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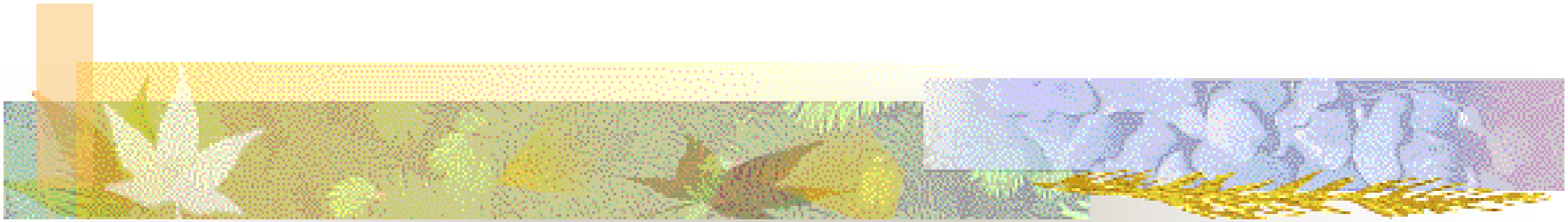
Biology Department



Lec. 2 Water and Plant cells

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Assist. Professor

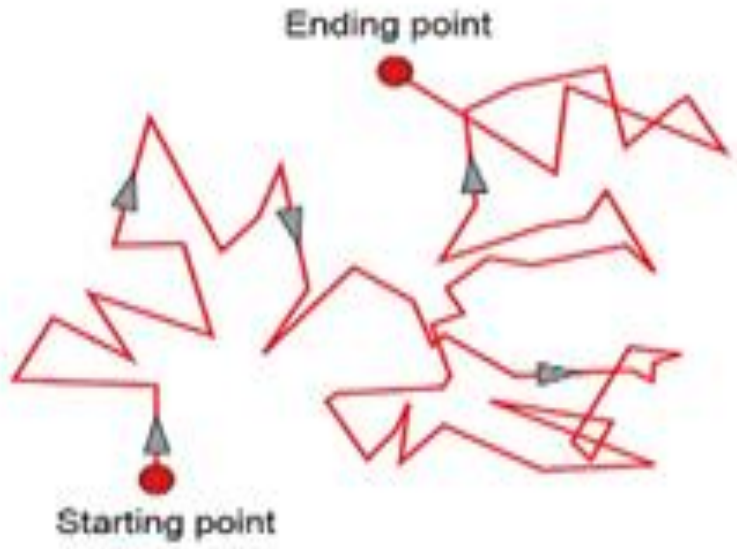
Plant Cells and Water

- Water plays a crucial role in the life of plants. It is the most abundant constituent of most organisms. Water typically accounts for more than 70 % of the weight of non-woody plant parts.
- The water content of plants is in a continual state of flux.
- The constant flow of water through plants is a matter of considerable significance to their growth and survival. The uptake of water by cells generates a pressure known as turgor.
- Photosynthesis requires that plants draw carbon dioxide from the atmosphere while simultaneously exposing them to water loss.

- Water must be absorbed by the roots and transported through the plant body to prevent leaf desiccation. Balancing the uptake, transport, and water loss represent an essential challenge for land plants.
- The thermal properties of water contribute to temperature regulation, helping to ensure that plants do not cool down or heat up too rapidly.
- Water has excellent solvent properties.
- Many biochemical reactions occur in water, and water is itself either a reactant or a product in many of those reactions.
- Plants need water, minerals, and food for their growth and survival. Roots and leaves take up water and minerals to prepare the food. These are then transported to the other parts of the plants. When we talk about transport, there should be some means of transportation. Diffusion is the main pathway of transportation in plants.

Molecular Movement

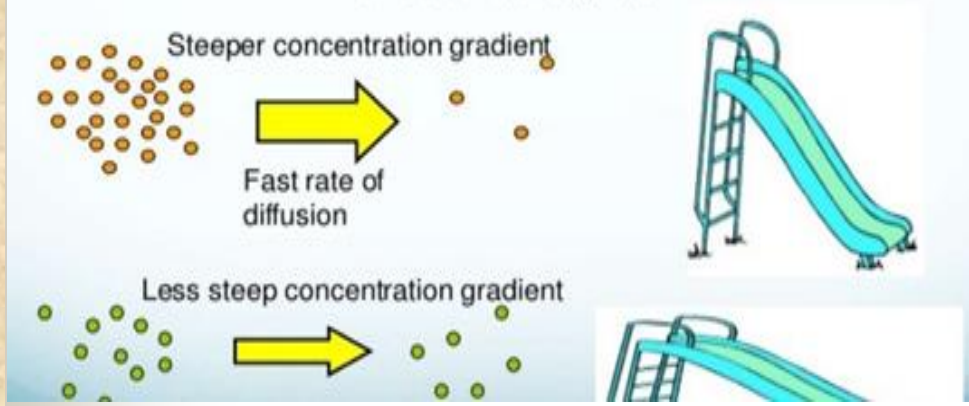
Molecules and ions are constantly in random motion. This motion, known as **Brownian movement**, results from the bombardment of the visible particles by invisible water molecules, which are in constant motion

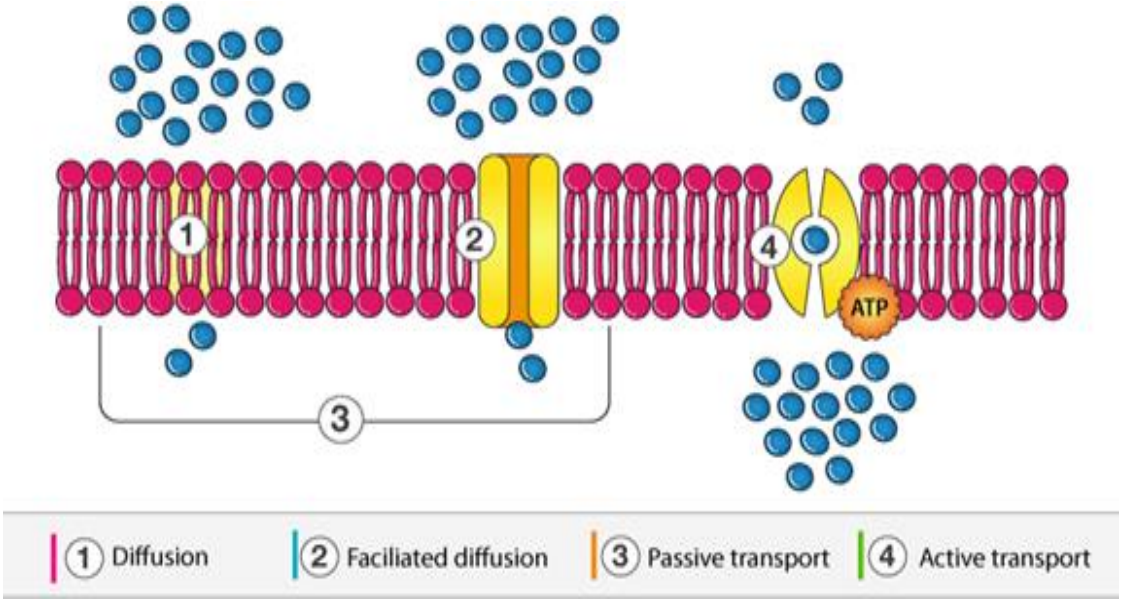


- **Diffusion**
- This movement of molecules or ions from a region of higher concentration to a region of lower concentration is called **diffusion**.
- Molecules moving from a region of higher concentration to a region of lower concentration are said to be moving along a **diffusion gradient**, while molecules going in the opposite direction are said to be moving **against a diffusion gradient**.
- When the molecules, through their random movement, have become distributed throughout the space available, they are considered to be in a state of **equilibrium**.

