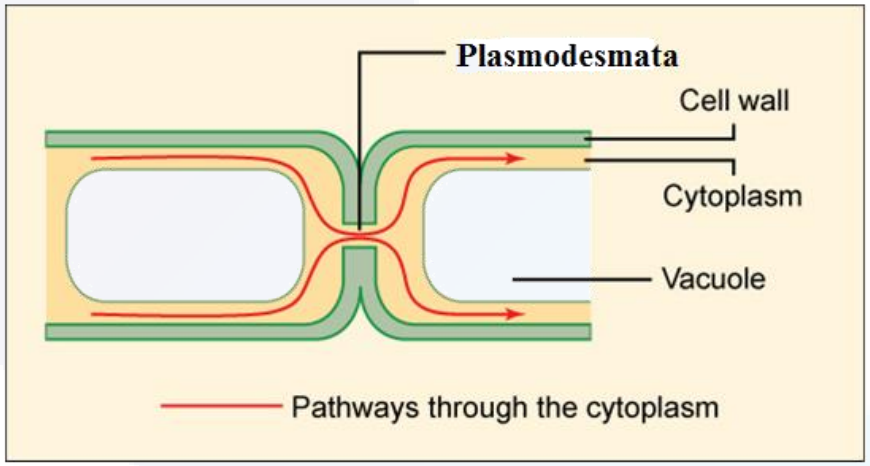
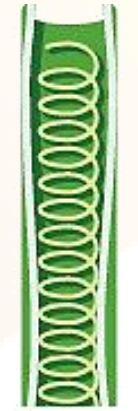
SYMPLAST

- During symplastic movement, water travels through the cells- their cytoplasm; intercellular movement is through the plasmodesmata.

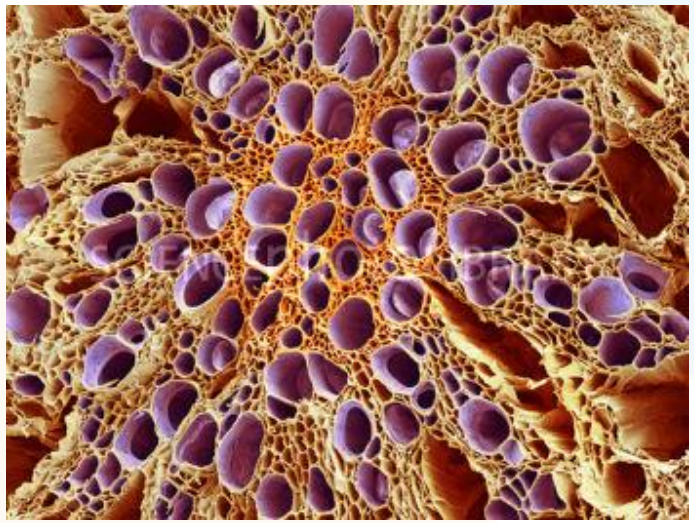


- Once inside the xylem, water is again free to move between cells as well as through them.

Through endodermis it will be symplast due to Caspary strip

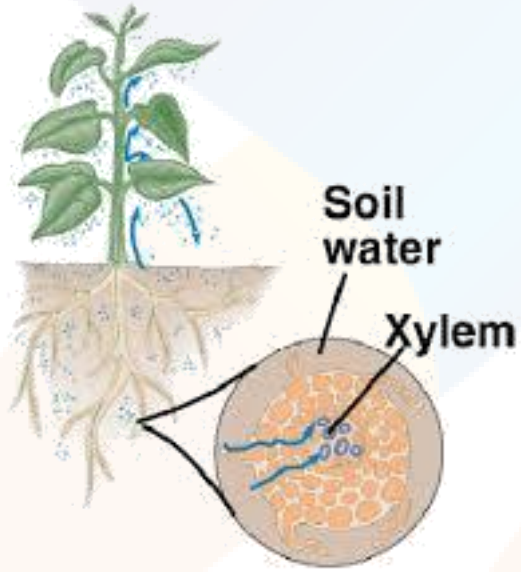


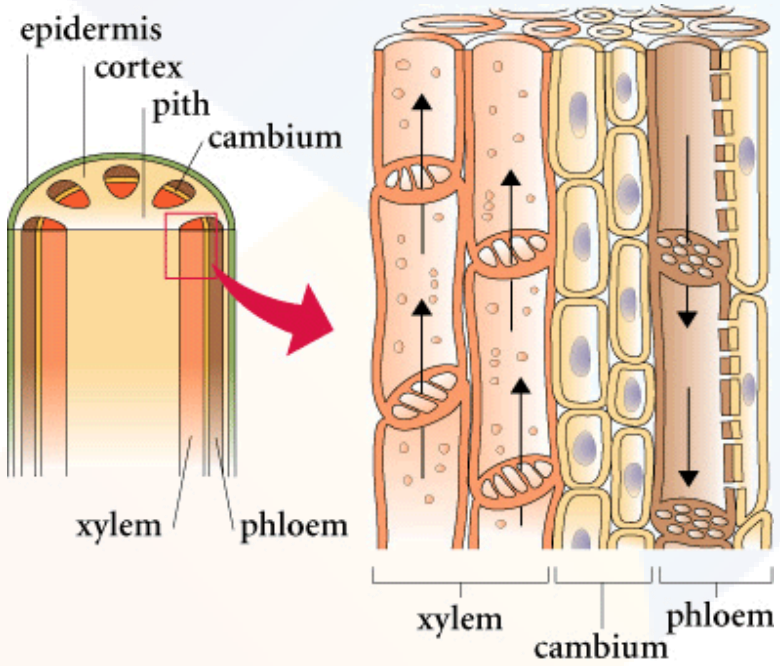
Xylem



ROOT PRESSURE

- As 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.

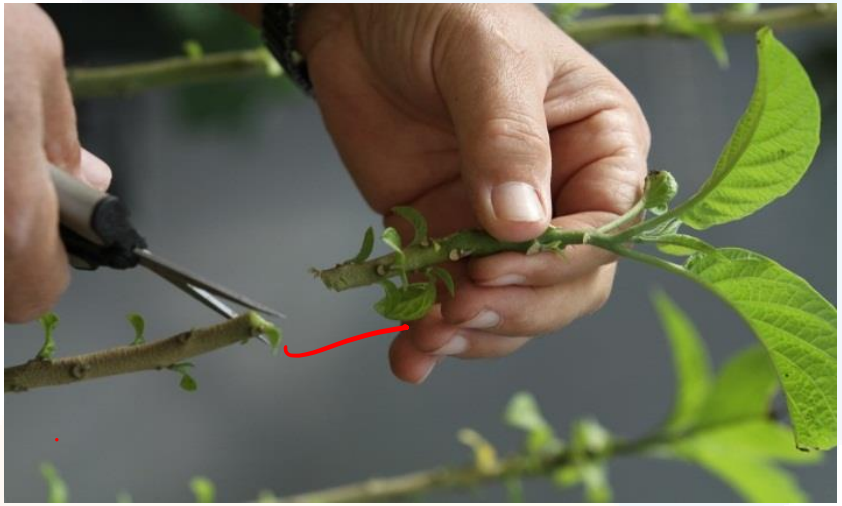




DEMONSTRATION OF ROOT PRESSURE

- In order to see the existence of root pressure, select a small soft-stemmed plant and on a day when there is plenty of atmospheric moisture, cut the stem horizontally near the base with a sharp blade early in the morning.

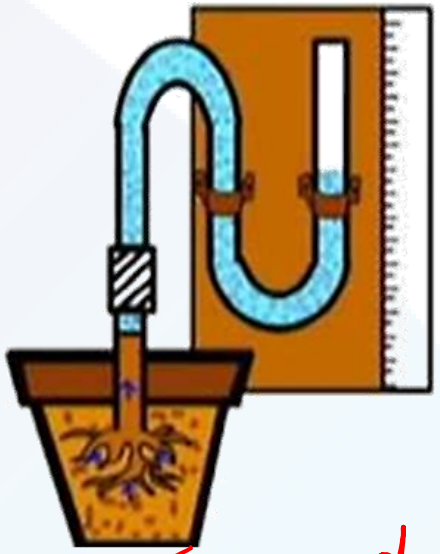
- You will soon see drops of solution ooze out of the cut stem; this happens due to the positive root pressure.



GUTTATION

- If you fix a rubber tube to the cut stem as a sleeve, you can actually collect and measure the rate of exudation, and also determine the composition of exudates.

- The effect of root pressure is also 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 tips of grass blades and leaves of many herbaceous parts.



Such water loss in its liquid phase is known as guttation.

Through hydathodes

ROOT PRESSURE IN TRANSPORT

- Root pressure can, at best, only provide a modest push in the overall process of water transport.

- It obviously does not play a major role in water movement in tall trees such as Sequoia sempervirens (gymnosperm).

