Absorption by Roots, Osmosis, and the Ascent of Sap

- **Roots and leaves** are the main absorbing organs of the plant.
  - Roots absorb *water and minerals* from the soil
  - Leaves take in *O₂ & CO₂* from the atmosphere

- **Reasons why plants need water:**
  a) **Turgidity** – Cell sap in vacuoles lends *rigidity* to the plant
  b) **Manufacture of food** – Water is used as a *raw material* in photosynthesis along with CO₂
  c) **Translocation** – *Minerals* absorbed by roots and *carbohydrates* prepared by leaves are transported in *solution form*
  d) **Cooling of plant** – When excess water is removed (by transpiration), the plant cools

- **Minerals and their Functions:**
  a) **Nitrogen** – protein synthesis; *growth*
  b) **Magnesium and iron** – *synthesis of chlorophyll*
  c) **Potassium** – *constituent of protoplasm; maintains osmotic balance in the cell; opening and closing of stomata*
  d) **Phosphorus** – promotes *nuclear and cell division*
  e) **Calcium** – *maintains the semi-permeability of the cell membrane*
  f) **Sulphur** – *constituent of amino acid (cysteine)*
  g) **Zinc** – *leaf formation*
  h) These minerals are taken in the form of *ions/radicals*; (Nitrogen absorbed as nitrates)

- **Functions of Roots:**
  i. Fix the plant in soil
  ii. Absorb water and minerals from the soil
  iii. Conduct the absorbed substances through its tissues to the upper parts of plant

- **Adaptations of Roots:**
  i. **Branching nature** – provides *large surface area*
  ii. **Thin, freely permeable cell wall** – allows movement of minerals in and out of cell by *diffusion*
  iii. **Semi-permeable cell membrane** – permits entry of water and restricts entry of salts by osmosis
  iv. **Concentration of H₂O in cell sap** – in root hair is less than that of soil – helps in absorption of water by *osmosis*
• **Root hair** – A hair-like outgrowth of a plant root that absorbs water and minerals from the soil. Root hairs are tubular extensions of the protoplasm that greatly increase the surface area of the root.

• **Significance of root hair:**
  1. Unicellular and thin-walled – provides enormous surface area for absorption of water/minerals
  2. Has cell sap with high concentration of water than that of surrounding soil so that plant can absorb water by osmosis
  3. Has extensive root system which grows rapidly in soil

• The interchange of material between plants take place through the physical processes of **Imbibition, Diffusion, Active Transport, and/or Osmosis.**

• **Imbibition:**
  → Definition: *The process by which living or dead cells, in their dry or semi-dry state, absorb water by surface attraction is known as imbibition.*
  → In an imbibing system, the water always moves from a saturated region to a dry region with some force.
  → E.g.: Wooden door gets warped in rainy season; Dry seeds placed in a beaker of water with lid swell up and cause the lid to burst open.
  → Both wood/cellulose & seeds/proteins have strong affinity to water (these are known as **hydrophilic substances**). Hence, they absorb/imbibe water or moisture from their surrounding and increase in size, i.e. swell up.
  → Significance of imbibition:
    1. Helps in uptake of soil water by root hairs
    2. Imbibition pressure helps in the ascent of sap (i.e. movement of water and salts upwards into the plant)

• **Diffusion:**
  → Definition: *The movement of gases or dissolved substances in a solution from their region of higher concentration to their region of lower concentration, when in direct contact.*
  → Direction of diffusion: from region of higher concentration to region of lower concentration
  → Rate of diffusion is dependent on the:
    a) Size of the molecules
    b) Temperature of the substance
    c) Concentration of the substance

If 2 soluble salts are placed in water, regardless of the presence of other, diffusion occurs.
Rate of diffusion is independent of presence of the other substances; Diffusion of solute and solvent molecules occurs independent of each other.

Diffusion in gases (White ring experiment)

The white ring of ammonium chloride is formed where the 2 gases meet. This experiment shows the diffusion in gases.