Concentration Gradient

The **steeper** the concentration gradient, the **faster** diffusion takes place



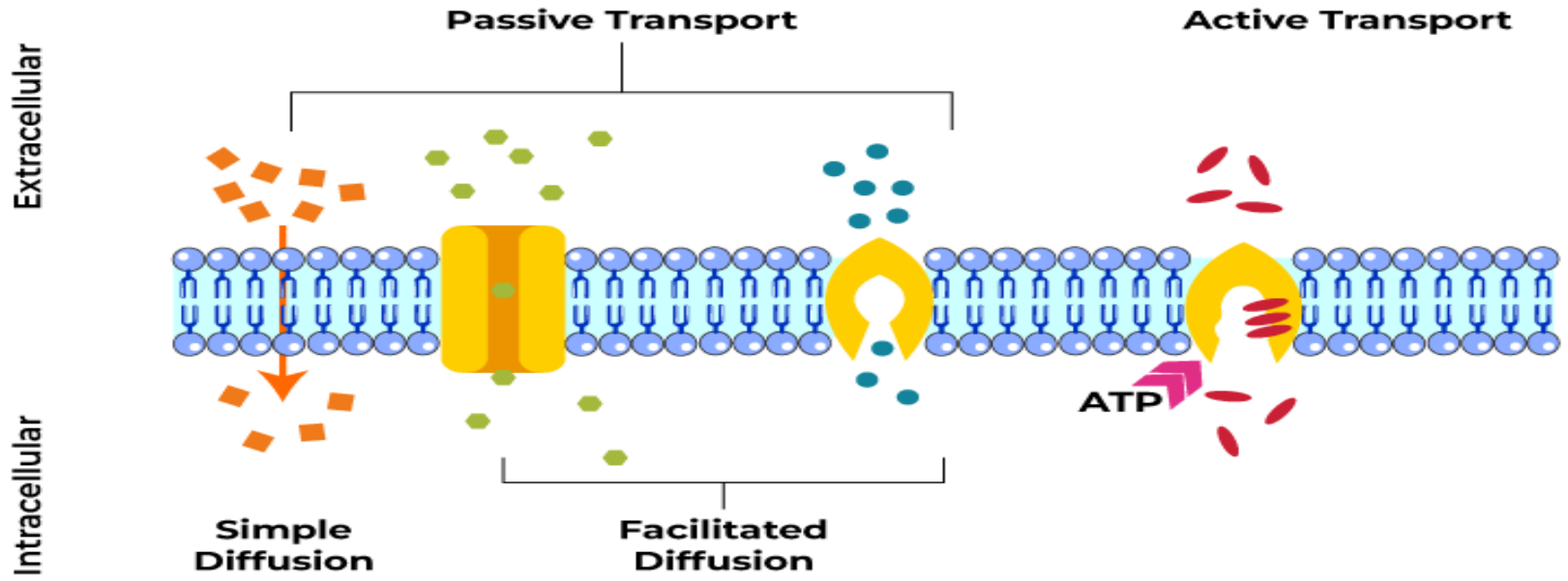


Importance of Diffusion in Plants

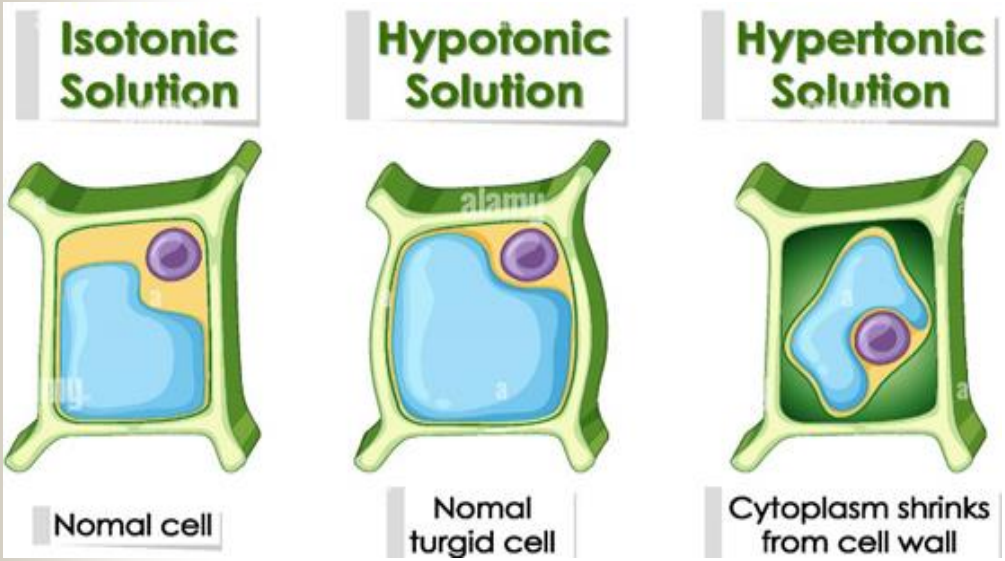
- The exchange of gases through stomata takes place through the process of diffusion.
- Transpiration occurs by the principle of diffusion.
- The ions are absorbed by simple diffusion.
- This process translocates the food material.
- This process keeps the walls of the internal tissues of the plant moist.
- It is responsible for spreading the ions and molecules throughout the protoplast.
- The aroma of flowers is due to the diffusion of aromatic compounds to attract insects.

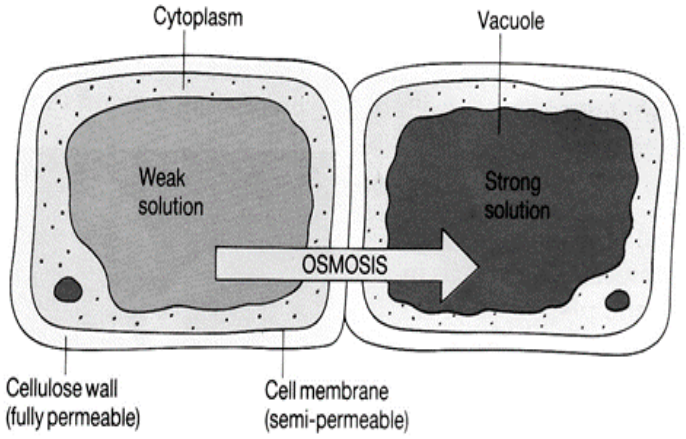
Active Transport

Active transport is defined as a process that involves the movement of molecules from a region of lower concentration to a region of higher concentration against a gradient or an obstacle with external energy.



Osmosis is the diffusion of water through a semipermeable membrane. It takes place in response to concentration differences of dissolved substances.





Significance of Osmosis

- Osmosis influences the transport of nutrients and the release of metabolic waste products.
- It is responsible for absorbing water from the soil and conducting it to the upper parts of the plant through the xylem.
- It stabilises the internal environment of a living organism by maintaining the balance between water and intercellular fluid levels.
- It maintains the turgidity of cells.

- It is a process by which plants maintain their water content despite the constant water loss due to transpiration.
- This process controls the cell-to-cell diffusion of water.
- Osmosis induces cell turgor which regulates the movement of plants and plant parts.
- Osmosis also controls the dehiscence of fruits and sporangia.
- Higher osmotic pressure protects the plants against drought injury.

Osmosis has a significant role to play in plants

- The absorption of water from the soil is due to osmosis. The plant roots have a higher concentration than the soil. Therefore, the water flows into the roots.
- The guard cells of the plants are also affected by osmosis. When the plant cells are filled with water, the guard cells swell up, and the stomata open.

