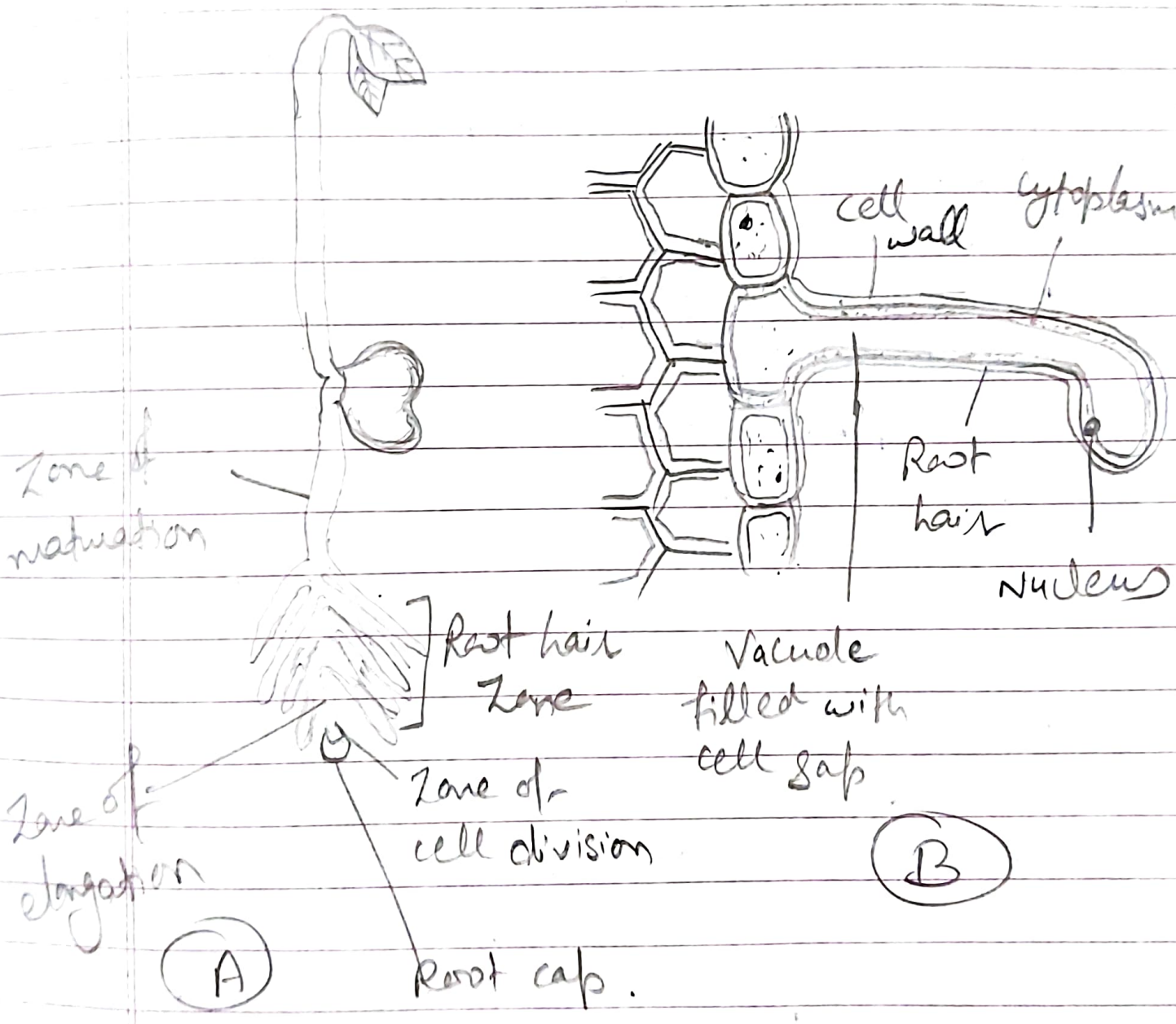
Absorption and Transport of Water

Root Hair :- Root hairs are the main water absorbing organs of plants.