Active Transport:

Definition: The movement of ions or molecules across a cell membrane in the direction opposite that of diffusion, i.e. from an area of lower concentration to one of higher concentration. Active transport requires the assistance of a type of protein called a carrier protein, using energy supplied by ATP.

Reason:
1. Root hair has a lower concentration of water than that of surrounding soil to enable absorption of water by osmosis (as water moves from higher conc. [soil] to lower conc. [root cell]).
2. This results in higher concentration of solute molecules (ions) in root hair than that of surrounding soil.
3. To absorb ions or radicals, mitochondria provide additional energy [In the form of ATP] to create force and absorb the ions (nitrates, phosphates, sulfates, calcium, sodium) from the lower concentration (soil) to higher concentration (root hair), against the concentration gradient. This is called ACTIVE TRANSPORT.
4. Note: Osmosis is a passive process.

Osmosis:

Condition for osmosis to take place:
“Two solutions having different concentrations/ solution and its pure solvent are separated by a semipermeable membrane”

Movement of solvent molecules take place in accordance with the concentration gradient i.e. from soln. of higher concentration to soln. of lower concentration or from pure solvent to its solution.

Terms related to osmosis and their definitions:

a) Osmosis – It is the movement of solvent molecules from the solution having a higher concentration of solvent molecules to the solution having a lower
**concentration of solvent molecules**, or from a pure solvent into the solution, through/across a semi-permeable membrane.

b) **Osmotic Pressure** – The pressure exerted by the liquid column, which just prevents the entry of the solvent through the semi-permeable membrane, is called osmotic pressure.

c) **Osmotic Potential** – Osmotic potential of the solution is the measure of the tendency of water molecules to diffuse out of it.

**Experiments on Osmosis:**

**Experiment 1: Thistle Funnel Experiment**

i. **Aim:** To demonstrate osmosis.

ii. **Setup & Procedure:**

- A thistle funnel, with wide bulb and narrow stem is placed on a retort stand. The wide mouth of the funnel is fastened with **parchment paper** and sealed with wax.
- 3 solutions of sucrose are prepared:
  1) 20% sucrose (80% water)
  2) 5% sucrose (95% water)
  3) 50% sucrose (50% water)

- Suspend each funnel with the following
  
  **Setup ‘A’** – Beaker: Water
  Funnel: 20% sucrose (80% water) solution
  
  **Setup ‘B’** – Beaker: 50% sucrose (50% water)
  Funnel: 5% sucrose (95% water)

- Mark the initial levels of sucrose soln. in the funnels and allow the apparatus undisturbed for a lapse of time.

<table>
<thead>
<tr>
<th>Observation</th>
<th>Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Setup A – level of soln. in the stem of funnel rises.</td>
<td>Water moves from the beaker (100% solvent) to the funnel (80% solvent) i.e. from the region of higher concentration to the region of lower concentration across the semi-permeable membrane (parchment paper)</td>
</tr>
<tr>
<td>2. Setup B – level of soln. in the stem of funnel falls.</td>
<td>Water moves from the funnel (95% solvent) to the beaker (50% solvent) i.e. from the region of higher concentration to the region of lower concentration across the semi-permeable membrane (parchment paper)</td>
</tr>
</tbody>
</table>
Experiment 2: Potato-osmoscope Experiment

{An osmoscope: An apparatus used for demonstrating osmosis}

i. **Aim:** To demonstrate osmosis using a *potato osmoscope*.

ii. **Setup & Procedure:**
   - Scoop a cavity in the *peeled potato* and slice bottom such that the base is flat.
   - Place it in a *petri-dish* containing *water*, such that half of the potato is immersed.
   - Fill the cavity with *25% sucrose solution* and mark its level by inserting a *pin*.
   - Allow this setup undisturbed for some time.

iii. **Observation**
    
    *Level of the liquid in the cavity rises.*

iv. **Inference**
    
    → Osmosis has taken place
    
    → Water (pure solvent) has moved across the cells of potato (semi-permeable cell membrane) and accumulated inside the cavity where the concentration of the solvent is lower.

v. **Alternative setup:**

    This experiment can be repeated with a *boiled potato*; on boiling, the *cells lose their semi-permeability* therefore preventing osmosis and accumulation of water in the cavity. Only *diffusion* takes place until the concentration is same in both sides.

