ABSORPTION OF WATER

Soil Water :

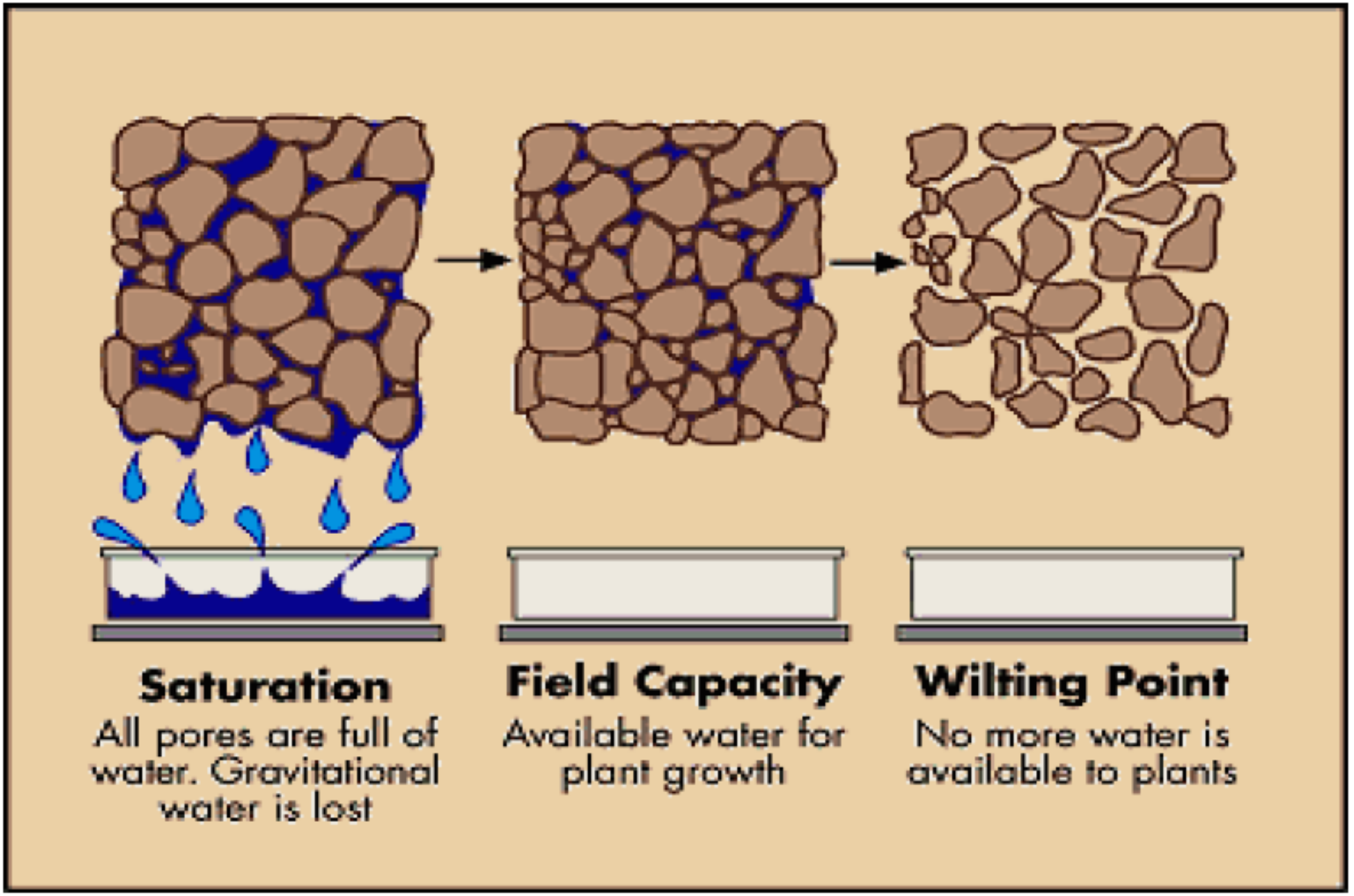
Hollard : Total soil water

Chesard : Available to plants

Echard : Non available to plants

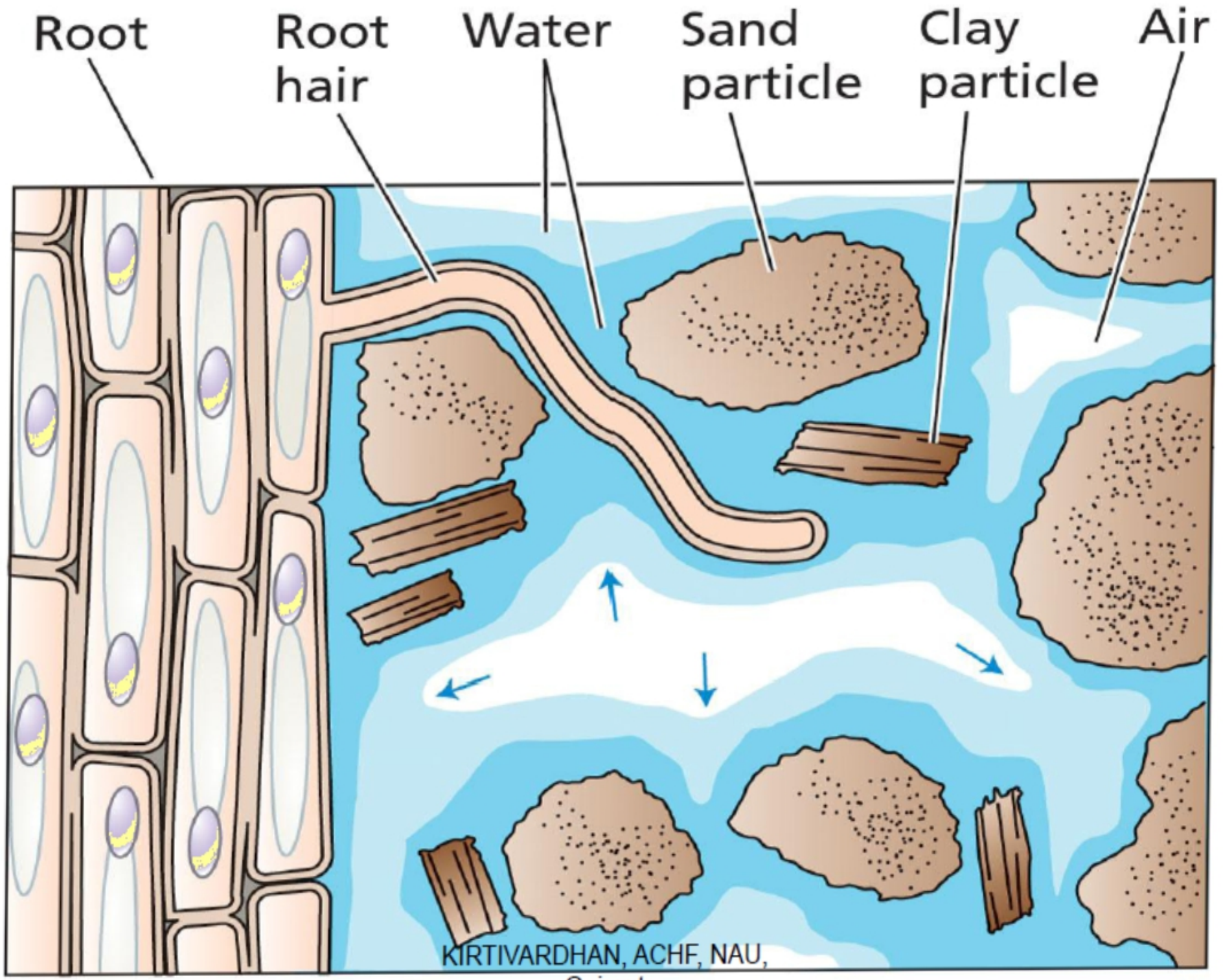
Types of soil water:

Stages of Water Holding



Water Moves through soil by bulk flow

- As water moves from soil into root the spaces fill with air
  - This ***reduces*** the flow of water
- **Permanent wilting point**
  - At this point the water potential (Ψw) in soil is so low that plants cannot regain turgor pressure
    - There is not enough of a pressure gradient for water to flow to the roots from the soil
    - **This varies with plant species**



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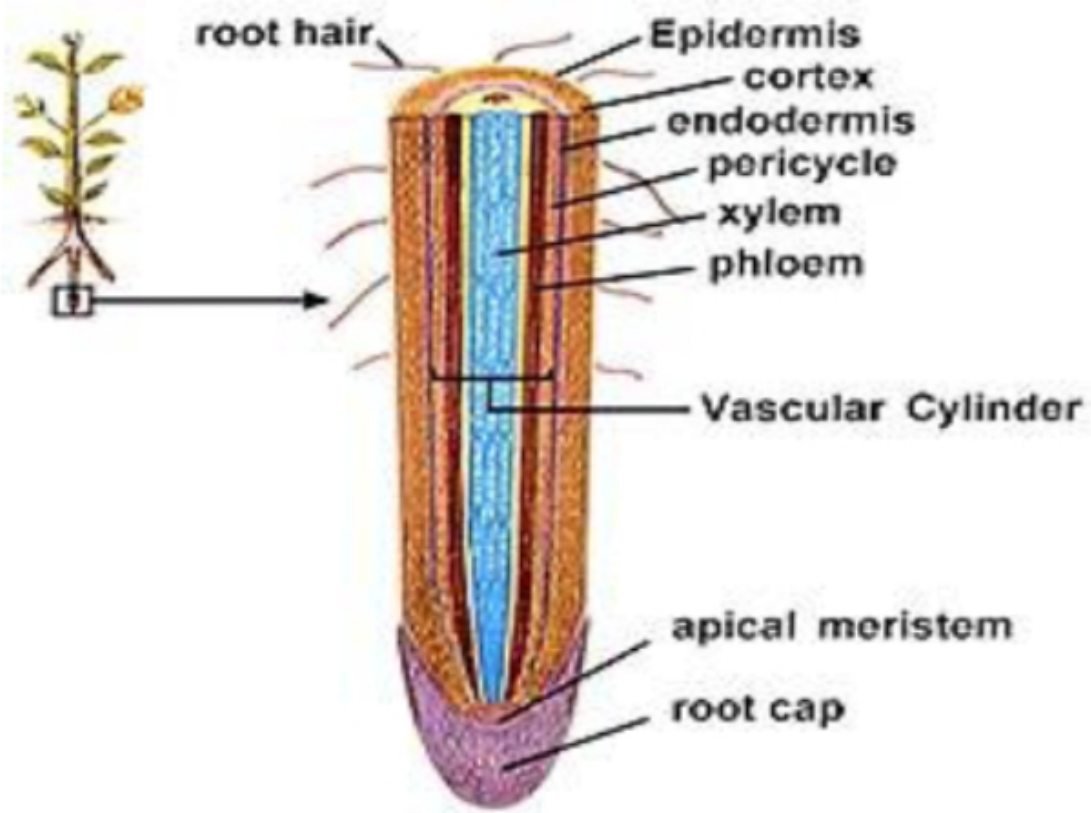
Root : Absorbing organ



Zone of Maturation - cell differentiation

Protoderm

Ground Meristem

Provascular

Zone of Cell Elongation - cell expansion

Notice how the growing zone has no root hairs or lateral roots!