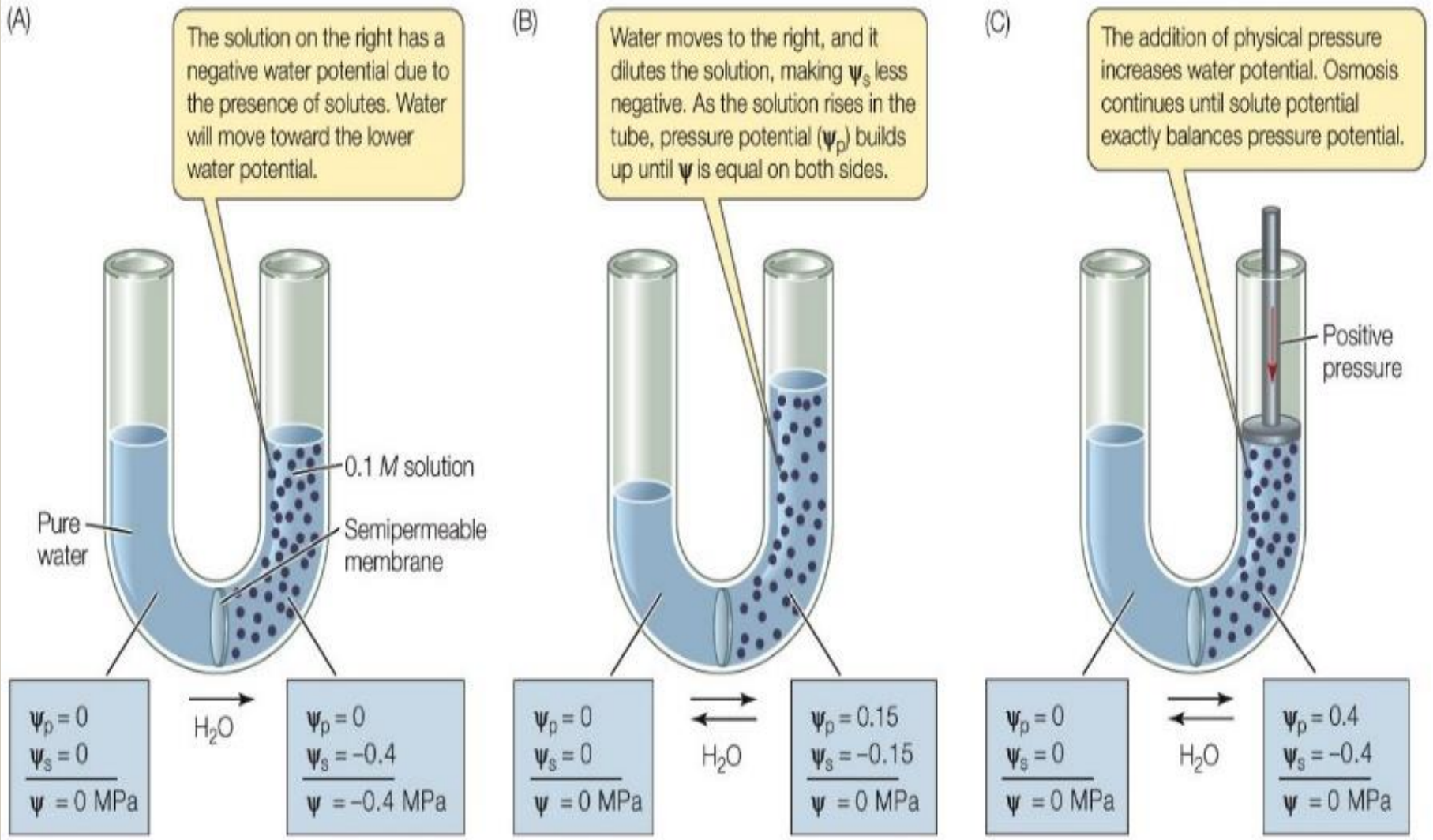
Water potential

All living things, including plants, require a continuous input of free energy to maintain and repair their highly organised structures and grow and reproduce. Chemical potential is a quantitative expression of the free energy associated with a substance.

The osmotic potential (represented by ψs) of a solution is a measure of the potential of water to move from one cell to another as influenced by solute concentration.

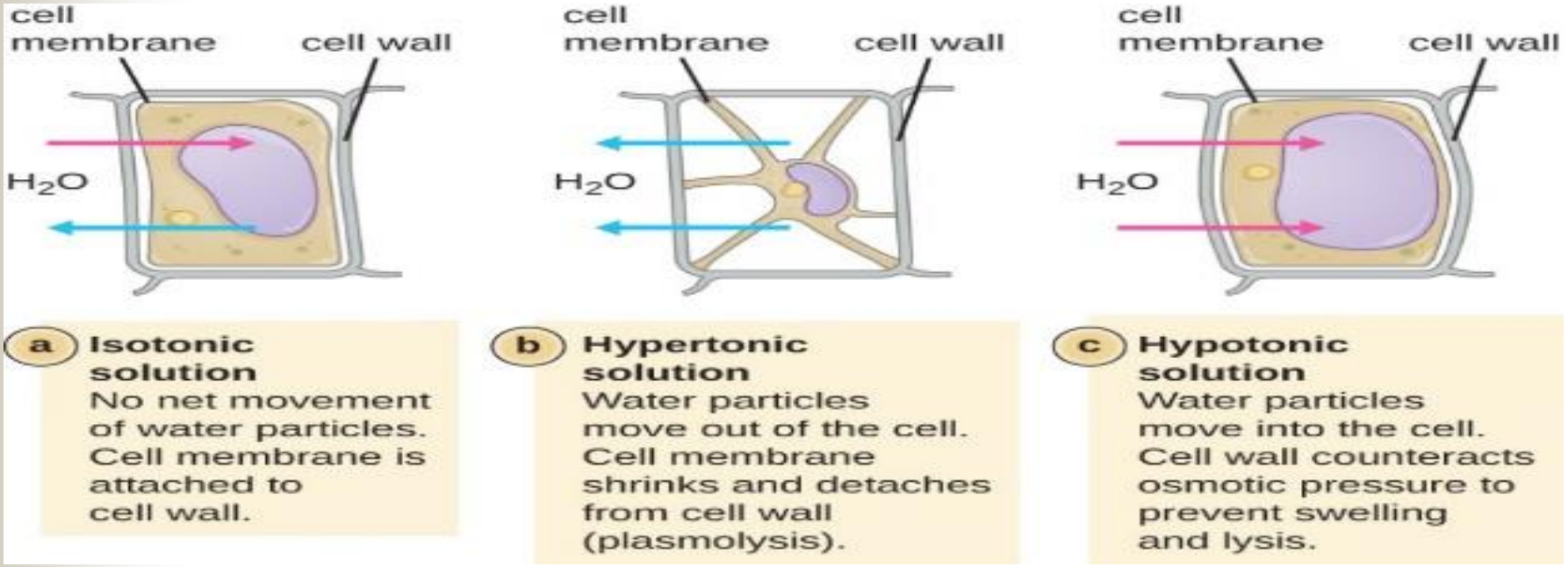
Water gained by osmosis may keep a cell firm or turgid. The turgor pressure that develops against the walls due to water entering the cell's vacuole is called **pressure potential** (represented by ψp).

The water potential (represented by ψw) of a plant cell is essentially its osmotic potential and pressure potential combined **(ψw = ψs + ψp)**


(A)
The solution on the right has a negative water potential due to the presence of solutes. Water will move toward the lower water potential.
0.1 M solution
Pure water
Semipermeable membrane
ψp = 0
ψs = 0
ψ = 0 MPa
H2O
ψp = 0
ψs = −0.4
ψ = −0.4 MPa
(B)
Water moves to the right, and it dilutes the solution, making ψs less negative. As the solution rises in the tube, pressure potential (ψp) builds up until ψ is equal on both sides.
ψp = 0
ψs = 0
ψ = 0 MPa
H2O
ψp = 0.15
ψs = −0.15
ψ = 0 MPa
(C)
The addition of physical pressure increases water potential. Osmosis continues until solute potential exactly balances pressure potential.
Positive pressure
ψp = 0
ψs = 0
ψ = 0 MPa
H2O
ψp = 0.4
ψs = −0.4
ψ = 0 MPa

Plasmolysis

Plasmolysis is the shrinkage of the cytoplasm away from the cell wall as a result of osmosis taking place when the water potential inside the cell is greater than the potential outside.



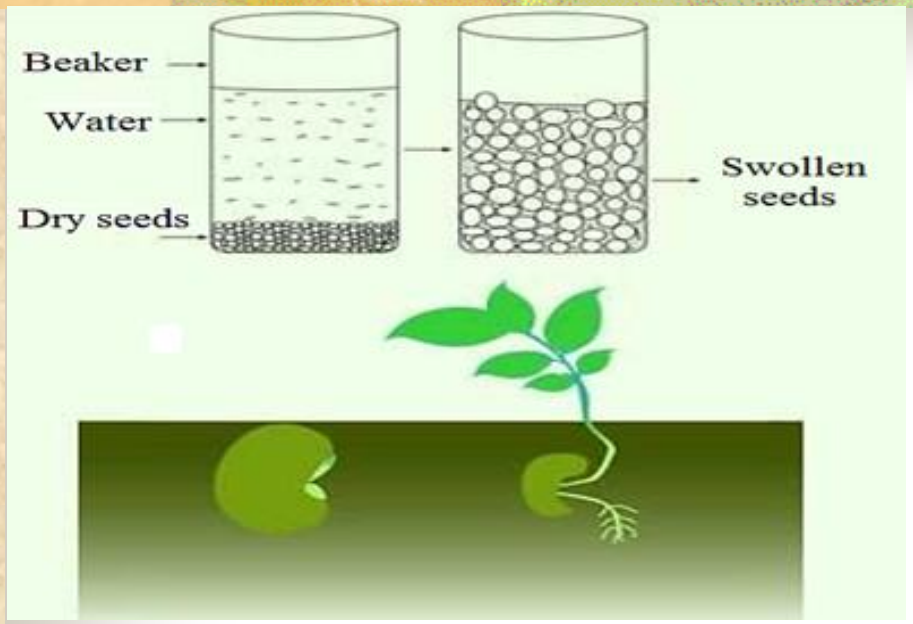
a **Isotonic solution**
No net movement of water particles. Cell membrane is attached to cell wall.

