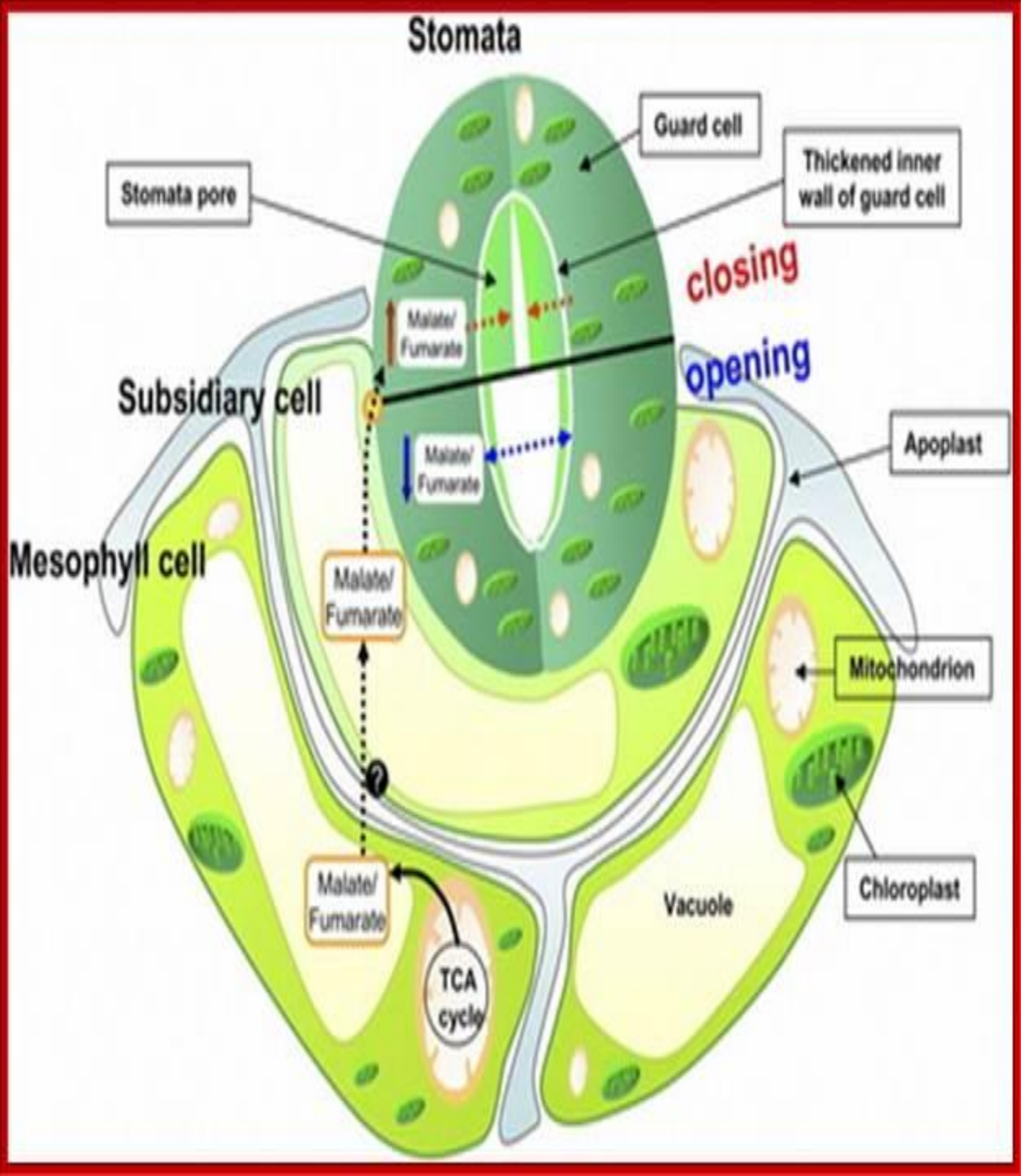
Gutation occurs at night and only in small plants growing under moist conditions. Because of the pressure build up, water in the xylem of leaf is forced out onto the surface of leaves in the form of droplets. These droplets usually can be seen easily in the morning. Salts can be forced out with water.