Zone of Cell Division - new cells by mitosis

Root Cap - penetration, padding

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Structure involved in water absorption

From the epidermis there are two pathways in which water can flow:

1: Apoplast pathway:

Water moves exclusively through cell walls without crossing any membranes

The apoplast is a continuous system of cell walls and intercellular air spaces in plant tissue

2: Transmembrane and symplast pathway:

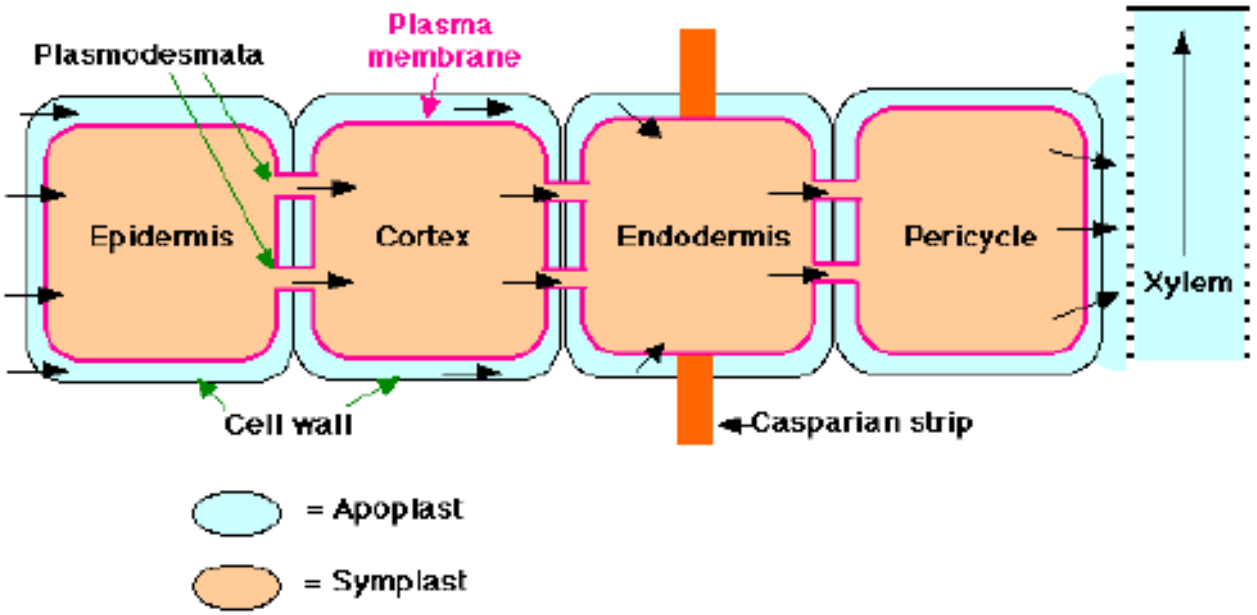
Water sequentially enters a cell on one side, exits the cell on the other side, enters the next cell, and so on.

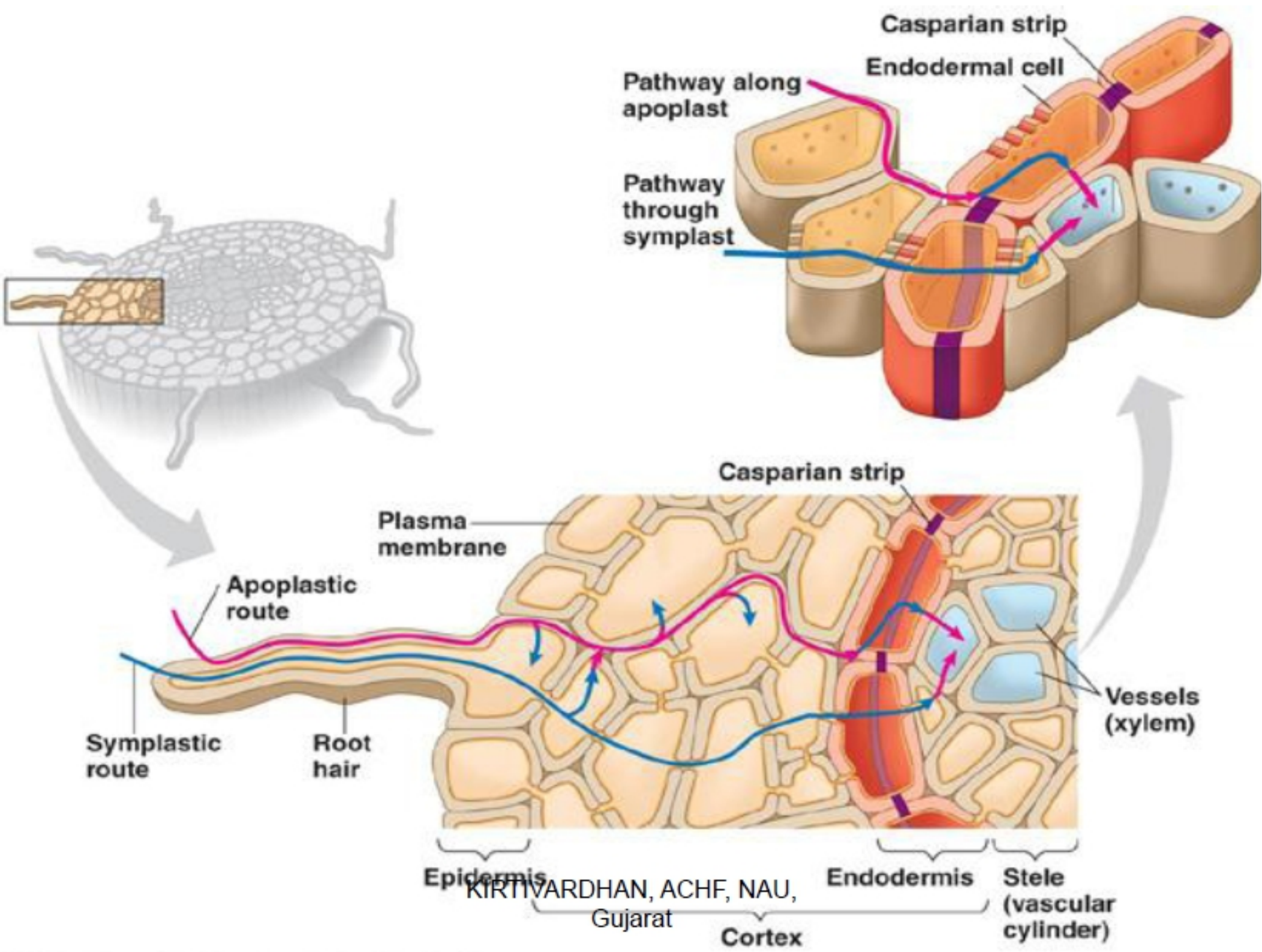
The symplast consist of the entire network of cell cytoplasm interconnected by plasmodesmata

Mechanism of movement

Water moves in root

- Apoplast
- Symplast
- Transmembrane



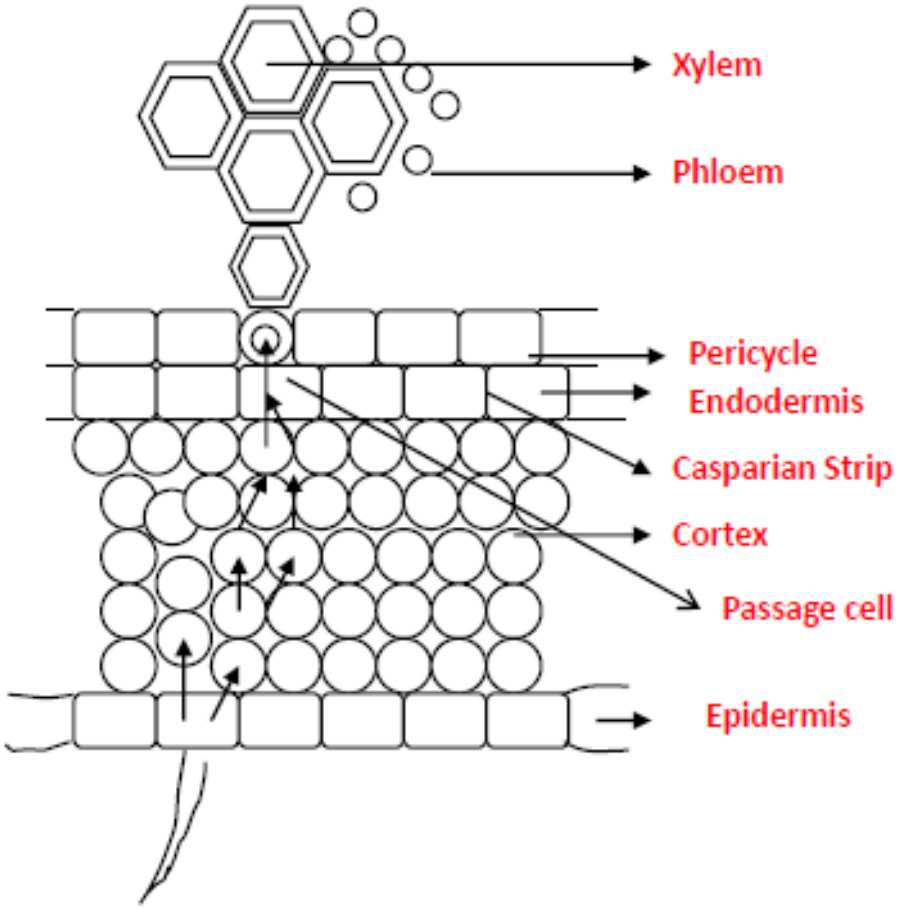


Water absorption

Active absorption

Passive absorption:-

Osmotic absorption



Steps involved

Imbibition of soil water by hydrophilic cell wall

↓

O.P Cell sap > O.P soil water

↓

DPD in root hair becomes higher

↓

Water from cell wall enter into them thro' membrane by osmotic diffusion

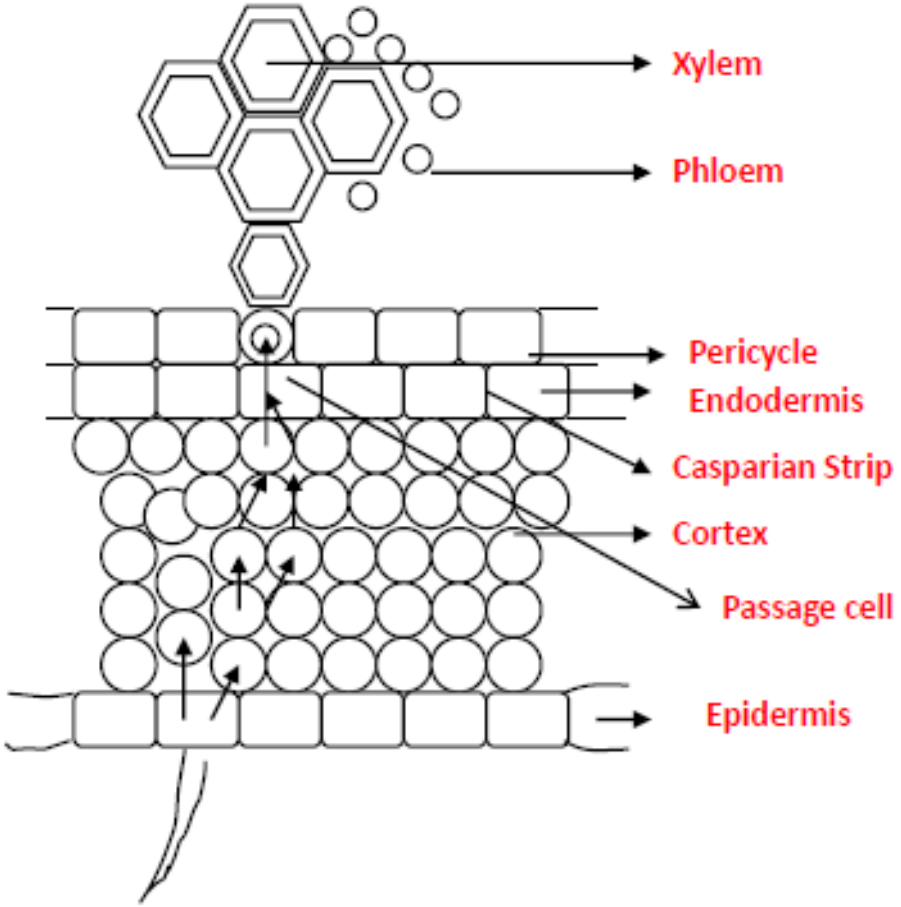
↓

As a result, O.P, DPD of root becomes lower and T.P increased

↓

Now the cortical cell adjacent to root hair have higher O.P, DPD in comparison to root hair by osmotic diffusion

