

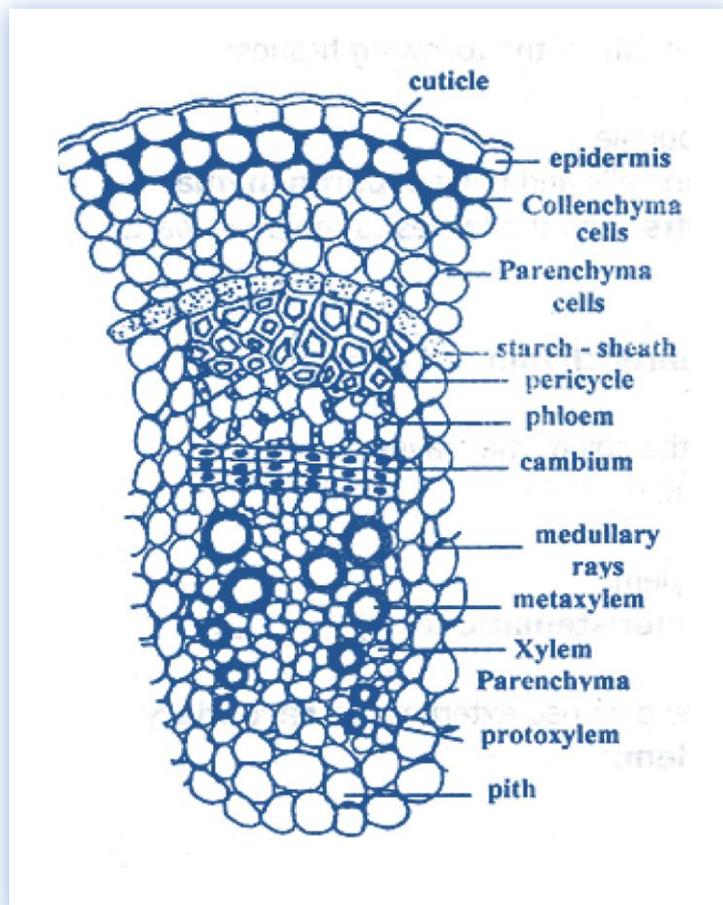
Chapter 2

Transport in living organism

<i>In case of green plants</i>		<i>In case of animals</i>	
<i>In primitive plants like algae, raw materials and product of photosynthesis move from one cell to another by osmosis, diffusion and active transport.</i>	<i>In higher plants gases move by diffusion while water, mineral salts and soluble products of photosynthesis are transported through specialized vascular tissue (xylem and phloem).</i>	<i>In small animals, like protozoa and hydra, both gases and food substances move by diffusion.</i>	<i>But, in higher animals there is a specialized transport system (circulatory system).</i>

TRANSPORT IN HIGHER PLANTS

Xylem and phloem tissues represent together the vascular bundle in the plant that extends from the root, through the stem, to the leaves.



The vascular bundle in the plant

Xylem (xylem vessels and tracheids)