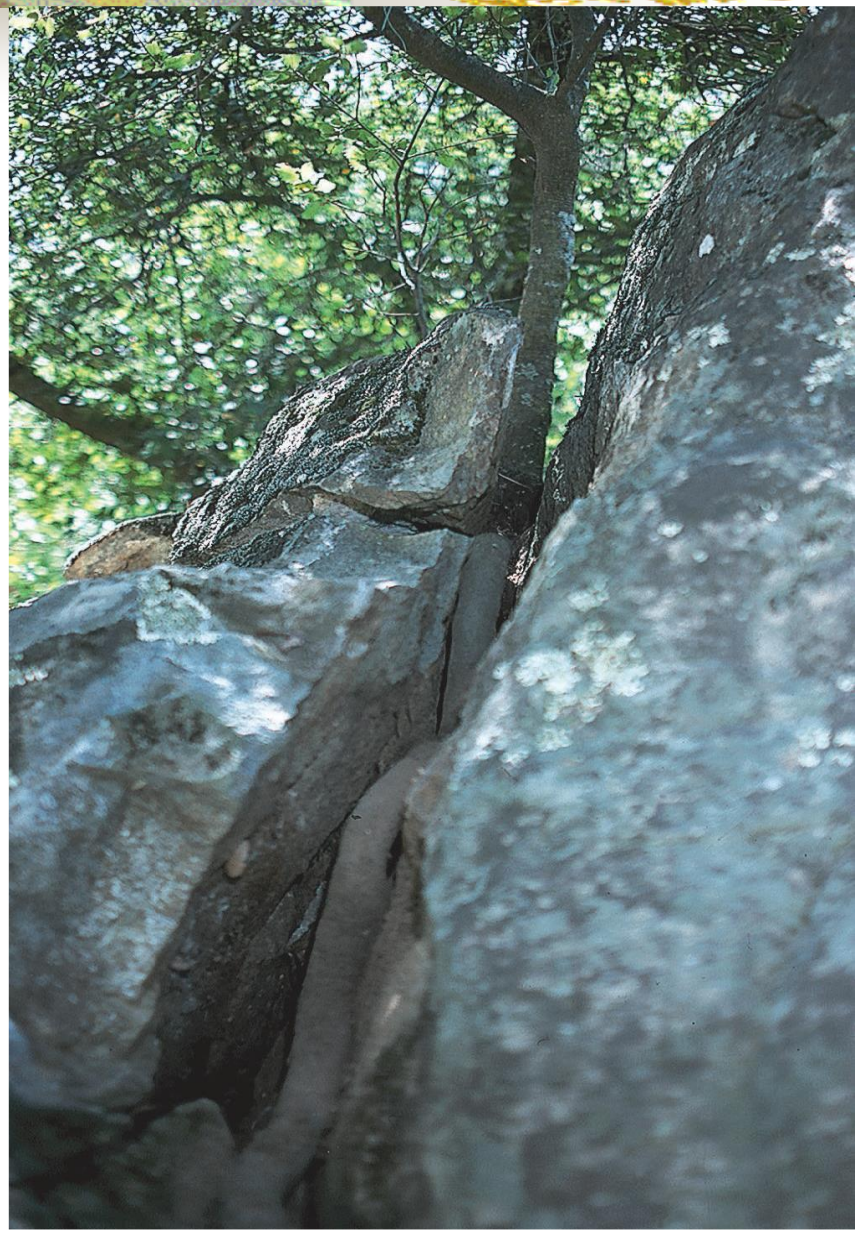
b **Hypertonic solution**
Water particles move out of the cell. Cell membrane shrinks and detaches from cell wall (plasmolysis).

c **Hypotonic solution**
Water particles move into the cell. Cell wall counteracts osmotic pressure to prevent swelling and lysis.

Imbibition

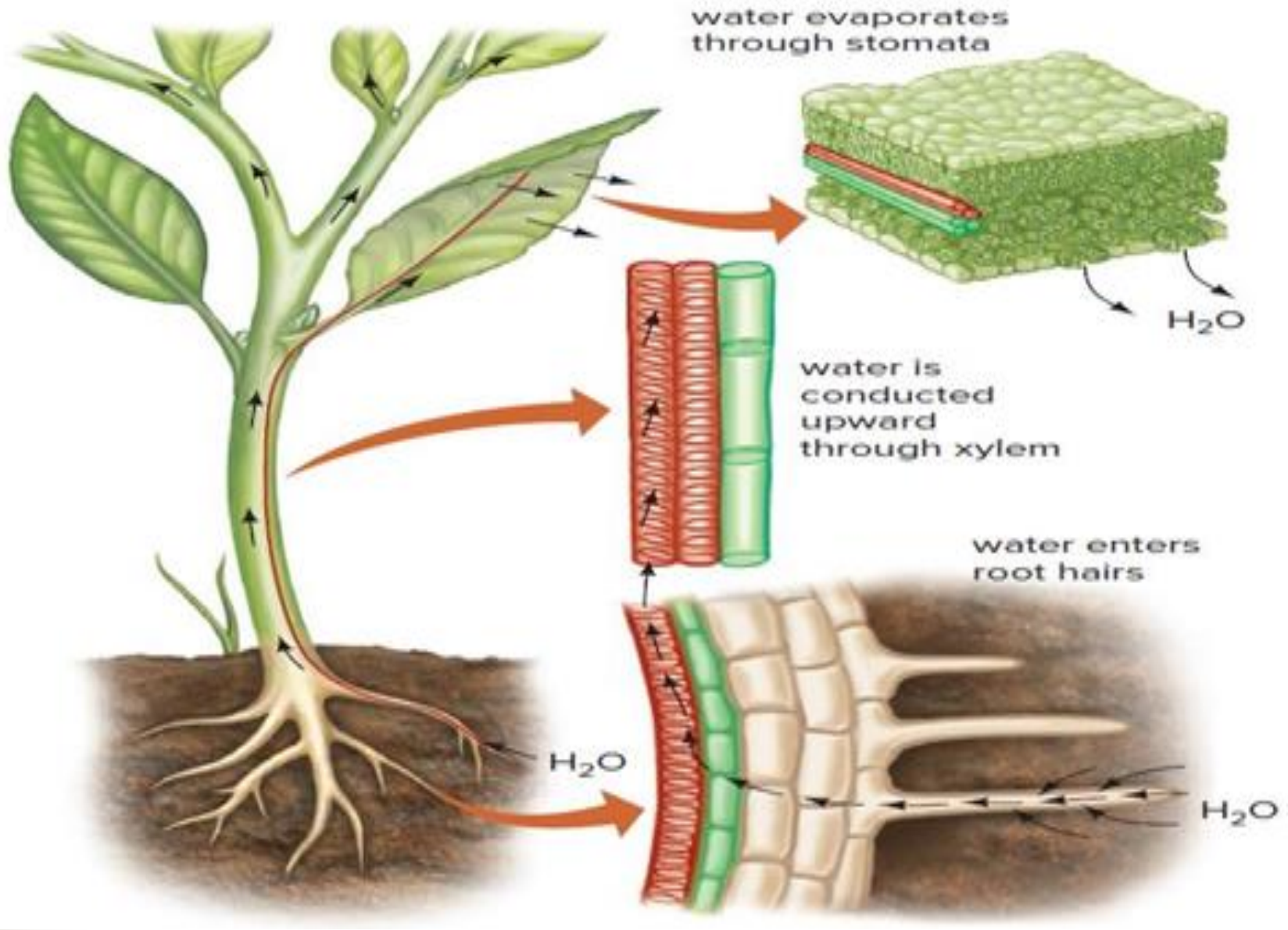
This process, known as imbibition, results in the **swelling** of tissues, whether alive or dead, often to **several times their original volume**. Imbibition is the **initial step** in the germination of seeds. The physical forces developed during germination can be tremendous, even to the point of causing a seed to split a rock weighing several tons. Imbibition is the **attraction** and **adhesion** of water molecules to the internal surfaces of materials; it results in **swelling** and is the initial step in **germinating seeds.**


Beaker
Water
Dry seeds
Swollen seeds



Water absorption by roots

Intimate contact between the root's surface and the soil is essential for effective water absorption. **Root hairs** are **filamentous** outgrowths of **root epidermal cells** that significantly **increase the surface area** of the root, thus providing **greater capacity** for the **absorption** of **ions** and **water** from the soil. Water enters the root most readily near the root tip. **The intimate contact** between the soil and the root surface is easily ruptured when the soil is disturbed. For this reason, newly transplanted seedlings and plants need to be protected from water loss for the first few days after transplantation


water evaporates
through stomata
H_2O
water is
conducted
upward
through xylem
water enters
root hairs
H_2O
H_2O

From the epidermis to the endodermis of the root, there are three pathways through which water can flow:

1- **The apoplast** is the continuous system of **cell walls** and **intercellular air spaces**. Water moves without crossing membranes in this pathway as it travels across the **root cortex**.

2- **The symplast** consists of the entire network of cell cytoplasm interconnected by **plasmodesmata**. In this pathway, water travels across the root cortex via the **plasmodesmata**.

3- **The transmembrane pathway** is the route by which water enters a **cell on one side**, exits **the cell on the other side**, enters the next in the series, and so on. In this pathway, water crosses the **plasma membrane** of each cell in its **path twice**.