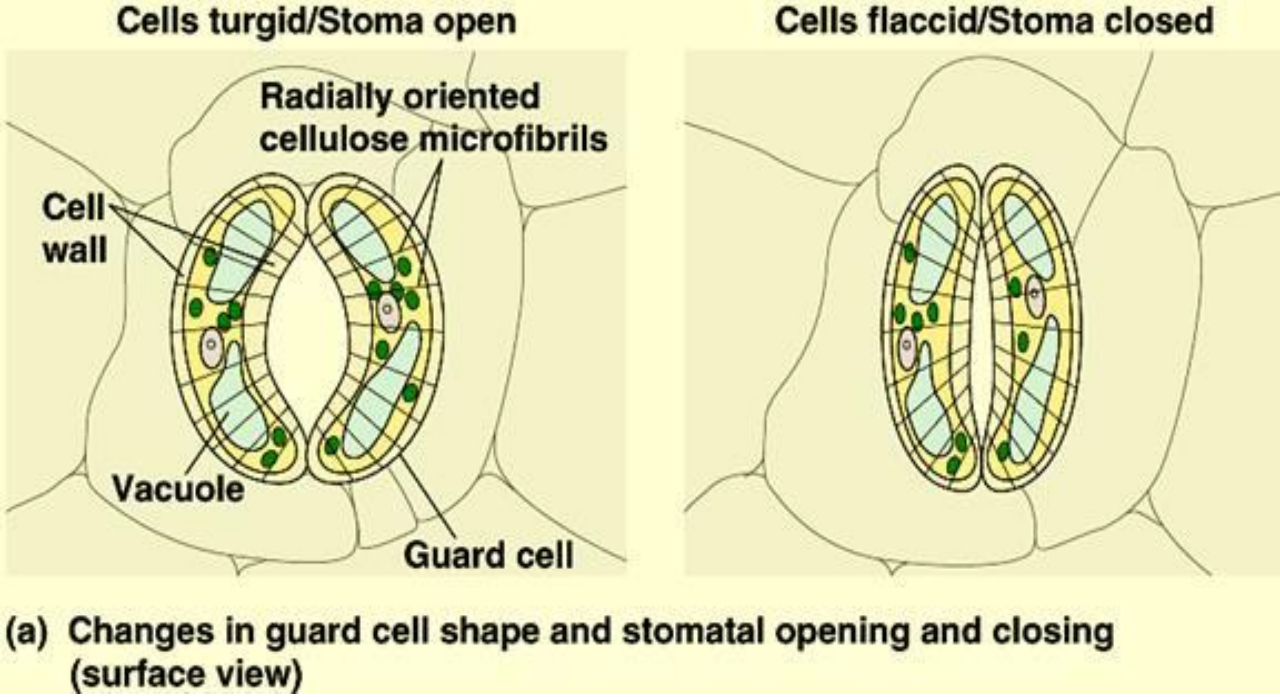
Dew drops (Çiğ)**:** They are the result of water vapor in the air condensing on cool leaf surface.

It must not be confused with gutation!!!

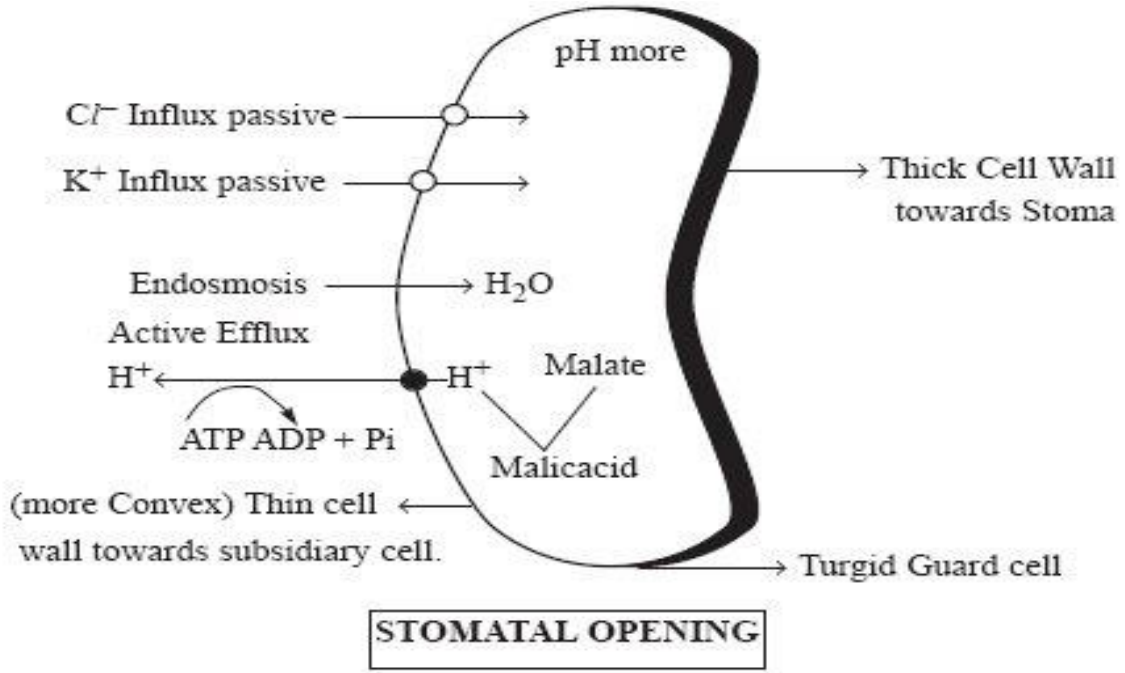








(a) Changes in guard cell shape and stomatal opening and closing (surface view)