Transpiration

- The liberation of water in the form of water vapour from the aerial parts of plant is called **transpiration.**

❖ Types of transpiration

- **Cuticular transpiration:** It takes place through cuticle. It is about 3-10% of total transpiration. It may be 50% in herbs and ferns
- **Stomatal transpiration:** It is about **50-97%** of total transpiration that occurs through stomata which are present on leaves only.
- **Lenticular transpiration :** Some water may be lost through lenticels present in woody stem and fruits **(0.1-1%)**

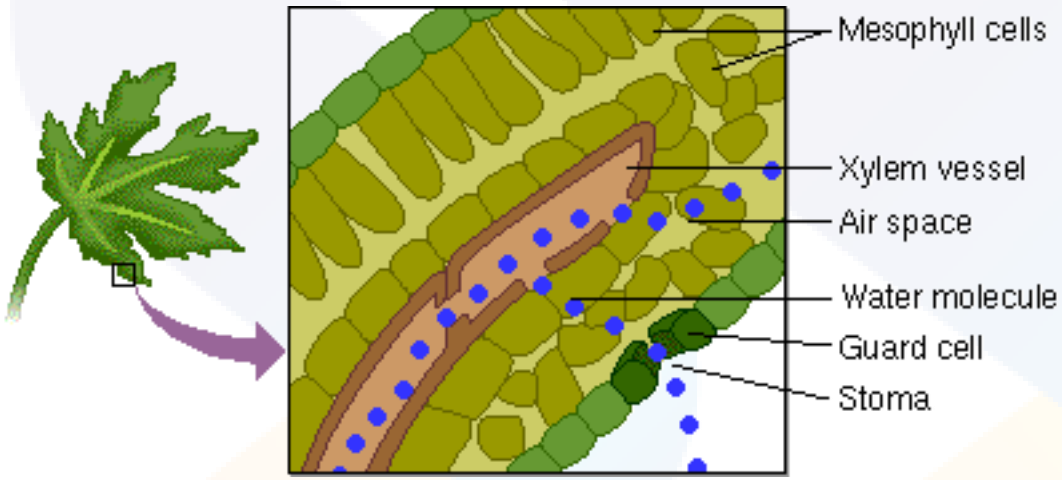
leaves

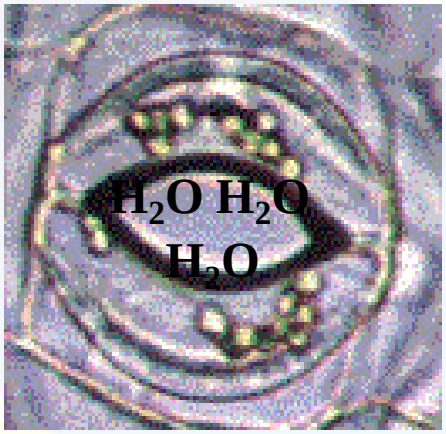
↳ Openings in woody stem

S > C > L

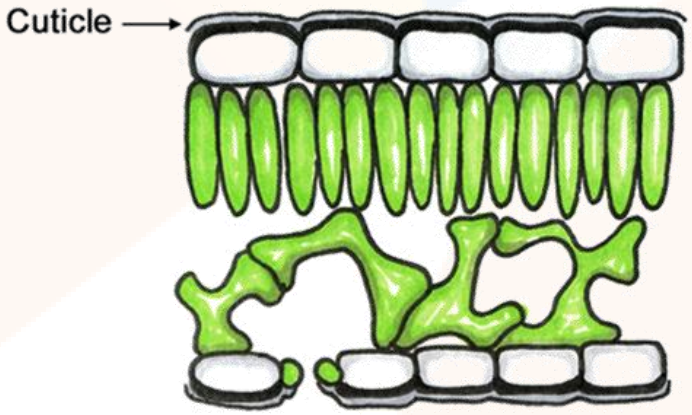
TRANSPIRATION

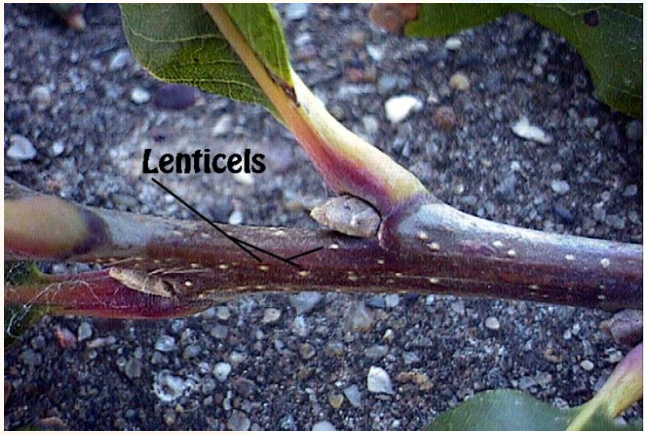
- The phenomenon of transpiration occurs mostly through stomata (singular stoma) located on leaves.





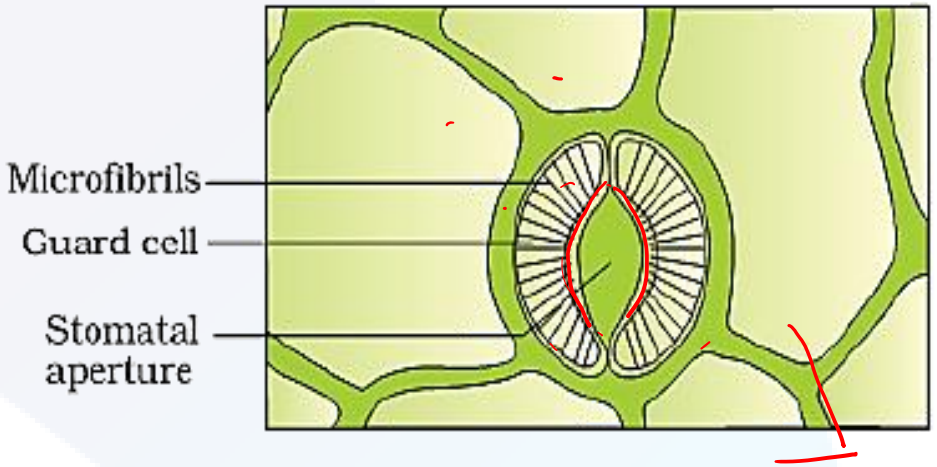
- It also occurs through cuticle and lenticels in insignicant quantities.





Structure Of Stomata

- Stomata consists of two bean shaped or kidney shaped guard cells contain chloroplasts.
- Their inner wall is thick concave and non - elastic and outer wall is thin, convex and elastic.
- Modified epidermal cells which surround the guard cell called **accessory or subsidiary** cells
- In the plants of **family Gramineae (eg. grasses)** guard cell are **dumb-bell shaped,** cell walls are thickened in the middle.
- In xerophytic plants subsidiary cells are found over guard cells so that the position of stomata is below from leaf surface. These stomata are called **sunken stomata**



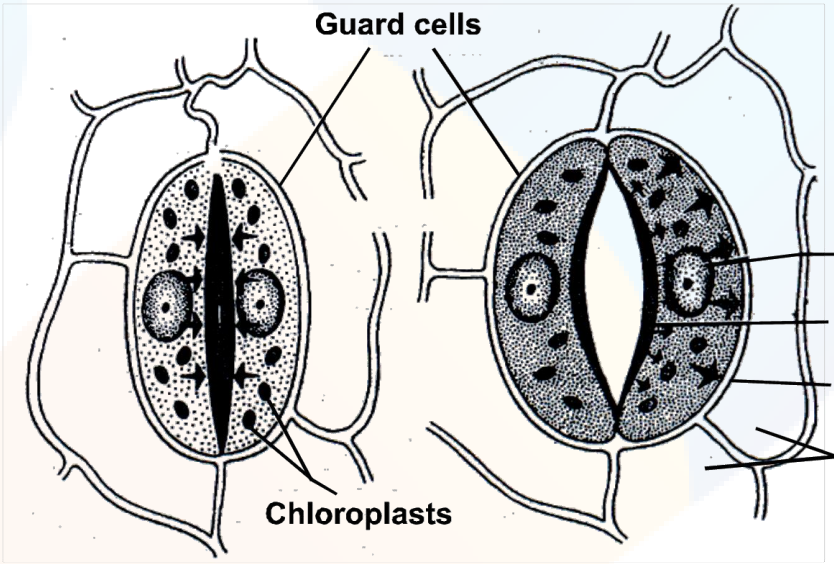


Fig:- (i) Closed stomata (ii) Opened stomata

Distribution of Stomata on Leaf Surface

- 1-2% part of leaf is surrounded by stomata. Number of stomata is, 1,000 to 60,000 in per sq. cm.
- Some bryophytes and Pteridophytes bears functional stomata.
- Stomata are usually found at the lower surface in dorsoventral leaf of dicots. It is called **hypostomatic condition.**
- While in monocots, stomata are located on both surface of isobilateral leaf. It is called **Amphistomatic condition.**

Types of Stomata

❖ On the basis of distribution

- **Apple or mulberry type:** Stomata are found only on lower surface of leaves (Hypostomatic Condition). **Ex: Apple, Walnut, Banyan**
- **Potato type:** Stomata are present on both surface, more on lower surface than upper surface. **Ex: Brinjal, Tomato, Potato**
- **Oat type:** Stomata are found equally on both the surface (Amphistomatic Condition). **Ex: Rice, Wheat, Oat**
- **Water lily type :** Stomata are present only on upper surface (Epistomatic Condition). **Ex: Nymphaea, Nelumbium, Water lily**
- **Potamogeton type :** Stomata either absent or function less. **Ex: Vallisnaria, Potamogeton**

❖ On the basis of Daily stomatal movement

- **Alfa - Alfa type :** The stomata are open all day and close at night. **Ex: Pea, Mustard**
- **Potato type :** The stomata are open whole day and night except for a few hours during the day time (evening). **Ex: Cabbage, Onion, Potato, Pumkin**
- **Barley type :** Stomata open only for few hours in day. **Ex: Wheat, Rice, Maize**
- **Equisetum :** The stomata never remain close. **Ex: Equisetum**
- **Succulent type :** The stomata remain closed through out the day but open at night. **Ex: Cactus, Opuntia**

SCOTOACTIVE STOMATA

- In succulent plants, it is noted that transpiration occurs at night through scotoactive stomata that open during the night and remain closed during the day time.