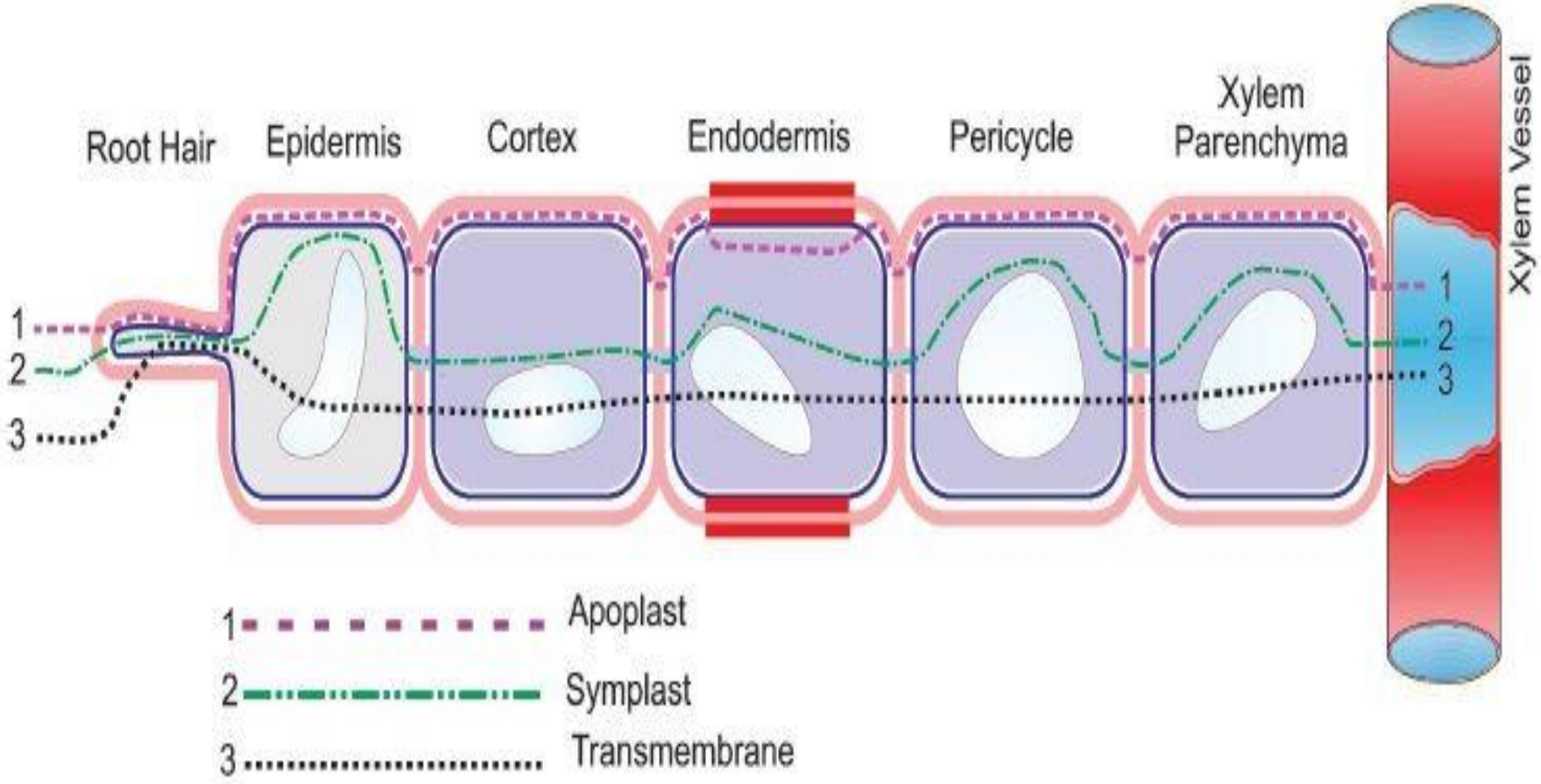
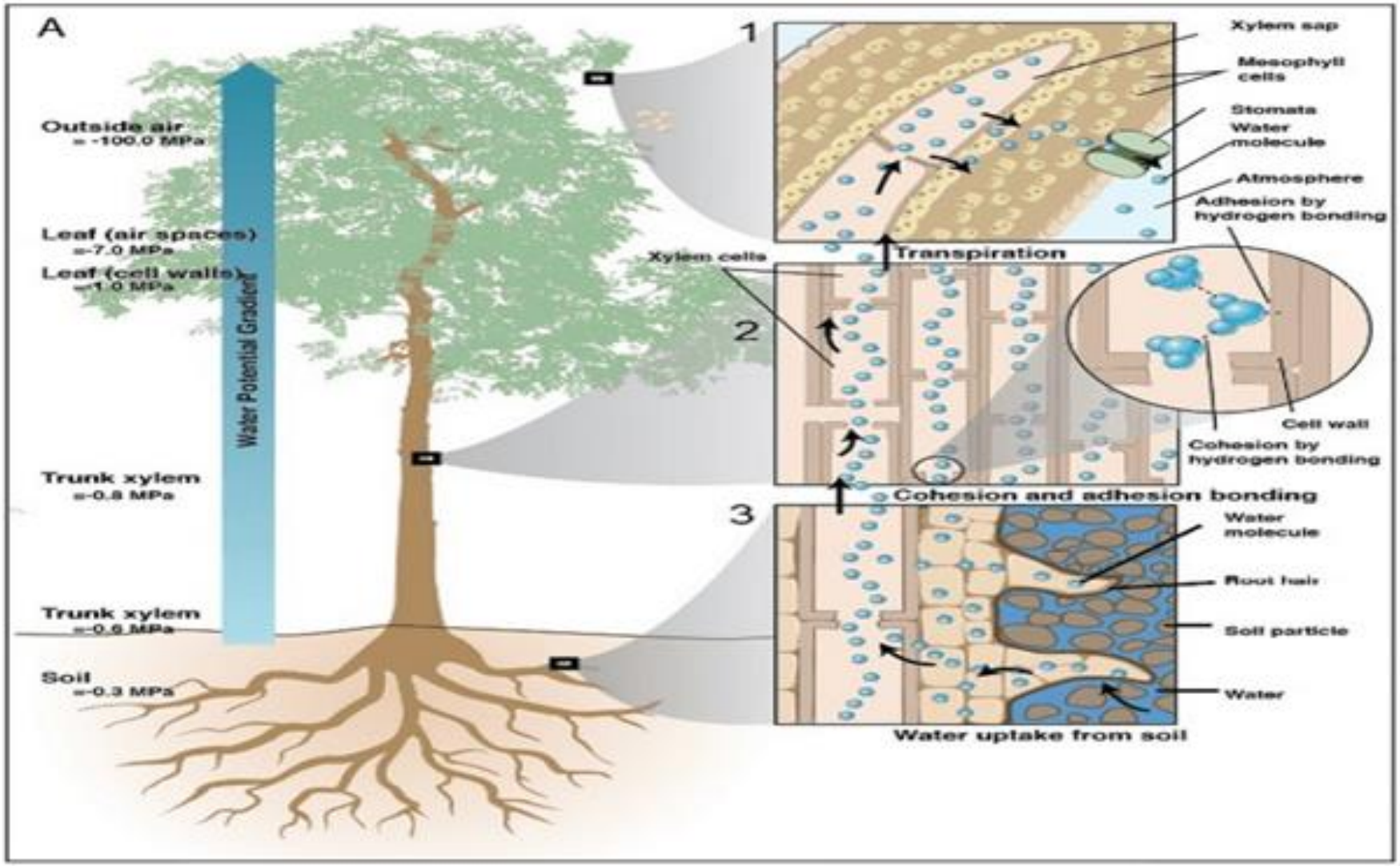


