11. TRANSPORT IN PLANTS

Plants do not have interstitial fluid and circulatory system. But they need to move various substances (water, mineral nutrients, organic nutrients, plant growth regulators etc.) over very long distances.

Direction of transport

- **Unidirectional transport:** E.g. Transport of water and minerals in xylem (from roots to the stems, leaves etc).
- **Multidirectional transport:** E.g.
  - Transport of photosynthates (organic compounds).
  - Transport of mineral nutrients.
- Sometimes, plant hormones and other chemical stimuli are transported in a strictly polarised or unidirectional manner from where they are synthesized to other parts.

MEANS OF TRANSPORT

1. Diffusion	2. Facilitated diffusion	3. Active transport
✓ ***Random movt. of molecules of substance from higher to lower conc.*** ✓ Only for short distance & is a slow process ✓ Very imp. to plants since it is the only means of gas movt.	✓ ***Diffusion of hydrophilic substances facilitated by membrane proteins across semi permeable membrane.*** ✓ ***Porins*** are proteins that form huge pores in the outer membranes of plastids, mitochondria and some bacteria. ✓ Based on the mode of transportation by protein, it is of 3 types- **Uniport, Symport** & **Antiport.**	✓ ***Transport of molecules across cell membrane against a conc. gradient with the expenditure of energy.***

Similarity

- ♥ Movt. of molecule is along concentration gradient.
- ♥ No energy (ATP expenditure) required.
- ♥ **Affected by** -
  (a) Conc. gradient
  (b) Membrane permeability
  (c) Temp& pressure,
  (d) Size of the molecule
  (e) Solubility in lipids.

- ♥ Require special membrane protein
- ♥ Very Specific (Selective)
- ♥ Liable to saturation (Transport reach at maximum when all the proteins are used)
- ♥ Sensitive to inhibitor

PLANT-WATER RELATIONS

Here we discuss the various physico-chemical parameters involved from the entry to exit of water in plant body.

- Water is a **universal solvent** essential for all physiological activities of plants.

Water Potential (Ψ_w)

- **Water potential (Ψ_w)-** *It is the P.E of water due to random motion of its molecules. Ψ_w for pure water is 0.*
- **Solute potential**(Ψ_s)-*Reduced water potential due to presence of solute. Always $^-$ve.*
- **Pressure potential**/ *turgor pressure* (Ψ_p)-*Pressure due to osmotic entry of water. Always $^+$ve.*

$$\Psi_w = \Psi_s + \Psi_p$$ Units- **Pascals (Pa)**

Osmosis

➔ *It is the diffusion of water across a semi-permeable membrane.*

- The ***cell membrane*** and the ***tonoplast*** (membrane of the vacuole) determine the movement of molecules in or out of the cell.
- The net direction and rate of osmosis depends on the **pressure gradient** and **concentration gradient**.

➔ **Osmotic pressure (π):** The pressure applied externally to stop osmosis.

External Soln.	***Flow of water***	***Cells become***
Isotonic (the osmotic pressure is same as that of cytoplasm)	No net flow	Flaccid
Hypotonic (more dilute than the cytoplasm)	Endosmosis	Turgid (swells- due to entry of water)
Hypertonic (more concentrated than the cytoplasm)	Exosmosis	***Plasmolysed*** (shrinks- Withdrawal of protoplast from the cell wall)

Imbibition

➔ ***It is the absorption of water by colloids causing them to increase in volume.***
E.g.:Absorption of water by seeds and dry wood.

- ✓ Seedlings are emerged out of the soil due to the **imbibition pressure.**
- Imbibition requires -
  - Difference in concentration gradient.
  - Water potential gradient between the absorbent and the liquid imbibed.
  - Affinity between the adsorbent and the liquid.

ABSORPTION & TRANSPORT OF WATER

- **Bulk flow**-Movt. of substances in bulk from one point to another as a result of pressure diff.
  - Water, minerals and food are generally moved by a mass flow system.
  - Can be achieved by +ve/-ve hydrostatic pressure
- **Translocation**-Bulk movt. of substances through vascular tissue.