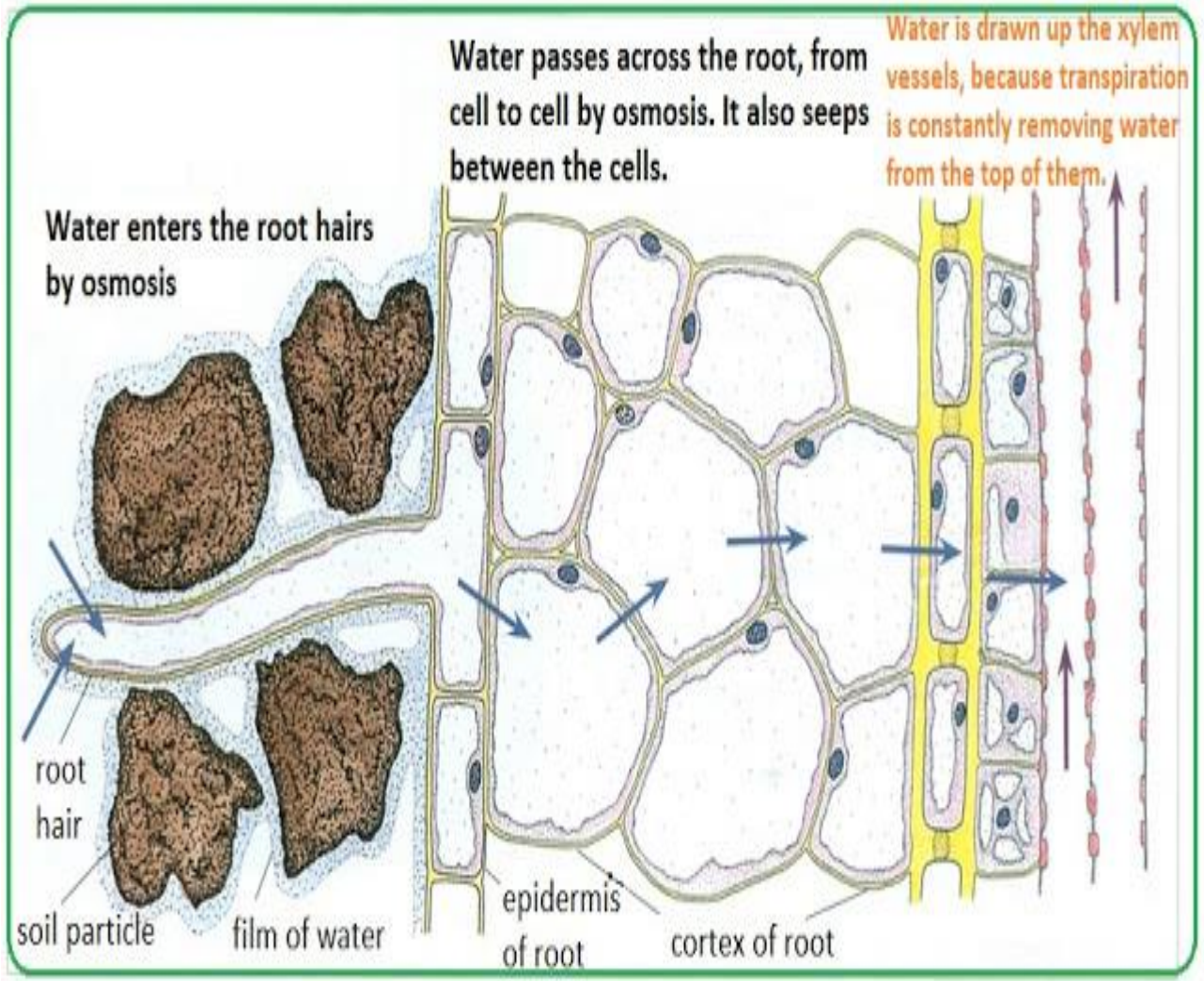
STOMATAL OPENING

4. Transpiration Pull

During transpiration, water molecules evaporate from the surface of leaf cells through stomata. The lost water is replaced by water in contact with water at the end of a water column in the leaf xylem. When this happens, other water molecules in the column are drawn into the leaf tissue by the strong attractive forces between water molecules. Consequently, the loss of water by evaporation creates a pull or tension on the columns of water in the xylem.

Water is pulled up through the xylem. This process is called transpiration pull.

Minerals absorption



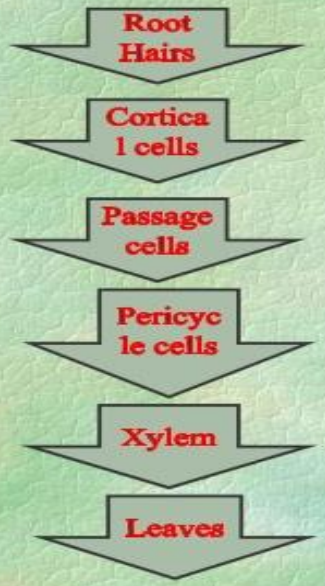
ACTIVE PROCESS	PASSIVE PROCESS
1. Occurs due to activity of root and root hairs.	1. Occurs due to activity of shoot and leaves.
2. Absorption occurs due to osmotic and non osmotic process.	2. Absorption occurs due to transpiration.
3. The rate of absorption depends upon the DPD .	3. The rate of absorption depends upon the transpiration
4. Shows symplast pathway.	4. Shows Apoplast pathway.

1.Active absorption

Proposed by Atkins (1916) & Priestly (1922)

- Active osmotic absorption.
- Active non osmotic absorption.

