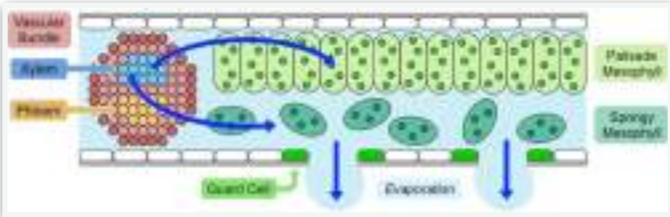
Chapter 9 —> Plant biology

8.1 Xylem transport



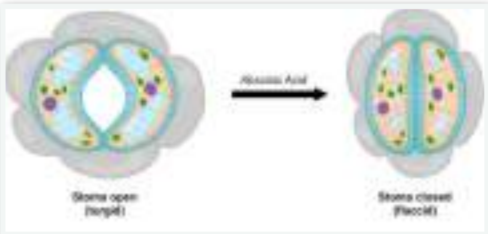
Transpiration:

- The loss of water vapour from the semi and leaves of plants
- An inevitable consequence of gas exchange in the leaf

1) light energy converts water in the leaves in vapour —> evaporates within the spongy mesophyll via the stomata —> creates a negative pressure gradient within the leaf
2) The negative pressure creates a tension force in leaf cell walls —> draws water from the xylem —> water is pulled from the xylem under tension due to the adhesive attraction water has
3) New water is absorbed from the soil by the roots —> difference in pressure created
4) Water flows via the xylem along the pressure gradient (transpiration stream and pull)

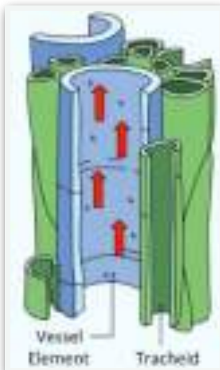
- The cohesive property of water molecules causes it to be dragged up in a continuous stream
- Adhesion makes water move up via capillary action —> pull inward on the xylem walls

Stomata:

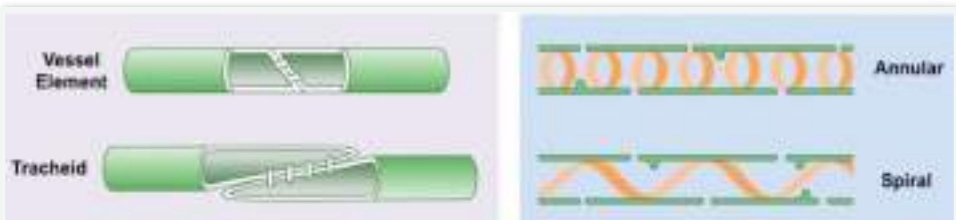


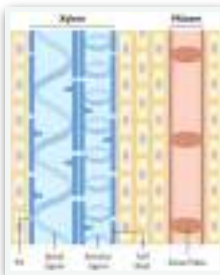
-Pores on the underside of the leaf which facilitate gas exchange
-The amount of water lost from the leaves is regulated by the opening and closing of the stomata
-Abscisic acid —> triggers the efflux of potassium from guard cells —> decreases turgor —> makes the stomatal pore close as the guard cells become flaccid and block the opening
-Affected by photosynthesis, humidity, temperature, light intensity and wind

Structure of they xylem:



- Specialised structure that facilitates the movement of water throughout the plant
- Composed of a tube made of dead cells that are hollow —> free water movement
- Because cells are dead —> water movement is all passive and in one direction
- Pits —> pores in the cell wall that enable water to be transferred between cells
- Lignin —> gives support to the structure (spiral or anular)
- Xylem composition —> Tracheids and vessel elements
- Tracheids —> tapered cells that exchange water solely via pits —> slower water transfer
- Vessel elements —> end walls fused to form a continuous tube —> faster rate





Root Uptake:

- Plants take up water and mineral ions from the soil via their roots (large SA needed)
- Fibrous roots —> highly branching root system
- Tap roots —> with lateral branches —> can penetrate the soil more
- Root hairs —> cellular extensions which further increase the SA for absorption
- Materials are absorbed by the root epidermis —> they diffuse across the cortex towards a central stele —> the stele is surrounded by an endodermis layer (casparian strip) —> water and minerals are pumped across this barrier by specialised cells (allow for controlled rate of uptake)