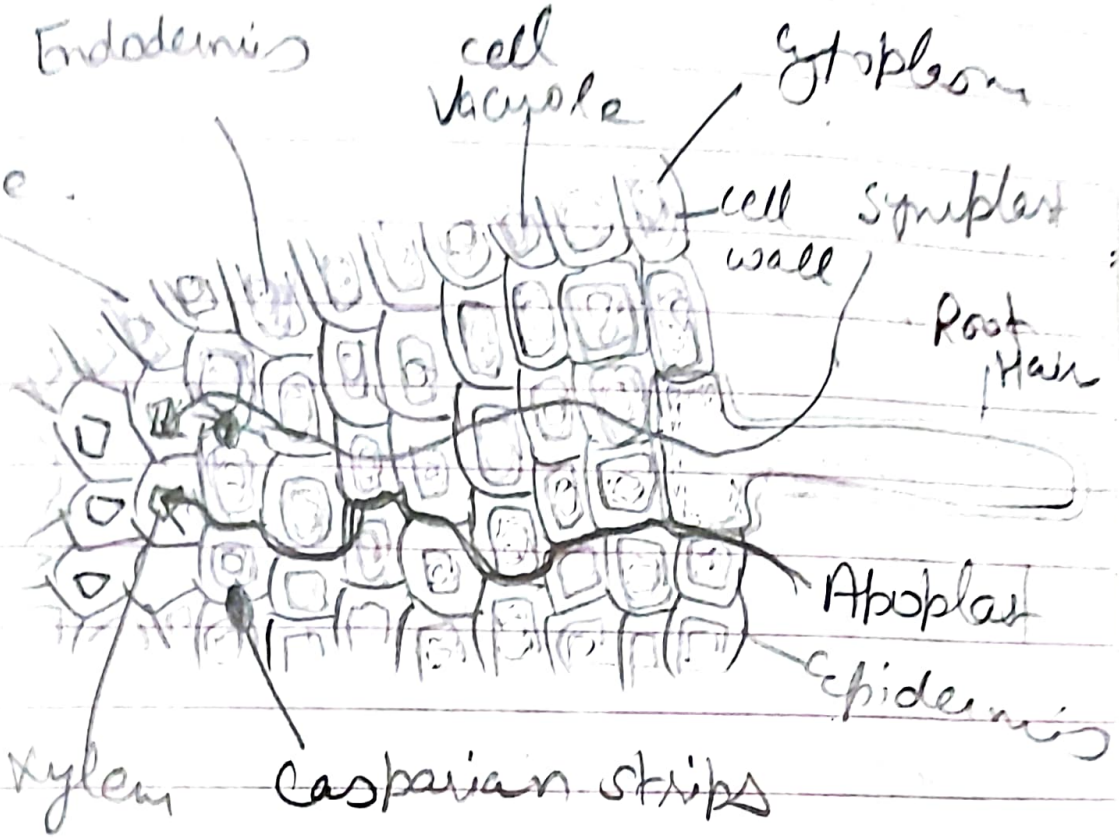
A → a terminal portion of root showing root hair zone

B → Structure of a single root hair.

- The root hairs develop mainly at the tip just above the zone of elongation.
- They are generally delicate and short lived.
- The cell wall of root hairs is composed of two distinct layers.
  - The outer layer, which is composed of pectic substances; helps to adhere soil particles.
  - The inner layer is made up of cellulose.
- The cell wall is permeable both to solute and solvent molecules.
- The cytoplasm encloses a big central vacuole that contains the cell sap.
- Nucleus of the cell is generally present at the tip.

⇒ Pathway of water across Root cells

The water is first absorbed by the root hair and other epidermal cells from the soil and then moves centripetally across the cortex, endodermis, pericycle and finally into the xylem.



→ Movement of water via Apoplast and Symplast pathway

Pathways for the movement of water across the cross:-

(i) Through a system of interconnecting cell walls and intercellular spaces, called Apoplast-pathway. This movement does not occur due to osmosis, but occurs through the capillary action.

(ii) Through the living cytoplasm via, plasmodesmata (i.e. Symplast pathway).

⇒ Ascent of Sap.

Definition :- The water is absorbed mainly by the roots and is moved upward to all the parts of plants via stem. Thus, the upward movement of water and dissolved substances through stem is called ascent of sap.

Path of Ascent of Sap :-

- After absorption by root cells, the water moves through several root tissues such as cortex, endodermis, pericycle and finally enters the xylem tissue.
- Once the water enters into the xylem, it continues its upward movement until it reaches the mesophyll tissues of the leaves.

Theories of Ascent of Sap :-

The following points highlight the top four theories of ascent of sap. These theories are :-

1.) **Root Pressure theory :-** (Given by Priestley 1916) :-

- Root pressure is a positive pressure that develops in the xylem sap of the root of some plants
- It is a manifestation of active water absorption.
- Root pressure is observed in certain seasons which favour optimum metabolic activity and reduce transpiration.
- It is maximum during rainy season and reduces due drought.

2.) **Vital Force Theory :-**

- A common vital force theory was given by J.C. Bose (1923).
- It is called pulsation theory.
- The theory believes that the innermost cortical cells of the root absorb water from the outer-side and pump the same into xylem channels.