Osmotic absorption



Likewise, water moves by osmotic diffusion and reaches endodermis

↓

Endodermis water moves thro' passage cell (because casparian cell)

↓

Now water reaches pericycle, pericylce becomes turgid and their DPD is decreased

↓

Last step, water is drawn into xylem from turgid pericycle cells (protoxylem in contact)

↓

Pressure is developed in the xylem of root by water entry – Root pressure

Active non-osmotic absorption

- O.P of soil water > O.P of cell sap
- Non-osmotic – against conc. Gradient – energy is required

Evidence

- Factors reducing respiration also decreases water absorption
- Poisons –metabolic activity –retard water absorption
- Auxin –increase metabolic activity of cell stimulate absorption of water

II. Passive absorption of water

Transpiration creates tension in water in the xylem of the leaves

↓

Tension is transmitted to water in xylem of root thro' xylem of stem and water rises upward to reach transpiring surface

↓

Hence soil water enters cortical cells thro' root hairs to reach xylem of roots to maintain the supply of water.

↓

The force for entry of water in leaves is due to rapid transpiration and root cells remain passive

Root pressure serve as best evidence for active absorption.

?

Root pressure not present in Gymnosperms

Root pressure Not observed in fast transpiring plants

Amount of water exuded from cut ends not equal to water lost due to transpiration.

External factors affecting absorption of water

Available soil water

- ✓ Amount of water
- ✓ Capillary water
- ✓ Soil aeration

Concentration of Soil Solution

- ✓ High salt concentration
- ✓ O.P – Problematic soil

Soil air

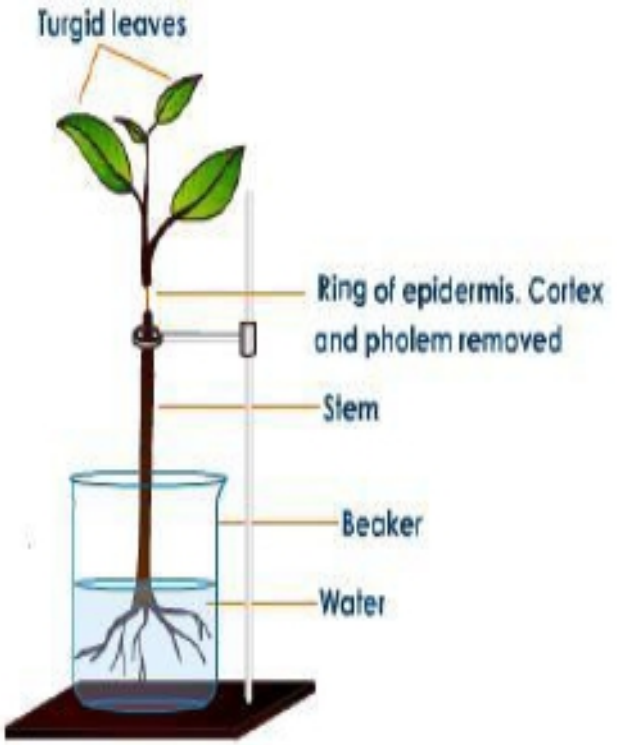
- ✓ Aeration in soil
- ✓ High CO_2 retard root respiration
- ✓ Growth of root hair
- ✓ Water logged soil – Physiologically dry

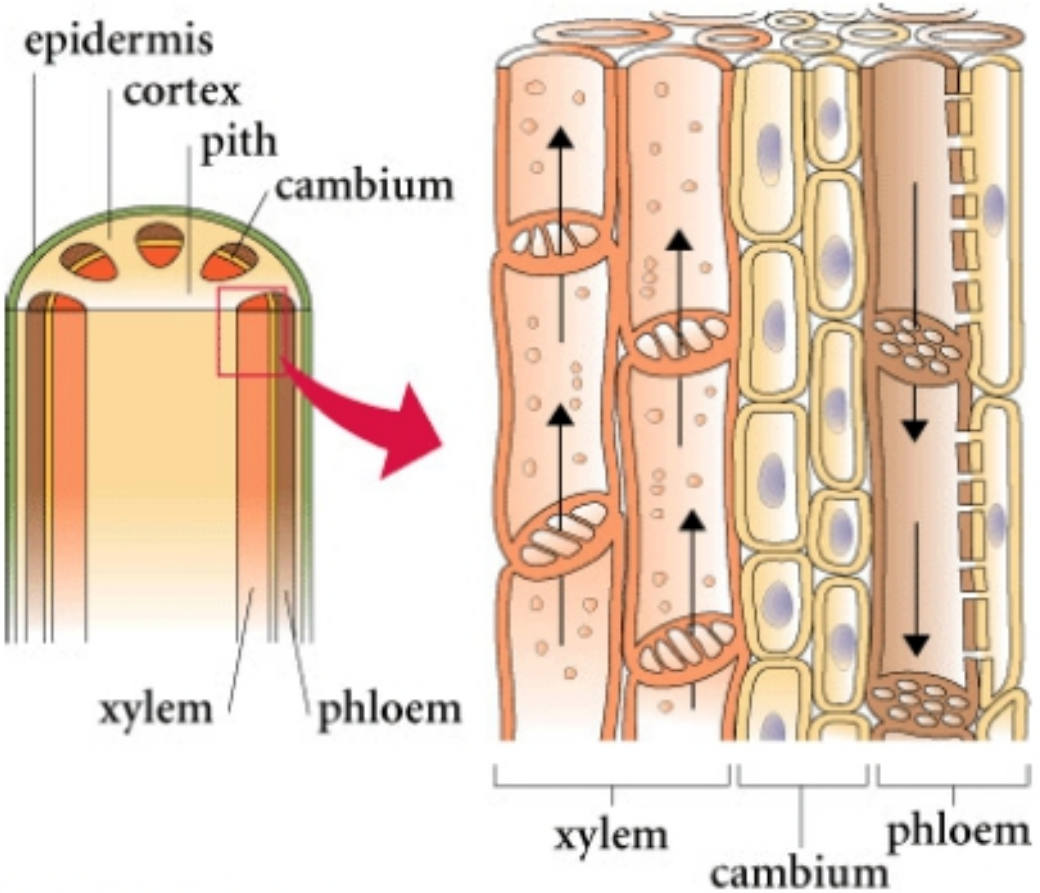
Soil Temperature

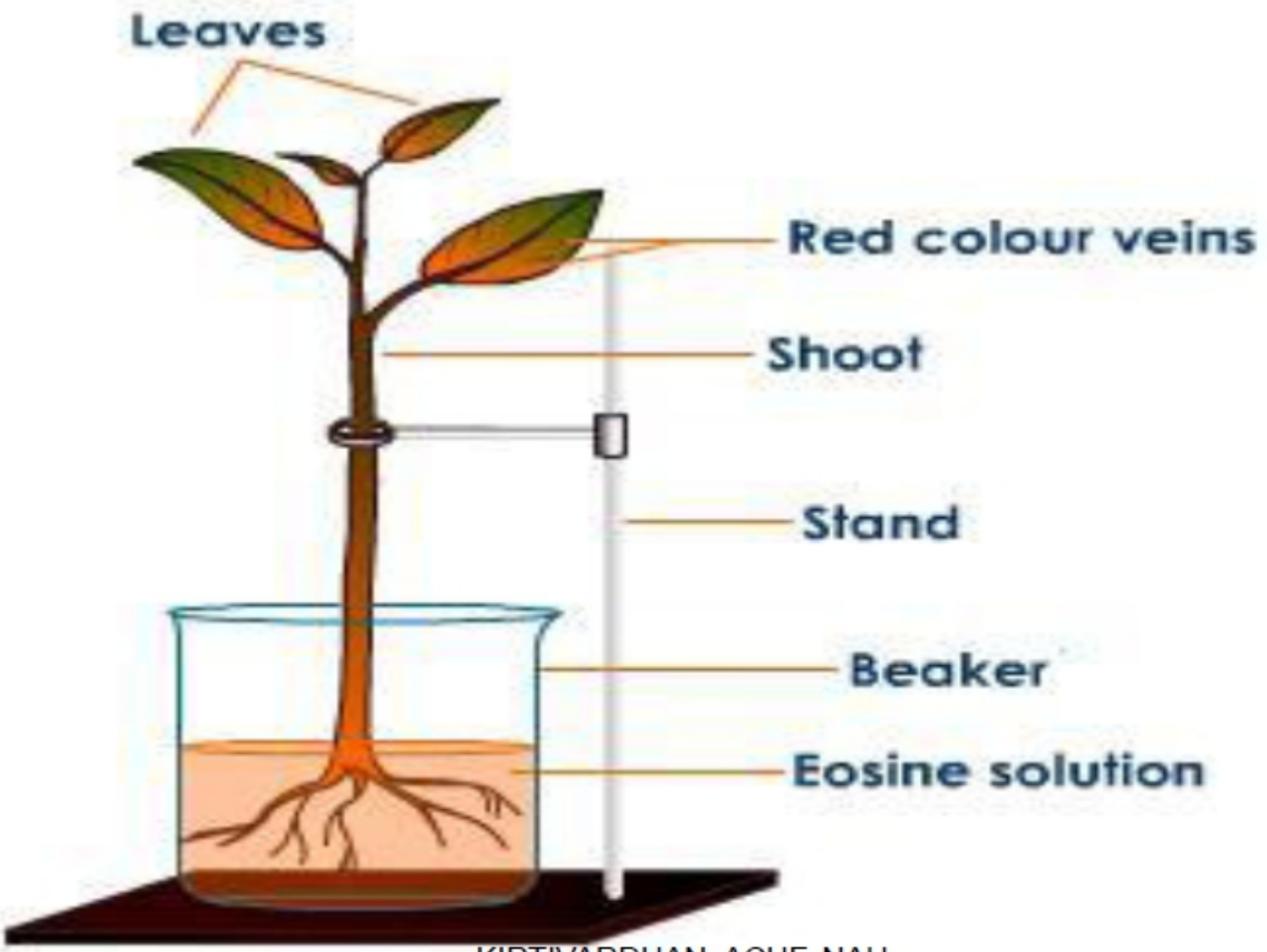
- ✓ Up to 30% favours
- ✓ Above 30% and low temp
  - ❑ Low temp – Viscosity of water and protoplasm is increased
  - ❑ Permeability of cell membrane is decreased
  - ❑ Metabolic activity is decreased

Ascent of sap

The phenomenon of ascending of absorbed water against gravitation through xylem is called ascent of sap.






