Absorption by Roots

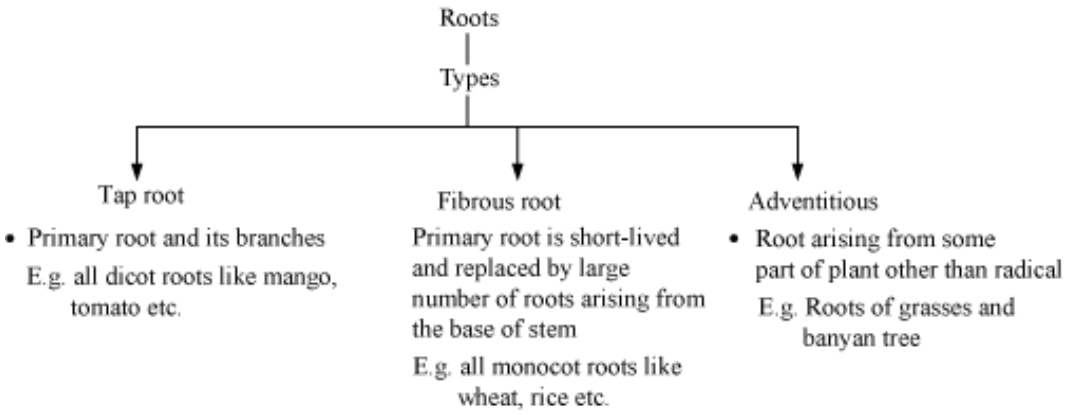
The Root

Angiosperms have diverse morphology, still they have the following structures in common:

- Roots
- Stem
- Leaves
- Flowers
- Fruits

The Root

- Primary root − direct elongation of radical which grows inside the soil
- Primary root bears several lateral roots termed as secondary roots, tertiary roots, etc.



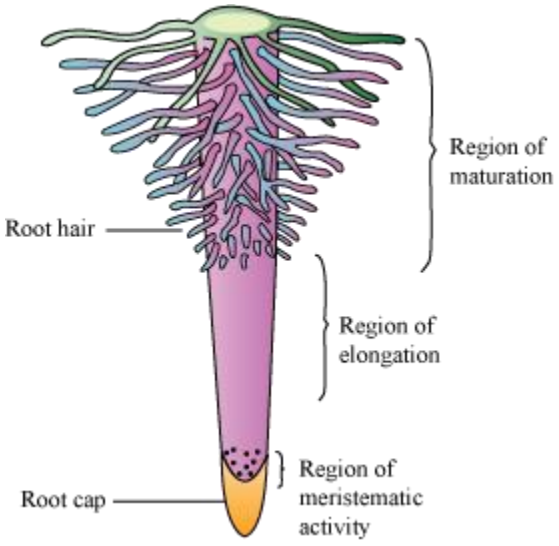
Functions of Root

- Absorption of water and minerals from the soil
- Provision of anchorage to the plant
- Storage of reserve food materials
- Synthesis of plant growth regulators

Region of the Root

A root has following regions:

- **Root cap** − thimble-like structure that covers the root at apex, thereby protecting it
- **Region of meristematic activity** − Lies above the root cap
- Cells in this region are small, thin-walled, and have dense protoplasm.
- These cells divide repeatedly.
- **Region of elongation** − Lies above region of meristematic activity
- Cells in this region undergo rapid elongation and enlargement.
- These cells are responsible for growth of root.
- **Region of maturation** − Lies above region of elongation
- Cells in this region are differentiated and mature.
- Epidermal cells of this region form delicate thread-like root hair.
- These root hair help in the absorption of water and minerals from the soil.



