Chapter V Water Metabolism – Water Absorption of Plant Root System

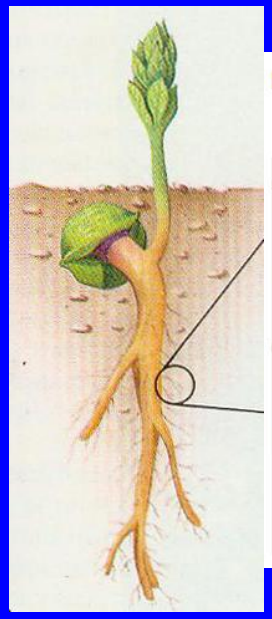
I. Main Water Absorbing Positions of a Plant

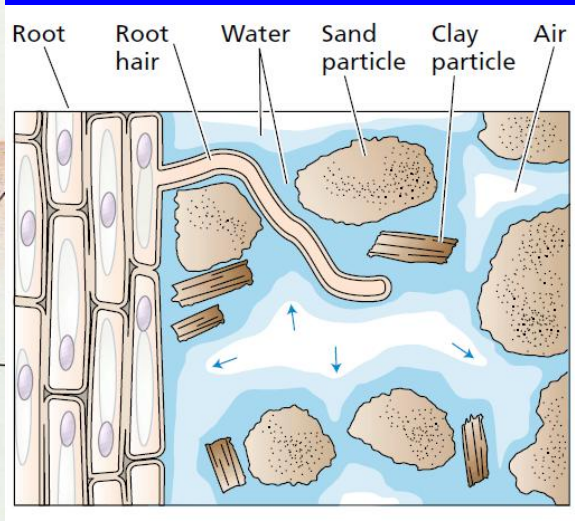
1. Root system is a major water absorbing organ for terrestrial plants;
2. The water absorption of the root is mainly conducted at root tip, and the root hair region has the highest water absorbing capacity, because

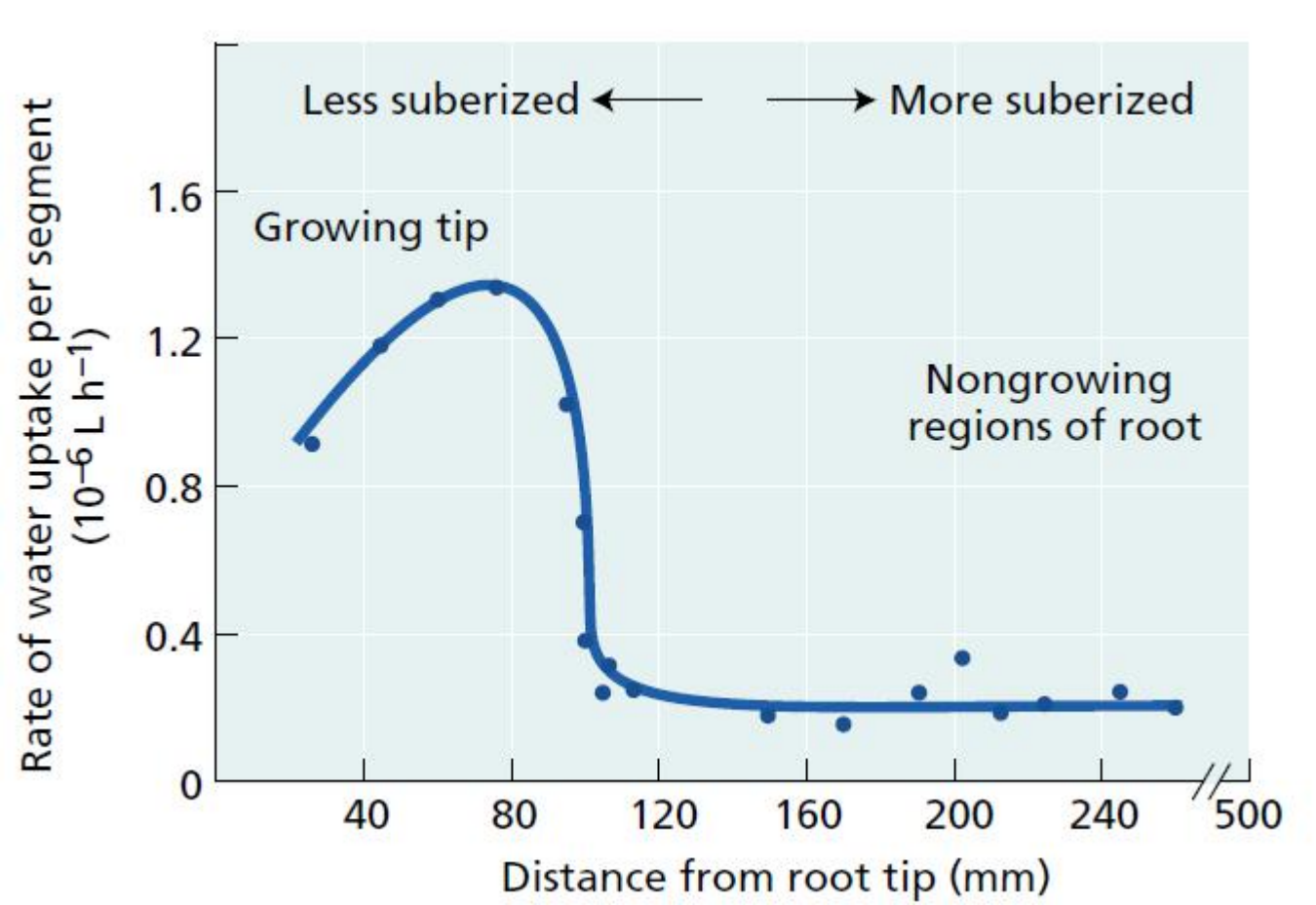
(1) The root hair increases absorption area;