Leaves
Red colour veins
Shoot
Stand
Beaker
Eosine solution

Mechanism of ascent of sap

In small trees and herbaceous plants, the ascent of sap can be explained easily,

but in tall trees like Eucalyptus and conifers reaching a height of 300- 400 feet), where water has to rise up to the height of several hundred feet,

To explain the mechanism of Ascent of sap, a number of theories have been put forward

1. vital theory
2. root pressure theory
3. physical force theory
4. transpiration pull and cohesion of water theory

Vital theories

According to vital theories, the ascent of sap is under the control of vital activities in the stem

1. According to Godlewski (1884) –

Ascent of sap takes place due to the pumping activity xylem tissues which are living

2. According to Bose (1923) –

upward translocation of water takes place due to pulsatory activity of the living cells of the inner most cortical layer just outside the endodermis

Root pressure theory

root pressure which is developed in the xylem of the roots can raise water to a certain height but does not seem to be an effective force in ascent of sap

due to the following reasons

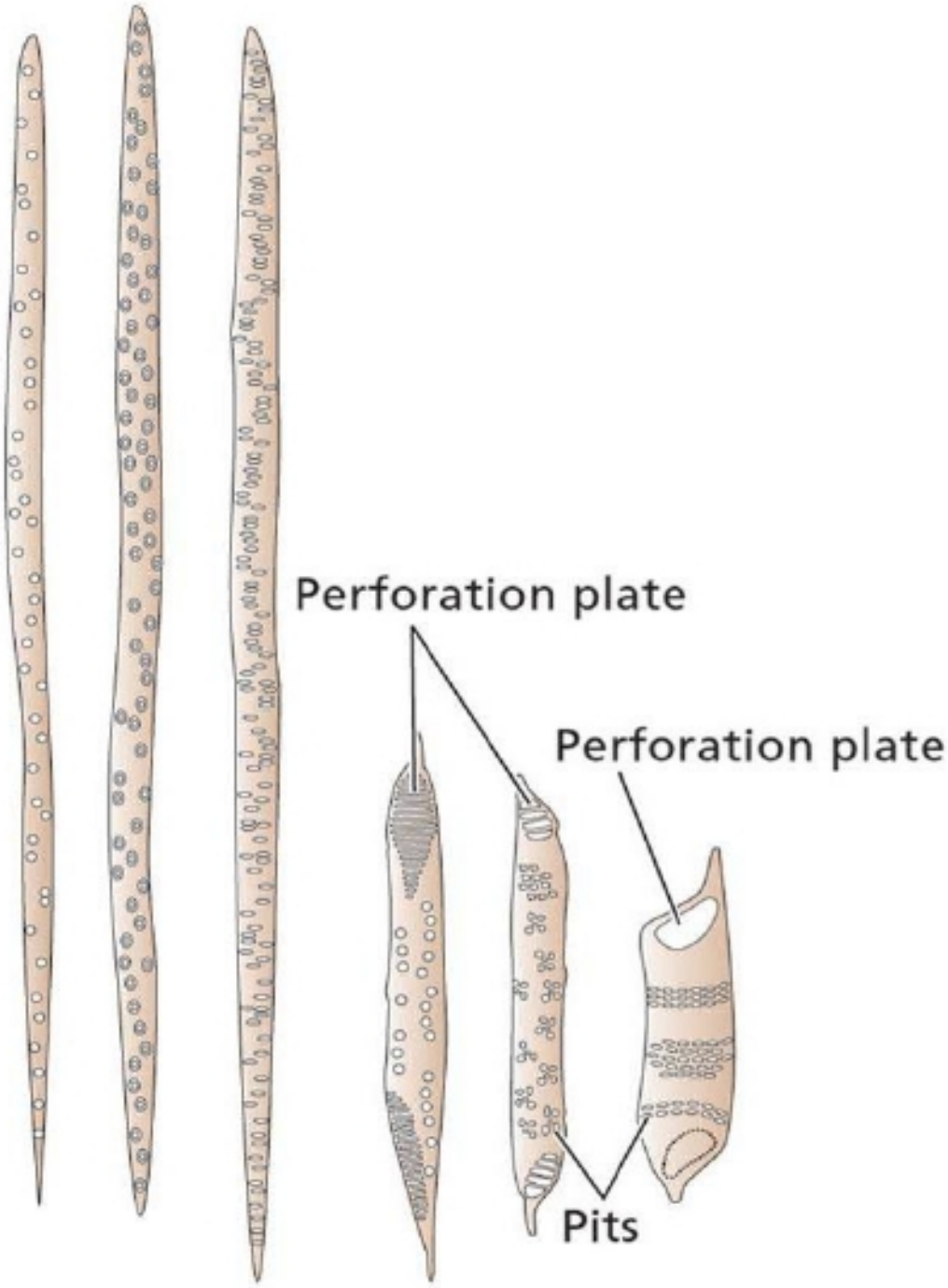
Magnitude of root pressure is very low (less than 0.1 Mpa)

Even in the absence of root pressure, ascent of sap continues

For example, when leafy twig is cut under water and placed in a beaker full of water it remains fresh and green for sufficient long time

Water transport through Tracheids and Vessels

- ***Tracheids***: Elongated spindle-shaped cells –arranged in overlapping vertical files.
  - Water flows between them via ***pits*** – areas with no secondary walls and thin porous primary walls
- ***Vessel elements***: Shorter & wider. The open end walls provide an efficient low-resistance pathway for water movement.
- Perforation plate forms at each end – allow stacking end on to form a larger conduit called a vessel
  - At the end there are no plates- communicate with neighboring vessels via pits



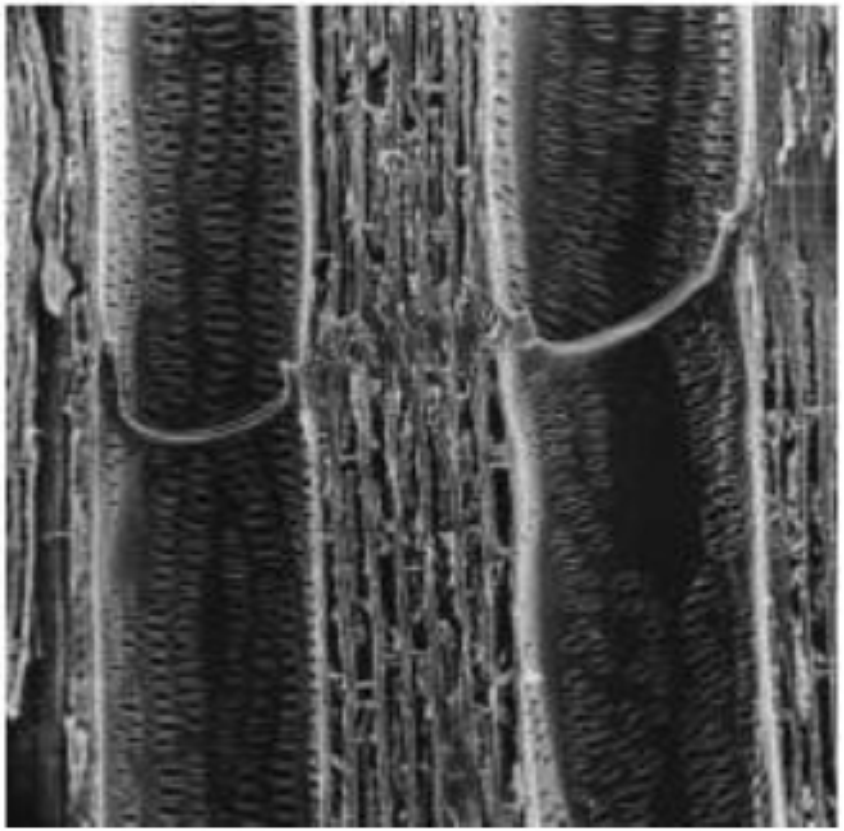
Why xylem suited to carry water from roots to the leaves?

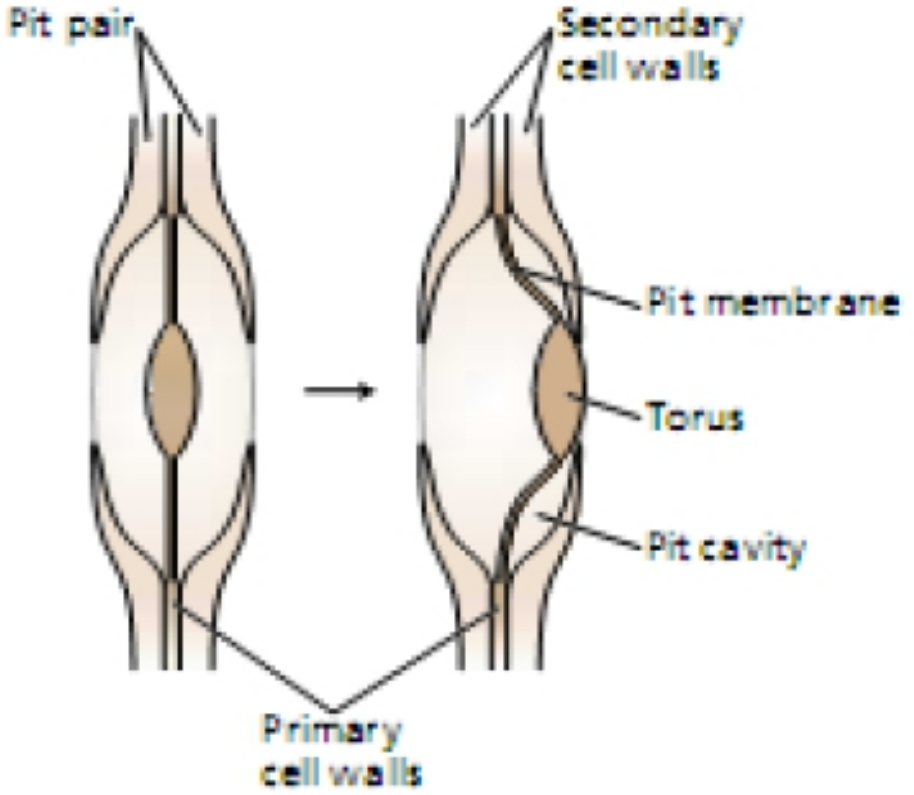
Water movement require less pressure in xylem than living cells.