Characteristics of Root for Absorbing Water

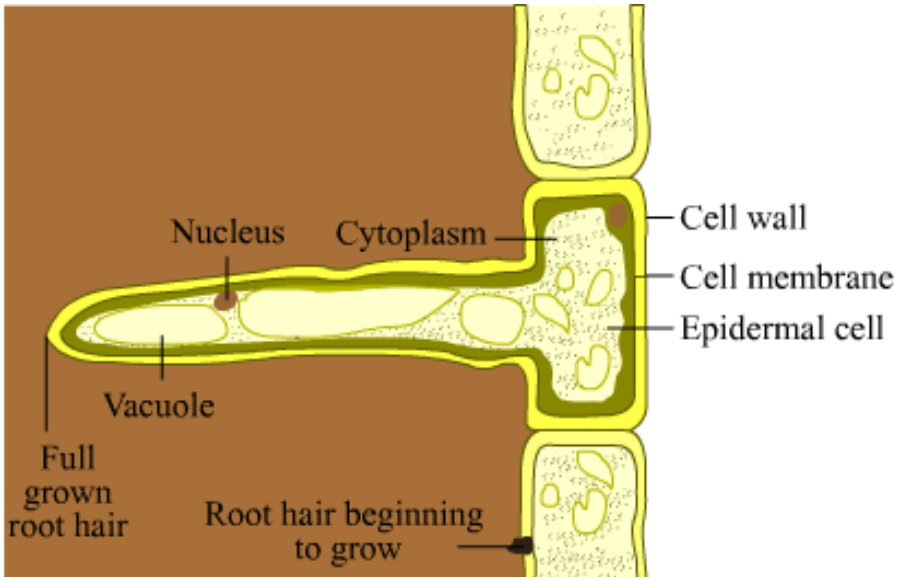
The nature of roots to draw water deep down from the soil depends on three main characteristics:

1. **Enormous Surface Area**: The surface area of the roots of all higher plants is very large. Larger the area covered by the roots, more water will be absorbed by them.

2. **Highly Concentrated Cell Sap**: The cells of root hairs contain salt-rich cell sap, that makes its concentration higher than that of the surrounding water. This helps in the occurrence of osmosis in the root hair, so that it can draw maximum water from outside.

3. **Thin-walled Root Hairs**: Root hairs have very thin and semi-permeable walls that allow maximum water to pass through.

Structure of a Full Grown Root Hair

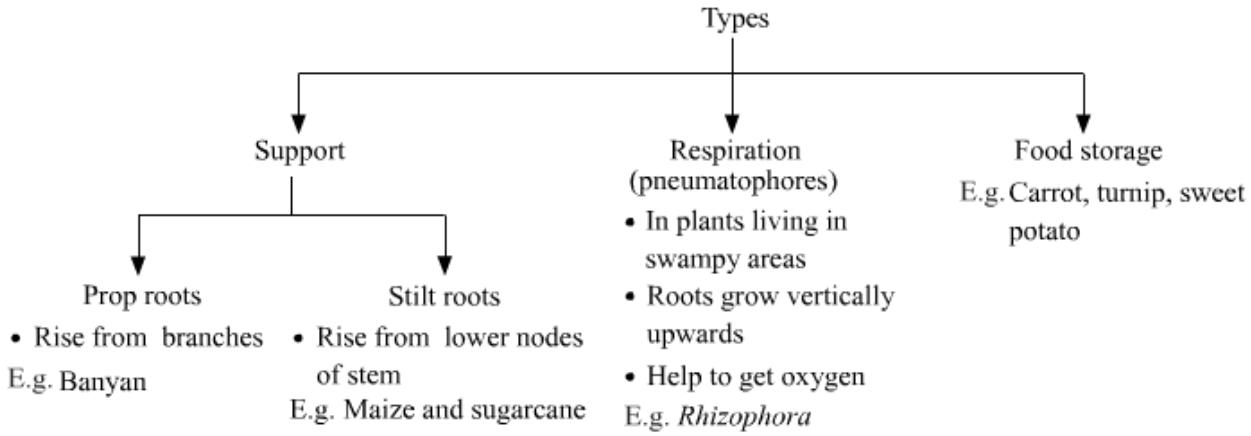


Modification of Root

- Roots of some plants modify their structure, shape, etc.

- These modifications are performing functions, other than absorption and conduction of water and minerals.

- Modified roots may perform functions such as support, respiration, and storage.



Means of Transport

Transport in Plants

- Short distance transport: By diffusion and cytoplasmic streaming, supplemented by active transport
- Long distance transport: Translocation (occurs through vascular system)
- Transport of water and minerals through the xylem: Unidirectional
- Transport of organic and mineral nutrients through the phloem: Multidirectional

Need of Water and Minerals for Plants

- Water is an essential requirement for sustaining life of all the living organisms, including plants. In plants, water is needed for four main purposes:
- **Photosynthesis** : Water is used as raw material for photosynthesis.
- **Transpiration** : To maintain the temperature of plants, water is needed.
- **Transportation** : Various substances are transported inside the plants through water.
- **Mechanical stiffness** : Water provides turgidity to plant tissues.
- **Need of Minerals :** Minerals are needed as nutrients for the plants,
- They act as important constituents of the cell and its organelles.
- They are required for the synthesis of a variety of compounds and enzymes inside the cell.