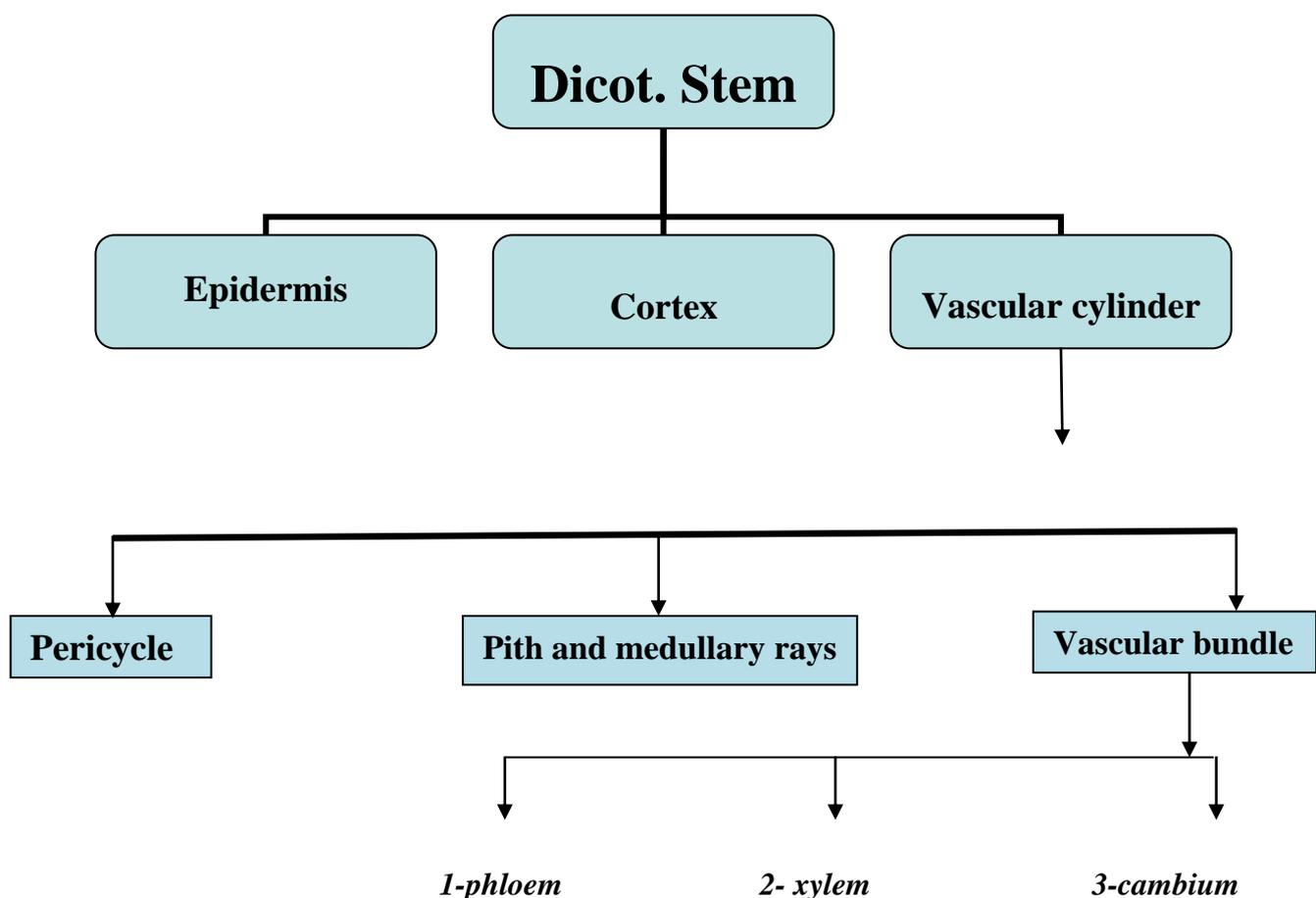
Function: to transport (translocate) water and mineral salts from the root to the leaves which carry out Photosynthesis.

Phloem

Function: the products of photosynthesis are transferred through the sieve tubes of the phloem from the leaves to different parts of the plant (roots, stems, fruits and seeds) to be consumed

The study of the internal structure of the stem and its role

If we examine a t.s. in a young dicot stem we find that it consists the following tissues



1-epidermis

It is one row of adjacent, barrel-shaped parenchyma cells.

Its outer wall is covered with cuticle.

2-cortex

It consists of several rows of collenchyma cells their corners are

Thickened by cellulose which acts as a mechanical tissue that supports the stem.

-Collenchyma cells contain chloroplasts so they take part in photosynthesis and are then called chlorenchyma.

-Collenchyma cells are followed internally by several rows of parenchyma cells with intercellular spaces for aeration.

-The innermost layer of the cortex is known as starch-sheath in which starch grains are stored.

Vascular cylinder

Which consists of the following tissues :

A) Pericycle: which consists of sclerenchyma fibers and parenchyma cells.

B) which are arranged in a cylinder .

Each bundle consists of the following tissues:

<i>1) Phloem</i>	<i>2) Xylem</i>	<i>3) Cambium</i>
<ul style="list-style-type: none">• Is the outer tissue of the bundle.• It consists of sieve tubes, companion cells and phloem• Function: Transport of organic food substances from leaves to different parts of the plant.	<ul style="list-style-type: none">• Is the inner tissue of the bundle• It consists of xylem vessels, tracheids and xylem parenchyma.• Function: It translocates water and solutes and acts as supporting tissue.	<ul style="list-style-type: none">• It lies between the phloem and xylem.• It consists of one row of meristematic cells which divide to give externally secondary phloem and internally secondary xylem

- The xylem and the phloem in the stem join with the root and the leaf xylem and the phloem forming a network of vessels that spread all over the plant.