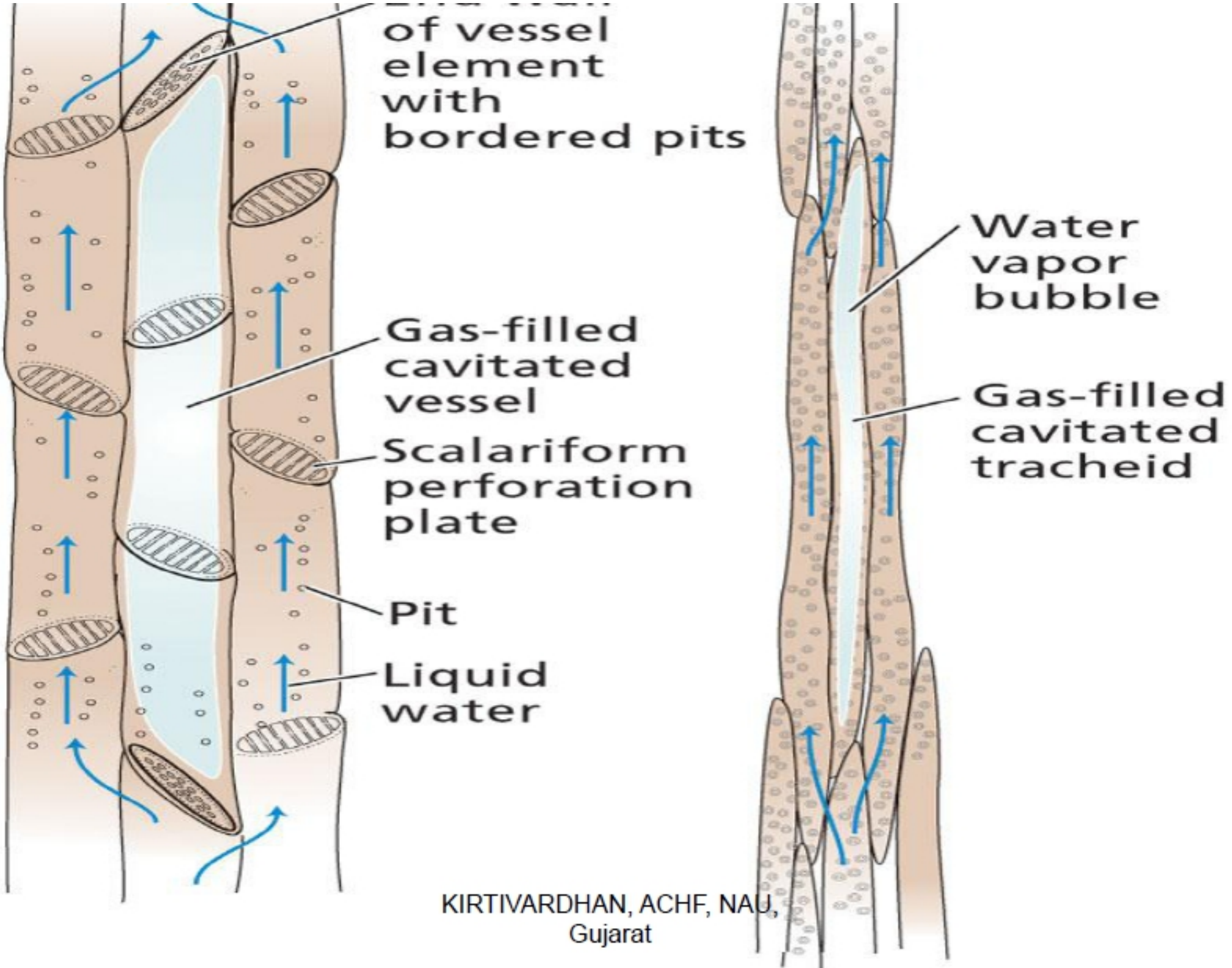
Xylem are adopted for the transport of water under tension.

Air bubbles can form in xylem, air can be pulled through microscopic pores in the xylem cell wall

- Gas bubbles can not easily pass through the small pores of the ***pit membranes***.
- Xylem are interconnected, so one gas bubble does not completely stop water flow
- Water can detour blocked point by moving through neighboring, connected vessels.




Pit pair
Secondary cell walls
Pit membrane
Torus
Pit cavity
Primary cell walls


of vessel element with bordered pits
Gas-filled cavitated vessel
Scalariform perforation plate
Pit
Liquid water
Water vapor bubble
Gas-filled cavitated tracheid

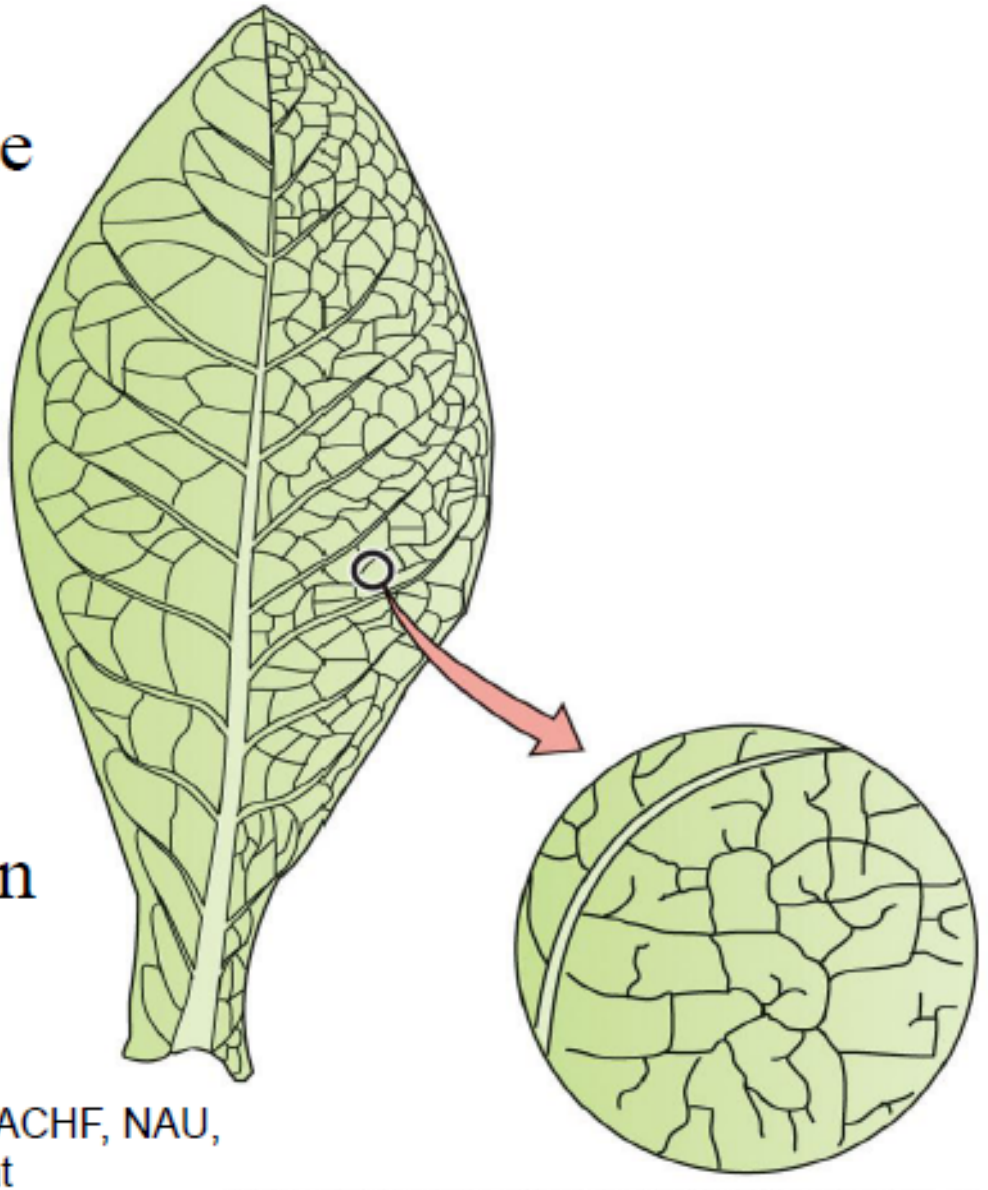
Transpiration pull and cohesion theory (cohesion tension theory)

The theory was originally proposed by Dixon and Jolly (1894)

- Water vapours diffuse out from the intercellular space to the atmosphere.
- Evaporation of water vapours from thin walled mesophyll cells (leaf) into the intercellular space.
- Reduced water content in the cell
- Increased osmotic potential in cell sap
- Movement of water from adjacent cell by osmosis
- Movement of water from xylem to adjacent cell

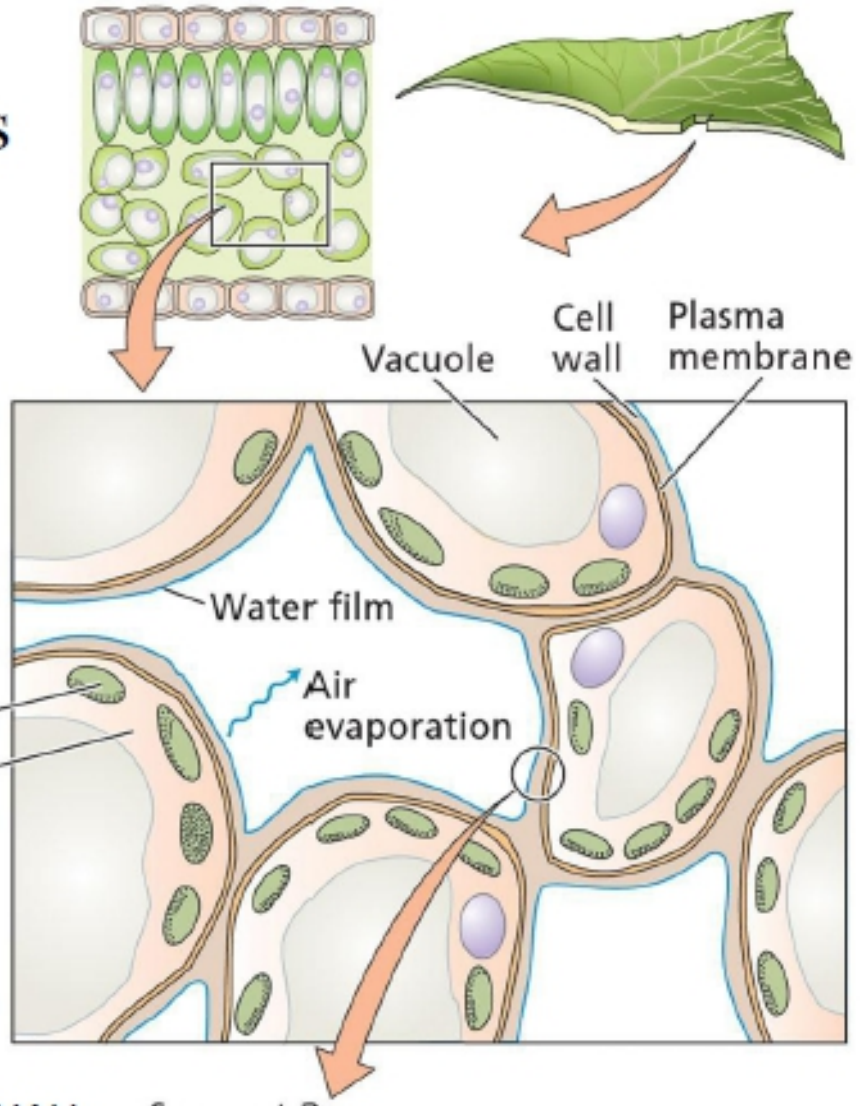
Water evaporation in the leaf affects the xylem

- The tensions needed to pull water through the xylem are the result of evaporation of water from leaves.
- Water is brought to leaves via xylem of the leaf vascular bundle, which branches into veins in the leaf.
- From the xylem, water is drawn in to the cells of the leaf and along the cell wall.