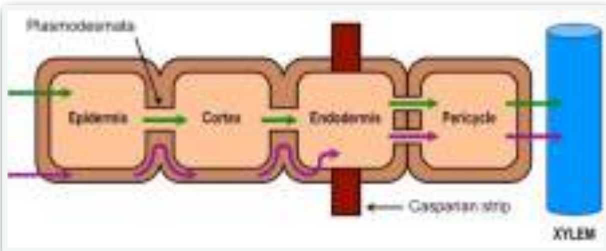
Mineral uptake:

- Fertile soil contains negatively charged clay particles —> positively charged mineral ions attach
- Minerals needed are Mg^{2+}, nitrates, Na^{+}, K^{+}, and PO_4^{3-}
- Minerals can passively diffuse into roots but mostly actively uploaded by indirect active transport

1) Root cells actively expel H^{+} ions in the soil with proton pumps
2) Ions displace the positively charge mineral ions from the clay —> diffuse into root via gradient
3) Negatively charged mineral ions bind to the H^{+} ions and are reabsorbed with the proton

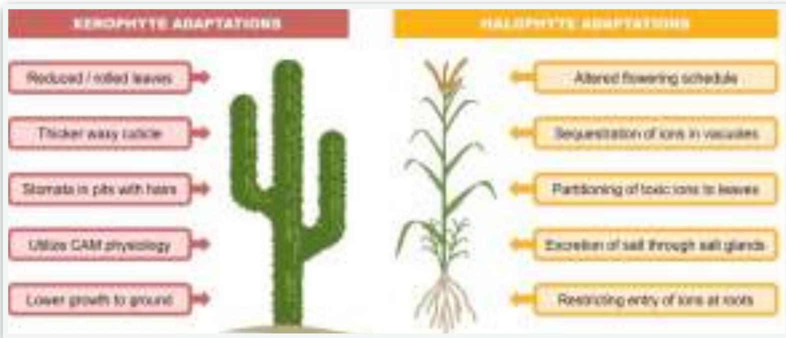
Water uptake:

- Water follows the mineral ions into the root via osmosis —> move towards higher solute conc.
- Aquaporins —> specialised water channels on the root which regulate water uptake
- Symplastic pathway —> water moves continuously through the cytoplasm of cells (plasmodesmata)
- Apoplastic pathway —> water cannot cross the casparian strip —> enters cytoplasm at endodermis



Water conservation:

- Xerophytes —> plants that grow in high salinity
- Halophytes —> possess various adaptations for water conservation



Plant experiments:

Capillary tubing:

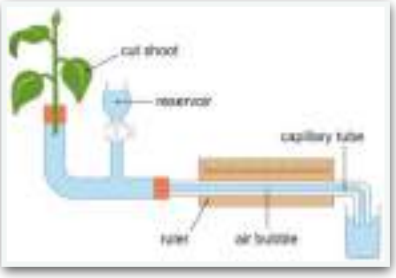
- Water has the capacity to flow along narrow spaces in opposition to external forces
- Due to combination of surface tension and adhesion with the tube walls
- The thinner the tube / less dense the fluid —> the higher the liquid will rise

Filter paper:

- Will absorb water due to both adhesive and cohesive properties
- The paper is composed of cellulose

Porous Pots:

- Semi-permeable container that allow for free passage of certain small materials through pores
- The water loss creates a negative pressure that draws more liquid upwards



Potometer:

-Can be used to test a number of variables that may affect the rate of transpiration in plants

-Variable : Temperature, humidity, light intensity and wind exposure

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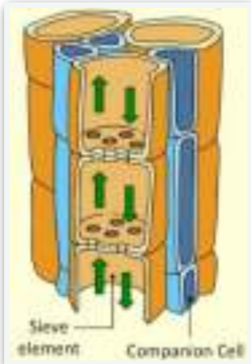
9.2 Phloem transport

Active translocation:

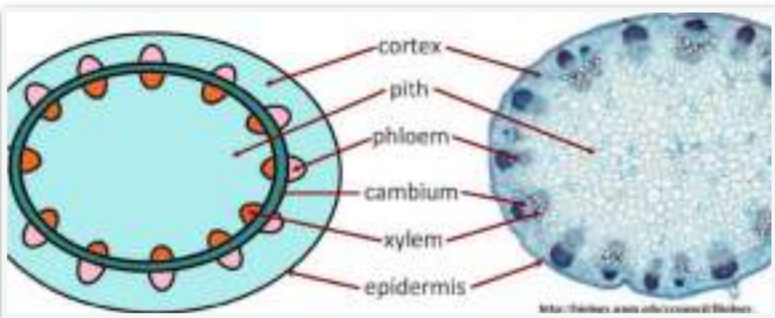


- Translocation —> the movement of organic compounds from sources to sinks
- Sources —> where the compounds are synthesised (leaves)
- Sinks —> where the compounds are delivered to for use or storage (roots, fruits and seeds)
- Phloem —> vascular tube that transports the compounds from sources to sinks
- Sugars are principally transported as sucrose (soluble and metabolically inert)
- Plant sap —> nutrient-rich viscous fluid in the phloem