Transportation

Leaf parenchyma
↑ **Transpiration pull**
Leaf vein
↑ **Transpiration pull & Root pressure**
Xylem
↑ ***Apoplast/ Symplast***
Root

Absorption

↑ **Diffusion**
Root hair

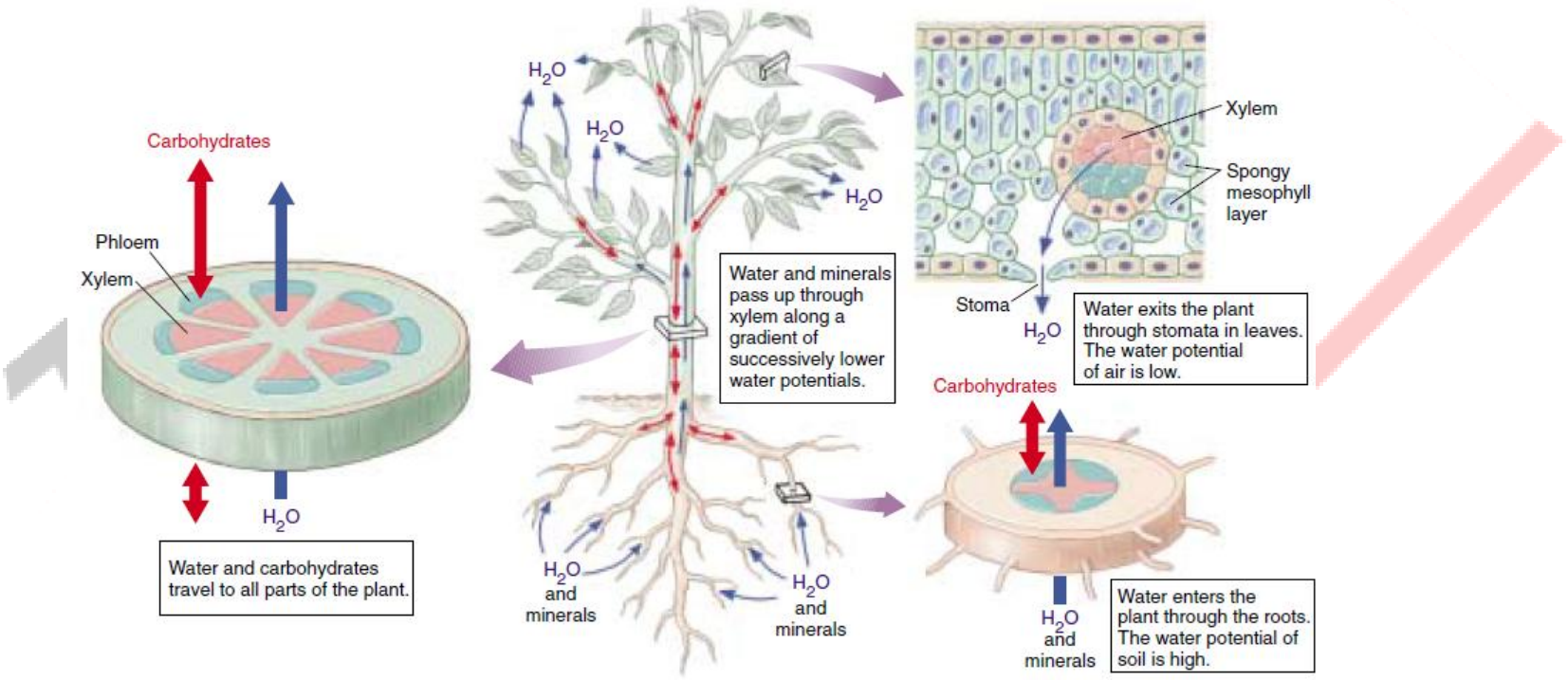
- **Root pressure**- Increased pressure due to water entered along with ions transported actively into the xylem.
  - ➔ It helps to push up water to small heights in the stem.
- **Transpiration pull**- Water is mainly 'pulled' to compensate the loss by transpiration. **Guttation also**.
  - ➔ Rate - Up to 15 m /hr for <u>130 metres high</u>.