(2) The outer wall of the root hair is composed of pectic substance and is highly hydrophilic;

(3) The conducting tissue is developed and has small resistance to water movement.







Rate of water uptake at various positions along a pumpkin root. (Kramer & Boyer 1995)

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II. Water Absorbing Pathways of the Root System

1. Apoplast pathway: Water moves fast via cell wall, intracellular space and other parts without protoplast.
2. Transmembrane pathway: Water moves from one cell to another cell and needs to pass through plasma membrane and tonoplast.
3. Symplast pathway: Water moves from the cytoplasm of a cell to the cytoplasm of another cell via piasmodesma slowly. The existence of casparian strip on endoderm limits water movement to symplast pathway only and is significant to selection.

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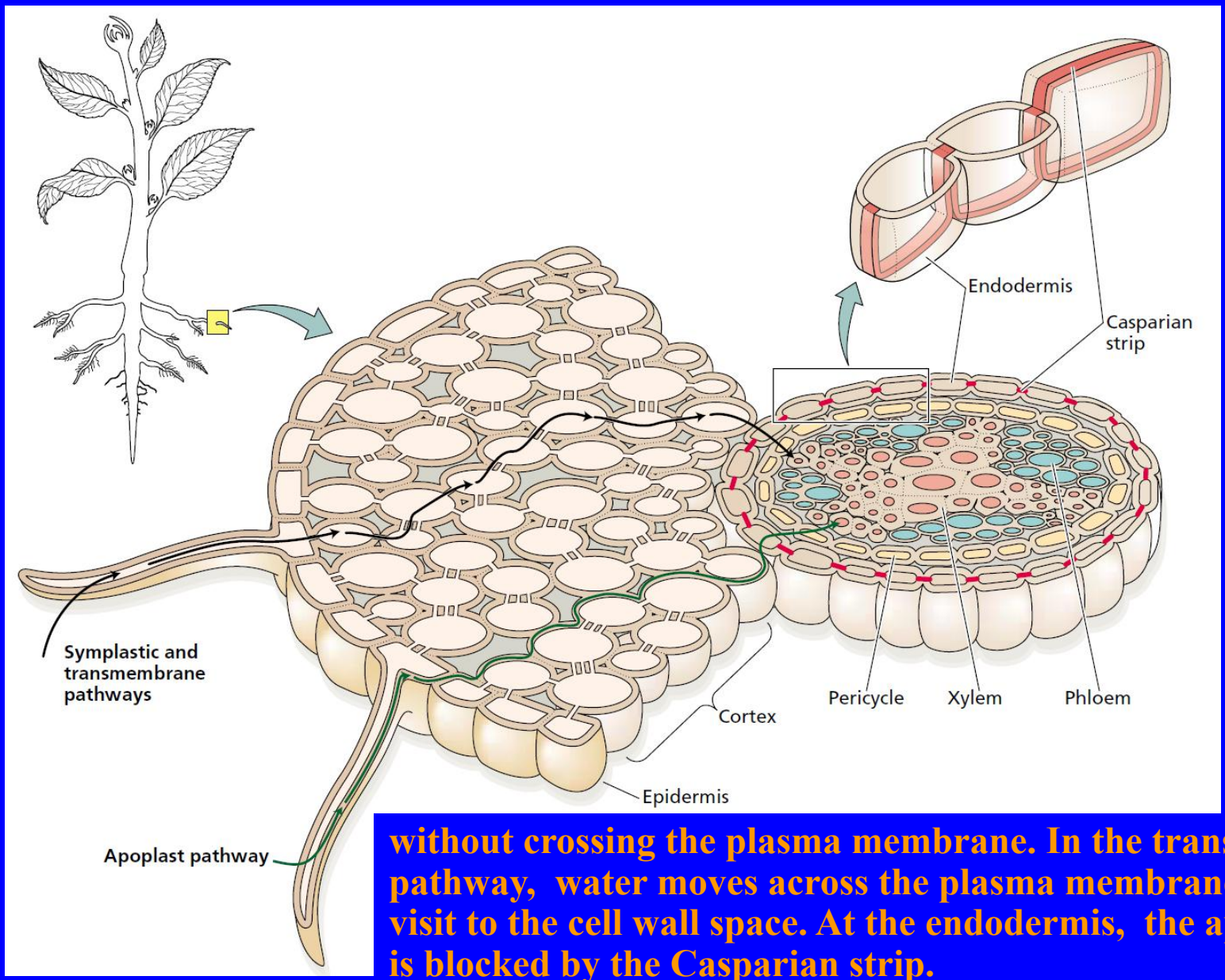
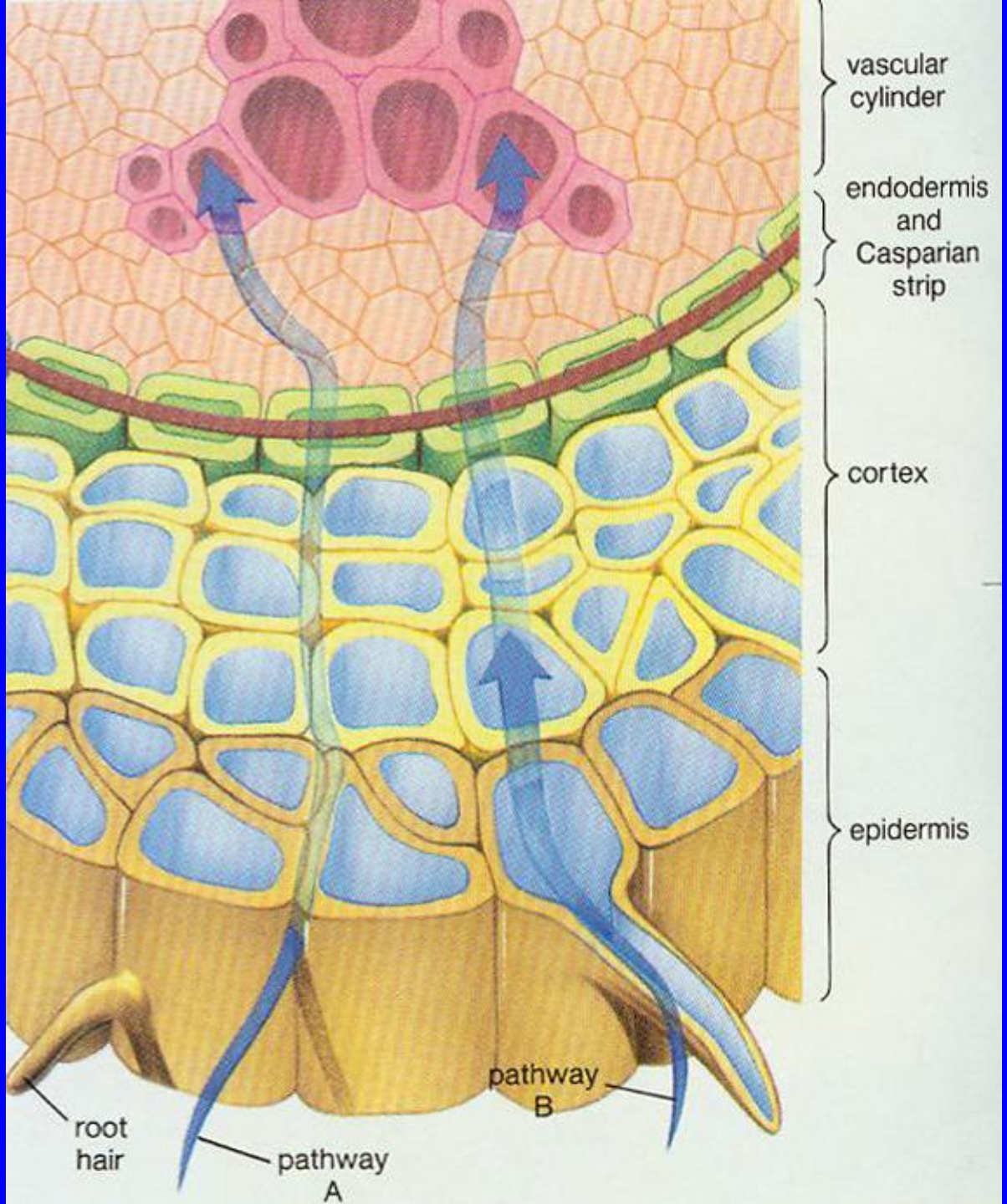