Figure 11.11: Path of water across root cells

Movement of water against gravity

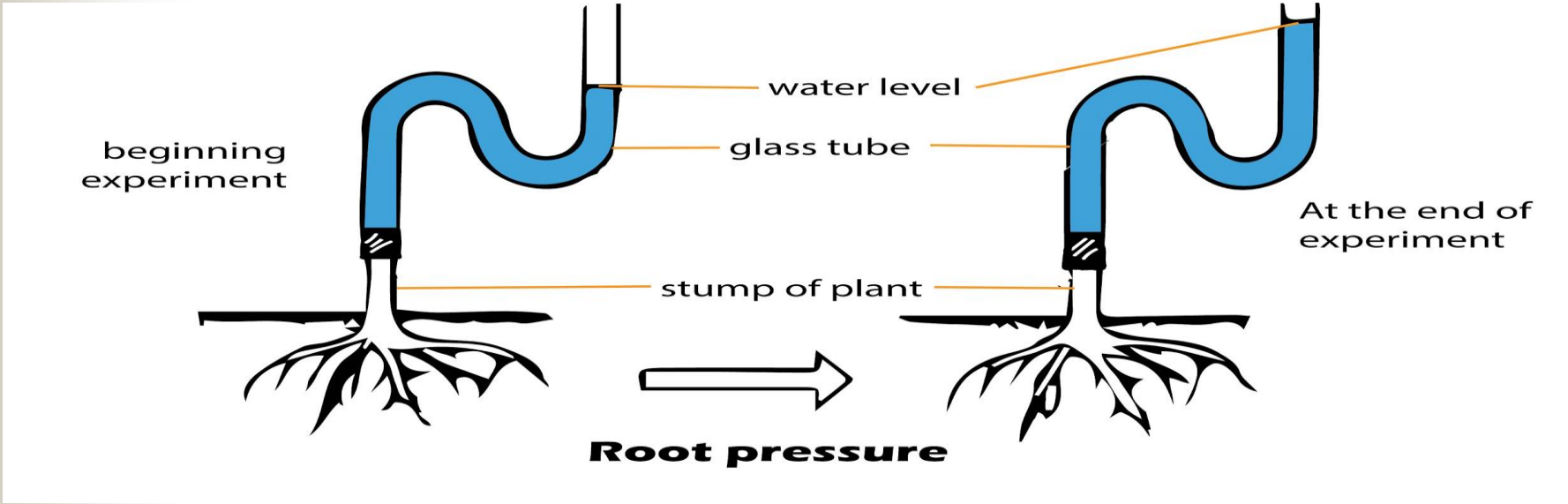


Movement of water against gravity

How is water transported up a plant against gravity when there is no "pump" to move water through a plant's vascular tissue? Three hypotheses explain the movement of water up a plant against gravity

1- Root pressure pushes water up

Root pressure relies on positive pressure that forms in the roots as water moves into the roots from the soil.



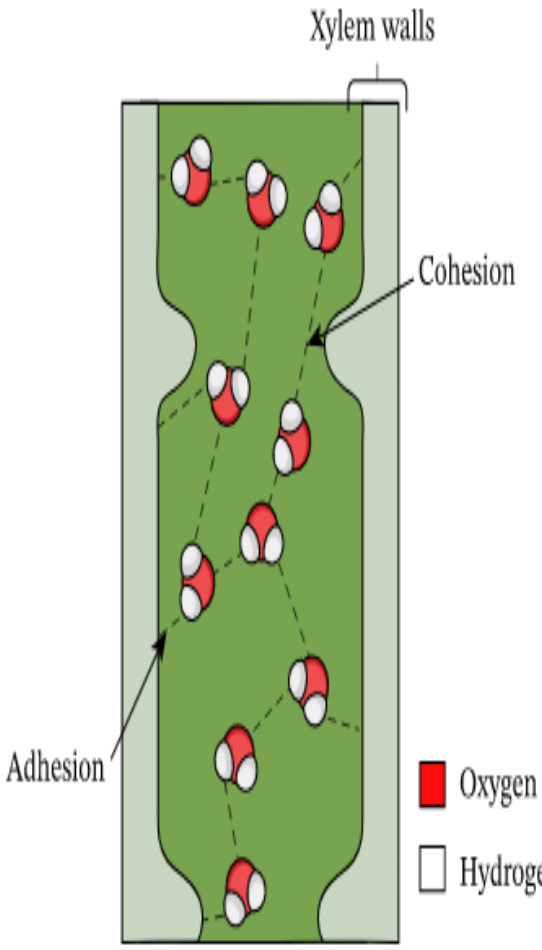
2- Capillary action draws water up within the xylem

Capillary action or capillarity is the tendency of a liquid to move up against gravity when confined within a narrow tube (capillary).

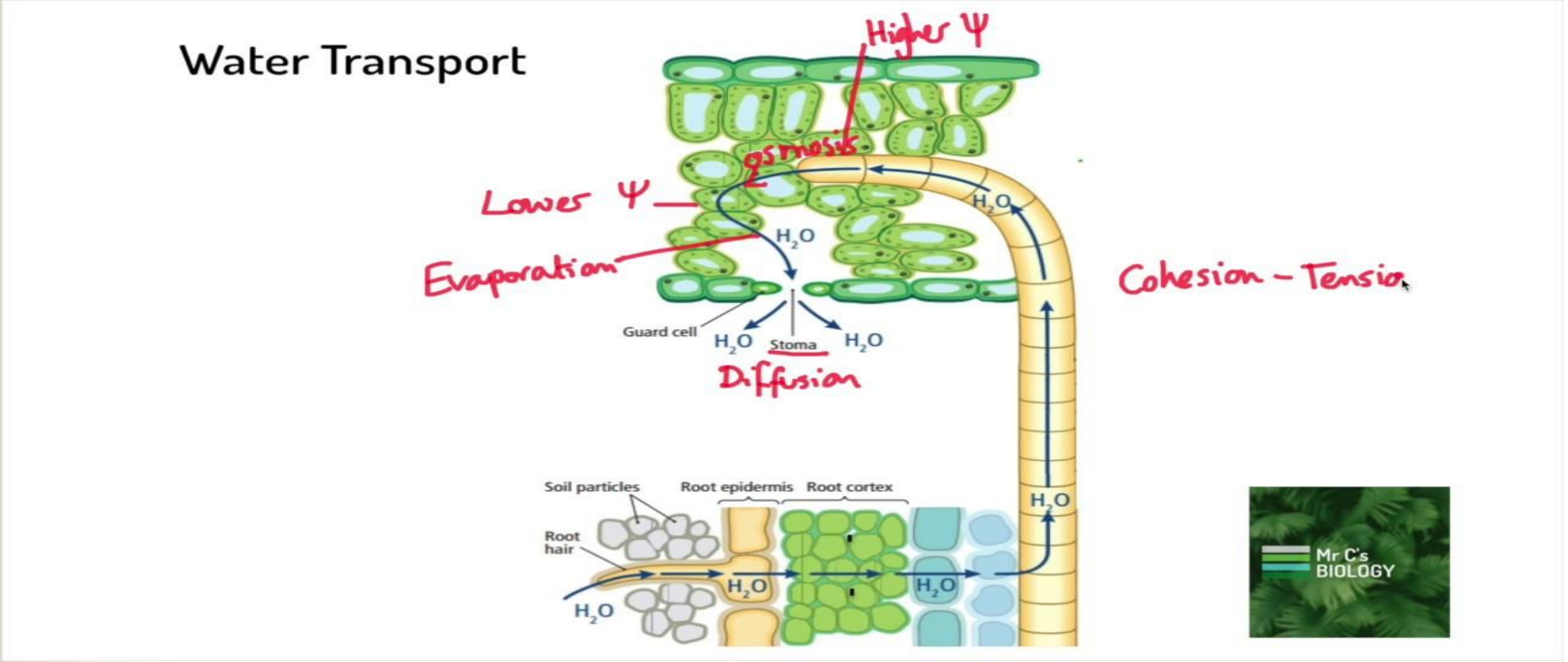
1. Surface tension occurs because hydrogen bonding between water molecules is stronger at the air-water interface than among molecules within the water.

2. Adhesion is a molecular attraction between "unlike" molecules. In the case of the xylem, adhesion occurs between water molecules and the molecules of the xylem cell walls.

3. Cohesion is a molecular attraction between "like" molecules. In water, cohesion occurs due to hydrogen bonding between water molecules.