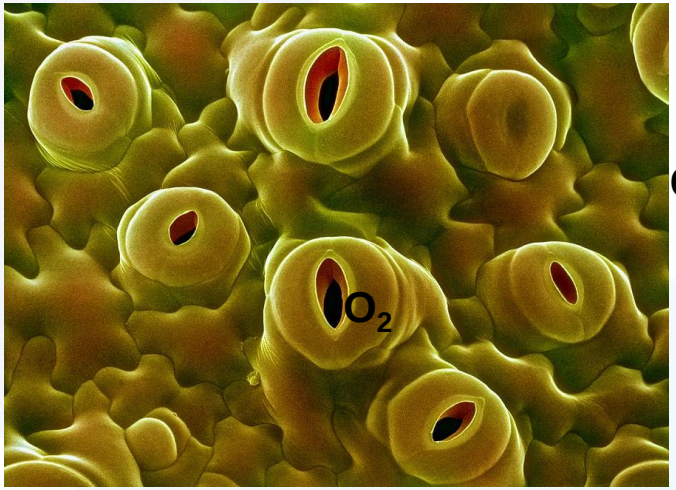
e.g.

Cacti

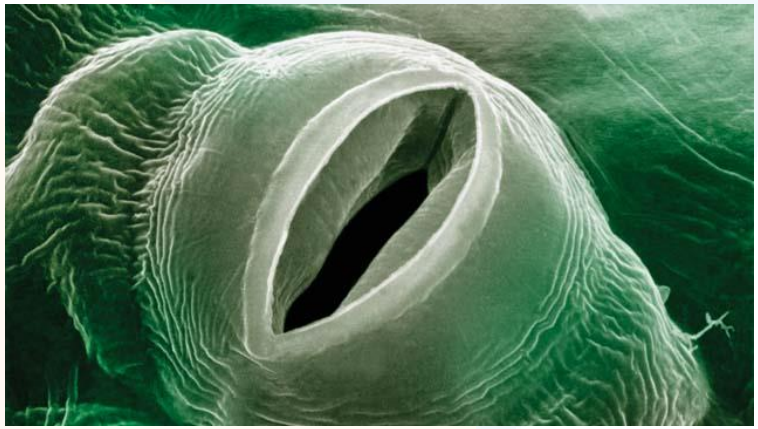
Bryophyllum

FUNCTIONS OF STOMATA

- Besides transpiration, exchange of oxygen and carbon dioxide also occurs through stomata.



- When turgidity increases within the two guard cells flanking each stomatal aperture or pore, the thin outer walls bulge out and force the inner walls into a crescent shape.



Mechanism of Opening And Closing of Stomata

- It mainly depends on the decrease and increase of turgor pressure in the guard cells.

❖ Photosynthetic theory

- Chloroplast of guard cells synthesize osmotically active sugar which resulted in endosmosis and increased turgor of guard cells in the presence of light.
- So stomatal aperture become widen. In the absence of photosynthesis during night turgidity of guard cells is reduced so stomata are closed.

❖ Starch sugar hypothesis

- Starch content of guard cell convert in to sugar in the presence of light. Sugar (glucose -1- phosphate) is soluble in water so that O.P. of guard cells increase and stomata are opened.
- While in night glucose -1- phosphate convert in starch which is insoluble in water. Thus O.P. of guard cells reduce and stomata are closed.

Active K^+ transport mechanism - In Light

❖ In Light

- The starch of guard cells convert into organic acids like malic acid in the presence of light

- Malic acids split in to Malate anions and H^+ ions in the guard cells.

- H^+ ions are transported to epidermal cells and K^+ are taken in to the guard cells. This process is called ion exchange.

- K^+ ions combine with malate to form potassium malate.

- Due to increase the concentration of potassium malate the osmotic concentration of guard cells increases. So guard cells absorb water from adjacent cells through endosmosis and swell up and stomatal aperture widens

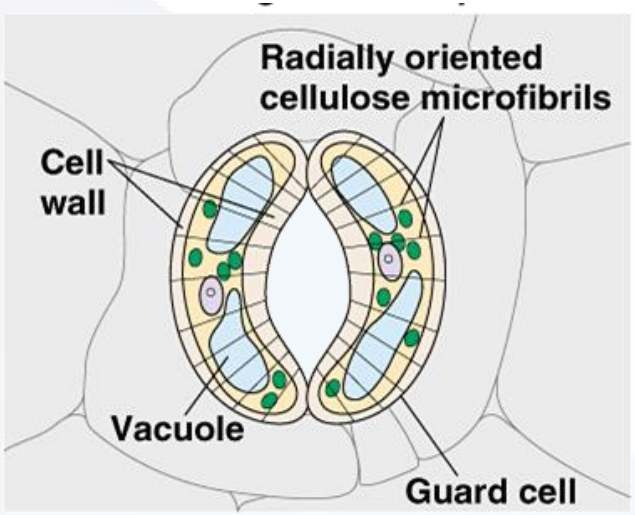
Active K^+ transport mechanism - In Dark

❖ In Dark

- During night concentration of CO_2 increases in guard cells. That reduces pH of guard cells.
- Abscisic acid is active in the presence of CO_2 which initiate the closing of stomata.
- Abscisic acid is responsible to change the permeability of guard cells. So that in take of K^+ stop.
- Now transfer of K^+ ions start from guard cells to epidermal cells. Whereas H^+ ions transfer from epidermal cells to guard cells.
- At low pH organic acids are again converted in to starch OP of Guard cells is decreased.
- Therefore water moves from guard cells to adjacent cells resulting guard cells become flaccid and stomata are closed.

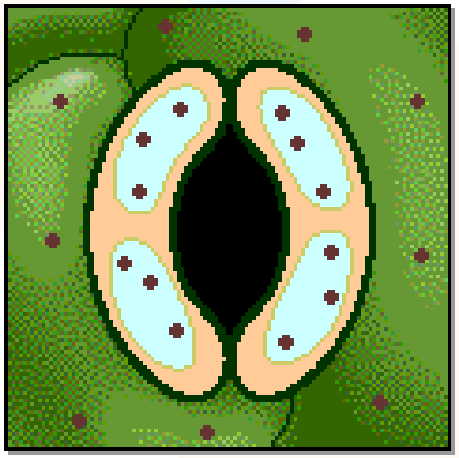
OPENING AND CLOSING OF STOMATA

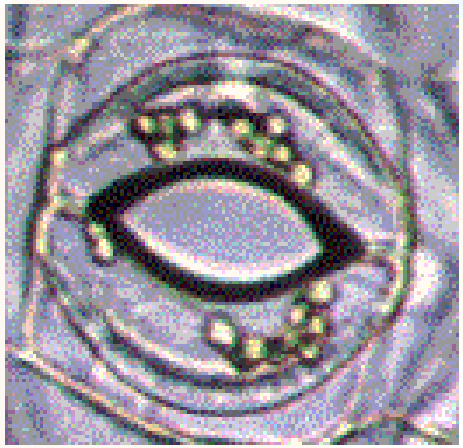
- The opening of the stoma is also aided by the orientation of the microfibrils in the cell walls of the guard cells.



- Cellulose microfibrils are oriented radially rather than longitudinally, making it easier for the stoma to open.

- When the guard cells lose turgor due to water loss (or water stress) the elastic inner walls regain their original shape, the guard cells become flaccid and the stoma closes.