Phloem structure:

- Phloem sieve tubes —> mostly composed of sieve element cells and companion cells
- Sieve element cells —> long and narrow cells that are connected together to form the sieve tube
  —> connected by sieve plates which are porous
  —> have no nuclei and reduced numbers of organelles (to maximise space)
  —> have thick and rigid cell walls to withstand the hydrostatic pressure
  —> unable to sustain independent metabolic activity without companion cell
- Companion cells —> provide metabolic support for SEC and facilitate load and unload of comp.
  —> possess an infolding plasma membrane (increased SA:V ration)
  —> many mitochondria to fuel the active t. of materials at sources and sinks
  —> contain appropriate transport proteins in the plasma membrane to move materials into or out of the sieve tube
- Plasmodesmata —> large quantity between sieve elements and companion cells
  —> connects cytoplasm of 2 cells + mediate symplastic exchange of metabolites

Phloem loading:



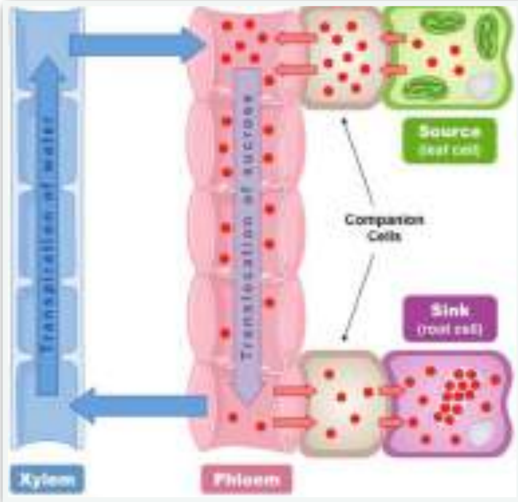
-Organic compound produced at the source are actively loaded into the phloem by companion cells

-Symplastic or apoplastic loading

-H^+ ions are actively transported out of phloem cells by proton pumps

-H^+ ions passively diffuse back into the phloem cell via a co-transport protein which requires sucrose movement

Mass flow:



At the source:

- The active transport of solutes such as sucrose makes the sap solution hypertonic —> causes water to be drawn from the xylem via osmosis (high solute concentration)
- Hydrostatic pressure increases —> due to the incompressibility of water
- The increase of hydrostatic pressure forces the phloem sap to move towards areas of lower pressure (mass flow down)

At the sink:

- The solutes are unloaded by companion cells and transported into sinks —> causes sap solution at sink to be hypotonic
- Water is drawn out of the phloem and back to the xylem by osmosis for this reason
- This ensures the hydrostatic pressure at the sink is lower than at the source
- Organic molecules at sinks are either metabolised or stored in vacuoles

Aphids:

- A group of insects which feed primarily on sap extracted from the phloem
- Possess a protruding mouthpiece (stylet) —> pierces the plant's sieve tube for sap extraction
- If the stylet is severed —> sap will continue flow from the plant because of hydrostatic pressure
- Can be used to collect sap at various sites along a plant's length

1) plant given radioactively-labelled carbon dioxide
2) The leaves will convert the CO_2 into radioactively-labelled sugars
3) Aphids are positioned along the plant's length and their stylet is severed
4) The sap is analysed in search of radioactively-labelled sugars
5) The rate of phloem transport can be calculated based on the time taken for the radioisotope to be detected at different positions along the plant

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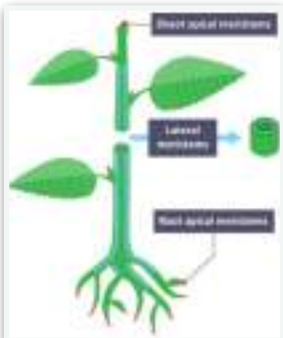
8.3 Plant growth

Meristems:



- Tissues in a plant consisting of undifferentiated cells capable of indeterminate growth
- Are analogous to totipotent stem cells in animals
- Meristematic tissue can allow plants to regrow structures or even new plants
- Can be either apical or lateral
- Apical meristems —> occur at shoot and root tips and are responsible for primary growth
- Lateral meristems —> occur at cambium and are responsible for secondary growth