- Active absorption – the absorption of water by the plant with the use of energy is known as active absorption. in this process, the root cell play active role in the absorption of water.
- Intake of water by the plants with the use of energy is called active absorption.
- The water is absorbed by the activity of root hair cells.
- The water is absorbed by the operation of osmotic forces by the use of energy.
- In osmotic active absorption, the water move from hypotonic solution to hypertonic solution.



I. Active Osmotic Absorption

- The intake of water by the root hairs by the operation of osmotic forces is called osmotic active absorption.
- Water is absorbed by the activity of root cells.
- Osmotic pressure, root pressure, turgor pressure and DPD play the main role.
- The water move from hypotonic solution to hypertonic solution.
- The root hair cells suck the soil water and the xylem vessel pumps the water upwards.

Factors affecting water absorption

1. External factors:

i. Available soil water:- Dry soil decreases the rate of absorption. Decreases in soil water reduces the rate of absorption.

ii. Concentration of solution: Soil much more concentration than the cell sap OP high of cell sap of root cells.

iii. Soil temperature: Max. absorption of water 20°C to 30°C.

If temperature ↑ absorption↓.

If 20°C↓ together absorption ↓.

If 0°C physiologically dry.

iv. Soil aeration: Oxygen is essential for water absorption by roots.

- In water logged soils, aeration is very poor and this poor aeration decreases the permeability of root cells to water.
- They are not good absorption of water. Therefore, such water logged soils are to be physiologically dry.

Passive absorption

- The intake of water by plants due to transpiration pull is called passive absorption.
- The water is absorbed due to transpiration activity in the top of the plants.
- The root hair cell has no role in absorption. It function as an absorptive surface.
- Water is absorbed through roots.
- Transpiration increase the concentration of cell sap and DPD in the leaves.
- As result water from the xylem vessels move into the mesophyll cells of leaves.
- The water in the xylem vessels is in the from of a column.
- Hence there is pulling up of water column.
- This result in a tension in the root hair cells.
- The water moves through apoplastic pathway, symplast pathway and transmembrane pathway.
- It is now largely greatest amount of water is pulled up by passive absorption.

I. Active Osmotic Absorption

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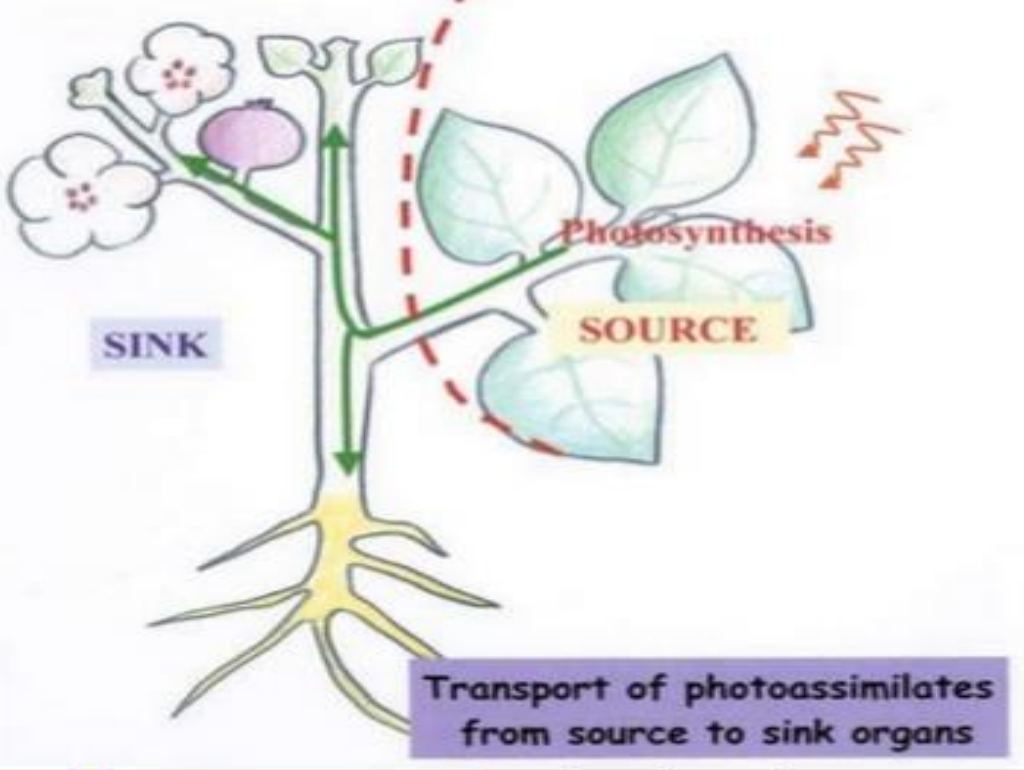
Transportation Of Nutrients