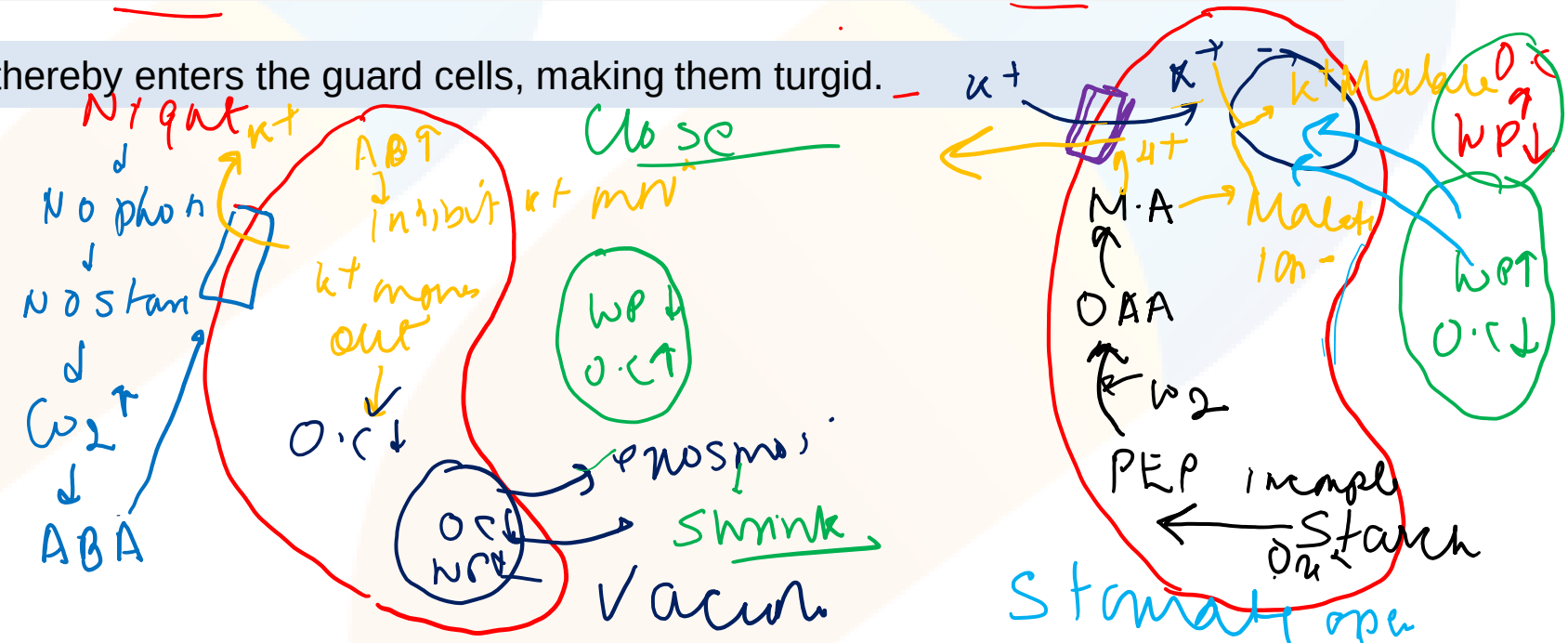




POTASSIUM PUMP THEORY

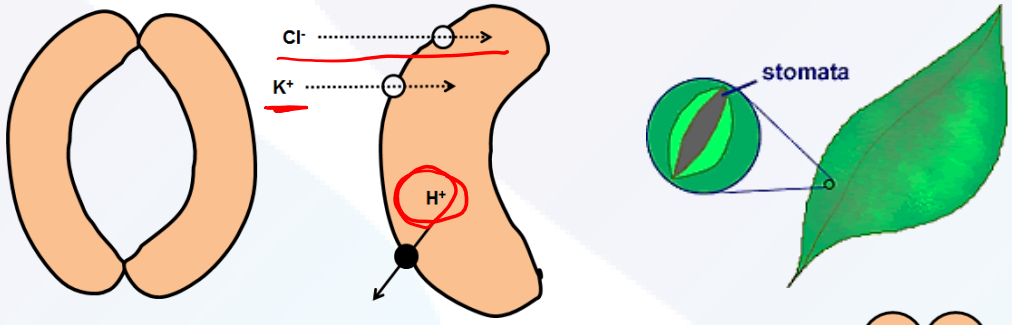
- Levitt (1974) proposed K^+ pump theory to explain the mechanism of opening and closing of photoactive stomata.
- According to this theory, accumulation of K^+ ions into the guard cells from the subsidiary cells occurs in the presence of light.
- This coupled with efflux of protons leads to increase in pH of the guard cells.
- Accumulation of K^+ ions into the guard cells is associated with passive influx of Cl^- ions thereby decreasing the water potential of the guard cells.

Water thereby enters the guard cells, making them turgid.

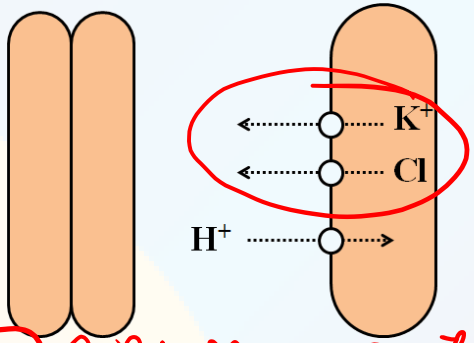


POTASSIUM PUMP THEORY – 2

- As the outer walls are thin and elastic, the guard cells expand outwardly, leaving a minute pore at the centre open.



- At night, in the absence of light, the K^+ and Cl^- ions move out of the guard cells due to which the water potential of guard cells increases and water starts moving out of them leading to closure of stomata.



- Under water stress conditions, abscisic acid (ABA), a natural anti - transpirant drives the K^+ ions out of guard cells making them close.

- In succulent plants, the water potential gradient established due to the accumulation of organic acids at night makes the guard cells become turgid, hence stomata open at night.

Factor Affecting Opening And Closing Of Stomata

1. Light
2. Temperature
3. CO_2 concentration
4. Minerals concentration
5. Water contents
6. Water contents of leaves
7. Growth hormones
8. Atmospheric humidity

Factor Affecting the rate Of Transpiration

(1) External factors

(2) Internal factors

(1) External factors :

(i) Atmospheric humidity

(ii) Temperature

(iii) Light

(iv) Wind velocity

(v) Atmospheric pressure

(vi) Available soil water

(vii) Anti transpirants

(2) Internal factors :

(i) Root / Shoot ratio

(ii) Leaf area

(iii) Water contents of the leaves

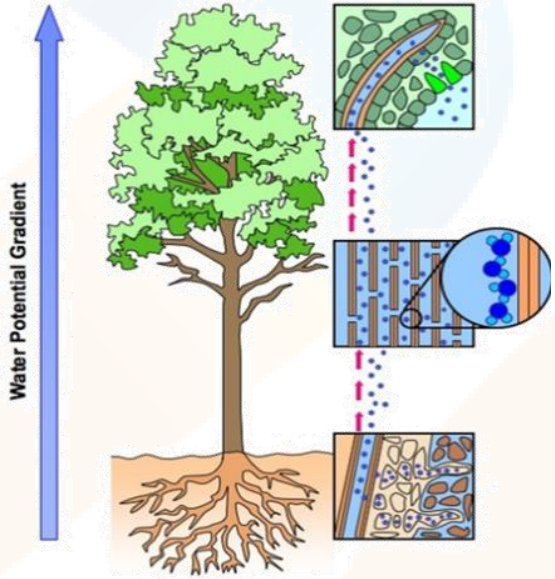
(iv) Orientation of leaves

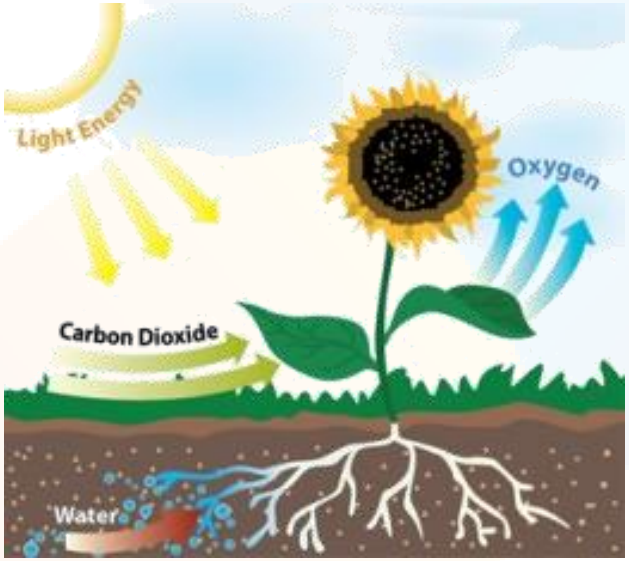
(v) Surface areas of Leaf Stomata

ROLE OF TRANSPIRATION

a) Transpiration and Photosynthesis – a Compromise

- ❖ Transpiration has more than one purpose;
- It creates transpiration pull for absorption and transportation in plants.
- It supplies water for photosynthesis.





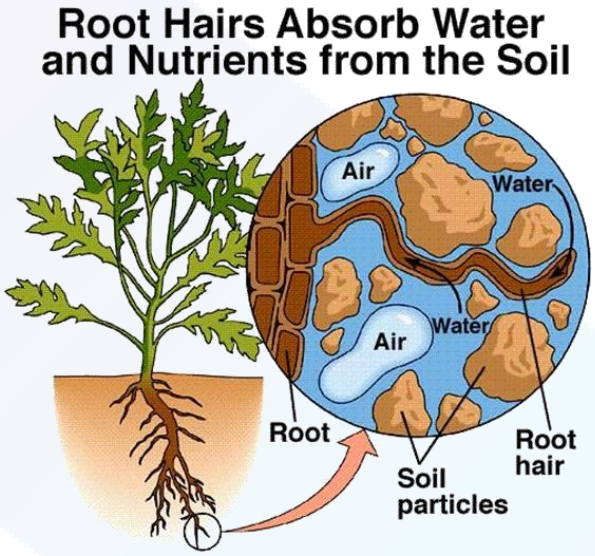
UPTAKE OF MINERAL IONS

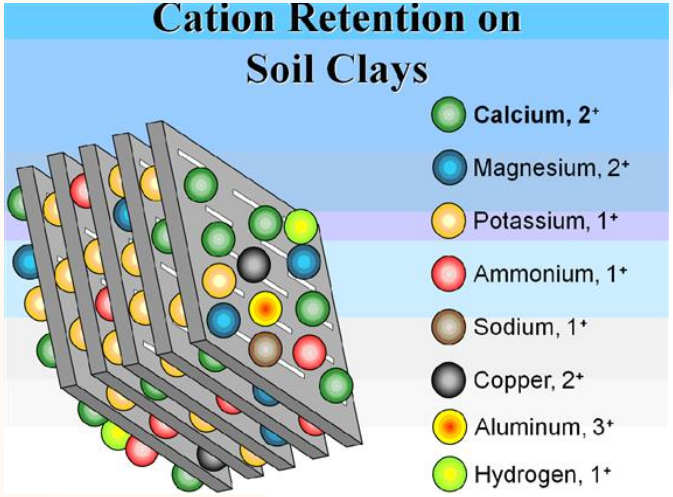
- Unlike water, all minerals cannot be passively absorbed by the roots.

- Two factors account for this:

(i) Minerals are present in the soil as charged particles (ions) which cannot move across cell membranes and

(ii) The concentration of minerals in the soil is usually lower than the concentration of minerals in the root.





Significance of Transpiration

❖ Beneficial effects

- **Ascent of sap :** DPD or suction pressure produces due to transpiration which is helpful in ascent of sap

- **Regulation of Temperature :** Transpiration causes a cooling effect thus it prevents the heating of plant leaves and maintain their temperature

- **Absorption of water :** Transpiration influences the rate of absorption of water from soil. During rapid transpiration a negative tension or transpiration pull is created from the xylem of root to the leaves. With the result, water is pulled into the root from the soil and transfer to the upper part.