3. Capillary theory:-

- This theory was given by Boehm (1809).
- Since the water moves upward through the lumen of xylem cells it was proposed that capillary force must be playing a definite role.
- This theory has now been rejected because the magnitude of capillary force is too low to account for rise of water in tall trees.

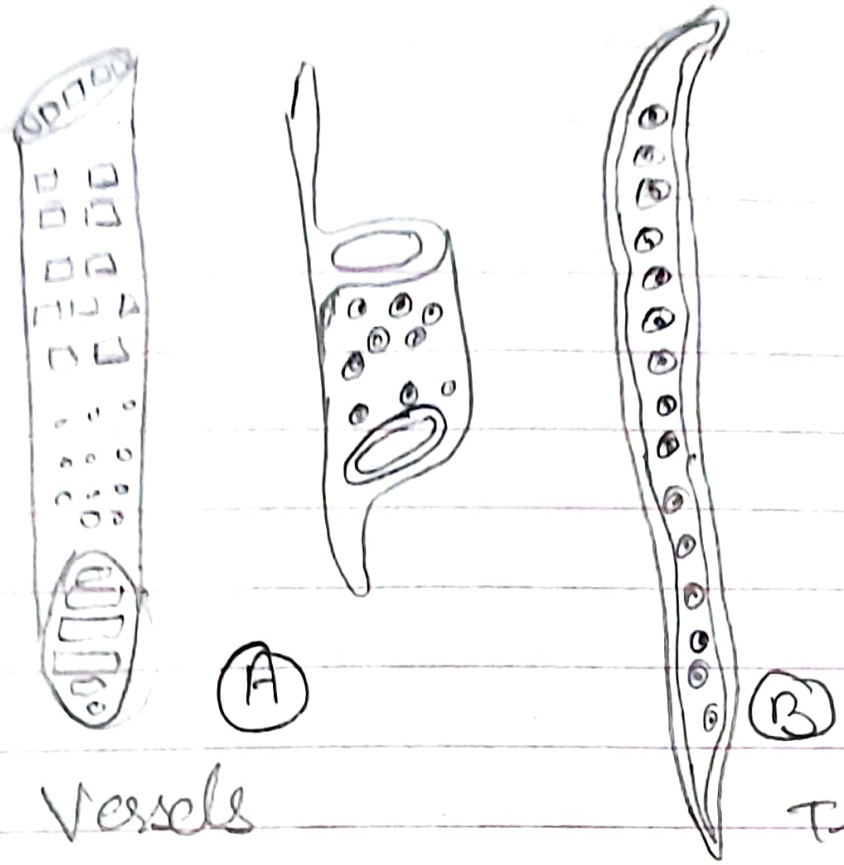
4. Transpiration Pull or Cohesion Tension Theory:-

Cohesion-tension theory was proposed by Dixon and Joly in 1894. Today most of the workers believe in this theory.

- The main features of the theory are:-

a) Continuous water column:-

- There is a continuous column of water from root through the stem and into the leaves