Apical growth:

- Growth is due to a combination of cell enlargement and repeated cell division
- Differentiation of the dividing meristem gives rise to a variety of stem tissues and structures
- Nodes —> were growth occurs in the stem
- Axillary buds —> have the potential to form new branching shoots with leaves and flowers

Auxins:

- Group of hormones produced by the tip of a shoot or root and regulate plant growth
- Auxin's influence cell growth rates by changing the pattern of gene expression in cells
- Auxin's mechanism of action is different in shoots and roots as different gene pathways are activated in each tissue
- Auxin efflux pumps —> can set up concentration gradients within tissues
  —> control the direction of plant growth by determining which regions of plant tissue have high auxin levels
- In the shoots auxin stimulates cell elongation, so high concentrations of auxin promote growth
- In the roots auxin inhibit cell elongation, so high concentrations of auxin limit growth

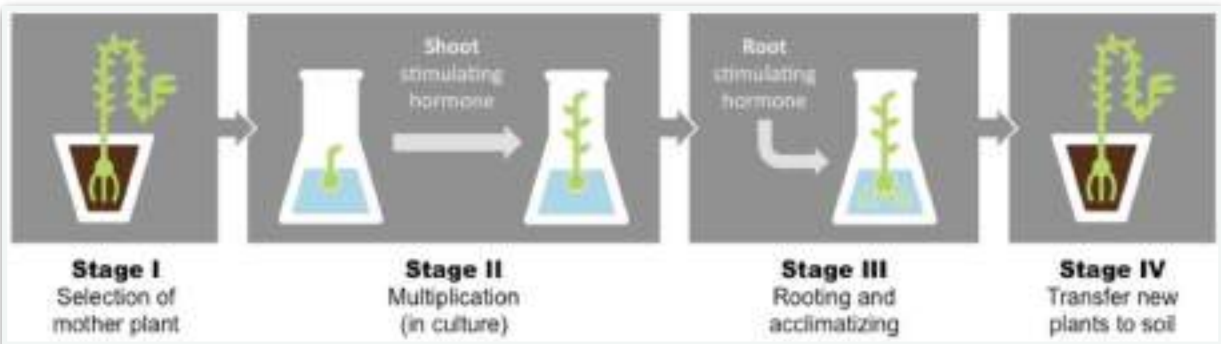
Tropisms:

- Describe the growth of a plant in response to a directional external stimulus
- Phototropism —> growth movement in response to an unidirectional light source
- Geotropism —> growth movement in response to gravitational forces
- Are both controlled by the distribution of auxin within the plant cells

Micropropagation:

- Technique used to produce large numbers of identical plants from a selected stock plant
- Vegetative propagation —> plant cutting used to reproduce asexually in the native environment
- Micropropagation —> plant tissues are cultured in the laboratory in order to reproduce asexually

1) specific plant tissue is selected from a stock plant and sterilised
2) The tissue sample is grown on a sterile nutrient agar gel with many auxins
3) The growing shoots can be continuously divided and separated to form new samples
4) Once the root and shoot are developed, the cloned part can be transferred to soil



- Rapid Bulking —> desirable stock plants can be cloned to conserve fidelity to selected charact.
  —> more reliable than selective breeding as new plants are genetically identical
- Virus-free strains —> viruses spread in infected plants via the vascular tissue (no in meristems)
  —> allows for rapid reproduction of virus-free strains
- Rare species —> used to increase numbers of rare or endangered plant species
  —> also used to increase numbers of species difficult to breed sexually (orchids, …)

9.4 Plant reproduction

- Types of reproduction for plants are —> Vegetative propagation, Spore formation, Pollen transfer

Pollen transfer:

Pollination:
- The transfer of pollen grains from an anther to a stigma
- Many plants possess both parts —> can self-pollinate or cross-pollinate (more genetic diversity)

Fertilisation:
- The fusion of a male gamete nuclei with a female gamete nuclei to form a zygote
- The male gamete is stored in the pollen grain and the female gamete is found in the ovule

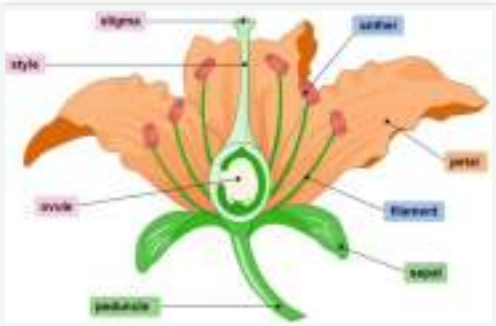
Seed dispersal:
- Fertilisation results in the formation of a seed —> moves away from the parental plant
- Seed dispersal reduces competition for resources between the seed and the parental plant
- Can be done throughout wind, water, fruits and animals