Guttation

- The loss of water in liquid form as droplets from Hydathodes of uninjured leaf margins. It is called guttation. The term Guttation was given **Burger stein.**

- Guttation is maximum when transpiration is low and absorption of water is high. It causes development of root pressure in root cells that pushes water in the xylem in upward direction, finally this water is accumulated in loosely arranged parenchymatous cells or epithem cells.

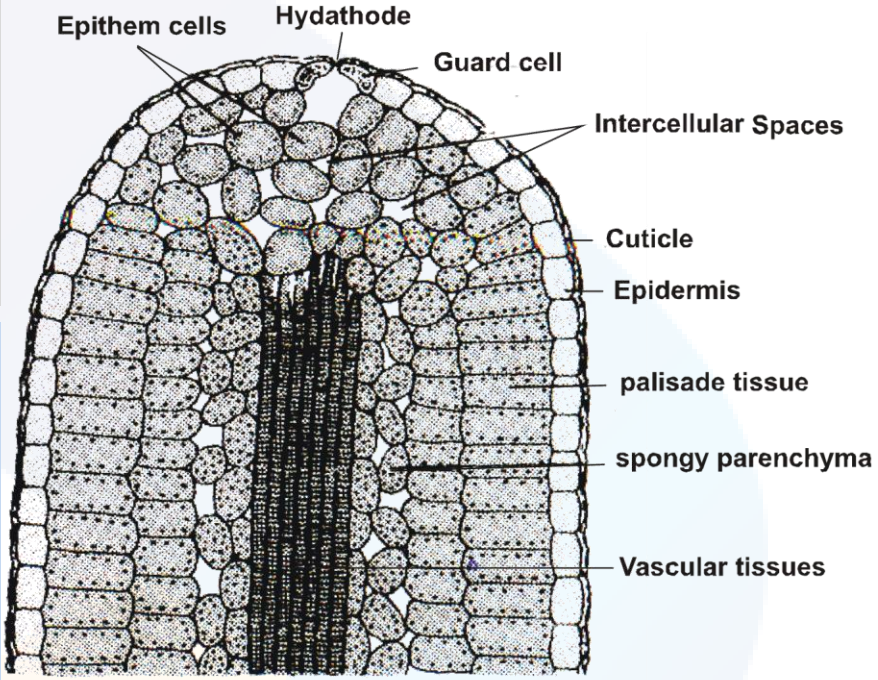


Fig:- Section of leaf showing Hydathode

- Now this water is released in the form of tiny droplets by Hydathodes of leaf tip. Guttated water contains organic and inorganic salts and is not pure. **Ex: Cucumber, Garden Nasturtium, Tomato, Oat, Sexifraga**

Bleeding

- Secretion of liquid from injured part or cut part of plants is called **bleeding**, Bleeding occurs due to root pressure. This process can be seen in Toddy palm, Rubber, Betula, Acer, Vitis.

- Today palm secrete approximately 50 litre juice/day through this process. Which is useful in the synthesis of Alcoholic beverage ‘Taddi’.

Ascent of Sap

- Upward conduction of water (in the form of dilute solution of 0.1% of mineral ions) against gravitational force from roots to leaves is called **ascent of sap**

❖ Path of Ascent of sap

Tracheid's and vessel of xylem is responsible for ascent sap which can be proved by girdling experiment or ringing experiment

Ringing experiment

- In this experiment two small twigs of healthy plant are taken.
- A ring of bark is removed from one (twig A) by a sharp knife. In second twig (B) xylem is removed without causing injury to the bark or xylem is blocked with wax or grease.
- The twigs A and B are placed individually in beakers contains water. After some time, it is found that leaves of twig A appear turgid where as in twig B drooped, In the first case (twig A), the leaves continue to receive water through xylem where as in the second case (twig B), water conduction is halted due to blocked xylem.
- This ring experiment proved that conduction of water takes place through xylem not phloem

Theories of Ascent Of Sap – Vital and Root pressure

❖ Vital theories

- **Relay pump theory:** It was put forward by **Godlewski (1884)**. According to this theory living cells of xylem parenchyma show rhythmic change in the osmotic pressure which causes upward movement of water.

- (2) **Pulsation theory:** It was proposed by **J.C. Bose (1923)**. He used electric probe apparatus in his experiment. According to this theory upward translocation of water is due to pulsatory activity of the living cells of inner most cortical layer (Just outside the endodermis).

  J.C. Bose is known as father of Indian plant physiology

❖ Root pressure theory

- The term root pressure was coined by **Stephan hales**

- If a stem is cut near its base is made in to a plant, xylem sap is seen to flow out. This phenomenon is known as exudation. According to priestly bleeding of xylem sap due to hydrostatic pressure which is developed in root system, It referred as root pressure

Theories of Ascent Of Sap - Physical forces theories

❖ Physical forces theories

- **Capillary force theory :** It was given by **Boehm (1809)**. According to this theory, capillary force of vessels and tracheid's is responsible for ascent of sap

- **Imbibition theory :** It was put forward by **Unger & Sachs (1878).** According to this theory imbibition activity of cell wall of xylem is responsible for ascent of sap

- **Atmospheric pressure theory :** According to this theory the water transpires the leaves which reduces the pressure in the xylem cells and this gap is filled by the water just below it due to atmospheric pressure

- **Chain theory :** According to this theory air bubble and water molecules are alternately arranged in vessels of xylem & form a chain. Due to expansion of air bubbles in this chain ascent of sap takes place.

Transpirational pull theory

Dixon & Jolly

➢ **Cohesion- tension theory or Transpiration pull theory :**

- **Transpiration pull :** The tension develops due to transpiration is called **transpiration pull**. It is developed from mesophyll cells of leaf to the xylem of root it also called **negative pull.**

- **Cohesion force of water :** Water molecules have mutual attraction due to cohesive force and therefore it forms a solid or compact water column. It has great tensile strength cell wall of xylem vessels show greater tension with water molecules. Strong adhesive force exists between water and wall of xylem vessels.

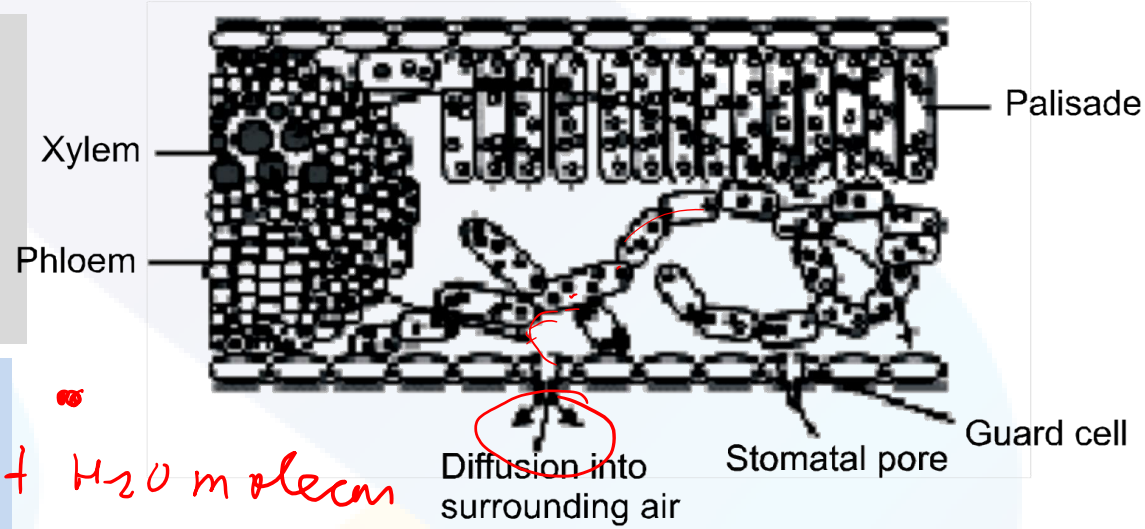


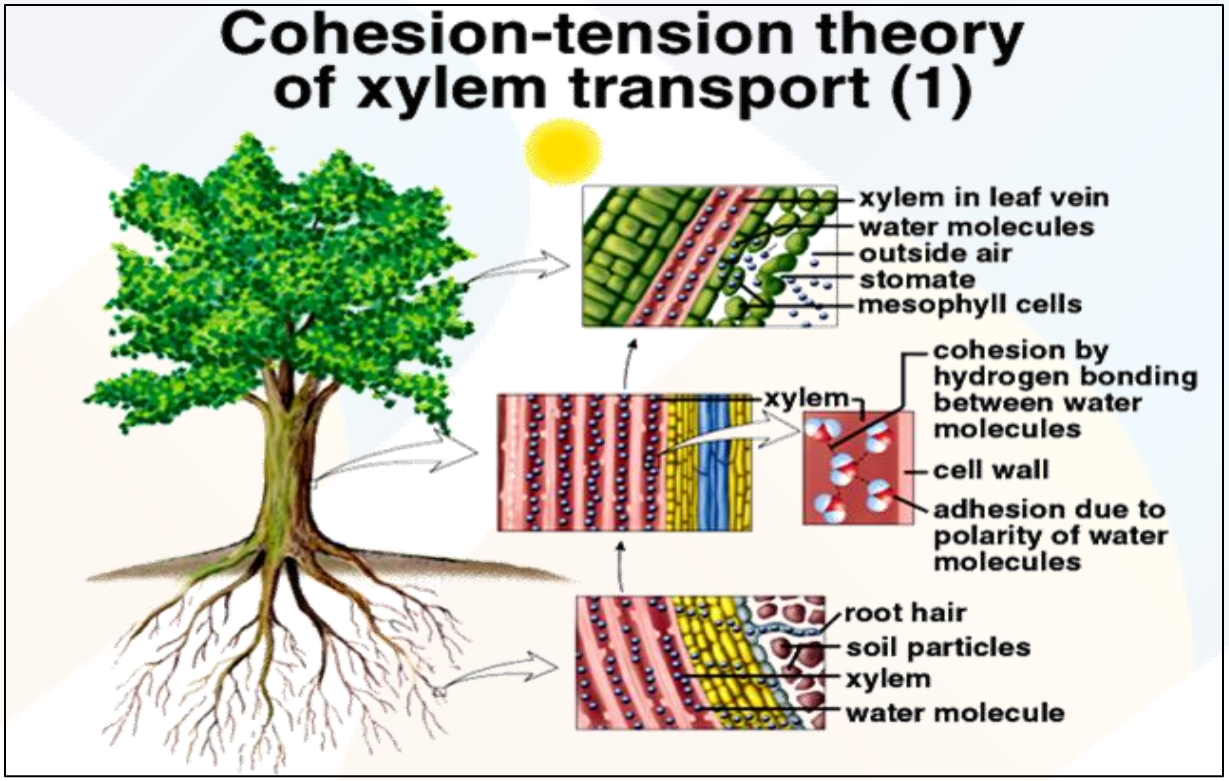
Fig : water movement in the leaf. Evaporation form the leaf sets up a pressure gradient between the out side air and the air spaces of the leaf. The gradient is transmitted into the photosynthetic cell and on the water - filled xylem in the leaf vein.