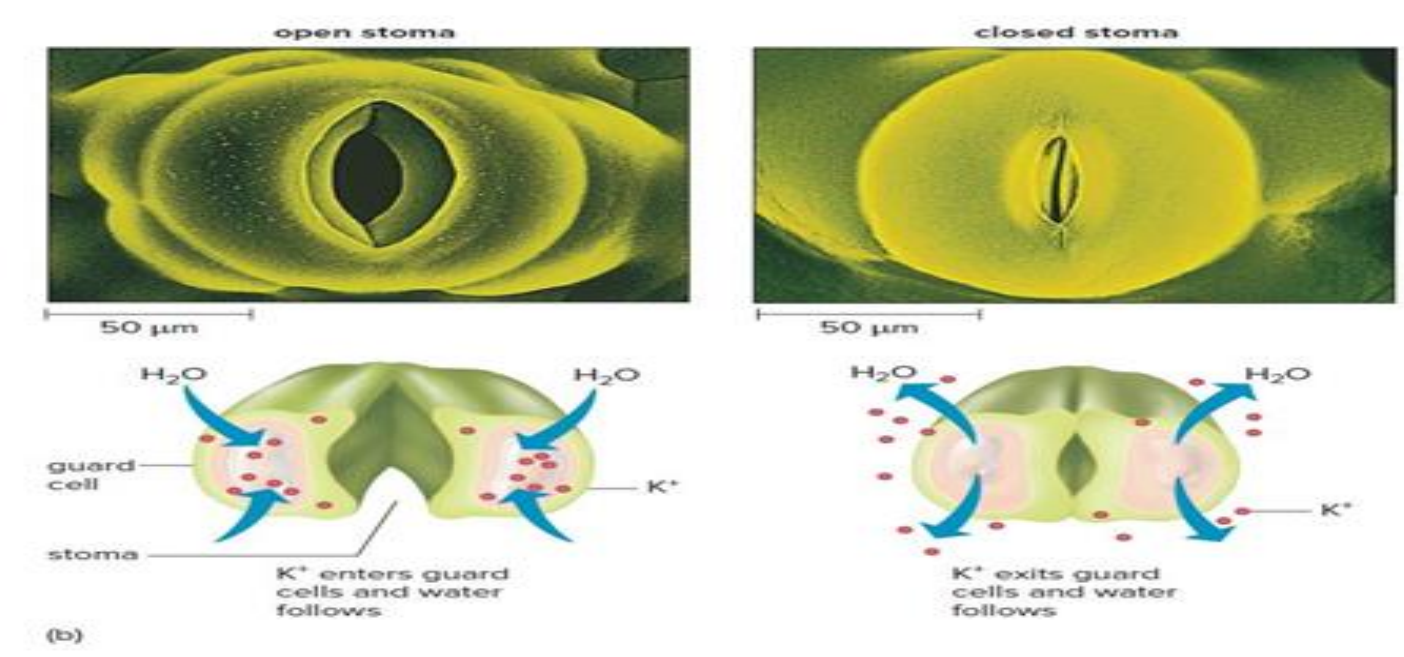


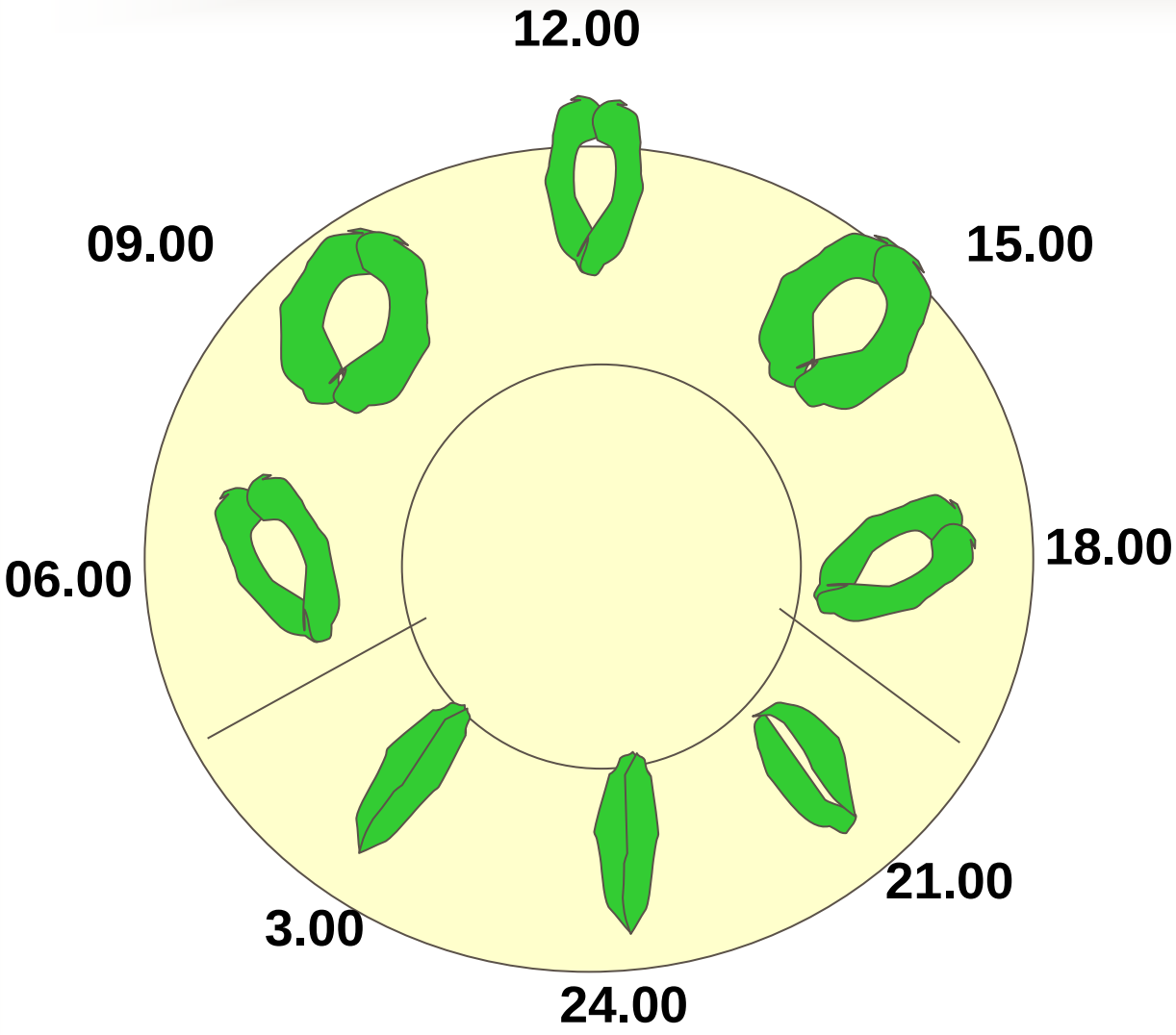
3- Cohesion-tension essentially combines the process of capillary action with transpiration, or the evaporation of water from the plant stomata.



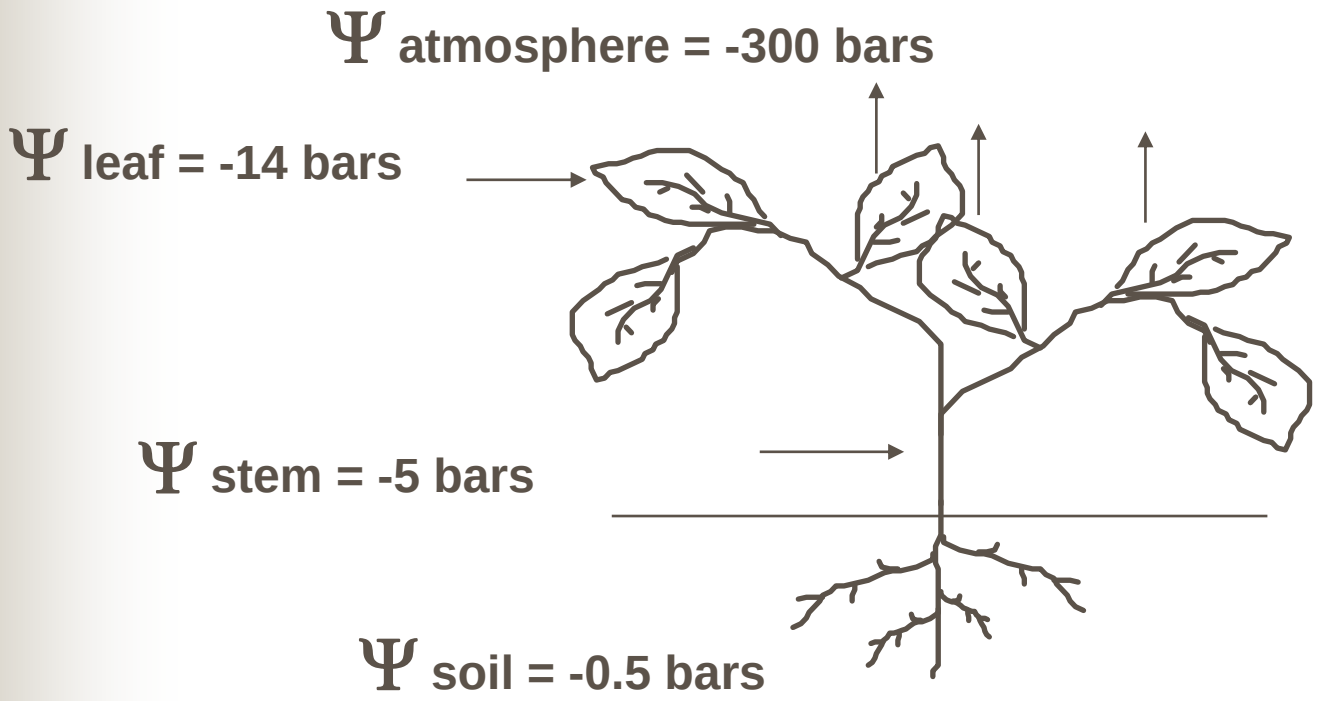
Transpiration in Plant

Like all living organisms, plants also require an excretory system to discharge excess water from their body. This process of eliminating excess water from the plant body is known as transpiration. It is generally the evaporation of water from the surface of the leaves.