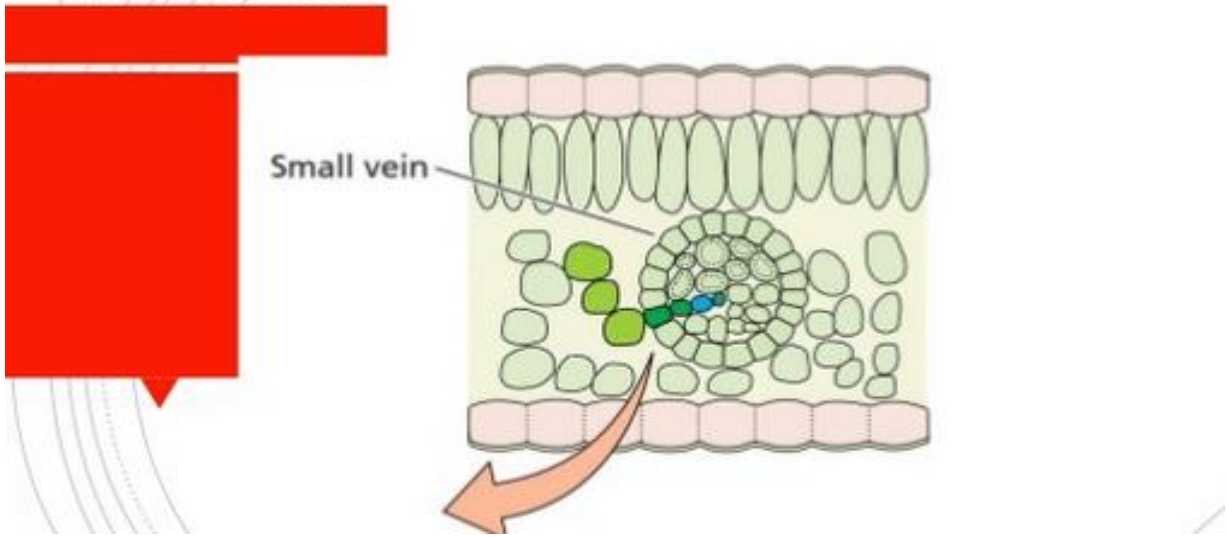
- Materials exported by cells for use elsewhere in the plant are transported through the phloem.
- The most abundant of these materials are sugars, other materials commonly exported by plant cells include hormones, amino acids and ions.
- Sugars produced in the leaves during photosynthesis are distributed to other cells in the plant where they are stored or used for energy. This movement of dissolved food through a plant is called **translocation**.

- Sugars and other cell products travel in a watery solution from source to sink.
- A **source** is a place where sugars are added to phloem.
  (The main sources are leaves)
- A **sink** is a place where sugars are removed from the phloem.
  (The main sinks are actively growing parts, such as emerging leaves and developing fruits)



In *source tissue*...

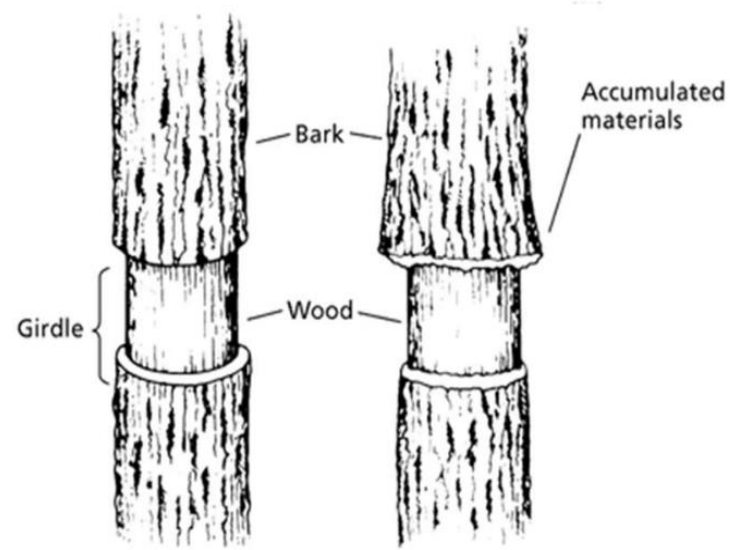
sugars are moved from photosynthetic cells and actively loaded (uses ATP energy) into companion cells and sieve tube elements.