Means of Transport

Three means of transport in plants:

- Diffusion
- Facilitated Diffusion
- Active Transport

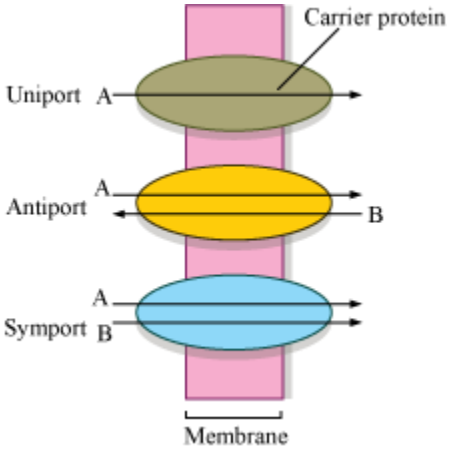
Diffusion

- An important means of transport inside the plant body
- Movement of molecules in a random manner, across the concentration gradient
- Slower process, involving no expenditure of energy
- Not dependent on the living system
- Depends upon:
- Concentration gradient
- Permeability of the membrane
- Temperature
- Pressure

Facilitated Transport

- Diffusion depends upon solubility in lipids. Therefore, substance having hydrophilic moiety finds it difficult to diffuse through the membrane. Hence, their movement has to be facilitated.
- In facilitated diffusion, the membrane proteins are involved. They provide a site for hydrophilic molecules to pass through the membrane.
- Concentration gradient is not provided through such proteins. It must already be present. In this case, no ATP (energy) expenditure is required.
- However, for diffusion against the concentration gradient, ATP expenditure is required.

- Proteins involved in the process form channels which may always be opened or controlled.
- Facilitated diffusion is very specific.
- Porins: Proteins that forms huge pores in the outer membranes of plastids, mitochondria, etc.
- Aquaporins: Proteins that facilitate diffusion of water molecules
- Some transport proteins allow diffusion only if two types of molecules move together (symport and antiport).



- Symport − both molecules move in the same direction
- Antiport − both molecules move in opposite directions
- Uniport − independent movement of molecules
- Maximum transport: When all proteins involved are saturated

Active transport

- Requires energy to pump molecules against the concentration gradient
- Requires special proteins which are very specific and sensitive to inhibitors
- Pumps proteins, using energy to transport substances through uphill transport
- Maximum transport: When all proteins involved are saturated

Comparison between simple diffusion, facilitated diffusion and active transport:

Characteristic	Simple diffusion	Facilitated diffusion	Active transport
Requirement of special membrane proteins	×	√	√
Selectivity	×	√	√
Saturation of transport	×	√	√
Uphill transport	×	×	√
Requirement of ATP	×	×	√

Osmosis, Plasmolysis and Imbibition

Osmosis

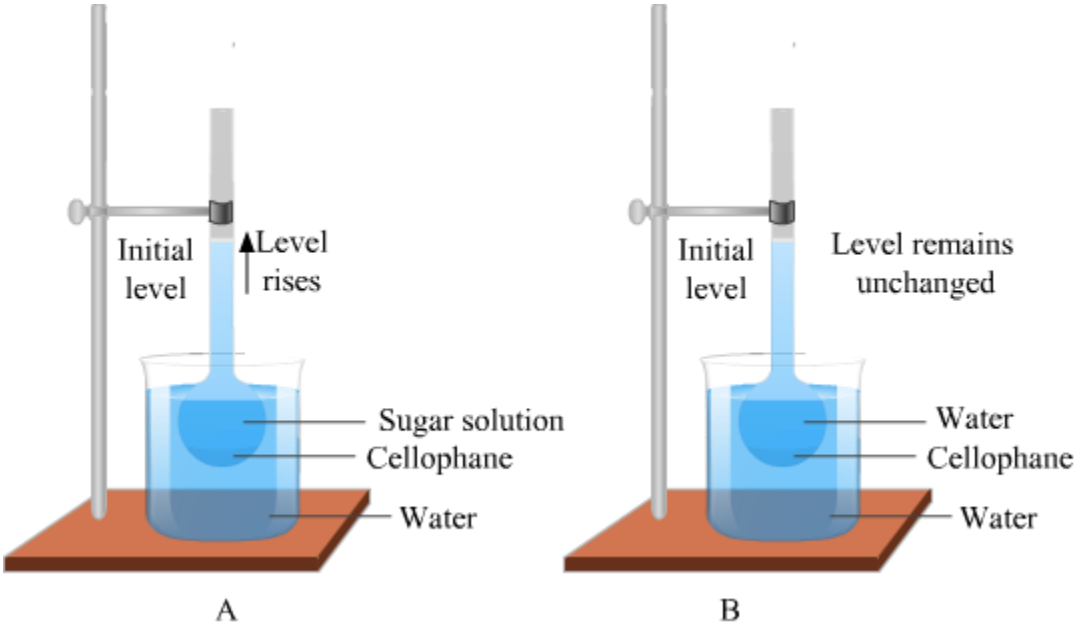
- It refers to the diffusion of water across a semi-permeable membrane.
- **Semi-permeable membrane** : It is a selectively-permeable membrane that allows only some substances to pass through it, hence, behaving as a barrier for different substances.
- Direction and rate of osmosis depends upon pressure gradient and concentration gradient.
- Water diffuses from its region of higher chemical potential to lower chemical potential until equilibrium is reached.
- Osmosis is of two types depending on concentration of solution around the cell.
- **Endosmosis**: It is the inward flow of water through a semi-permeable membrane when the surrounding solution is less concentrated. This causes swelling of the cell.
- **Exosmosis**: It is the outward flow of water through a semi-permeable membrane when the surrounding solution is more concentrated, resulting in shrinking of cell.