24h Cycle of Stomatal Opening and Closing



Steep gradient from leaf to atmosphere

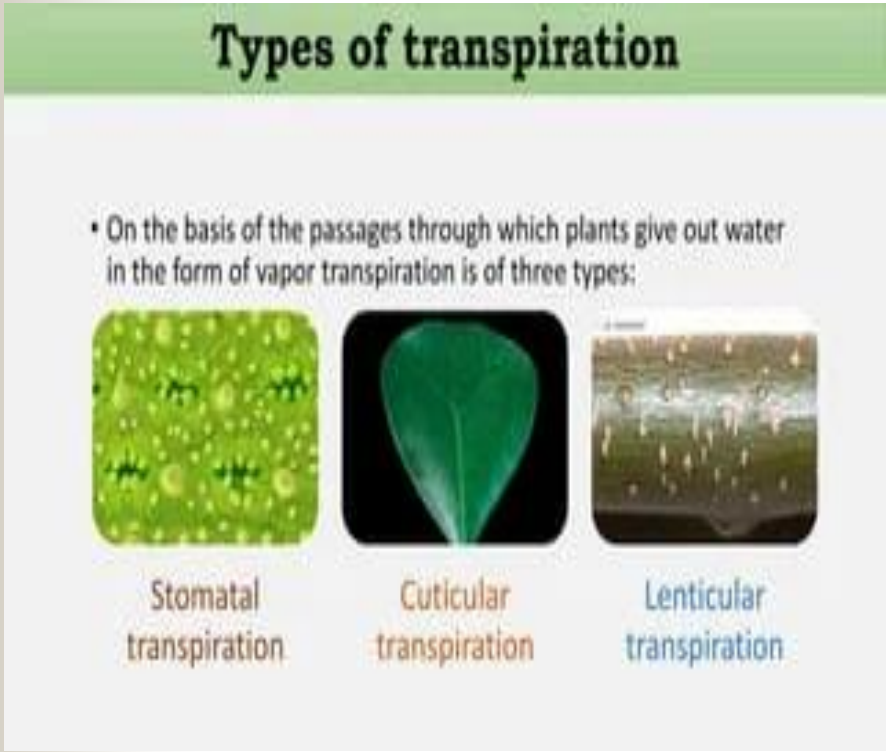
continuous water column through soil, root, stem, and leaf

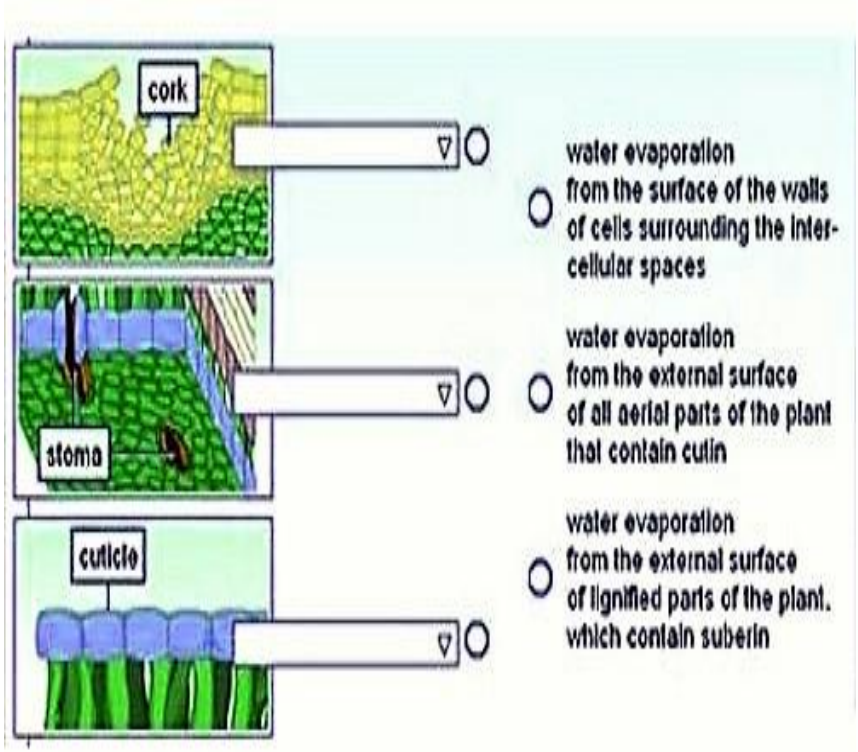
Types of Transpiration

1- Stomatal Transpiration

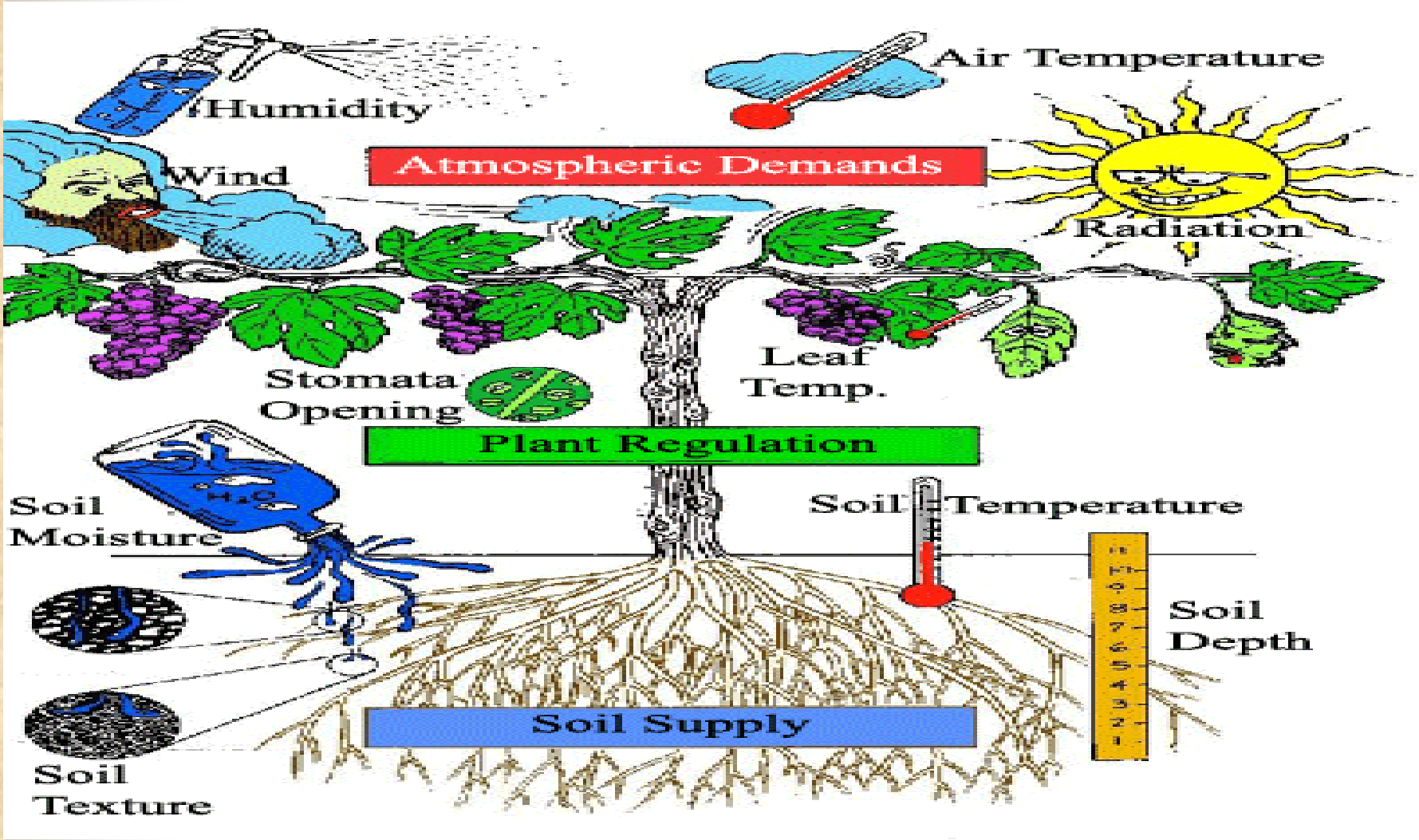
2- Lenticular Transpiration

3- Cuticular Transpiration





Factors Affecting Transpiration in Plants



Factors Affecting Transpiration in Plants

1- Cellular Factors

The cellular factors affecting the rate of transpiration are:

- The orientation of the leaf,
- The water status of the plant,
- Structural Peculiarities of the leaf,
- Total number and distribution of stomata in a leaf.

2- Environmental Factors

The environmental factors affecting the rate of transpiration are:

- Light,
- Humidity,
- Temperature,
- Atmospheric pressure,
- Wind speed or velocity.

3- Relative Humidity

4-Temperature

5- Light

The stomata open during the day and close in the dark. The presence of light is directly proportional to the rate of transpiration.

6- Air

7- Water Availability

8- Surface Area of the Leaves