The absorbed water is moved deeper into root layers by-

a. **Apoplast**- through the intercellular spaces and the walls of the cells (except at the **casparian** strips of the endodermis). As water evaporates into the intercellular spaces or the atmosphere, tension develops in the continuous stream of water.

b. **Symplast**- through interconnected protoplasts by **plasmodesmata**.
- Movement is relatively slower.
- Only way water and solutes can enter the vascular cylinder.

Millions of root hairs present at the root tips increase the surface area for absorption.



Water movement through a plant.

Purposes of Transpiration:

- Creates transpiration pull for absorption and transport.
- Supplies water for photosynthesis.
- Transports minerals from soil to all parts of the plant.
- Cools leaf surfaces, sometimes 10 - 15°, by evaporation.
- Maintains the shape and structure of the plants by keeping cells turgid.

Factors affecting transpiration: -

I. **External factors:** Temperature, light, humidity, wind speed etc.
II. **Plant factors:**
- Number and distribution of stomata.
- Number of stomata opens.
- Water status of the plant.
- Canopy structure etc.

UPTAKE & TRANSPORT OF MINERAL NUTRIENTS

Translocation

Sink
↑ **Diffusion & Active uptake**
Xylem
↑ **Transpiration stream Diffusion**
Root

Uptake

↑ **Active / Passive absorption**
Soil

The **chief sinks** for the mineral elements are apical & lateral meristem/ Young leaves/ developing flower, fruit& seeds/ Storage organ etc.

Unloading of mineral ions occurs at the fine vein endings through diffusion and active uptake by these cells.
- ➔ Mineral ions such as P, S, N and K mobilize from older parts to younger leaves.
- ➔ Some elements like Ca are not remobilized.

- <u>Most minerals are actively absorbed by the roots because-</u>
  i. Minerals occur in the soil as charged particles (ions) which cannot move across cell membranes.
  ii. The concentration of minerals in the soil is usually lower than the concentration of minerals in the root.

- Some of the N travels as inorganic ions while most of it is carried in the organic form such as amino acids and related compounds.
- Small amounts of P and S are also carried as organic compounds. There is also exchange of materials between xylem and phloem. Hence, we <u>cannot clearly say that xylem transports only inorganic nutrients while phloem transports only organic materials</u>.

PHLOEM TRANSPORT

- It is the long distance movement of organic substances (food, primarily sucrose) from a **source** (region of synthesis the food i.e., the leaf) to a **sink** (region of storage or utilization of food) through the phloem.
- The source and sink may be reversed depending on the season, or the plant's needs.
  E.g. In early spring, the sugar stored in roots is moved to the tree buds for growth and development of photosynthetic apparatus. Thus root becomes the source and buds the sink.
- The direction of movement in the phloem can be upwards or downwards, **(bi-directional)**. In xylem, the movement is always upwards **(unidirectional).** Hence, food in phloem sap can be transported in any direction.
- Phloem sap is mainly water and sucrose, but other sugars, hormones and amino acids are also **translocated**.

The Pressure Flow (Mass Flow) Hypothesis

- It is the hypothesis that explains the mechanism of translocation of sugar (phloem transport).

(Step-1) The glucose prepared at the source (by photosynthesis) is converted to **sucrose** (a disaccharide).

(Step-2) Sucrose is moved into the **companion cells** and then into the living **phloem sieve tube** by **active transport (loading).** It produces a hypertonic condition in phloem (water potential decreases). Sieve tube cells form long columns with holes in **sieve plates.** Cytoplasmic strands pass through the holes in the sieve plates, so forming continuous filaments.

(Step-3) Water in the adjacent xylem moves into the phloem by **osmosis.** As **osmotic pressure/hydrostatic pressure** builds up, the phloem sap moves to areas of lower osmotic pressure (sink).

(Step-4) The sucrose from the phloem sap actively moves into the cells. The cells convert the sugar into energy, starch, or cellulose.