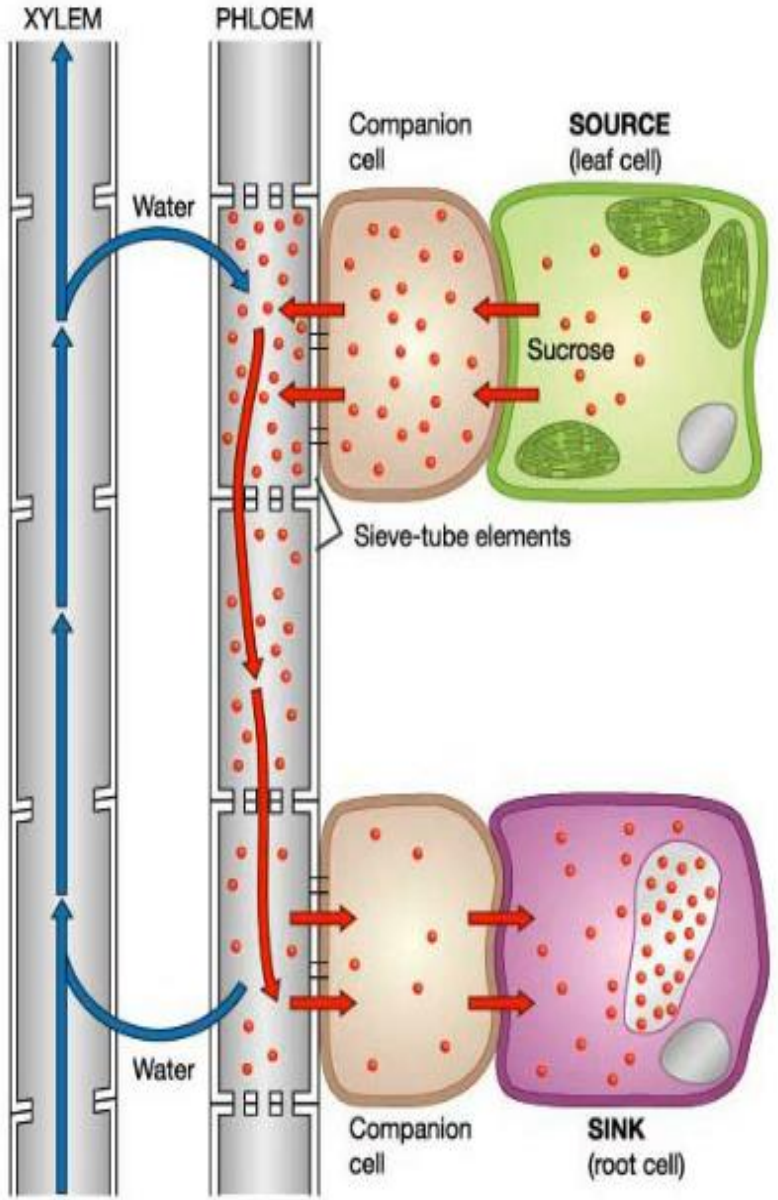
- ***Pathway of translocation***:
  - Sugars and other organic materials are conducted throughout the plant in the phloem by means of sieve elements
    - *Sieve elements display a variety of structural adaptations that make the well suited for transport*
- ***Patterns of translocation***:
  - Materials are translocated in the phloem from *sources* (usually mature leaves) to *sinks* (roots, immature leaves)

- ***Materials translocated in phloem***:
  - Translocated solutes are mainly carbohydrates
  - Sucrose is the most common translocated sugar
  - Phloem also contains:
    - *Amino acids, proteins, inorganic ions, and plant hormones*
- ***Rate of translocation***:
  - Movement in the phloem is rapid, well in excess of rates of diffusion
    - *Average velocity is 1 meter per hour*

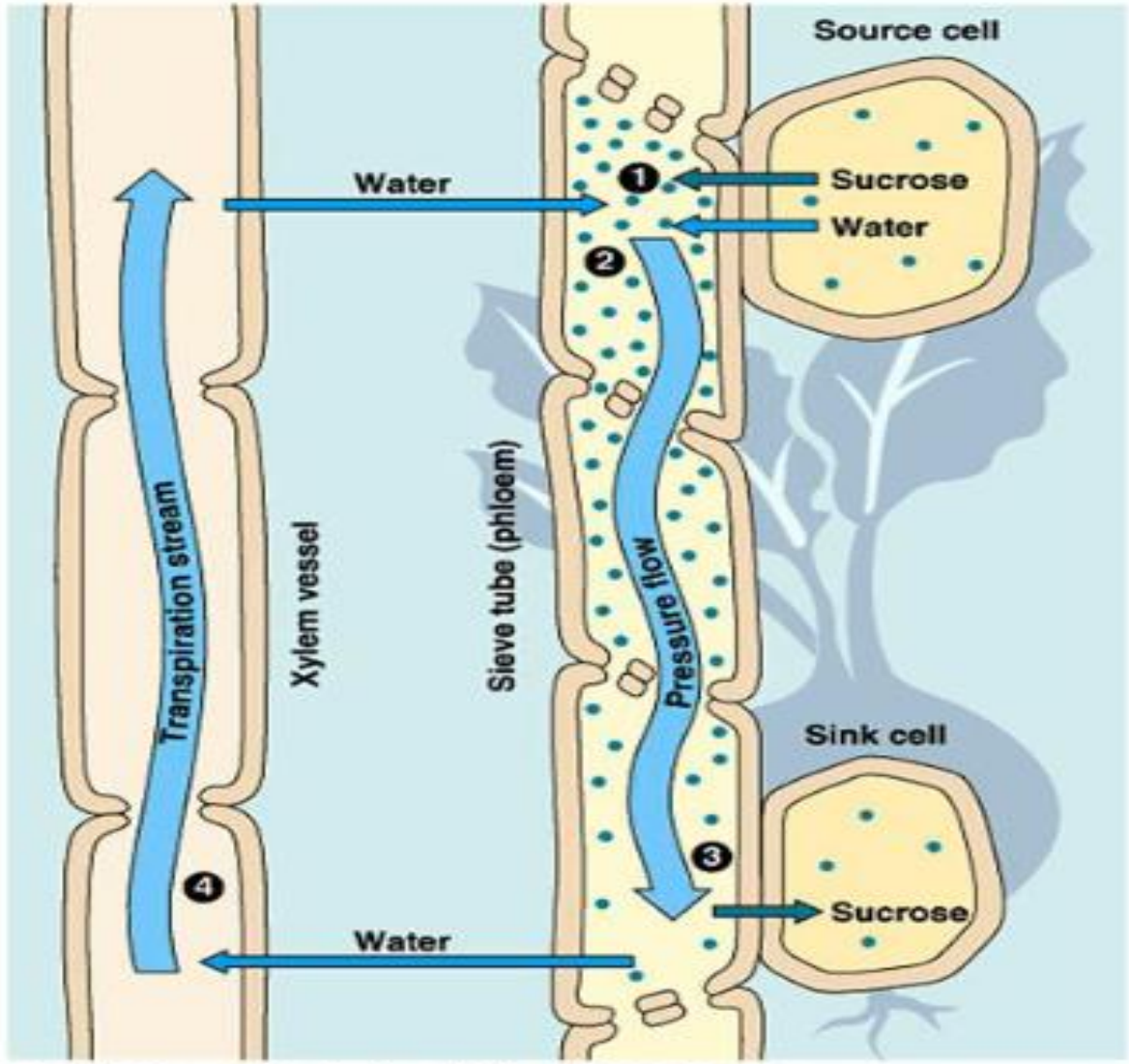
- A plant will die if phloem transport through its stem is blocked. This phenomenon is known as girdling, sometimes happens in trees where phloem forms the inner layer of bark. Porcupines, rabbits and other mammals seeking food in winter may gnaw on the bark all around the trunk at their particular feeding height. A wound distrups the phloem. A swelling develops just above the girdled area as the downward flow is blocked. The tree dies several years later, after the root has exhausted its supply of starch.