Pathways for water uptake by the root. Through the cortex, water may travel via the apoplast pathway, the transmembrane pathway, and the symplast pathway. In the symplast pathway, water flows between cells through the Plasmo-desmata without crossing the plasma membrane. In the transmembrane pathway, water moves across the plasma membranes, with a short visit to the cell wall space. At the endodermis, the apoplast pathway is blocked by the Casparian strip.



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Water and minerals can travel one of two pathways across the cortex to the xylem of the vascular cylinder

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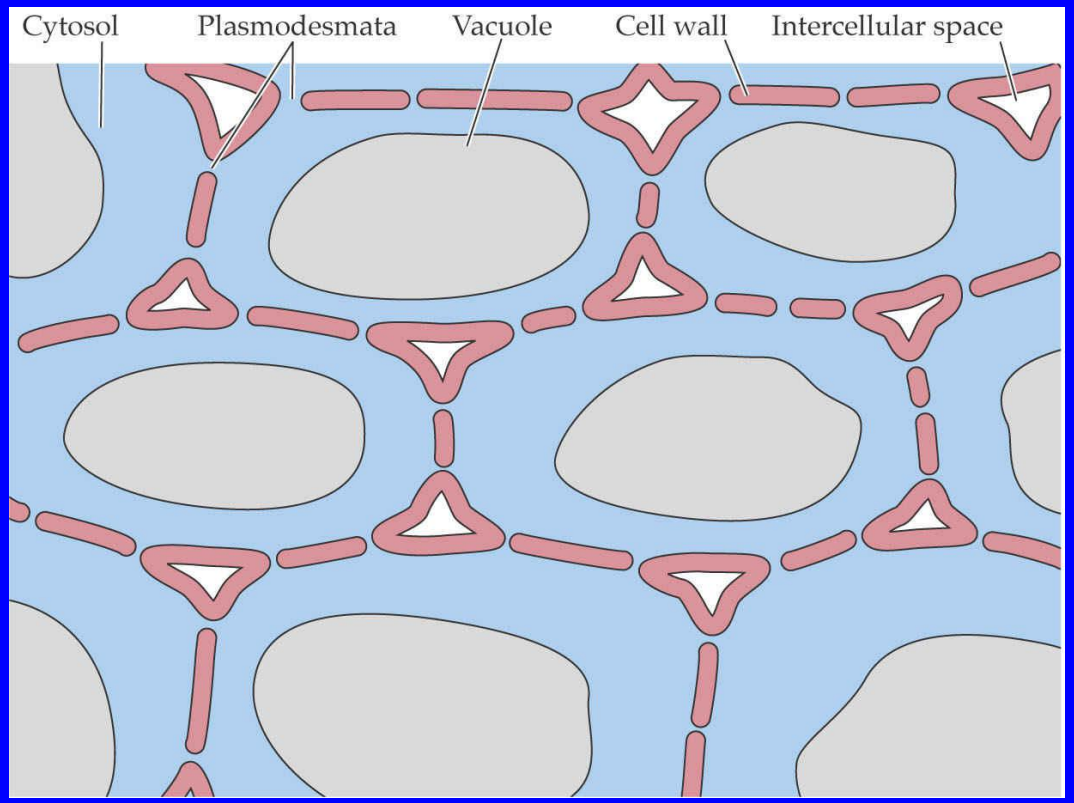
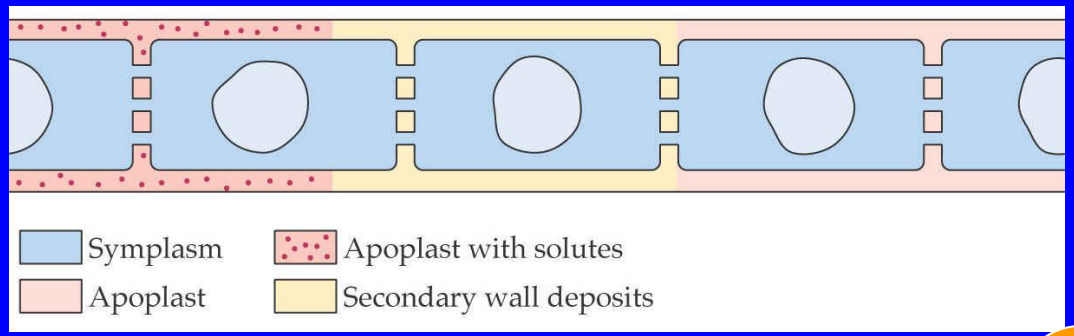
Diagram of the apoplast/symplasm concept in its simplest form.



By limiting apoplastic solute movement, secondary wall deposits can result in locally sharp water potential gradients.



III. Driving Force of Water Absorption of the Root System

(I) Root pressure

1. Concept: The physiological activities of the root system form a water potential gradient. As a result, pressure is generated after water enters the vascular cylinder. This pressure is called root pressure. It results in active water absorption.

2. Bleeding and bleeding sap

   ① Bleeding: A phenomenon that liquid flows out from injured or broken plant tissue.