Experiment 3: Osmotic Pressure Experiment

**What is osmotic pressure?**

Osmotic pressure, actually is the *pressure exerted by the solvent molecules in the solution*. When osmosis takes place, solvent molecules accumulate on the side of the semi-permeable membrane that has a lower concentration of solvent molecules. This *process continues until the pressure due to the liquid column becomes equal to the force with which the solvent molecules try to diffuse into the solution*. Thus, the force on both sides of the semi-permeable membrane is maintained and equilibrium exists.

Definition: *The pressure exerted by the liquid column which just prevents the entry of the solvent molecules through the semi-permeable membrane is called Osmotic Pressure.*

i. **Aim:** To demonstrate osmotic pressure.

ii. **Setup and procedure:**
   - A *thistle funnel*, with wide bulb and narrow stem is placed on a *retort stand*. The wide mouth of the funnel is fastened with *parchment paper* and sealed with wax.
   - This funnel is filled with 20% sucrose solution and suspended in a beaker with water such that the mouth of the funnel is in water.

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• Introduce a piston of narrow diameter that comfortably fits into the stem of the funnel, such that the piston is in contact with the surface of the liquid.
• When the piston is seen to move upwards, weights are placed on the piston, until the piston stops moving.

iii. Explanation:
• The piston moves upwards as the solvent molecules gradually accumulate in the funnel. The motion of piston is stopped by an external force/pressure. (weights)
• This happens because the solute molecules possess motion/kinetic energy and occupy the entire space available by diffusion and exert pressure, which prevents the entry of solvent molecules. This pressure exerted by the solute molecules is said to be osmotic pressure.
• If the concentration of the solution is increased i.e. more sugar is added, more weight will be required to be placed on the piston and to stop its motion. Hence osmotic pressure is directly proportional to the concentration of the solution.
• Factors affecting osmotic pressure
  a) Concentration of the solution - Amount of solute in the solution: Osmotic pressure is directly proportional to the concentration of solution
  b) External pressure
• Pressure only develops in a closed system. Similarly, osmotic pressure in true sense can develop only in a closed system such as cell.
• Osmosis takes place from a region having lower osmotic pressure to a region having higher osmotic pressure.

Endosmosis and Exosmosis:

- In setup A, when raisins are put into a petri dish, they swell up and become firm. This is an example of Endosmosis:
  Endosmosis is the inward movement of solvent molecules through the semi-permeable membrane by the process of osmosis.
- In setup B, when fresh grapes are put in a sugar/salt solution, they shrive; up and become firm. This is an example of Exosmosis
  Exosmosis is the outward movement of the solvent molecules, through the semi-permeable membrane into the hypertonic medium, by the process of osmosis.
**Experiment 4: Endosmosis and Exosmosis Experiment**

i. **Aim:** To demonstrate endosmosis and exosmosis

ii. **Procedure:**
Fill a bag made of semi-permeable membrane with 2% sucrose solution and suspend it in a beaker of water. After a lapse of time suspend the same bag in 10% sucrose solution and leave it undisturbed for some time.

<table>
<thead>
<tr>
<th>iii. Observation</th>
<th>iv. Inference</th>
</tr>
</thead>
<tbody>
<tr>
<td>When suspended in the beaker of water, the bag becomes turgid and fully distended.</td>
<td><strong>Endosmosis</strong> takes place when the bag is placed in a hypotonic solution (pure water)</td>
</tr>
<tr>
<td>When suspended in the beaker of 10% sucrose solution, the bag contracts and becomes limp.</td>
<td><strong>Exosmosis</strong> takes place when the bag is placed in a hypertonic solution (10% sucrose solution)</td>
</tr>
</tbody>
</table>

- **Tonicity** is the external osmotic environment of the cell.