Water evaporation in the leaf affects the xylem

- ***Transpiration pull***, which causes water to move up the xylem begins in the cell walls of leaf cells
- Water adheres to cellulose and other hydrophilic wall components.
- Mesophyll cells within leaf are in direct contact with atmosphere via all the air spaces in the leaf



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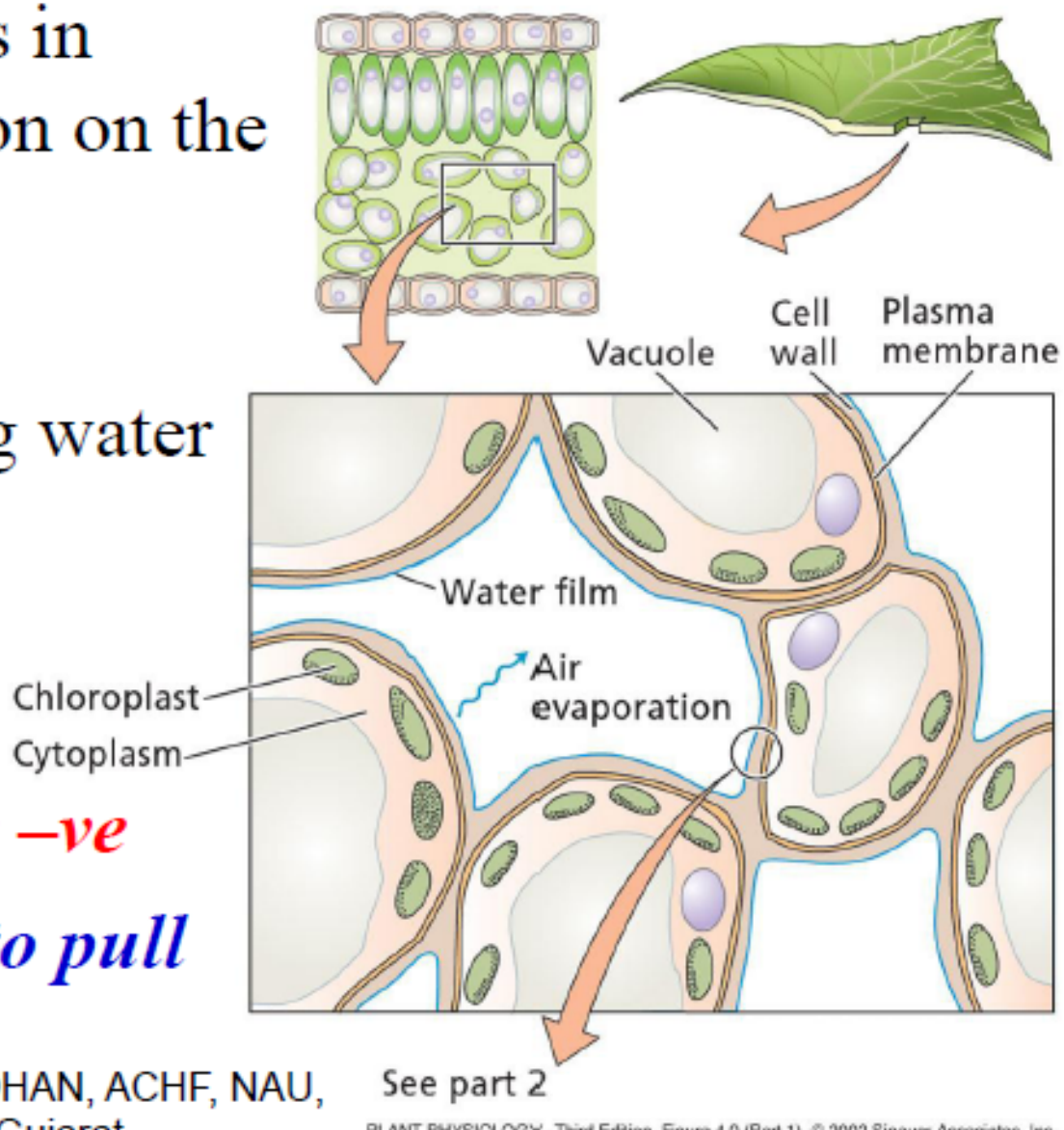
Water evaporation in the leaf affects the xylem

- So, negative pressure exists in leaves- cause surface tension on the water

As more water is lost to the atmosphere – the remaining water is drawn into the cell wall

As more water is removed from the wall the pressure of the water becomes ***more –ve***

This induces a motive force to pull water up the xylem



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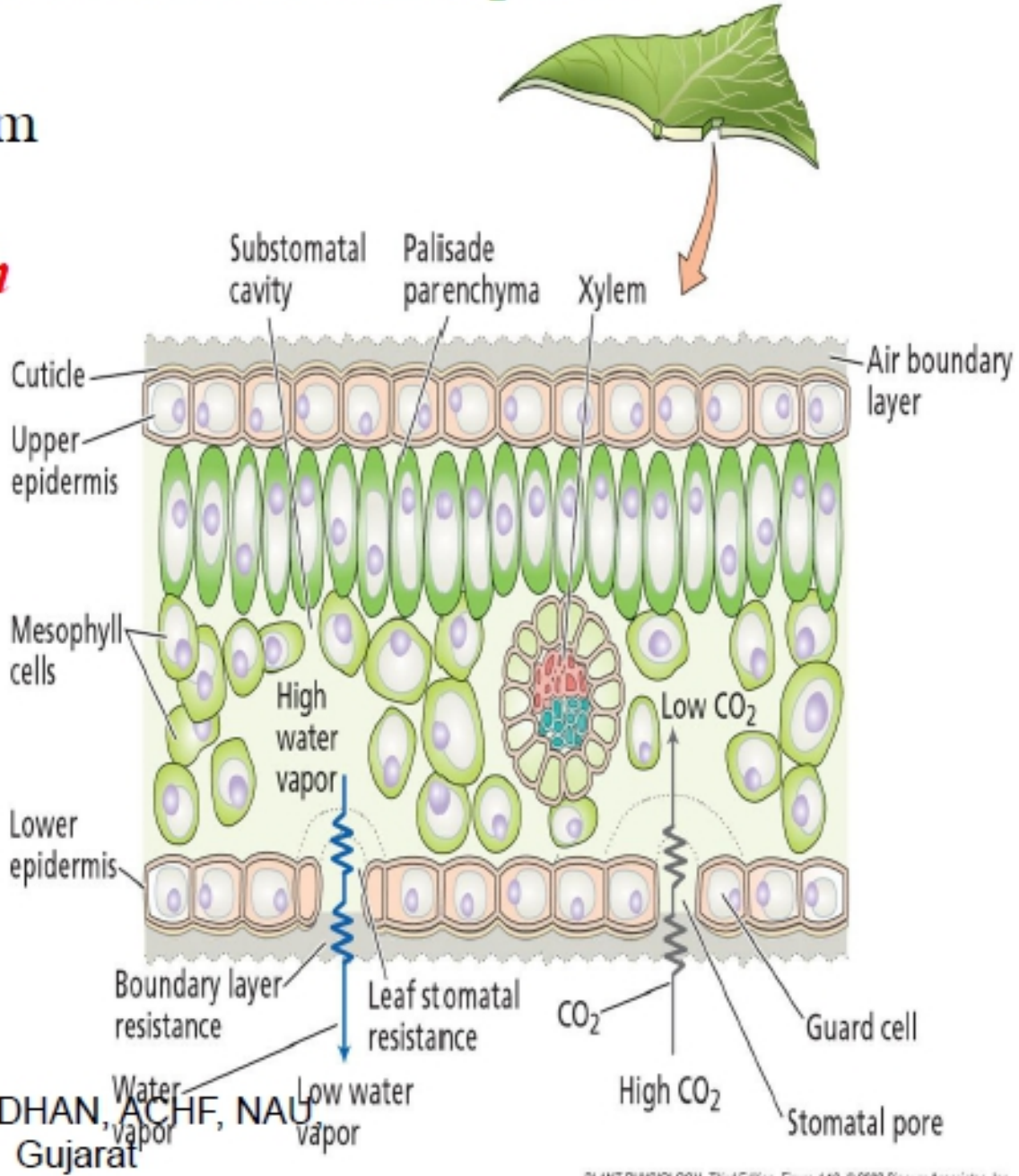
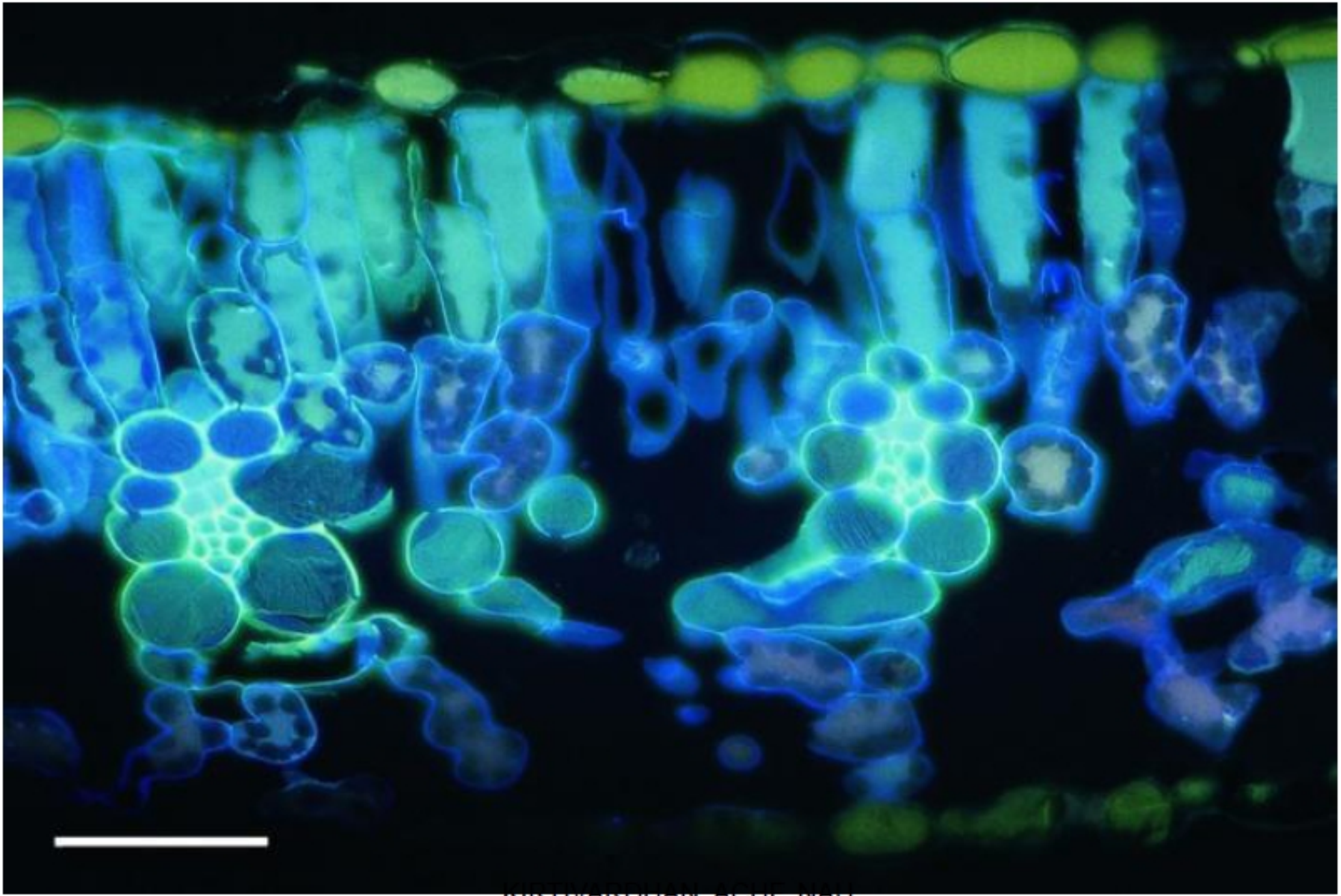
Water movement from leaf to atmosphere

- After water has evaporated from the cell surface of the intercellular air space ***diffusion*** takes over.
- So: the path of water
  - Xylem
  - Cell wall of mesophyll cells
  - Evaporated into air spaces of leaf
  - Diffusion occurs – water vapor then leaves via stomatal pore
  - Goes down a ***concentration gradient***.