   ② Bleeding sap: The juice flowing out is bleeding sap; the main components are water as well as inorganic salts, organic matters and plant hormones; the amount of bleeding sap is different in different plants or in a same plant in different seasons; its amount or composition is an indicator measuring the activity ability of the root system.

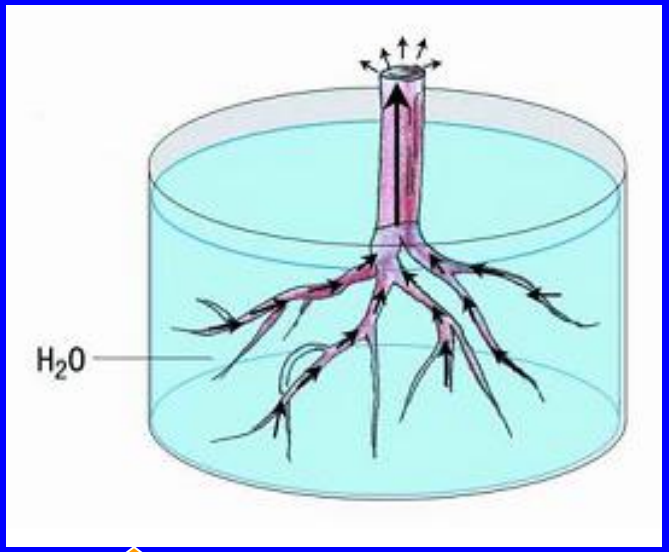
3. Guttation: A phenomenon that liquid drops come out from uninjured leaf apex or margin. It may also be used as an indicator for the physiological activity of the root system.

4. Mechanism for generation of root pressure

① Osmotic theory: Living cells around root canal →secrete inorganic salts and organic matters to the canal →water potential of the canal↓→water potential of living cells↑→water flows into the canal continuously (water potential experiment)

② Metabolism theory: The energy released from respiration takes part in the water absorption process of the root system (temperature, partial pressure of oxygen and respiratory inhibitor experiment)

Drops of guttation water on the edges of a strawberry leaf.



A schematic diagram of root pressure.

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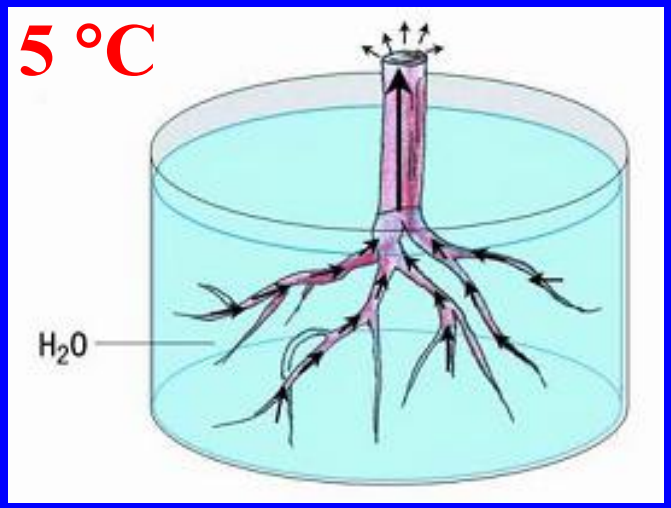
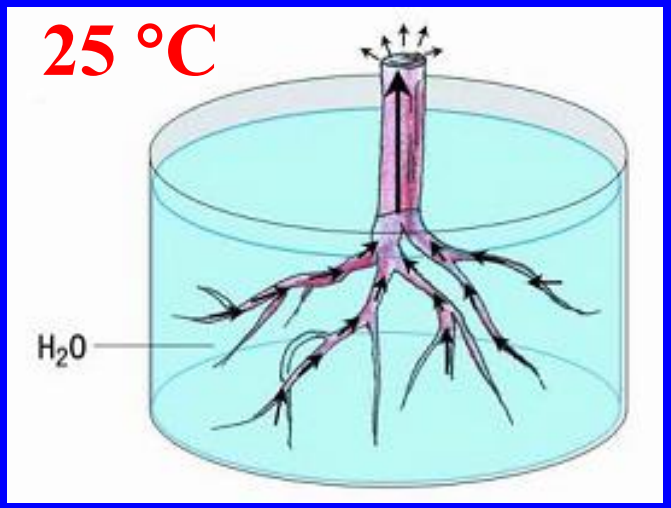
Less **More**