1. **Isotonic Solutions**
Solutions having the same osmotic pressure at the same temperature are called *isotonic solutions*.
Occurrence in 2 cases:
→ Case 1: When 2 solutions having **same solutes** are separated by a semi-permeable membrane.
→ Case 2: When 2 solutions having **different solutes** are separated by a semi-permeable membrane. In this case, strength of the solutions may differ, but the molecular concentration will be same.

2. **Hypotonic Solution**
Solution that has a lower concentration of solute molecules (dilute solution) and a lower osmotic pressure is known as a **hypotonic solution**.

3. **Hypertonic Solution**
Solution that has a higher concentration of solute molecules and a higher osmotic pressure is known as a **hypertonic solution**.

**Note:** During osmosis, movement of water takes place from a hypotonic solution to a hypertonic solution.
Osmotic Potential:

“Osmotic Potential of a solution is the tendency of water molecules to diffuse out of the solution.”

→ Very concentrated solution ⇔ low osmotic potential (few molecules of water)
→ Dilute solution ⇔ High osmotic potential (larger conc. of water molecules)
→ Osmosis takes place from a solution having high osmotic potential to low osmotic potential across the semi-permeable membrane.

Significance of osmosis:

A. In plants
   1. Absorption of water from soil:
      It is only by the process of osmosis that the water is absorbed by the root hair and the cortical cells and then reach the xylem vessels.
   2. Opening and closing of stomata:
      • From recent theory, it is universally accepted that opening and closing of stomata is regulated by K+ pump. The major solute absorbed by the guard cells is potassium.
      • The accumulation of K+ ions, is electrically balanced by absorbing negative charged malate ions and Cl- ions.
      • The uptake of K+ creates water potential gradient between the guard cells and the water moves into the guard cells and become turgid and swell in size, resulting in stomatal opening.
      • With a decline in solutes, water moves out of the guard cells thereby closing the stomata.
      • In brief: The opening and closing of stomata is controlled by the osmotic movement of water in or out of the guard cells along the water potential gradient. This, in turn, triggers the osmotic flow of water into the guard cells raising the turgor pressure.

B. In animals
   1. Amoeba:
      • Fresh water animal and hence has to maintain the water balance with environment
      • Water enters the body by osmosis and gets accumulated in the contractile vacuoles of the endoplasm.
      • Function of contractile vacuoles: Excretory function – gets collapsed and discharges wastes out of the cell
   2. Fish and Frog
      • Wastes get accumulated in the blood of the fresh water animals and raises the osmotic pressure of the internal body environment.
      • Hence these animals tend to absorb water from the surroundings and dilutes the blood and interferes with vital processes and hence kidneys extract the excess water from blood by osmosis and eliminate it as urine.

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3. Land animals

- Get water by food and fluid intake; water and salt is balanced by kidney in these organisms.

**Q:** Why does a marine animal burst when placed in tap water?

Being in a hypertonic environment, these animals tend to lose water and get dehydrated; therefore they are adapted to accumulate salts and equalize the osmotic pressure. When placed in tap water, solvent moves from high concentration to low concentration (fish – high conc. of salt; low conc. of water) they swell up and burst.

**Turgidity and Turgor pressure:**

**Turgidity:** A cell charged with water with its wall in a state of tension is said to be turgid, and the phenomenon is called turgidity.

**Factors influencing turgidity:**

- Semi-permeable membrane
- An adequate supply of water
- Formation of osmotically active substances inside the cell

**Flaccidity:** A cell that is no longer charged with water is said to be flaccid, and the phenomenon is called flaccidity.

<table>
<thead>
<tr>
<th>Turgor Pressure</th>
<th>Wall pressure</th>
<th>Suction Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Outward pressure exerted on the cell wall by the fluid contents of the cell under fully turgid condition is called turgor pressure.</td>
<td>• Inward pressure exerted on the fluid contents of the cell by the cell wall under fully turgid condition is called Wall pressure</td>
<td>• Measure of the water absorbing power of cell. Also, the force exerted on water to drive it into the absorbing material.</td>
</tr>
</tbody>
</table>

• In a turgid cell, turgor pressure is counteracted by the wall pressure.