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PASSIVE ASCENT OF SAP

Transpiration creates tension in water in the xylem of the leaves

↓

Tension is transmitted to water in xylem of root thro' xylem of stem and water rises upward to reach transpiring surface

↓

Hence soil water enters cortical cells thro' root hairs to reach xylem of roots to maintain the supply of water.

↓

The force for entry of water in leaves is due to rapid transpiration and root cells remain passive

In the intact plant,

water is brought to the leaves via the xylem of the leaf vascular Bundle

From the xylem, water is drawn into the cells of the leaf and along the cell walls

negative pressure that causes water to move up through the xylem develops at the surface of the cell walls in the leaf.

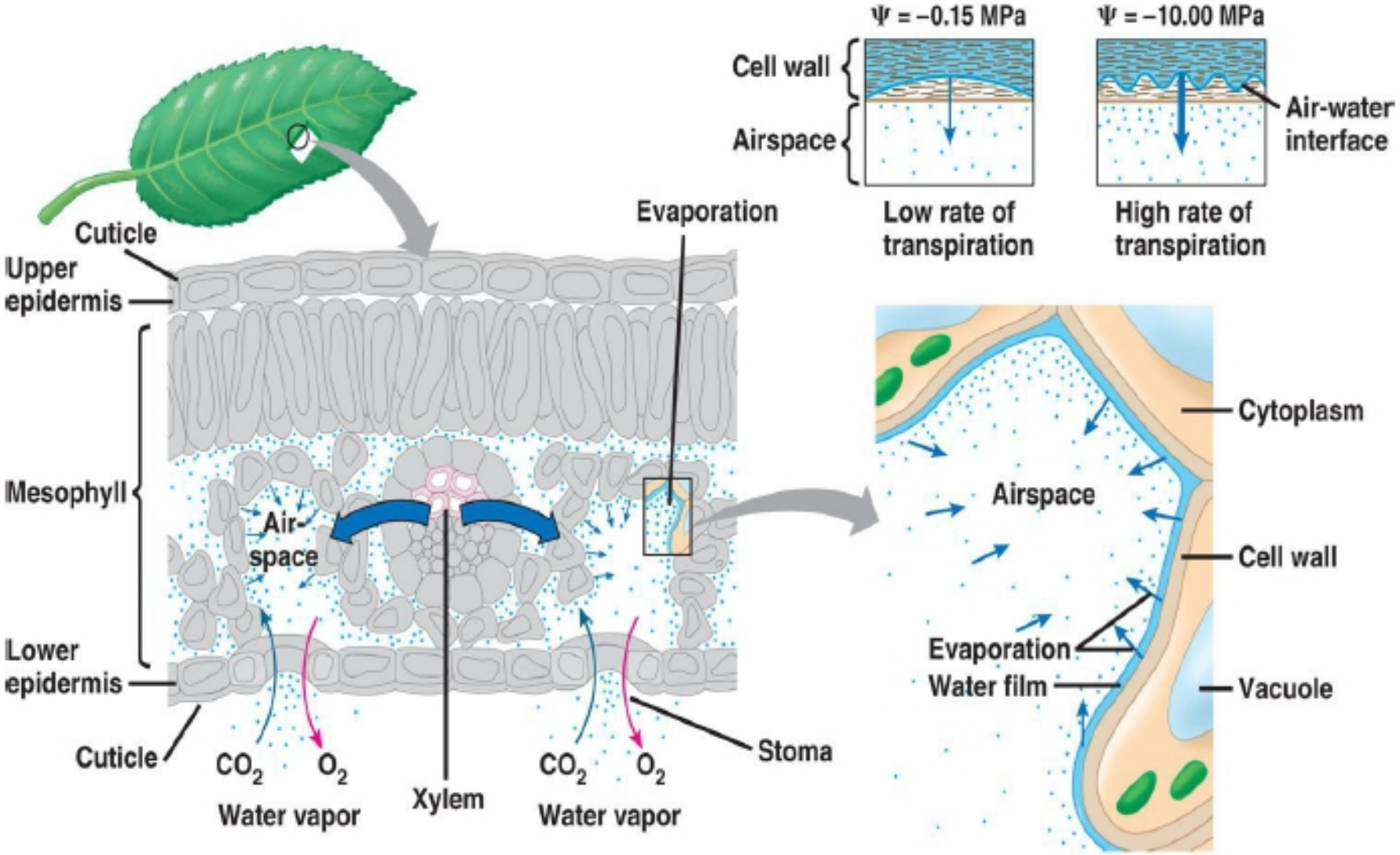
Initially water evaporates from a thin film lining these air spaces.

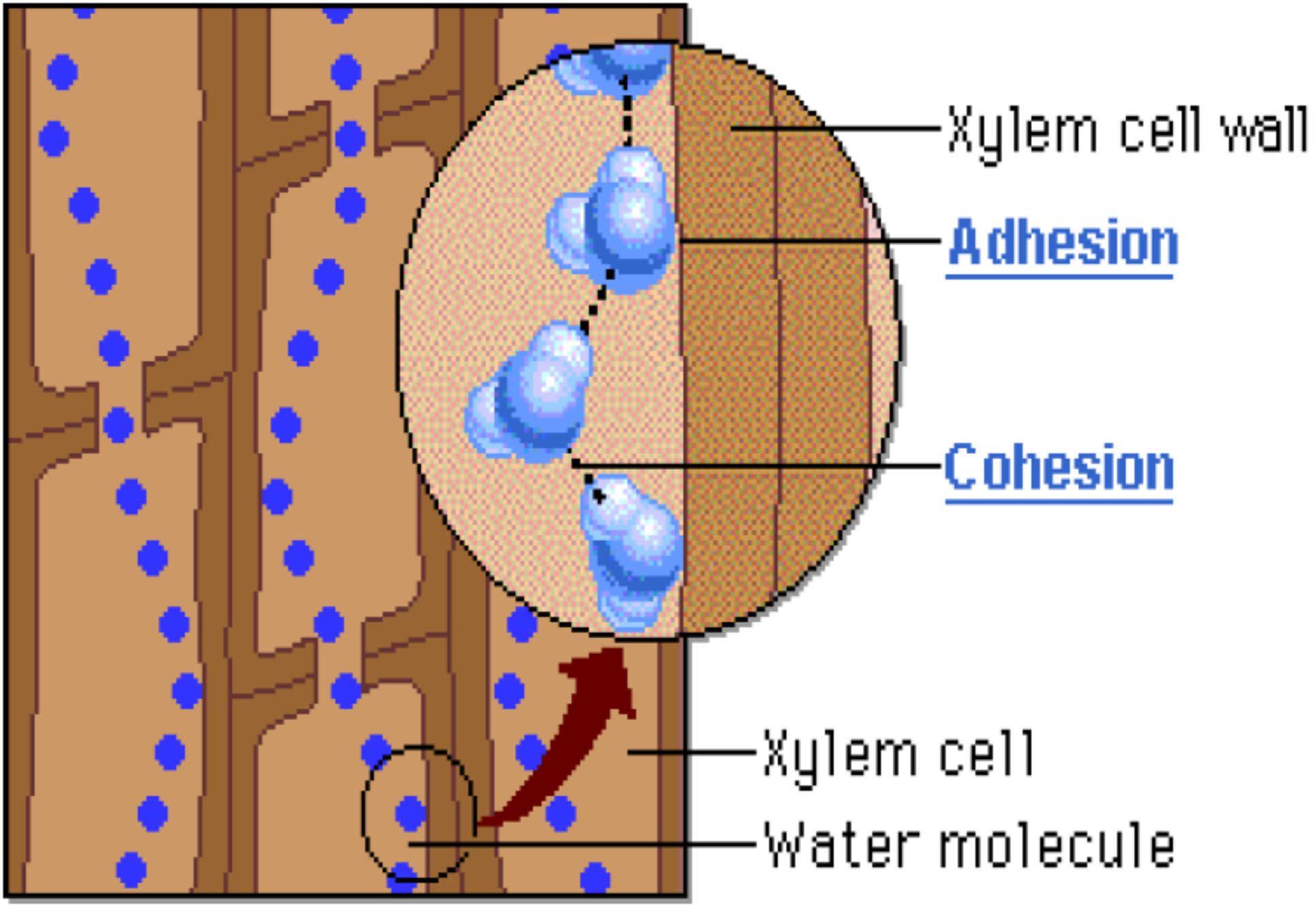
As water is lost to the air, the surface of the remaining water is drawn into the interstices of the cell wall

where it forms curved air–water interfaces

As more water from the wall radius of curvature of the air–water interfaces decreases and the pressure of the water becomes more negative