An Experiment to Understand Osmosis

Take some concentrated sugar solution inside a thistle funnel (say A). Using a cellophane paper cover its mouth and tie it securely. Take some water in a beaker;

invert the funnel A and suspend it into the beaker. Mark the level of sugar solution in thistle funnel. Take another thistle funnel (say B) and repeat the same procedure with water solution inside the thistle funnel.

- After few hours, we will observe that:
- The level of sugar solution has increased in funnel A.
- The level of water solution is same in funnel B.
- The level of water in the beaker has decreased in which funnel A was suspended.
- When the water of beaker with sugar solution is tasted, it does not taste sweet.



Conclusions:

- Some water has passed through the cellophane paper to enter the funnel A.
- Sugar from thistle funnel A has not passed to the beaker.
- The cellophane paper acts as a semi-permeable membrane and allows only water to pass through, not sugar.
- This happens because of difference in concentration.

- **Osmotic pressure** − External pressure applied to prevent the diffusion of water
  It depends upon solute concentration.
  Osmotic pressure ∝ Solute concentration

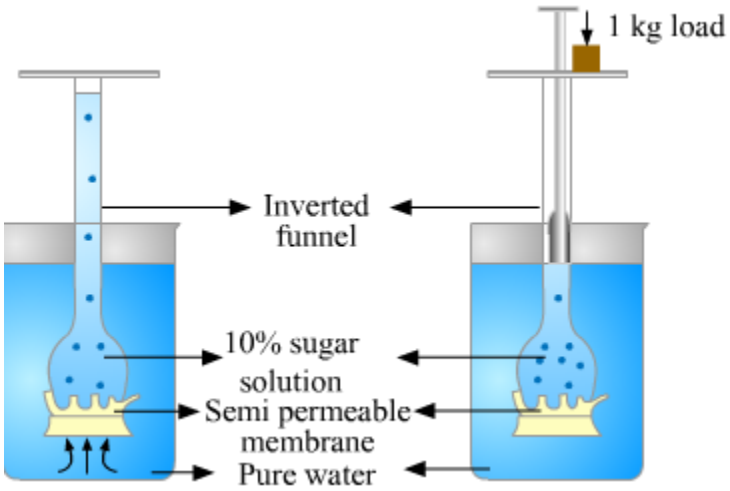
- Numerically: osmotic pressure = osmotic potential

- Osmotic pressure has positive sign.
- Osmotic potential has negative sign

An Experiment to Understand Osmotic Pressure

Take a thistle funnel containing sugar solution and place an airtight piston bearing some weight on its one end. Cover the other end with a cellophane paper and suspend it into a beaker containing water. Leave it undisturbed for a few hours.

After few hours, you will see that no change has occurred this time. Osmosis did not take place. This is all because of the Osmotic pressure applied by the piston which did not allow the water to pass through as it built pressure on the funnel.



Conclusion:

- Osmotic pressure does not allow osmosis to take place.

Tonicity

It is the relative concentration of solution and its surroundings to find the direction and extent of diffusion performed by the solution.