- **Continuity of water column :** Water column form due to cohesive-adhesive force xylem luman on account of tension created by transpiration the water column of the plant is pulled up passively from below to the top of the plant like a rope.

DIXON AND JOLLY THEORY

- This is referred to as the cohesion-tension-transpiration pull model of water transport.

- This model is proposed by Dixon in 1914.

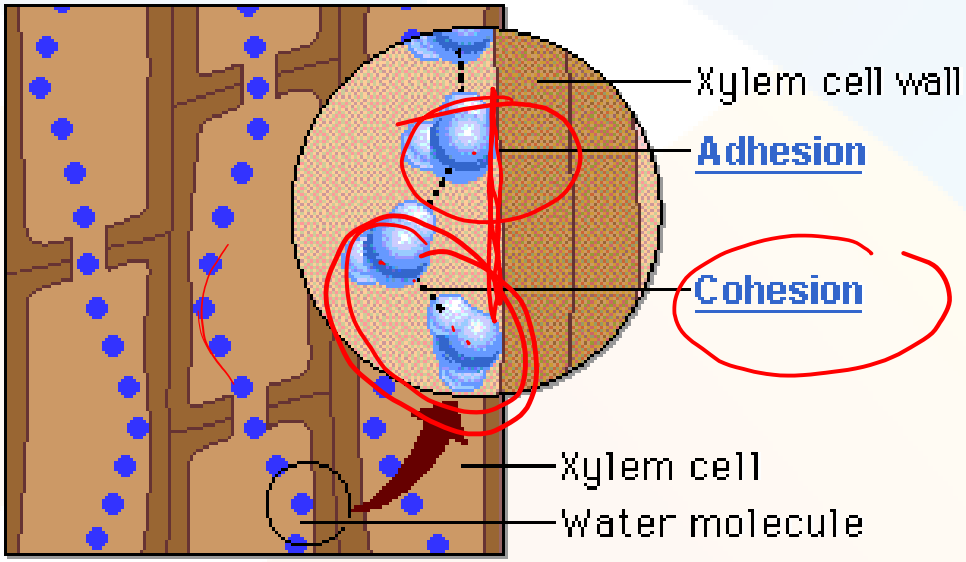


DXON AND JOLLY THEORY

❖ The transpiration-driven ascent of xylem sap depends mainly on the following physical properties of water:

- Cohesion-mutual attraction between water molecules.

- Adhesion-attraction of water molecules to polar surfaces.



CAPPILARITY

- These properties give water .....

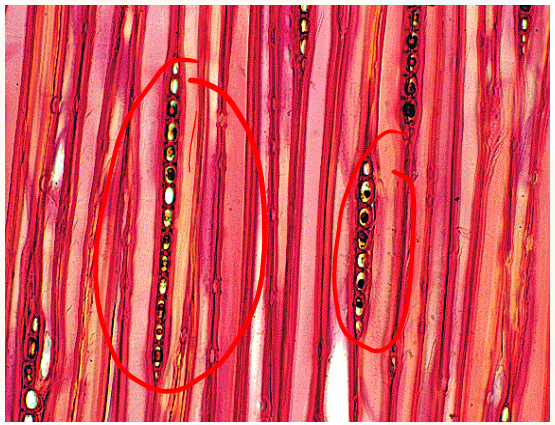
High tensile strength.

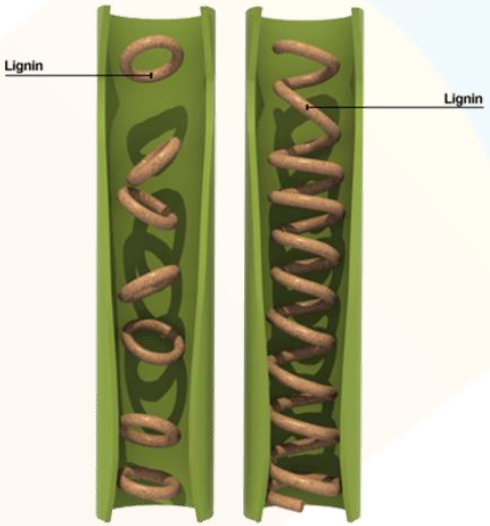
An ability to resist a pulling force.

High capillarity.

The ability to rise in thin tubes.

- In plants capillarity is aided by the small diameter of the tracheary elements- the tracheids and vessels.





TRASPIRATIONAL PULL

- The system of xylem vessels from the root to the leaf vein can supply the needed water.

What force does plant use to move water molecules into the leaf parenchyma cells where they are needed?

The process of photosynthesis required water.

As water evaporates through stomata, the thin film of water over the cells is continuous, it results in pulling of water molecule by molecule, into the leaf from the xylem.

Also, because of lower concentration of water vapour in the atmosphere as compared to the substomatal cavity and intercellular spaces, water diffuses into the surrounding air.

This creates ‘transpiration pull’.

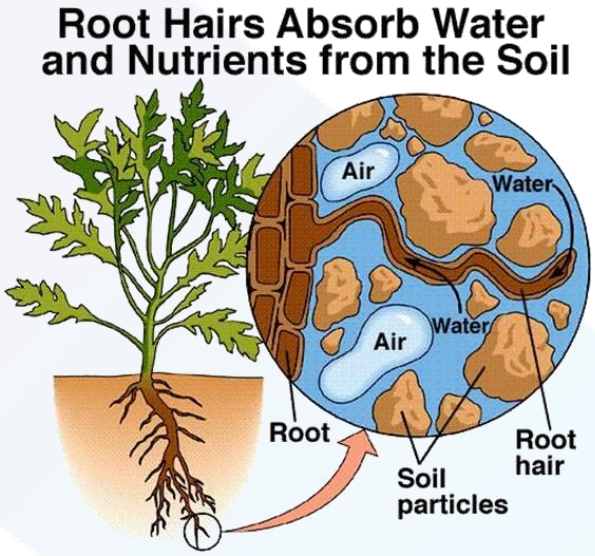
UPTAKE OF MINERAL IONS

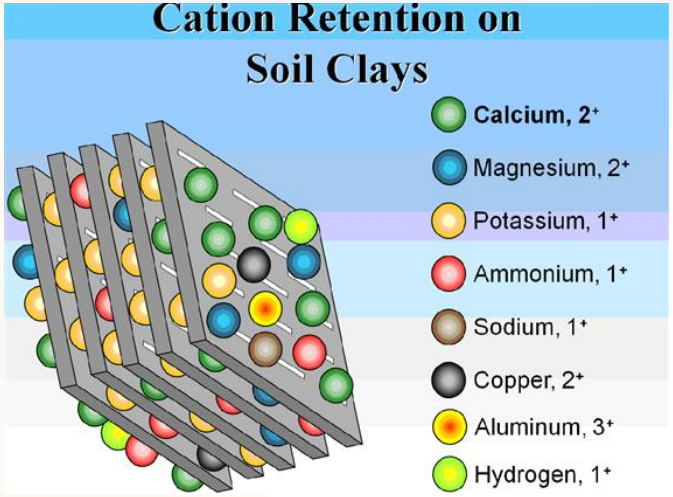
- Unlike water, all minerals cannot be passively absorbed by the roots.

- Two factors account for this:

(i) Minerals are present in the soil as charged particles (ions) which cannot move across cell membranes and

(ii) The concentration of minerals in the soil is usually lower than the concentration of minerals in the root.