• In a flaccid cell, wall pressure exceeds turgor pressure.

• It is the difference between Osmotic pressure and turgor pressure

\[ SP = OP - TP \]

Diagram depicting turgor pressure and wall pressure.
Significance of Turgidity:

1. **Brings about water movement**: especially in cortex; water moves from turgid to flaccid cells.
2. **Initial growth**: During germination, cells increase in size due to turgidity and not due to increase in no. of cells.
3. **Rigidity**: provided to thin parenchyma tissues, young leaves and regions because of turgidity.
4. **Roots**: penetrate through the soil since their tips are turgid; due to turgor pressure, roots are able to grow through walls.
5. **Guard cells**: When guard cells are turgid, their walls bulge and stomata opens; When guard cells are flaccid, stomata closes.
6. **Cells of the pulvinus**: The drooping of leaves of *Mimosa Pudica* is brought about by the change in turgidity of the swollen base of the petiole – pulvinus.
7. **Root pressure**: developed due to turgidity; it forces water through the cortex and through the Xylem.

Plasmolysis and De-plasmolysis

1. **Plasmolysis**: The shrinkage of cell membrane and cytoplasmic content of the cell from the cell wall when the cell is placed in a hypertonic solution is called plasmolysis.
2. **De-Plasmolysis**: The return of the plasmolysed cell to its normal condition when placed in a hypotonic solution is called De- Plasmolysis.

Stages of Plasmolysis:

- **A**: Cell wall and plasma membrane pressed against each other; vacuole presses against the cell wall.
- **B**: Cell membrane, along with cytoplasmic contents begins to shrink away from the cell wall.
- **C**: The cell wall and the cell membrane become visibly distinct from each other.
- **D**: Cytoplasmic contents form a rounded mass.

Note: The space is filled by the hypertonic solution in ‘C’ & ‘D’
**Experiment 5: On Plasmolysis and De-plasmolysis**

i. **Aim:** To study the changes within a cell when placed in a hypotonic and hypertonic solution.

ii. **Procedure:**
   - A section of a *hydrilla leaf* is taken and observed under the microscope.
   - This section is placed under a petri dish containing 10% sucrose solution. After 5-10 mins, the petri dish is removed and mounted on slide with same solution and then observed.
   - The same slide is then place in a petri dish containing distilled water. After some time it is mounted on water and then examined under the microscope.
   - Repeated after dipping a fresh section in boiling water.

iii. **Observations:**
   - **Observation 1 – Before placing in the solution:**
     → The plasma membrane is pressed against the cell wall and both cannot be distinguished from one another.
     → A large colorless vacuole that presses the cytoplasm against the cell wall is seen.
     → The cytoplasm is green due to chlorophyll.
   - **Observation 2 – After placing it in a 10% sucrose solution:**
     → The entire cell contacts; The protoplasm along with cytoplasm and cell organelles is withdrawn from the cell wall and forms a rounded mass in the center.
     → The vacuole completely diminishes; the cell wall and cell membrane are now seen distinctive from each other.
   - **Observation 3 – After placing it in distilled water:**
     → The protoplasm returns to its normal state and the vacuole reappears.
   - **Observation 4 – On repeating the experiment after dipping it in boiling water:**
     → None of the above stated observations are seen
     → [Inference: Cells become dead and semi-permeability of the cell membrane is lost]

iv. **Inferences:**
   - **Inference – 1:** *‘When the cell is placed in a hypertonic solution, exosmosis takes place’*
     As the water moves out of the cell, the protoplasm and the cell wall are no longer in state of tension. *Continued loss of water results in the shrinkage of the cell.*
   - **Inference – 2:** *‘The separation of the cell membrane from the cell wall implies the cell wall’s permeable nature and cell membrane’s semi-permeable nature’*
     → **Cell membrane:** only allows solvent molecules to diffuse out of it.
     → **Cell wall:** is permeable to both solute and solvent molecules. These molecules enter through the cell wall and are unable to pass through the cell membrane resulting in pushing the cell membrane and protoplasm away from the cell wall.
     → The space between cell wall and cell membrane is filled with the sugar solution.
   - **Inference – 3:** *‘Protoplasm can retain osmotically active substances of the sap’*
     → Evident from the fact that protoplasm returns to its normal condition and the vacuole reappears on placing the cell in distilled water.
Occurrence and Significance of Plasmolysis:

Plasmolysis is an extreme condition and rarely occurs in nature:

→ **Excess Fertilizer:** If soil is added with excess fertilizer, plasmolysis occurs. In such case, plants get wilted.