Behaviour of Plant Cell Depending Upon the Surrounding Solution

1. **Isotonic solution**

1. When concentration of external solution = Concentration in cytoplasm

2. No change in cell size

2. **Hypotonic solution**

1. When concentration of external solution < Concentration in cytoplasm

2. Cells swell.

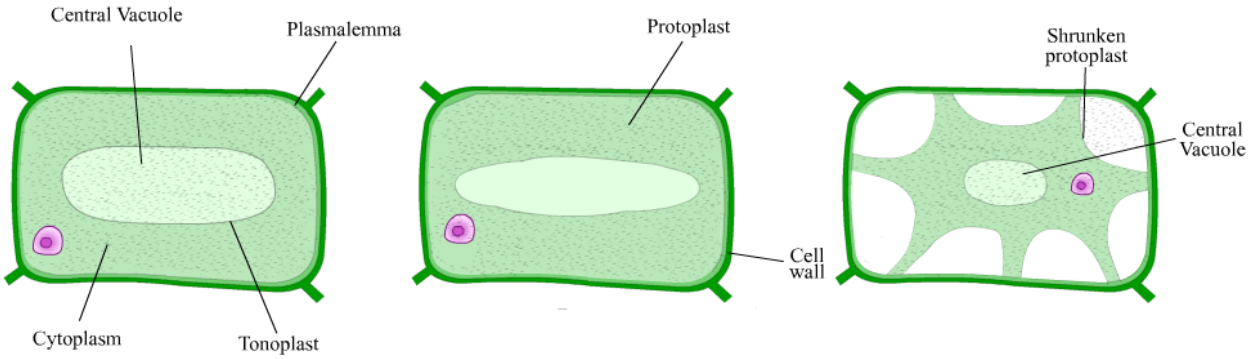
3. **Hypertonic solution**

1. When concentration of external solutions > Concentration in cytoplasm

2. Cells shrink

Plasmolysis

- It occurs when cell is placed in hypertonic solution.
- Water moves out, first from cytoplasm and then from vacuole.
- Cell membrane shrinks away from the cell wall.
- This phenomena of shrinkage of plasma membrane from cell wall is called plasmolysis.
- The cells in this state are called **flaccid** and this condition of cells is called **flaccidity.**



Deplasmolysis

- It refers to reversal of plasmolysis by placing the flaccid cells in water.
- If not dead, the protoplasm will absorb water
- The cells will thus return to their original state.

In isotonic solution, water flowing into the cell = water flowing out of the cell.

In hypotonic solution, water diffuses into the cells and cells enlarge and extension growth of cells occurs.

As water diffuses in, cytoplasm builds up a pressure against the cell wall. This pressure is called **turgor pressure**.

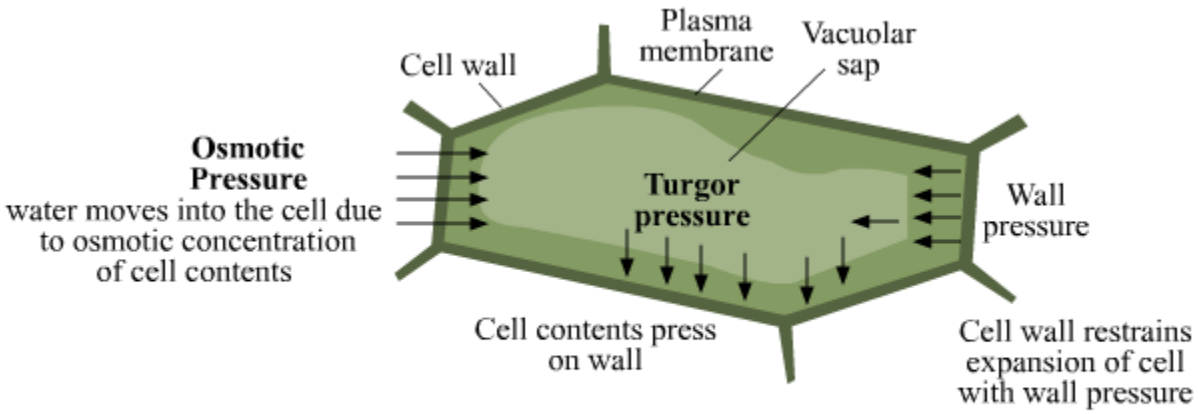
Because of rigidity of cell wall, the cell does not rupture but enlarges.

Turgid : When the cell cannot accommodate any more water, it is referred as a **turgid** cell and this condition is called **turgidity.**

Uses of Turgidity

- Provides rigidity to soft tissues
- Helps plant growth in hard ground
- Builds root pressure
- Helps in opening and closing of stomata
- Promotes turgor movement

Wall pressure: The pressure exerted by the cell wall on the contents of the cell.