***N.B:** intravascular cambium Meristematic cells lie between the vascular bundles.*

C) Pith

• *It occupies the center of the stem.*

• *It consists of parenchyma cells that store food.*

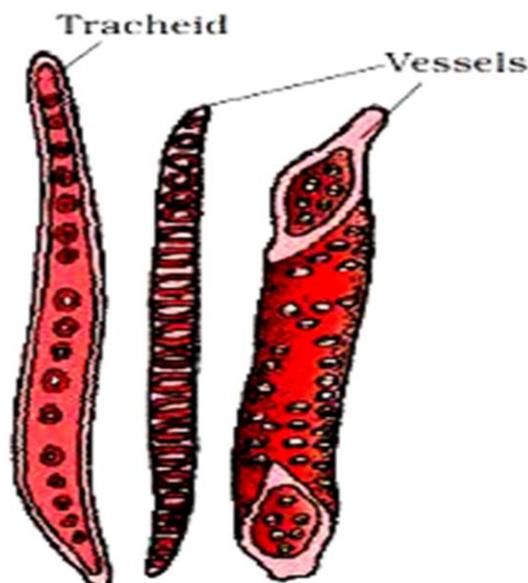
D) Medullary rays

- Are parenchyma cells which extend between the vascular bundles joining the cortex endodermis with the pith.

Mechanism of transport of water and mineral salts from the root to the leaf through xylem.

Structure of the xylem and how it is adapted to its function

1-vessel	2-Tracheids
<ul style="list-style-type: none">• Xylem vessels are tubes• Each vessel (tube) is a vertical row of elongated cylindrical cells joined end to end, their transverse horizontal walls dissolved completely forming one tube and their contents have died forming a hollow vessel (tube).• At the same time the outer cellulose walls are thickened by lignin which is impermeable to water and solutes.	<p><i>They are similar to xylem vessels except that;</i></p> <ol style="list-style-type: none">1- <i>They appear in a t.s. in a pentagonal or hexagonal form and not circular as in xylem vessels.</i>2-<i>their ends are not open but pointed and pitted</i> <ul style="list-style-type: none">• <i>In both vessel and tracheids numerous pits are scattered all over the wall where the primary cellulose wall is left without thickening by lignin.</i>• <i>So pass water from the inside the vessel to the outside</i>



Tracheid and vessels – xylem

-Lignin is added to the inner lining of xylem vessels and tracheids in various forms, which are known as the forms of lignification.

These forms are: Annular, spiral, scalar form, reticulate and pitted.

-Annular and spiral forms are common in protoxylem but other forms are common in metaxylem.

-These forms of thickening support the vessel and prevent the collapse of its wall.

ROLE OF XYLEM IN TRANSPORT

Factors responsible for the ascent of the sap.

There are different theories which explain the ascent of water in the plant, some of these theories are:

<i>1- Root pressure Theory</i>	<i>2- Imbibition theory</i>	<i>3- Capillary theory</i>	<i>4- Transpiration pull, cohesion, adhesion, theory</i>
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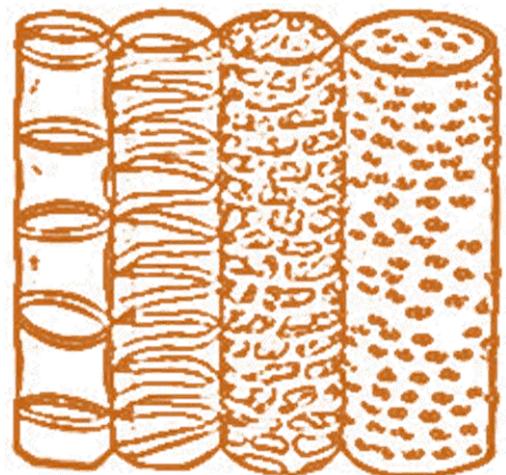
1- Root pressure theory

Guttation

Which means that, if a plant stem is cut very near to the soil level, water comes out of the stump (rest of the stem).

i.e. it is a natural phenomenon through which the water exudates out of a cut stem near the root "soil" due to the root pressure.