Application of Plasmolysis:

- **Preservation of food stuff:**
  1. **Jams** – contain high concentration of sugar, creating a hypertonic medium; if fungi or bacteria enters the medium, it gets plasmolysed and perishes.
  2. **Pickles** - contain high concentration of salt and spices, creating a hypertonic medium; if fungi or bacteria enters the medium, it gets plasmolysed and perishes.
  3. **Vegetables, meat, fish** are salted and dried for the same reason.
- **Leech:** The blood sucking annelid can take blood ten times its weight at a single meal, securing food for 9 months by injecting anti-coagulant to keep the blood flowing. By sprinkling salt on it, the leech gets plasmolysed and shrinks thus releasing its prey.
- **Salt solution for throat infection:** The salt solution acts as hypertonic solution for the bacteria which gets plasmolysed and die.
- **On sprinkling common salt on weeds growing in a farm, the weeds are killed:** Surrounding water becomes hypertonic, hence water from root hair cells come out by process of exosmosis and cells get plasmolysed and die. Thus, weeds are killed.

Transportation in Plants:

- **Mechanism of water uptake from roots:**
  → Due to transpiration, there is a constant water loss in the aerial parts of the plant.
  → This loss of water tends to lower the conc. of water in the cell sap. Root hair, with its semi-permeable membrane and hypertonic cell sap establishes an osmotic system with the water available in the soil surrounding the root hair.
  → First, water passes from the semi-permeable membrane of the root hair and then into the root hair.
  → Second, water accumulated in the root hair has higher conc. compared to the cells of the cortex. Hence, an osmotic system is developed and water passes from the root hair to the cortex.
  → Third, the cortex establishes an osmotic system with inner cortical cell and water passes inwards the cell.
  → Then to the endodermis, and lastly to the xylem vessels.

→ In brief: By a cell to cell osmosis, water from the soil passes into root hair, the cortical cells and finally reaches the Xylem vessels through the passage cells and the unthickened areas of the endodermis.
• **Ascent of Sap:**  
The upward movement of water and minerals from the roots to the leaves through the xylem vessels is called ascent of sap. (Water has to move upwards against the gravitational force)

**Factors responsible for root pressure:**

1. **Root pressure:**  
   → **Definition:** *Pressure exerted by the cortical cells of the root upon their liquid contents, under fully turgid condition, forcing a quantity of them into the xylem vessels and through them upwards into the stem.*
   → **Reason for formation:** Due to cell-to-cell osmosis, the cortex cells become turgid and flaccid alternately. *This process of alternate expansion and contraction of the cell result in an intermittent pumping pressure (root pressure).*
   → Root pressure **generates 2 atmospheric pressure, enough to raise water through 19m.** Hence root pressure is adequate to raise water in *herbs, shrubs and small trees.*

2. **Cohesive Force, Adhesive Force and Transpirational Pull:**
   → Water is lost by transpiration and consumed in photosynthesis; although water column through xylem gets greatly stretched, the continuity of flow of water never breaks – due to adhesive force and cohesive force
   → **Adhesive force** is the *force of attraction between unlike molecules* – between water molecules and walls of Xylem vessels.  
   **Cohesive force** is the *property of same molecules sticking together.* As water is lost by transpiration, water is pulled up due to cohesion.

   → **Transpirational pull:**  
In botany, transpiration pull refers to the suction, force, or pull that draws water up through a plant. It is a biological process where the water molecules and ions are absorbed up from the roots, and then evaporation occurs within the leaves, spreading water throughout the plant.