Cross-pollination:
- Transferring pollen grains from one plant to the ovule of a different plant
- Can be done by wind or water but animals are more common
- Mutualistic relationship —> both species benefit from the interaction (bees and plants)

Flowering:

- Flowers are the reproductive organs of angiospermophytes (flowering plants) —> develop from shoot apex
- Changes in gene expression trigger the enlargement of the shoot apical meristem —> the tissue differentiates to form the different flower structures (spells, petals, stamen and pistil)
- The activation of genes responsible for flowering are influence by abiotic factors
    - —> amount of pollinator levels
    - —> photoperiodism

Flower structure:



-Male part of the flower —> stamen and is composed by the anther and the filament
-Female part of the flower —> pistil and is composed by the ovule, the stigma and the style

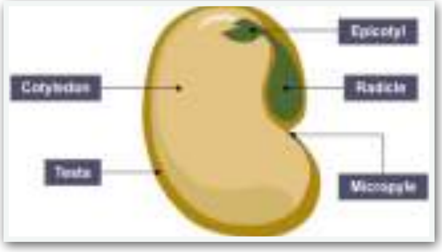
Photoperiodism:

- Phytochromes —> leaf pigments which are used by plants to detect periods of light and darkness
- Critical factor responsible for flowering are the length of light and dark periods
- Photoperiodism —> the response by the plant to the relative lengths of light and darkness

- Only Phytochrome far red is capable of causing flowering
- Plants can be classed as short-day or long-day plants, but night length is the critical factor

- Short-day plants —> flower when the days are short —> night period to exceeds critical factor —> P_{fr} inhibits flowering —> flowering requires low levels of P_{fr}
- Long-day plants —> flower when the days are long —> night period is less than critical factor —> P_{fr} activates flowering —> flowering requires high levels of P_{fr}
- Horticulturalists —> manipulate the flowering of short and long-day plants by controlling light

Seed structure:



-Testa —> outer seed coat —> protects the embryo
-Micropyle —> small pore for water passage
-Cotyledon —> contains food stores and form embryonic leaves
-Plumule (epicotyl)—> the embryonic shoot
-Radicale —> the embryonic root

Germination:

- The process by which a seed emerges from a period of dormancy and begins to sprout
- Oxygen, Water, Adeguate temperature, Adeguate pH are required for germination to occur
- Additional conditions are: Fire, Freezing, Digestion, Watching, Scarification

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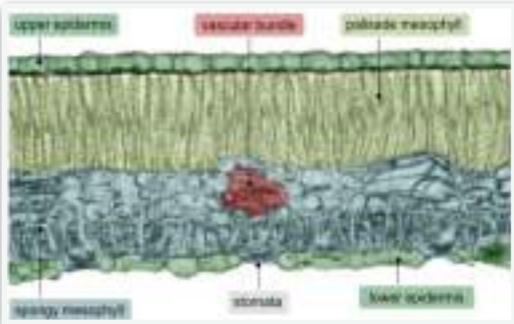
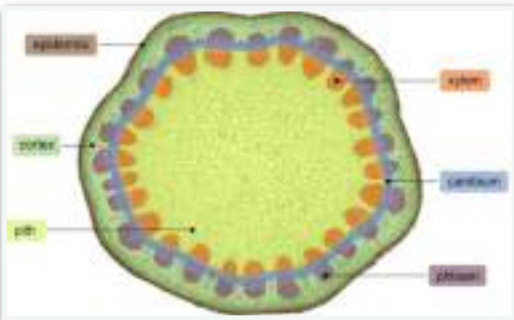
Leaf tissue:

- Palisade mesophyll —> the site of photosynthesis —> located on the upper surface of the leaf
- Spongy mesophyll —> the main site of gas exchange —> located on the lower surface of the leaf
- Stomata —> are on the underside of the leaf —> keeps open channel for gas exchange
- Waxy cuticle —> prevents water absorption (would affect transp.)—> top thick surface of leaf
- Vascular bundles —> (xylem and phloem) —> located centrally for optimal access by leaf cells