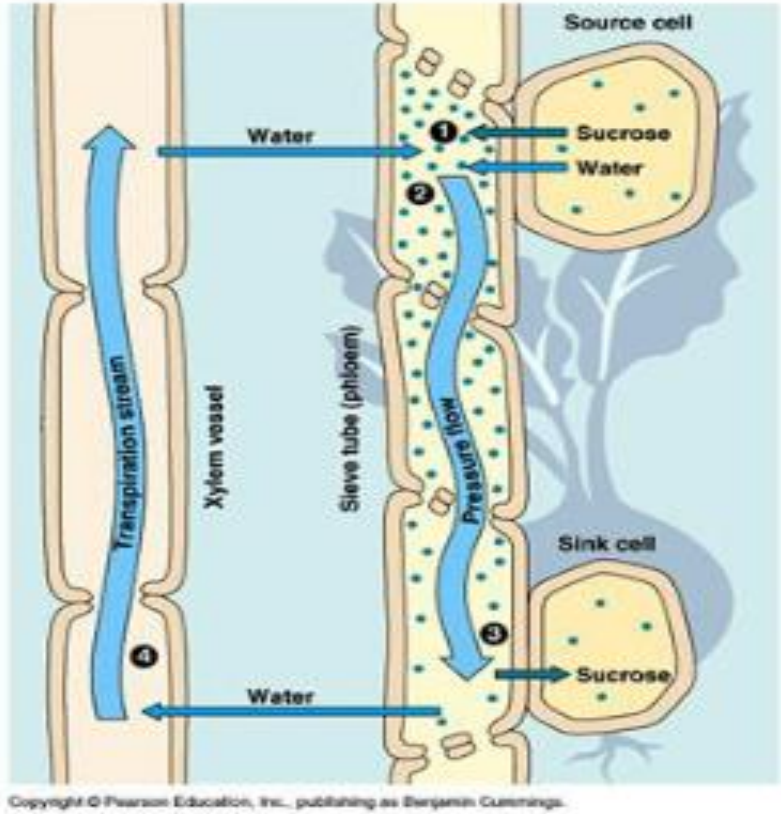
- In the source, sugars are actively transported into companion cells.
- They then flow via plasmodesmata into the phloem tube.
- The higher concentration of sugars inside the tube pulls in water by osmosis, creating a higher water pressure.
- The sugary solution then flows away from this part of the phloem tube.
- In the sink, sugars flow into companion cells and then are pumped, by active transport into other cells.
- The concentration of sugar in the phloem tube decreases and water is drawn out by osmosis, creating a lower water pressure.
- Fluids then flow into this part of the phloem tube.