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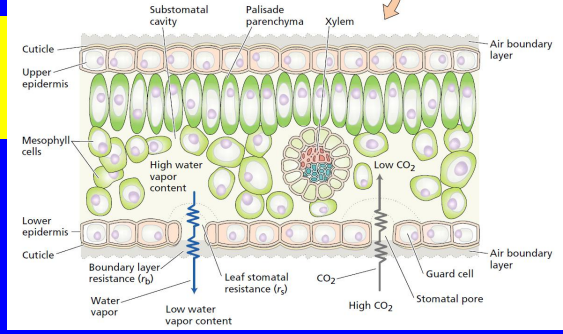

(II) Transpiration pull

During blade transpiration, the mesophyll cells near the substomatic cavity lose water →water potential ↓→absorb water from adjacent cells →for example, absorb water from another cell→→→absorb water from the canal→→→absorb water from the root. The whole process is caused by the pull generated from transpiration and water loss. (Experiment of local anesthesia and rootless branch water absorption)

The water absorption of plants with strong transpiration is mainly caused by transpirational pull; only when blades don't spread out in spring, root pressure is a major force to water absorption.

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IV. Soil Conditions that Influence Water Absorption of the Root System

(I) Available water in soil

1. Water absorbing ability of root >water retaining ability of soil →water absorption of plant

2. The available water in soil is relevant with the fineness of soil particles and the quantity of colloid: coarse sand >fine sand >sandy loam>loam>clay

