Transport in Plants

Plant structure

Leaf:

Xylem and phloem appear in the midrib and veins of the leaf.

Stem:

Epidermis:

- Single layer of cells.
- Helps maintain shape.
- Reduces water loss.
- Stomata allows exchange of gases for respiration.
- Woody stems - epidermis is replaced by bark (layers of dead cells.)

Vascular bundle:

- Made up of groups of specialised cells.
- Transport water, salts, food up and down the cell.
- Vascular bundle in root, stem, leaf connect to form transport system.

Cortex:

- Tissue between the vascular bundle and epidermis.
- Acts as packing tissues, providing support.
- Cells often store starch.
- Green stems - store chloroplasts.

Pith:

- Central tissue.
- Provides support.

Root:

- Vascular bundle present in centre of root unlike stem where vascular bundle is present as cylinders in the cortex.

Outer layers and root hair:

- No distinct epidermis.
- Root tip - several layers of cells forming the root cap.
- Cells worn away as root pushes through soil, and are rapidly replaced.
- Region above root tip - root hair cells.
- Tiny, tube-like outgrowths from cells called root hair.
- Root hair takes up water by osmosis, salts by active transport.
- Root hair grows between soil particles, sticks closely to them.
- Root hair - remain alive for a short time.
- New root hair grows below the root hair zone, root hair at the top shrivels.
- Region above the root hair zone is more impermeable.
- Large number of root hairs increase absorbing surface.

Vascular bundles:

- Consists of xylem and phloem.
- Xylem - carries water and salts.
- Phloem - food substances.

Xylem vessels:

- Cells in the xylem that carry water.
- Vessel is made up of long cells joined end to end.
- When the region of a plant stops growing:
    - End walls of these cells are digested away, forming a continuous, fine tube.
    - Cell walls thickened and impregnated with lignin.
    - Lignified cell walls - strong and impermeable.
    - Cytoplasm dies to allow free passage of water and nutrients.
- Xylem also contains many long, lignified supporting cells called fibres.

Sieve tubes (phloem):

- Conducting cells remain alive, unlike in xylem.
- Formed by vertical columns of cells.
- End walls have perforations to allow substances to pass from cell to cell.
- Cell walls are not lignified.
- Cell contents do not die.
- Nuclei are lost.
- Perforated end walls - sieve plates.
- Phloem also contains supporting cells.

Transport in Plants

Function of vascular bundle:

- Water travels up xylem (roots to leaves.)
- Food travels either up or down phloem, from source to sink.
- Vascular bundle supports stem, leaves, etc due to vessels, fibres, elongated and lignified cell walls.
- Vascular bundle arranged in a cylinder, short distance from epidermis - resists the plant bending sideways because of wind (stem).
- Root - vascular bundle arranged in centre to resist pulling forces caused by shoot being blown about in wind.
- Veins in leaves support the soft mesophyll tissues, resisting stresses that could cause tearing.

Water uptake:

- Water tension is developed in vessels due to transpiration.
- Transpiration pull draws water and salts from soil, into root hair cells.
- Water is passed into the root cortex and diffuses into xylem.
- In the root, water passes through cell walls rather than cytoplasm - path of least resistance.
- Less transpiration - osmosis more important in water uptake.
- Cytoplasm is more concentrated than soil.
- Water flows into the root hair cell - increases turgor pressure - water is forced into the next cell through the cell wall.

Uptake of salts:

- Some salts are carried in through transpiration pull.
- Some salts enter through diffusion.
- Active transport is important as:
    - Salts are absorbed even when concentration is higher in cytoplasm.
    - Respiration affects uptake of salts.
- Growing region of the root, root hair zone absorbs the highest amount of salts.
- Salts carried first in xylem, but also appear in phloem.
- Salts used to make important molecules, eg. nitrates + carbs = amino acids.

Ascent of sap:

- Cohesive forces between the water molecules allow transpiration to pull water up as a single stream.
- Adhesive force between the water and xylem walls allows water to be pulled up through the xylem.
- Capillary movement takes place in xylem as there is unidirectional movement up a narrow tube.

Transpiration:

- Loss of water from leaves by evaporation of water on the surfaces of the mesophyll cells followed by the diffusion of water vapour through the stomata.
- Cell sap exerts turgor pressure on the cell wall, forcing water out of the cell wall, evaporating into air space between cells.
- Water vapour passes by diffusion through the air spaces and out through stomata.
- Air spaces between spongy mesophyll become saturated with water, allowing vapour to diffuse out through stomata.
- Cell walls losing water draw water from the nearest vein.
- Water travels along cell walls without entering the cell.
- Large surface area of all leaf cells - more diffusion of water out of the cells.
- Most water taken in is to replace evaporated water.

- Transpirational pull is strong enough to draw up water 50 m or more in trees.
- When turgor pressure falls, a small amount of water enters the cell, restoring turgor pressure.
- Wilting occurs when water loss is greater than water intake.
- Water loss makes leaves flaccid.

Importance of transpiration:

- Rapid water flow needed to obtain sufficient mineral salts.
- Cool the leaf, help the plant maintain its temperature - cytoplasm will die due to sunlight. Evaporating water cools down the leaf.
- Transpiration can be considered an invariable consequence of stomata being open to absorb CO_2
- Creates a negative pressure needed for water uptake.

Role of stomata:

- Opening and closing of stomata can be triggered by light intensity, CO_2 concentration, humidity.
- If water loss is greater than water uptake, the stomata close to prevent wilting.

Factors affecting rate of transpiration:

Light intensity:

- Allows stomata to open for gas exchange.
- At night, stomata are closed, reducing the rate of transpiration.
- Transpiration speeds up when light intensity increases.

Humidity:

- Reduces concentration gradient, vapour diffuses out more slowly.
- More humidity, transpiration slows down.

Temperature:

- Warm air can hold more vapour than cold air.
- More kinetic energy causes faster diffusion.
- Increased rate of evaporation.

Air movement:

- Air movement near stomata removes water molecules that leave from the leaf.
- Water vapour is swept away, speeding up transpiration.

Translocation:

- Movement of sucrose and amino acids in the phloem, from region of production (source) to regions where they are stored or used (sink).
- In the phloem, the solution can travel up and down, unlike xylem, at the same time.
- Glucose produced is converted to and transported as sucrose.
- Sucrose is transported from leaves (source) to fruits, buds, roots or other storage organs (sink).
- The solution of sucrose is created by movement of water from xylem to phloem through xylem pits by osmosis.
- Sieve plates regulate movement of sucrose, which takes time to absorb.
- When photosynthesis does not take place, roots or other storage organs become the source.
- Insects such as aphids have syringe-like mouth parts to pierce the stem and extract liquid from phloem.
- Pressure of sucrose solution is so great that solution is forced through its gut and droplets of sticky liquid exude from anus.