Guttation is caused by the root pressure.



Types of thickening in xylem vessels

Root pressure is caused by the continuous flow of water through xylem and it forces (pushes) water upwards through xylem vessels for a short distance (a certain level)

Root pressure cannot explain the ascent of water to high levels in tall trees because.

- a) The maximum root pressure is very low and does not exceed 2 atmospheres.
- b) Pinus and other conifers have no root pressure although they are very tall trees.
- c) *The root pressure is affected by external factors.*
- d) **At a certain level, the water stops because the opposite pressure of the water column becomes equal to the root pressure.**

2- Imbibition theory

-The colloidal nature of cellulose and lignin helps the walls of xylem vessels to imbibe water.

-But imbibition has a limited effect on the ascent of sap because

- a) *It explains the ascent of the sap along the walls of the xylem vessel and not through its cavity and the sap ascends through the cavities of the xylem vessels and not along their walls.*
- b) *It causes the transport of water along the cell walls of root cells until it reaches the wall of vessels in the root, and also from these vessels to the neighboring cells in the leaves.*

3- Capillary action (capillary) theory

- *Water rises through tiny tubes against gravity by capillarity.*

Xylem vessels are capillary tubes with a diameter ranging from 0.02 to 0.5 mm, so water rises up through them by capillarity.

Capillarity has also a limited effect on the ascent of sap because the maximum height of water column in the finest capillary tube is 150 cm, so it does not explain the ascent of the sap in tall trees.

4- Transpiration pulls - cohesion - adhesion theory

- Which is made by the two scientists Dixon and Joly in 1895, and it states that:
- The ascent of water through xylem vessels depends upon three forces which pull water up to 100 meters high.

These forces are:

<i>Cohesive force</i>	<i>Adhesive force</i>	<i>Transpiration pull of the leaf</i>
<i>-Is the strong mutual attraction between water molecules (inside the vessel) -This force explains the presence of a continuous water column.</i>	<i>-Is the attraction between water molecules and xylem molecules. - This force holds the water column against gravity.</i>	<i>•The continuous process of transpiration in the leaves attracts (pulls) the water column upwards</i>

The transpiration pull (pulling force) of water in vessels will be higher if xylem vessels have the following conditions

1-Xylem vessel should be a capillary tube.

2-The walls of the tube must have adhesive force to attract water.

-The tubes must be free of any gas bubbles to avoid breaking in the water column that may cause its descent.

N. B

- Some seedlings fail to grow when transplanted from a nursery (green house) to an open soil, especially if they are exposed to the sun for a long time before they are transplanted in the soil because, they will lose large amount of transpiration water which are not compensated by absorbing water from the soil, and also because air or gas bubbles may be formed in xylem vessels which will break water column causing its descent.

The pass of (ascent of) the sap from the root to the leaves in the leaf

In the leaf

-Transpiration will decrease the amount of water in the air chamber of the stoma (stomata chamber), so water will evaporates quickly from the mesophyll cells surrounding the chamber, so their water content will decrease and their osmotic pressure will increase. So they will pull water from their surrounding cells.

-This will be repeated and continue till it reaches xylem vessels, so a great pulling force (transpiration pull) will pull water up through xylem vessels and tracheids of both the stem and the root which are connected with the leaf xylem vessels.

Transpiration pull of the leaf will not only pull water that reached the root vascular cylinder but, it pulls water from the root hairs (lateral pull)