(II) Soil aeration condition

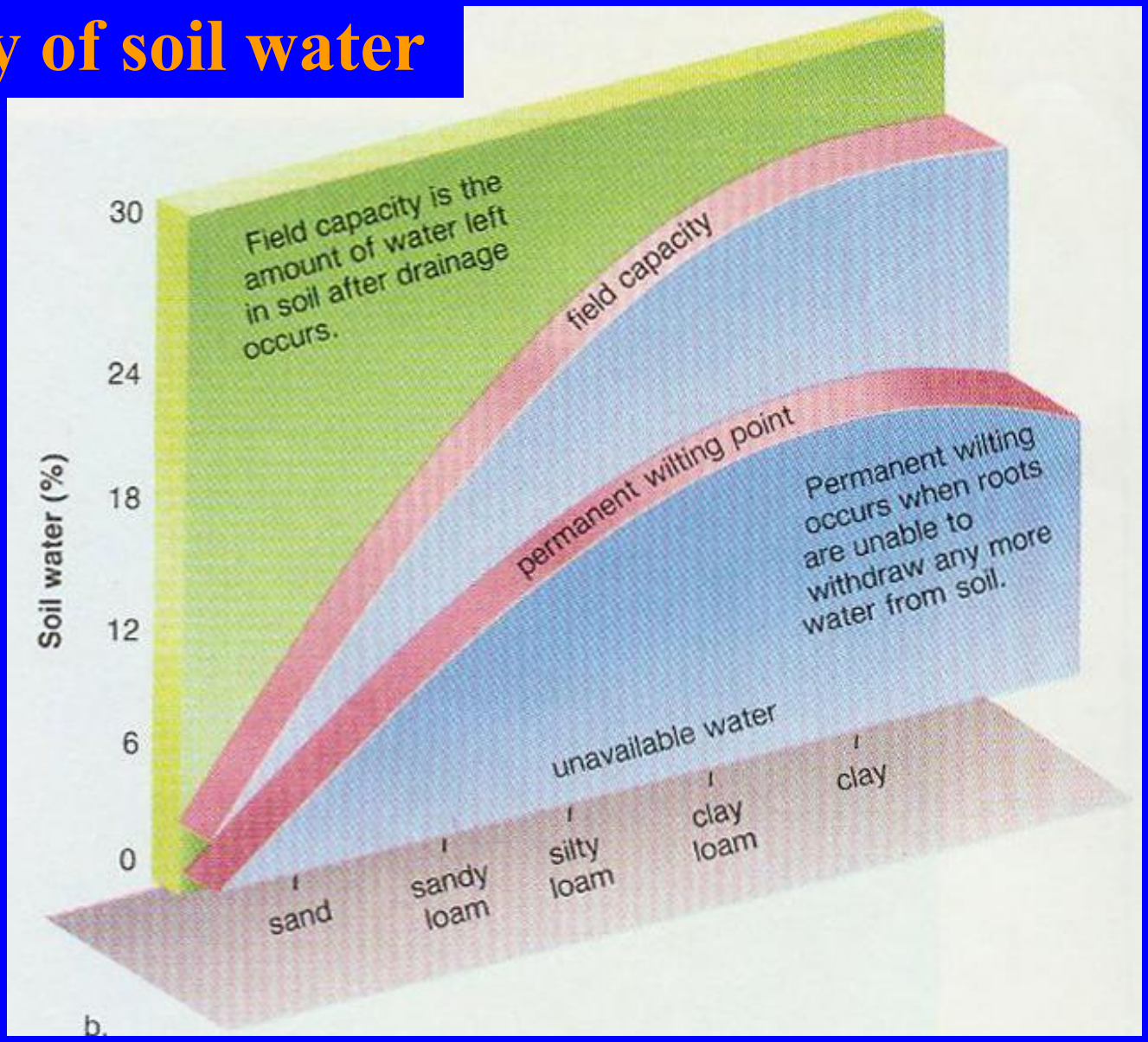
1. CO_2 treats the root, and the water absorption rate of seedling is reduced:

Hypoxia→respiration ↓→root pressure↓→obstruct water absorption

anaerobic respiration → alcohol accumulation →intoxication of the root system →water absorption↓

2. Aggregate soil may make soil have enough water and good aeration condition at the same time.

Availability of soil water



(III) Soil temperature

1. Low temperature reduces the water absorption rate of the root system:

① Viscosity of water ↑→diffusion rate↓;