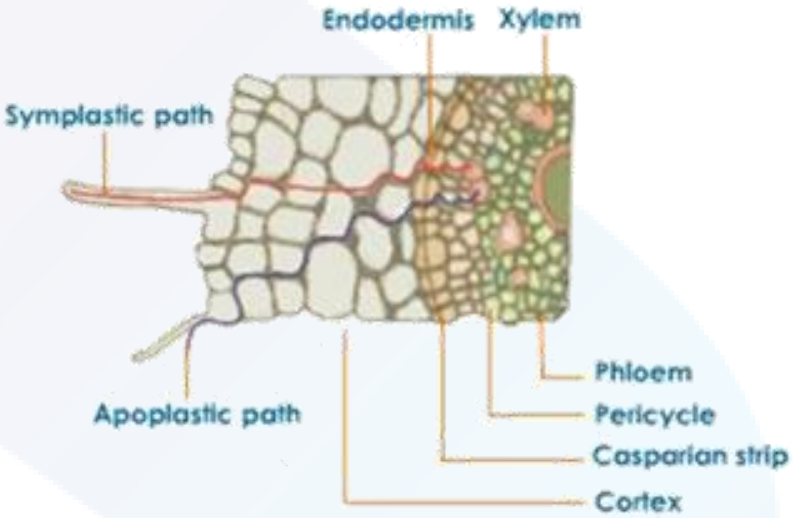
MINERAL TRANSPORT

- Therefore, most minerals must enter the root by active absorption into the cytoplasm of epidermal cells.

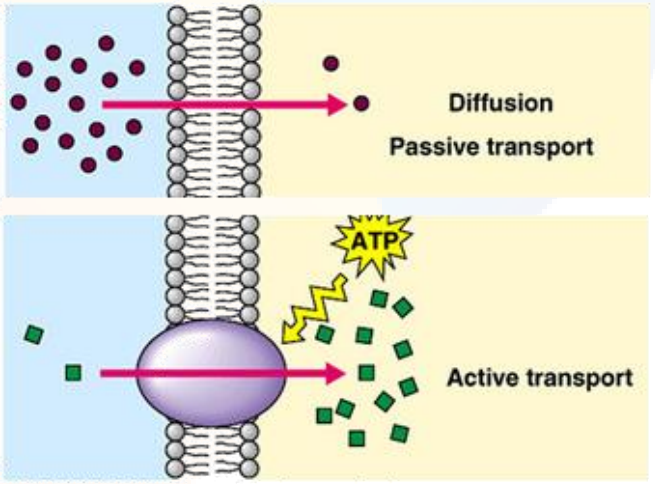
This needs energy in the form of ATP.

- Ions are absorbed from the soil by both passive and active transport.

- Specific proteins in the membranes of root hair cells actively pump ions from the soil into the cytoplasms of the epidermal cells.

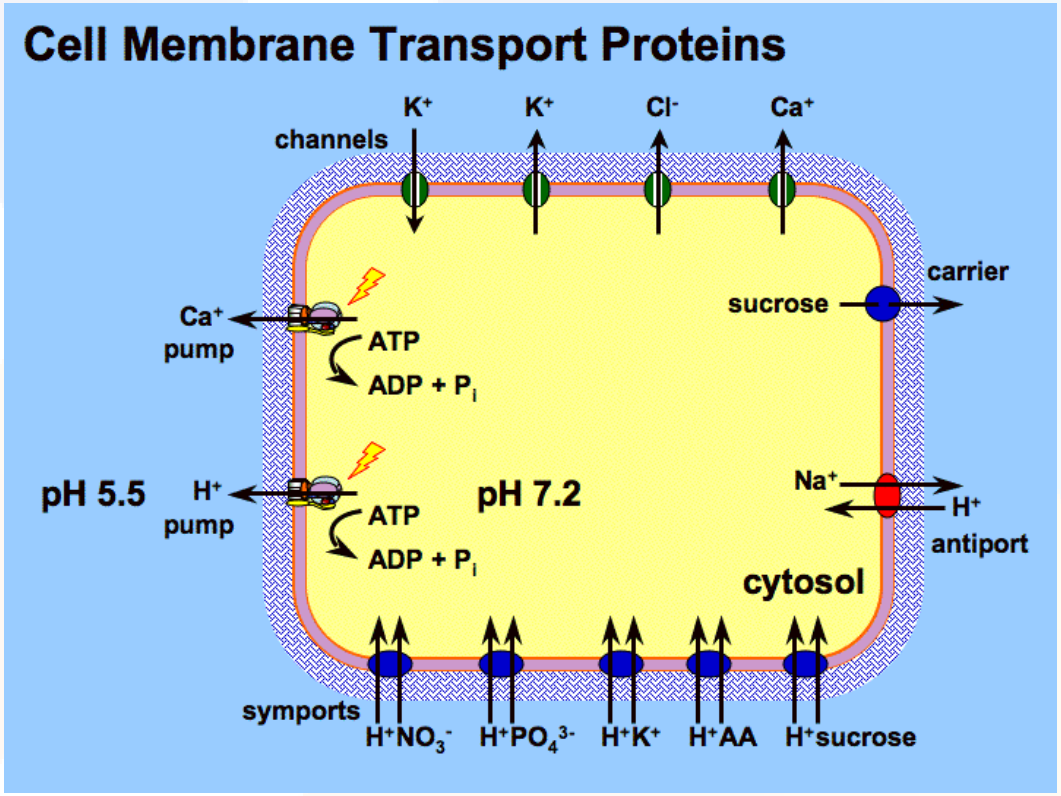


Anatomical aspect of symplastic and apoplastic pathways of ion absorption in the root hair region



TRANSPORT PROTEINS IN THE CELL MEMBRANE

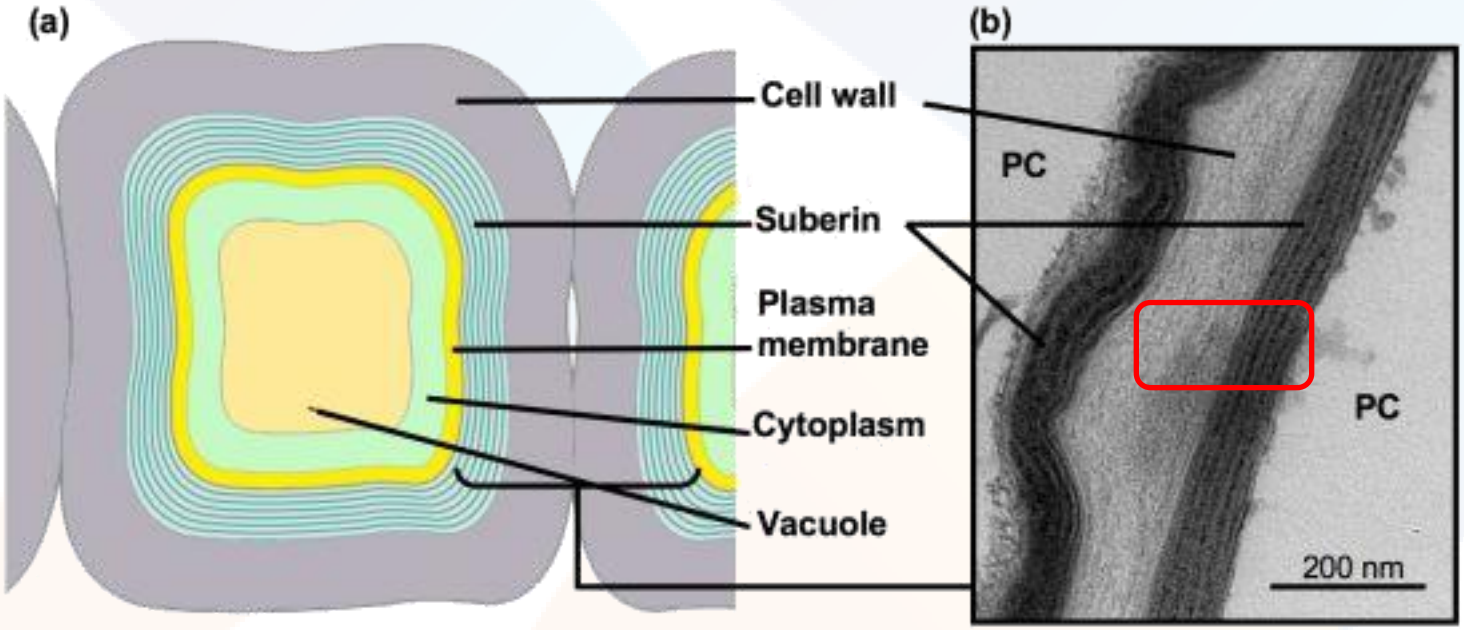
- Like all cells, the endodermal cells have many transport proteins embedded in their plasma membrane; they let some solutes cross the membrane, but not others.