Transpirational Pull





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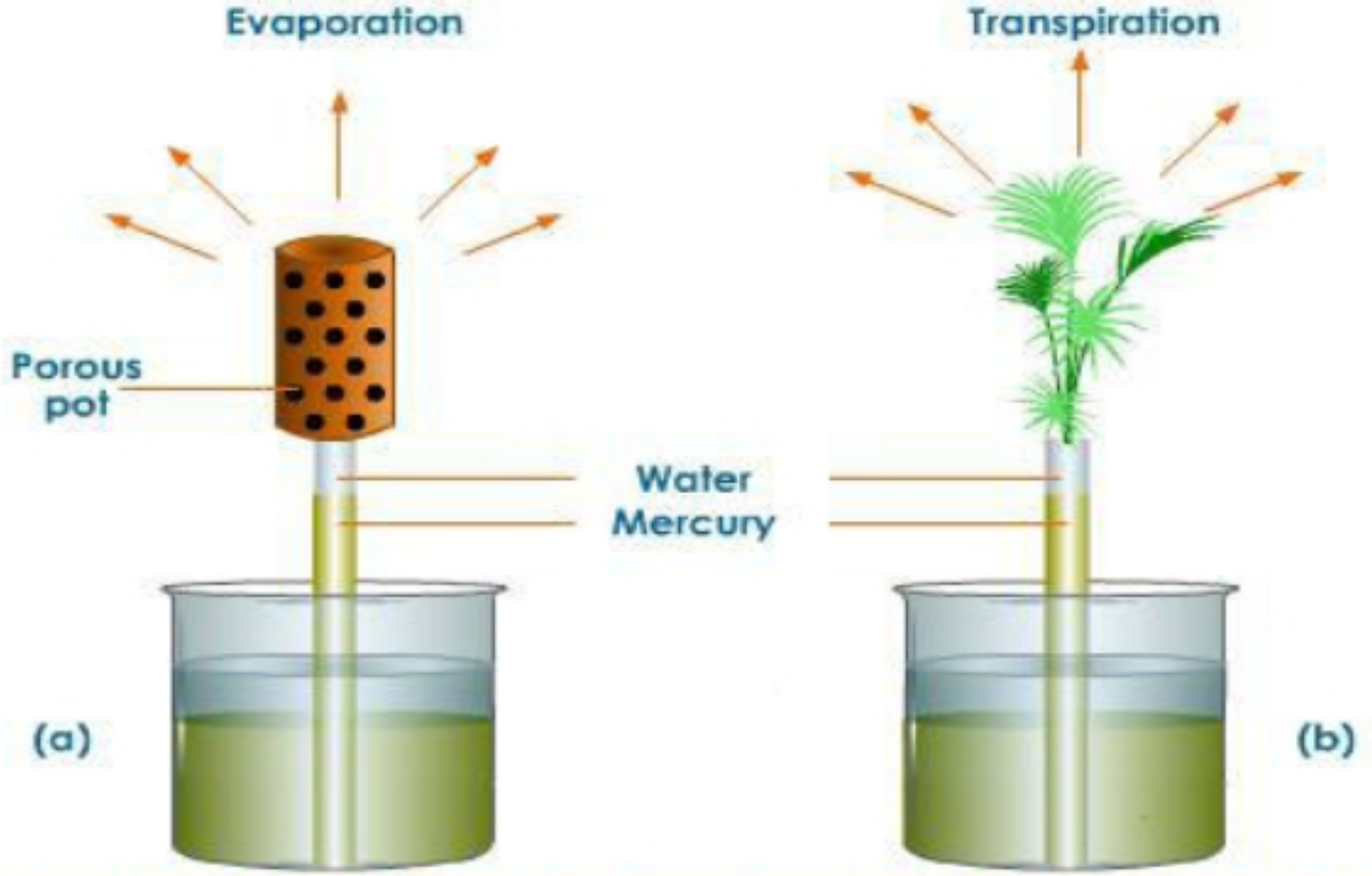
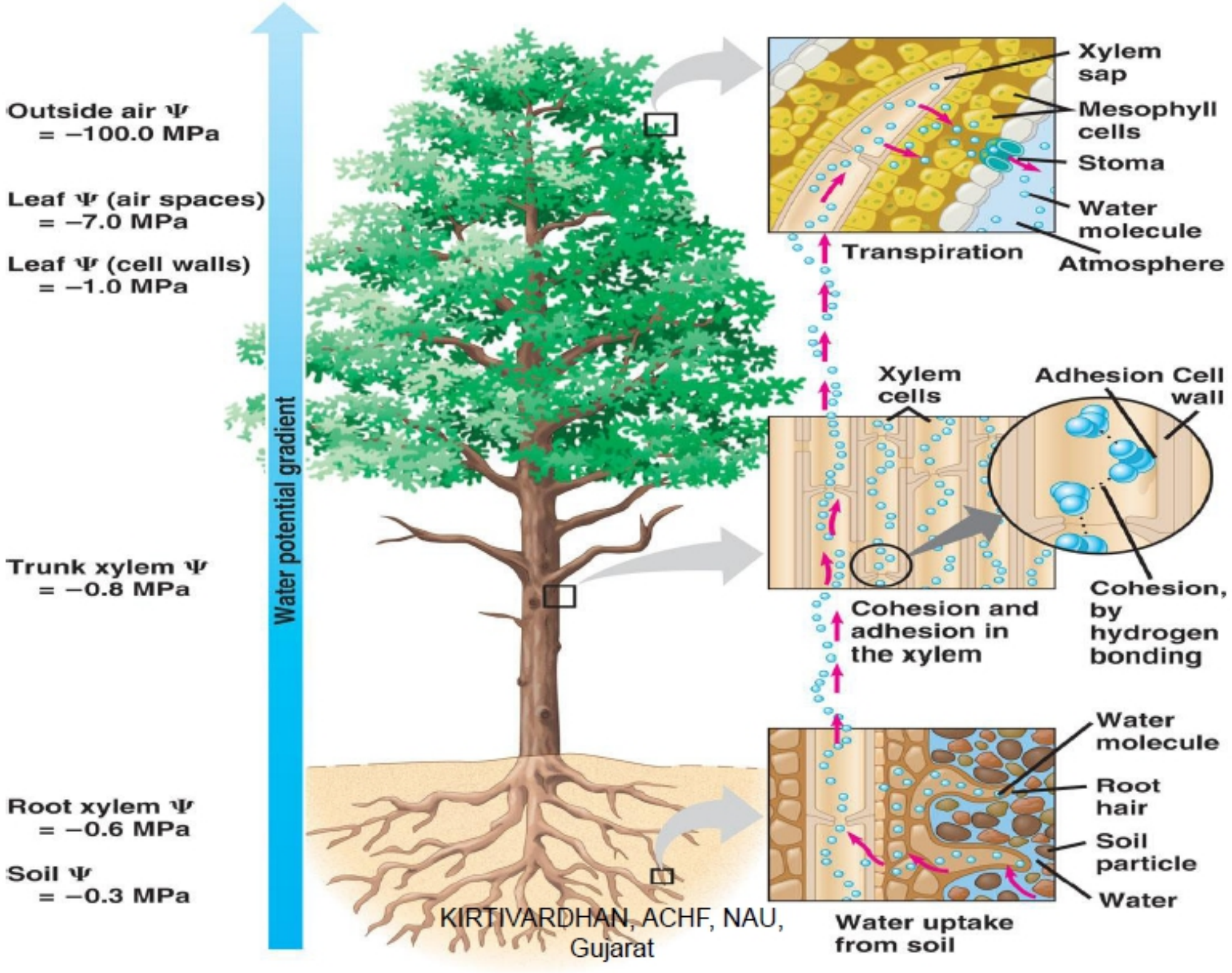


Demonstration of Cohesion theory of water translocation (a) Evaporation (b) Transpiration


Outside air Ψ
= −100.0 MPa
Leaf Ψ (air spaces)
= −7.0 MPa
Leaf Ψ (cell walls)
= −1.0 MPa
Trunk xylem Ψ
= −0.8 MPa
Root xylem Ψ
= −0.6 MPa
Soil Ψ
= −0.3 MPa
Water potential gradient
Xylem sap
Mesophyll cells
Stoma
Water molecule
Atmosphere
Transpiration
Xylem cells
Adhesion
Cell wall
Cohesion and adhesion in the xylem
Cohesion, by hydrogen bonding
Water molecule
Root hair
Soil particle
Water
Water uptake from soil
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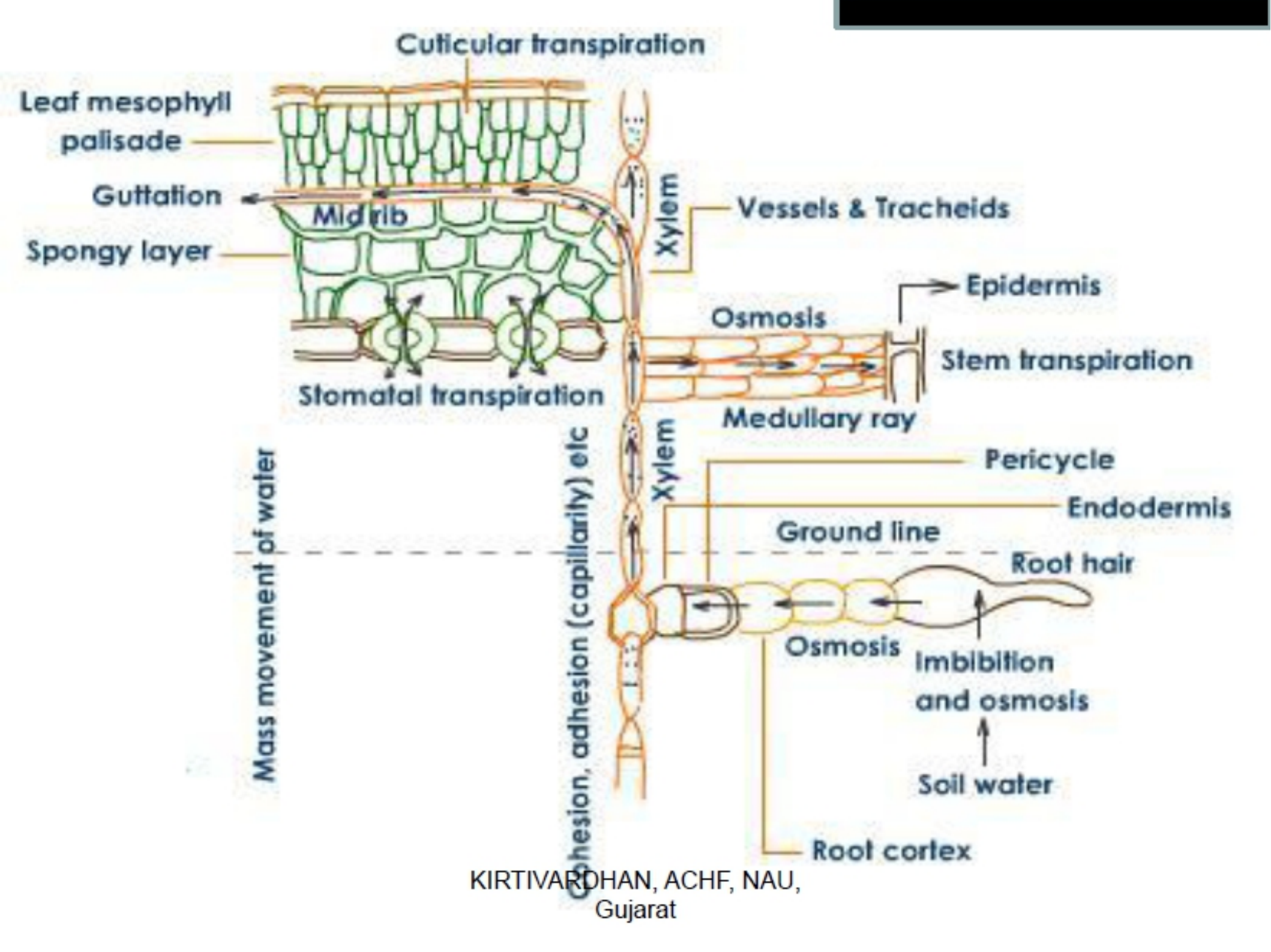
Cuticular transpiration
Leaf mesophyll
palisade
Guttation
Midrib
Spongy layer
Stomatal transpiration
Xylem
Vessels & Tracheids
Epidermis
Osmosis
Stem transpiration
Medullary ray
Xylem
Pericycle
Endodermis
Ground line
Root hair
Osmosis
Imbibition
and osmosis
Soil water
Root cortex
Mass movement of water
Cohesion, adhesion (capillarity) etc


Thank You