② Viscosity of cytoplasm ↑→it is not easy for water to pass;

③ Respiration ↓→root pressure ↓;

④ Root system growth rate ↓→water absorbing surface area ↓.

2. Excess temperature is not conducive to water absorption:

High temperature→ enzymatic inactivation →active water absorption ↓

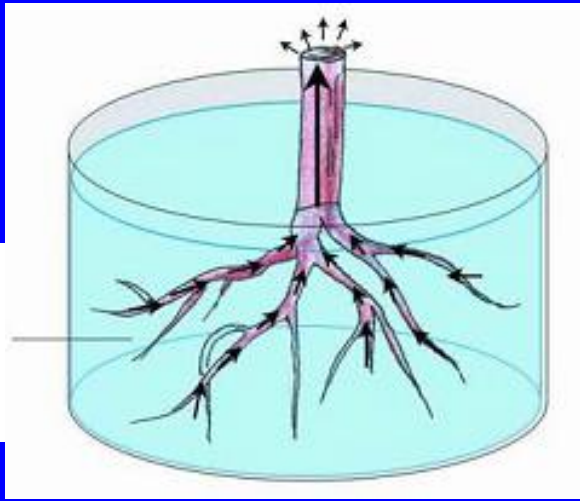
└→root aging↑→xylem reaches root tip →absorption area↓→ water absorption ↓

(IV) Soil solution concentration

Low soil solution concentration →high water potential →water absorption of the root system

Less **More**

0.1 M KCl



0.01 M KCl