(Step-5) As sugars are removed, the osmotic pressure decreases (water potential increases) and water moves out of the phloem.

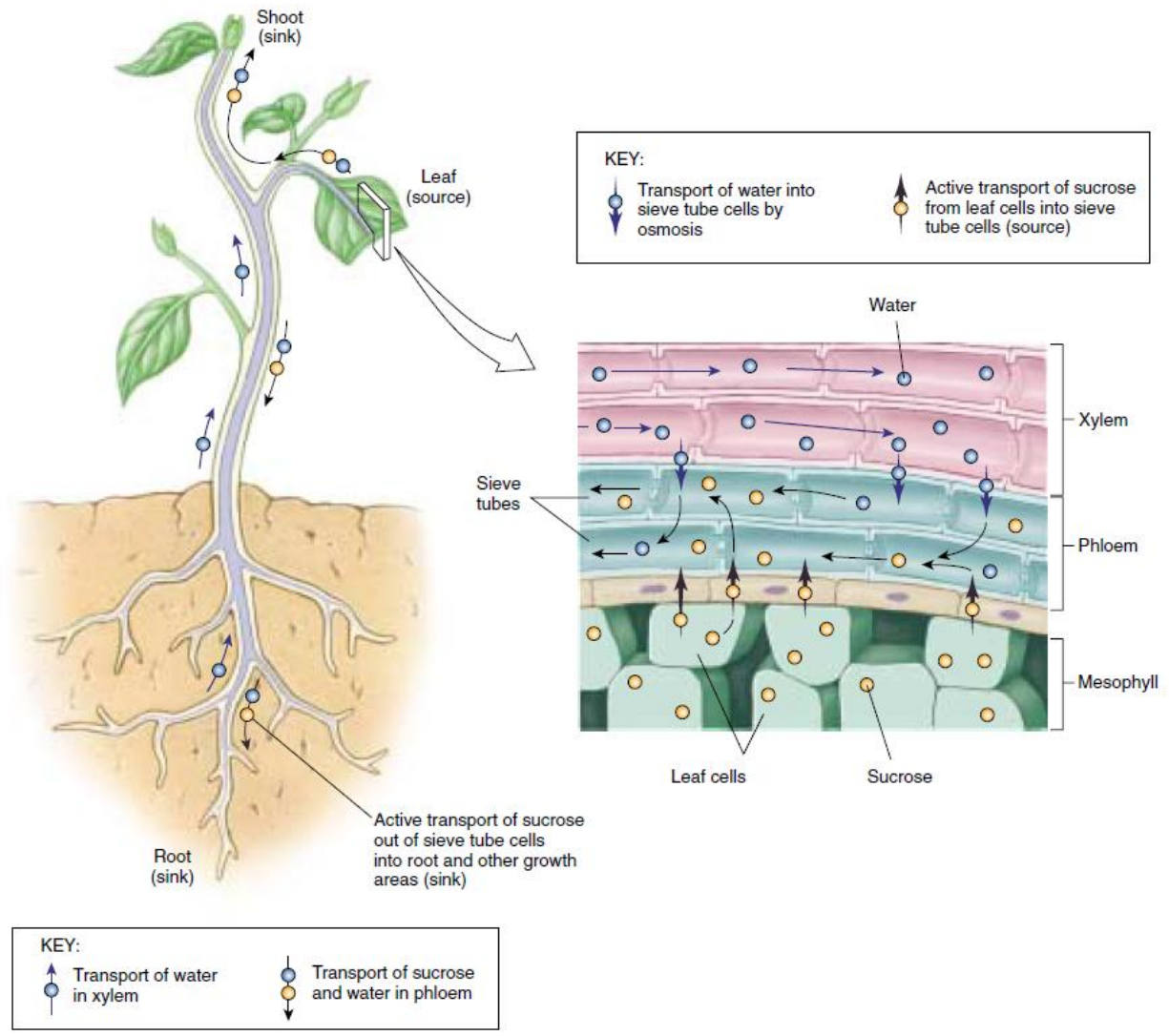


Diagram of mass flow.