TRANSPORT PROTEIN OF ENDODERMAL CELLS

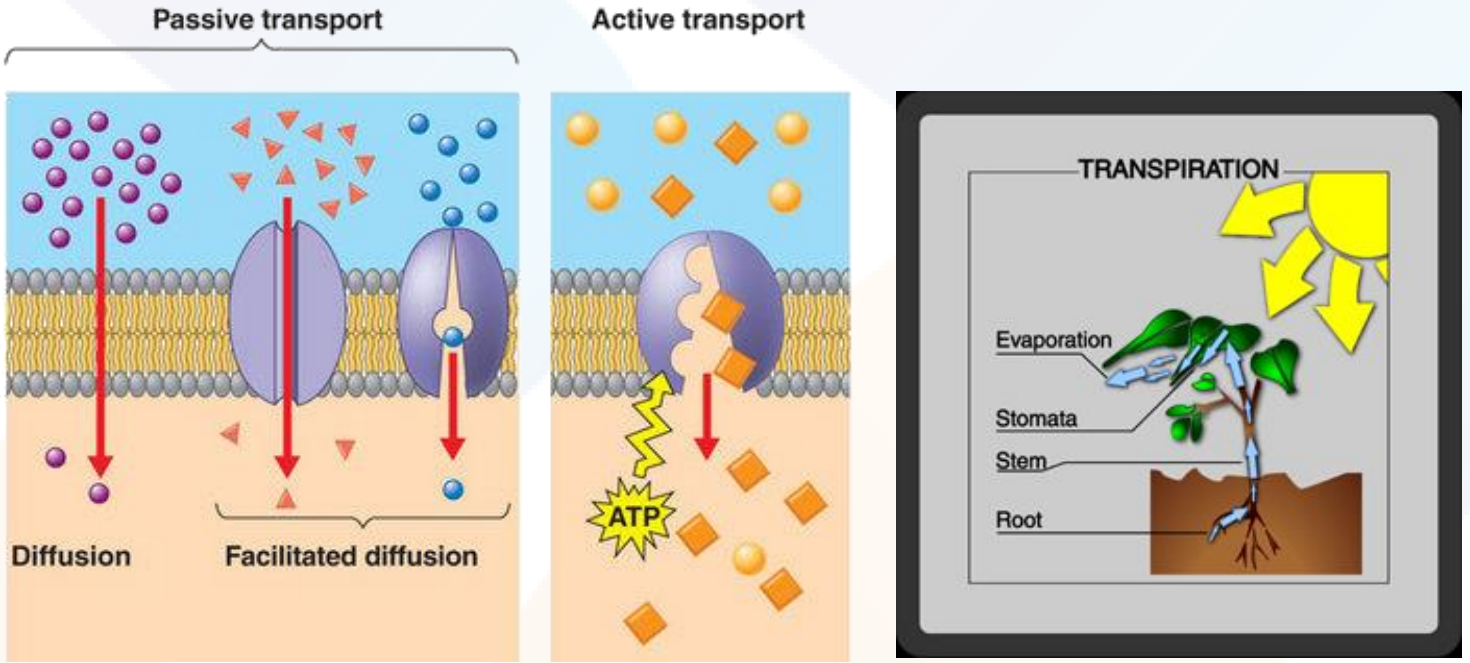
- Transport proteins of endodermal cells are the control points, where a plant adjusts the quantity and types of solutes that reach the xylem.

- Note that the root endodermis, because of the layer of suberin, has the ability to actively transport ions in one direction only.



TRANSLOCATION OF MINERAL IONS

- After the ions have reached xylem through active or passive uptake, or a combination of the two, their further transport up the stem to all parts of the plant is through the transpiration stream.



Mass flow hypothesis

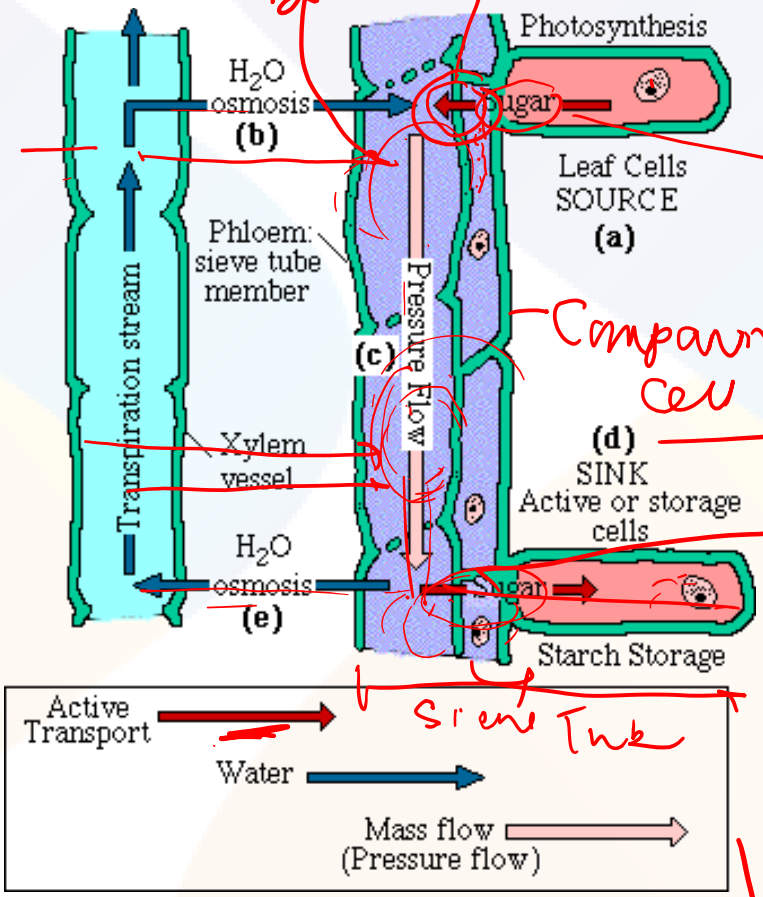
- Organic solutes like glucose, sucrose produced during photosynthesis are translocated by phloem of plant.
- The long distance movement of organic solutes (Photosynthates) from the **source (leaves)** or supply end to the region of utilization or **sink (roots, tubers, fruits, apices)** is called translocation of organic solutes
- The direction of movement of Photosynthates in the phloem can be upwards or downwards **(bidirectional)** & they move in the form of **non-reducing sucrose**

❖ Theories related to Translocation of Organic solutes

- **Cytoplasmic streaming Hypothesis:** It was proposed by **De Vries (1885)** and later developed by **Curtis (1935).** According to this, transport takes place by combination of two forces, diffusion and cytoplasmic streaming.
- **Mass flow or Pressure flow hypothesis:** It was proposed by **Munch (1929).** It is most accepted theory for translocation of organic solutes
- Glucose is formed at the source (by photosynthesis in the mesophyll cells of leaves) and converted into sucrose. Which is shifted in the companion cells and then into the living sieve tube of phloem by active transport as a result hypertonic condition is developed in phloem.
- The water of adjacent xylem moves into the phloem by osmosis resulting turgor pressure and water potential increase in the phloem sap. TP of phloem sap is higher than TP of sink **(Ex: roots)**. A low turgor pressure is maintained in the sink region by converting soluble organic substances into insoluble form Water passes back into xylem by Apoplast.

MASS FLOW

- Water and minerals, and food are generally moved by a mass or bulk flow system.



Translocation by phloem

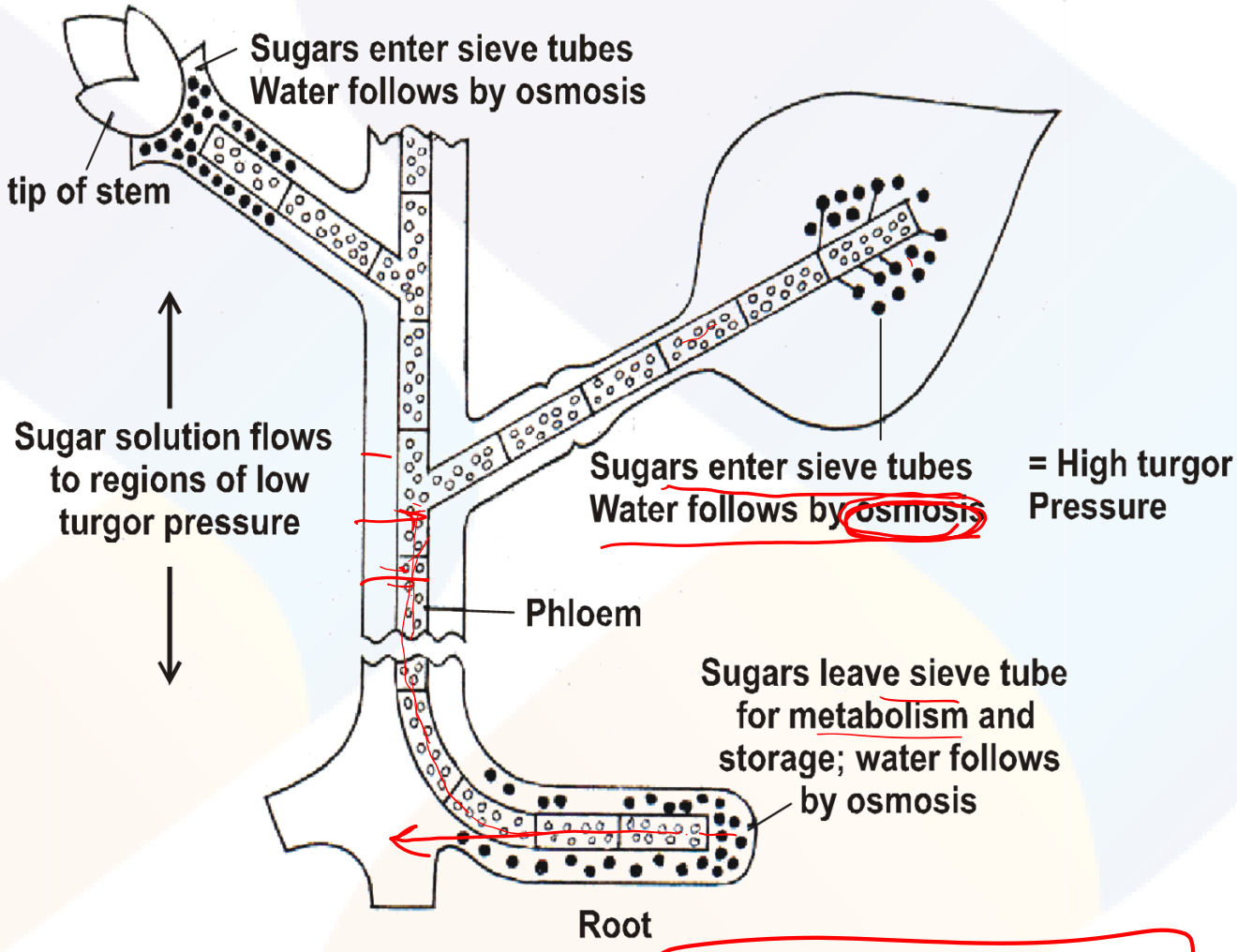


Fig :- Pathway and mechanism of phloem translocation