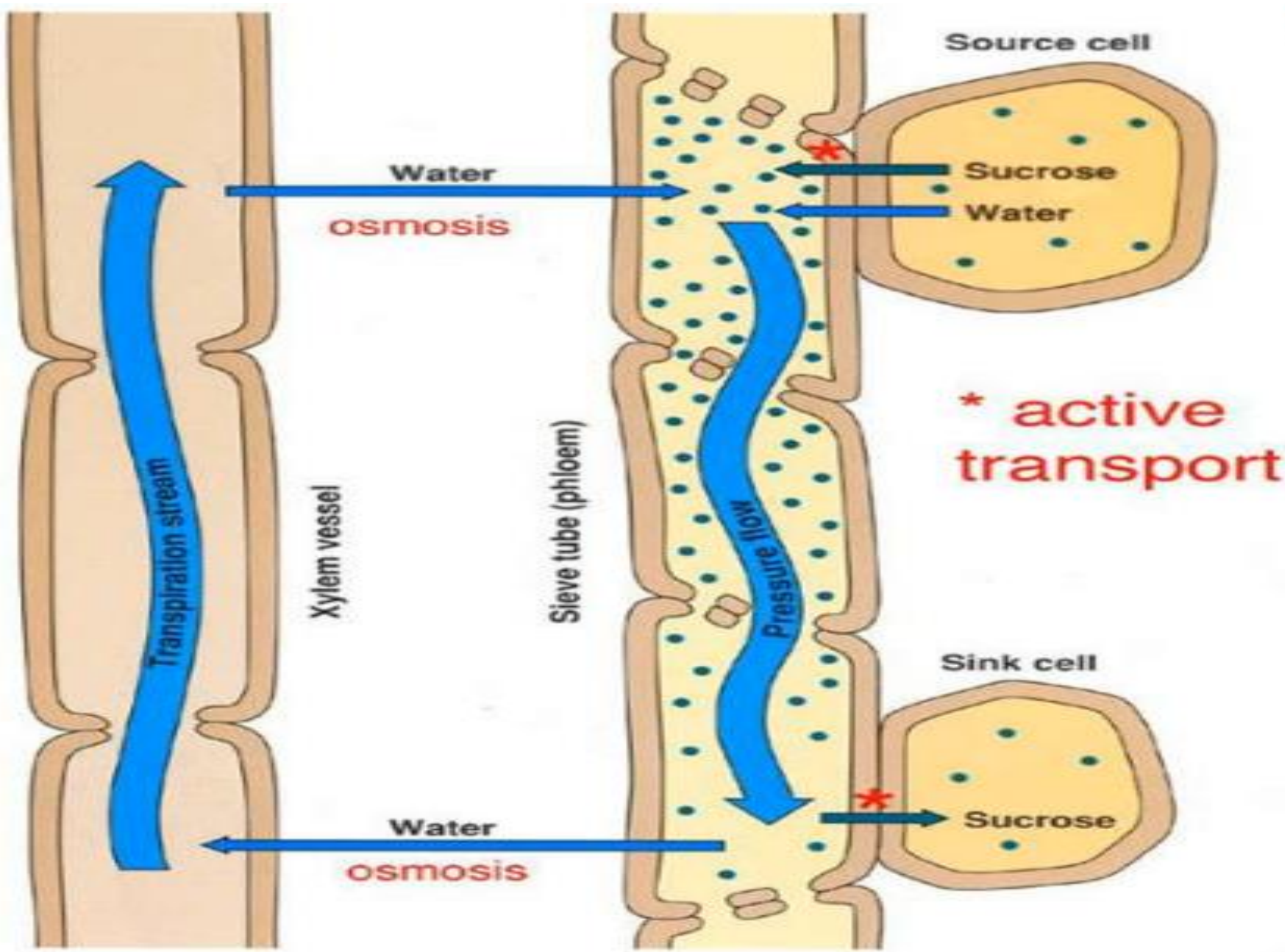
As the concentration of sugar in a sieve tube rises, water is drawn in by osmosis. The inflow of water raises the water pressure, and the fluid is pushed to regions of the tube where water pressure is lower:



A sink develops wherever sugar leaves a sieve tube. In a root, sugar travels from the sieve tube via plasmodesmata to a companion cell. The companion cell pumps the sugar into other cells of the root. As sugar leaves the sieve tube, water follows by osmosis. The water pressure in this part of the sieve tube then drops, and fluids flow into it from other parts:



The transport of fluid within a sieve tube from source to sink does not require energy. Energy is required to create a source and sink to pump in sugar at one end of the sieve tube and to pump out sugar at the other end.


Source cell
Water
osmosis
Sucrose
Water
* active transport
Transpiration stream
Xylem vessel
Sieve tube (phloem)
Pressure flow
Sink cell
Sucrose
Water
osmosis

Factors affecting translocation

Temperature : Optimum temperature for translocation ranges between 20-30°C. The rate of translocation increases with the increase of temperature upto an upper limit and then starts declining. At low temperature, the rate of translocation decreases.

Light : Hartt and his coworkers (1964) proposed that the movement of assimilates of a leaf can depend upon radient energy. The increase in light intensity more food starts being translocated to roots than to shoots. At lower intensity the growth of root and shoot is inhibited thereby the rate of translocation also decreases.

Hormones : Cytokinins have a pronounced effect on the translocation of water soluble nitrogen compounds.

Oxygen : Oxygen is necessary during transfer of food from mesophyll cells into phloem which is called as phloem loading.

Minerals : Boron is highly essential for translocation of sugar. Phosphorus also helps in translocation of solutes.

Water : Translocation of photosynthates out of the leaves is highly sensitive to the amount of water in the plant cells.

Metabolic inhibitors : The metabolic inhibitors which inhibit the process of respiration (*e.g.*, iodoacetate, HCN, carbon monoxide etc.) adversely affect the process of translocation because phloem loading and unloading require ATP.