Transpiration pull is a passive process that functions without any energy input from the plant. However, it is a critical process and is the strongest force that pulls and transports water to the leaves of all plants.

**Experiment 6 – On cohesive force and transpirational pull**

*i. Aim:* To demonstrate Cohesive Force and Transpirational Pull.

**ii. Procedure:**

1. **Setup A:**
   i. A water column is taken and filled with water. Keep a wet sponge at the upper end and place a finger in lower end and placing it in a beaker containing water with a layer of oil to prevent evaporation
   ii. Mark the initial level of water in the beaker.
   iii. Leave the setup undisturbed for some time
Observation for ‘A’ - water level in the beaker is reduced

Inference for ‘A’ - Water is lost in sponge due to evaporation and replaced by water from tube, which, in turn is replaced by water from beaker. The upward pull and continuity of water column is maintained by the cohesive force.

2. Setup B

   i. Fix a leafy shoot at the upper end in a water column filled with water and place the lower end in mercury.
   ii. Keep the setup undisturbed for some time.

Observation for ‘B’ – Mercury rises in the tube

Inference for ‘B’ – As the shoot loses water by transpiration, water is pulled from the water column, which in turn pulls the mercury from beaker. Therefore, mercury rises due to transpirational pull. Transpirational pull is sufficient to raise water up to the top of tallest trees.

3. Capillarity: Phenomenon by which liquids rise to their greatest height in tubes having the narrowest diameter. Xylem vessels can be regarded as several capillary tubes in which water rises by action. The magnitude of capillarity force cannot account for ascent of sap beyond 2m.

4. Imbibition Force: Water rises through the walls by the process of imbibition. This force is called imbibition force. However, the force is not sufficient for rapid rise of water due to heavy loss during transpiration.

   - Transpirational pull and root pressure play an important role in ascent of sap while capillarity and imbibition force play a comparatively minor role.
   - Root pressure pushes water into xylem vessels while transpirational pull pulls water from xylem vessels.
   - Exudation through cut parts of the plant is called bleeding.
   - Due to root pressure, hydrostatic pressure guttation takes place.
Experiment 7: Ring or Girdling Experiment

i. **Aim:** To study the role of xylem and phloem in ascent of water and translocation of food

ii. **Procedure:**
- **A** – The phloem and other peripheral tissues are removed leaving the xylem intact. The twig is then suspended in a beaker of water with a help of retort stand
- **B** – The xylem is carefully removed from another twig with the help of a scalpel. The twig is then fixed on a retort stand & suspended on a beaker of water.

<table>
<thead>
<tr>
<th>iii. Observation</th>
<th>iv. Inference</th>
</tr>
</thead>
</table>
| 1. Setup A – The leaves remain turgid and adventitious roots are seen developing above the cut portion. The part below the ring eventually shrivels. | 1. There is no decrease in upward movement of water and solutes – can be inferred from the turgid condition of the shoot which is healthy and continues to grow.  
2. Food fails to reach below the cut portion; roots are only developed above the cut portion.  
*Thus water is transported upwards by xylem and food translocated downwards by phloem.* |
| 2. Setup B – leaves become flaccid & the shoot eventually dies.                  | Water fails to reach above the ring; since water does not reach the leaves, hardly any food is prepared. Hence the shoot dies.  
*This shows that water is transported upwards by xylem.*                           |

**Translocation of Food:** *The transportation of photosynthates in the solution form through the phloem from the site of their preparation to the storage organs or regions where they are utilized, is known as translocation.*

**Munch’s Hypothesis:**

“The mass flow of organic solutes takes place from the site of higher concentration (source) to the site of lower concentration (sink).”

**In young plants:** The cotyledons are food source and the roots are sink; translocation of solutes takes place from cotyledons to roots.

**In older plants:** Glucose is synthesized at leaves (source). The osmotic pressure and turgor pressure of the cells increases and due to this some of the solute passes through the sieve cells. The non-green parts/storage parts of the plant convert glucose into insoluble starch, lowering osmotic pressure and turgor pressure. This gives rise to turgor pressure gradient between the supply site (source) and the storage site (sink).