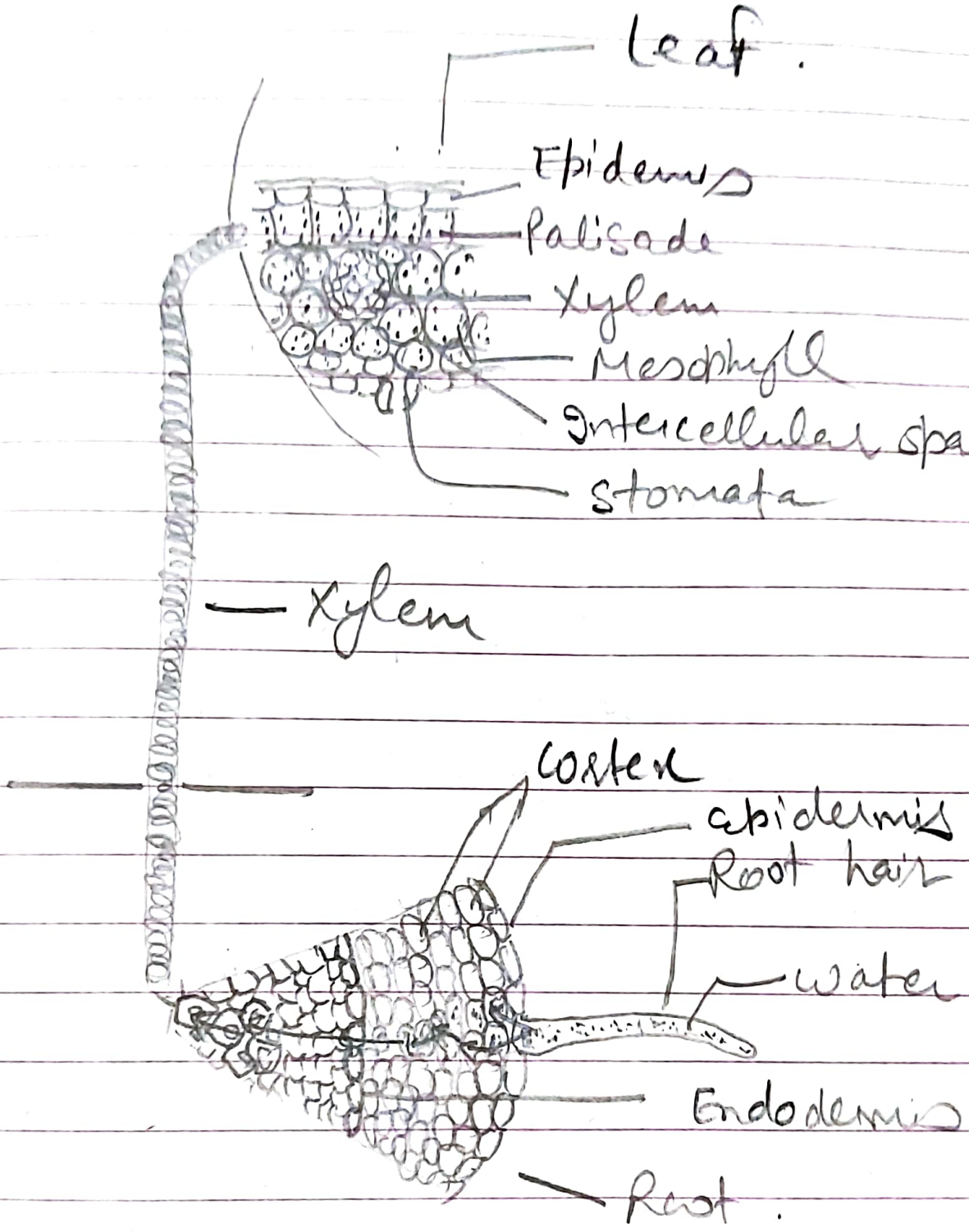
- The water column is present in tracheary elements.
- The tracheary elements form a continuous system through their unthickened areas.
- Since there are a large number of tracheary elements running together, the blockage of one or a few of them does not cause any breakage in the continuity of water column.

b) Cohesion or Tensile Strength:-

- Water molecules remain attached to one another by a strong mutual force of attraction called cohesion force.
- The mutual attraction is due to hydrogen bonds formed amongst adjacent water molecules.
- Water column does not further break its connection from the tracheary elements (vessels and tracheids) because of another force called adhesion force between their walls and water molecules.

c) Transpiration Pull:-

- In plants the pull is generated by the process of transpiration which is known as transpiration pull.
- The water vapours evaporate from mesophyll cells to the inter cellular spaces as a result of active transpiration.
- The water vapours are transpired through the stomatal pores.



Path of Ascent of Sap showing Transpiration Pull

- Loss of water from mesophyll cells causes a decrease in the water potentials.
- The water moves from cell to cell along the water potential gradient (from higher water potential level to lower water potential level).
- Finally the movement of water within the leaf is transmitted to the water filled in the xylem elements.
- This exerts a pull and the water, filled in the xylem, comes in a state of tension. This pull is called transpiration pull.
- This tension, generated at the top of the unbroken water column, is transmitted downwards from petiole, stem and finally reaches to the roots.

Thus, the theory strongly suggests that the transpiration pull is responsible for the upward movement of sap in the plants.

Evidences in support of Cohesion-tension theory:-

- If water is under tension, the strain in the vessels should cause their diameters to decrease. A decrease in diameter of tree stems have been observed when the transpiration is high.
- A leafy twig cut under water and the cut end of twig sealed to the top of a mercury manometer has been shown to pull the mercury above barometric level.
- The rate of water absorption and hence ascent of sap closely follows the rate of transpiration.

Criticism:-

- The gases dissolved in sap shall form air bubbles under tension and high temperature. Air bubbles would break the continuity of water column and stop ascent of sap due to transpiration pull.

- Cohesion theory assumes tracheids to be more effective than vessels. Recent

findings, however shown that vessels, instead of tracheids, are more efficient in upward movement of water and truely so the dominant flora adapted vessels in place of tracheids.

⇒ Factors affecting Ascent of Sap :—

Since the water transport is regulated by root pressure and transpiration, all these factors which effect the rate of water absorption and transpiration also influence the ascent of sap.

Factors such as :—

- high temperature
- low atmospheric humidity
- High atmospheric pressure
- High wind velocity

permits more rapid transpiration and thus these factors also promote upward transport of water.