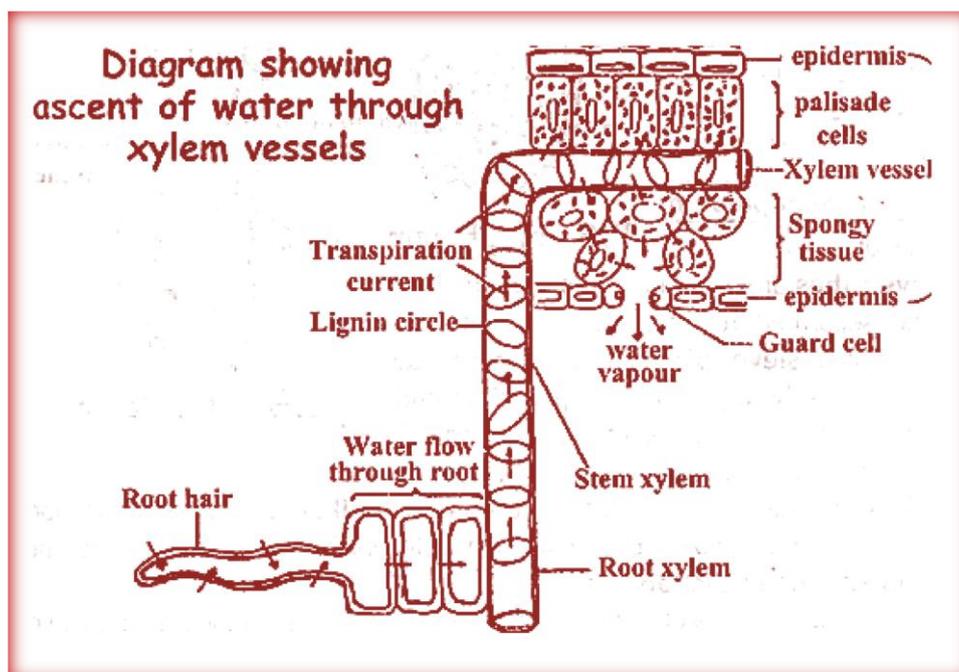
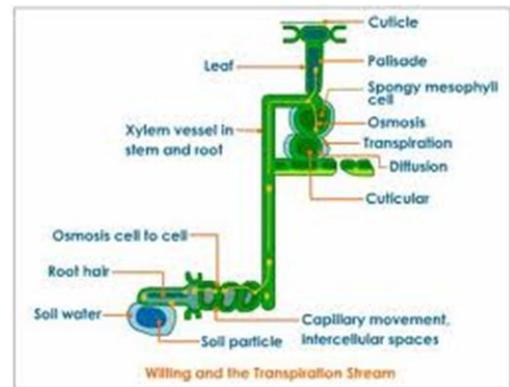


Diagram showing ascent of water through Xylem vessels plant

Transport of manufactured food (from the leaf to other parts of the Plant)

The function of phloem is to translocate high-energy organic substances from the leaf in photosynthesis to all parts of the plant. i.e. upwards to feed buds, flowers and fruits and downwards to feed the stem and the root system.

-The structure of the phloem and the role of sieve-tubes in transport

The phloem consists of sieve tubes.

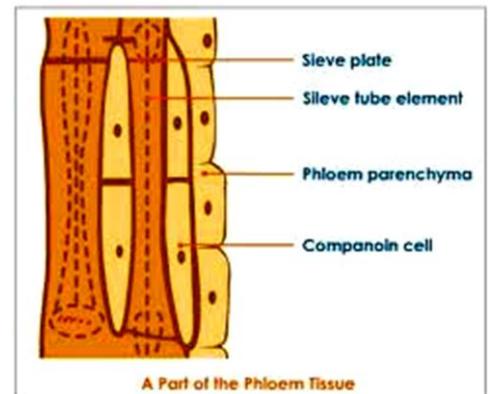
Each tube is a vertical row of elongated cells, arranged end to end and they contain cytoplasm without a nucleus.

Each sieve tube element has a nucleated companion cell.

The sieve tube activities are organized by the ribosomes and mitochondria of the companion cell.

The sieve tube cells (elements) are separated from each other by perforated cross walls (sieve plates) through which cytoplasmic strands extend from one cell to another.

The experiments which proved the role of sieve tubes is the transport of ready-made food substances are:



Phloem (L . S)

Rapaden and Boher exp. in 1945	Mittler's experiment (Aphid insect experiment)
<ul style="list-style-type: none"> in which supplied a green bean plant leaves with CO₂ containing radioactive carbon'' ¹⁴C They discovered that carbohydrates containing radioactive carbon are trans located upwards and downwards in the stem. So they only proved that ready-made foods are transported to different parts of the plant 	<ul style="list-style-type: none"> in which he collected the contents of sieve tubes using Aphid insect He found out that these contents are organic substances (sucrose and amino acids) made in the leaves. To make sure that this was the phloem content, he sectioned the region of the plant where the proboscis of the insect was inserted. It appeared to be inserted in a sieve-tube.



Mittler's experiment (Aphid insect experiment)