A plant cell showing osmotic pressure, turgor pressure and wall pressure represented together

Imbibition

- Diffusion in which water is absorbed by solids i.e. colloids, causing them to enormously increase in volume
- Substances are absorbed without forming a solution.
- Diffusion is along the concentration gradient and depends upon affinity between adsorbent and liquid being adsorbed.

  Example − Imbibition of water by seeds that causes seedling to emerge out of soil

Difference between Diffusion and Osmosis

Diffusion	Osmosis
It refers to the movement of substances from higher concentration to lower concentration.	It refers to the movement of water through a semi-permeable membrane.

It may occur in any medium.	It occurs in liquid medium.
It helps in equalising the concentration in the available space.	It does not equalise the concentration of solvent on either sides.
It does not depend on solute potential	It depends on the solute potential.

Water Movement up in a Plant

As the water is absorbed by the roots from the soil and moved to the vascular system, it has to be transported to various parts of the plant.

Two forces responsible for transporting the water up in a plant are root pressure and transpiration pull.

Root Pressure

- Positive pressure created inside the xylem when water follows the ions transported along the concentration gradients into the vascular system

- Guttation − Loss of water in its liquid phase from special openings near tip of grass blades and leaves of herbaceous plants
  This is an effect of root pressure and is observable at night and early morning when rate of transpiration is low.

- Does not account for majority of water transport
  It works to re-form the broken chains of water molecules in xylem that may break under enormous tension created by transpiration.

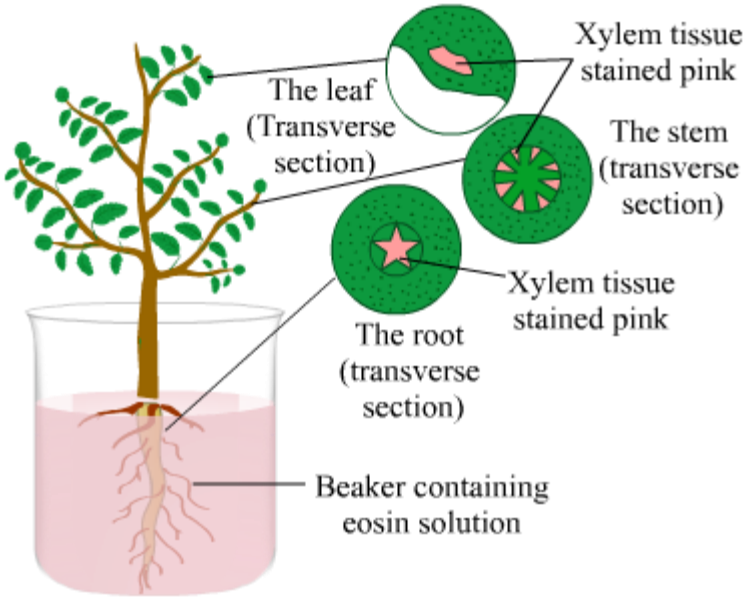
Majority of water is transported through transpiration pull.

An experiment to show that water is conducted upwards through xylem:

Take a medium sized Balsam plant. Wash it and place in a beaker containing a pink coloured stain, called eosin solution in water. Submerge the roots completely in the solution. Leave it undisturbed for 4-5 hours.

After 4-5 hours, take out the plant from the solution and wash it thoroughly. After that, make transverse sections of root, leaf and stem and examine them under the microscope.

In all of the sections, xylems vessels will be stained red by the dye and thus will appear distinct from rest of the tissues.



Conclusion:

- Water and salt are transported from the roots to the other parts of a plant through xylem.

Transpiration pull

- Pull of water as a result of tension created by transpiration is the major driving force of water movement upwards in a plant. (cohesion − tension − transpiration pull)
- Transpiration accounts for loss of 99% of water taken by the plant. Loss is mainly through stomata.
- 3 physical properties of water affect the ascent of xylem sap due to transpiration pull.
- *Cohesion* − Mutual attraction between water molecules
- *Adhesion* − Attraction of water molecules to polar surface (xylem cell wall surfaces)
- *Surface tension* − Attraction of water to each other in liquid phase to a greater extent than to water in gaseous phase
- These properties give water high tensile strength and high capillarity.
- *Tensile strength* − Ability to resist pulling force
- *Capillarity* − Ability to rise in thin tubes (Aided by small diameter of tracheary elements such as tracheids and vessel elements)