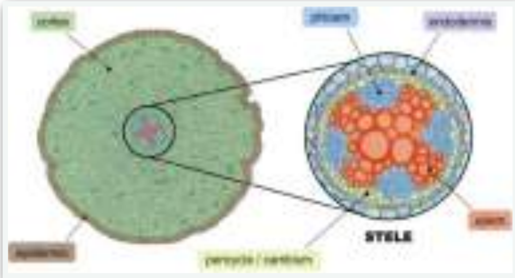
Stem tissue:

- Epidermis —> covers the outer surface and functions to waterproof, protect the stem and control gas exchange
- Cortex and pith —> found internally and assist in the transport and storage of materials within the stem
- Cambium —> circular layer of undifferentiated cells responsible for lateral growth of the stem
- Vascular bundles —> arranged in bundles near the outer edge of the stem to resist compression and bending

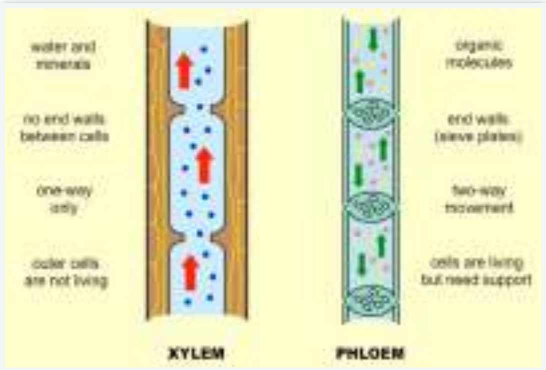


Root tissue:

- Epidermis —> may have protrusions called root hairs to increase available surface area for material exchange
- Stele —> central region surrounded by an endodermis with a Casparian strip (controls water transport)
- Pericycle / cambium —> provides strength to the root and is responsible for the development of lateral roots
- Vascular bundle —> located centrally to withstand stretching forces and allow for material transport control



Xylem vs Phloem:



Storage organs:

-A part of a plant specifically modified to store energy (e.g. carbohydrates) or water
-Usually found underground (for protection from herbivores) (due to changes to roots, leaves or stems)
-Bulbs, storage roots and tubers are common examples

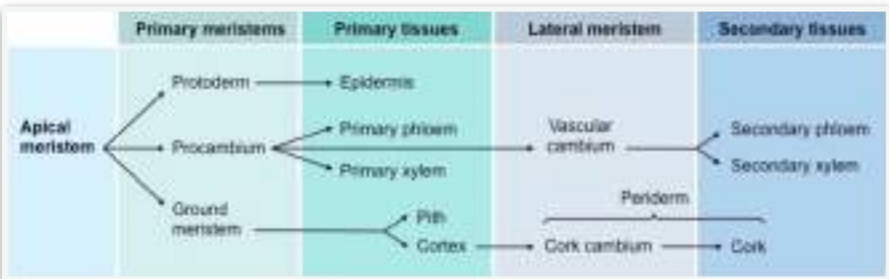
Fungal hyphae:

- Hyphae are tubular projections of multicellular fungi that form a filamentous network: mycelium
- Fungal hyphae release digestive enzymes in order to absorb nutrients from food sources

1) The hyphae penetrate into the plant's root tissue in response to chemical exudates produced by both plants and fungus
2) Within the cortical cells of the root, the hyphae forms arbuscular projections which absorb nutrients from the plant cells
3) In return, the fungus transfers minerals absorbed from the soil into the plant, so both species benefit from the interaction

Apical growth:

- Apical meristems give rise to the primary tissues needed to increase a plant's length and grow new leaves and fruits



Lateral secondary growth:

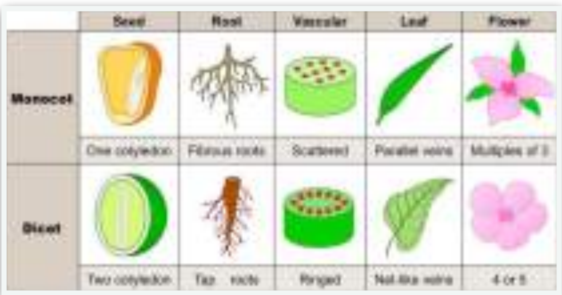
- Lateral meristems give rise to the secondary tissues needed to support an increase in the plant's width (e.g. bark)
- The thickening of a plant's stem (secondary growth) is controlled by the cambium (where lateral meristems are found)
- Growth rings can be counted to estimate the age of the plant (dendrochronology)

Plant hormones:

- Plant growth and development are controlled by plant hormones (phytohormones)
- Auxins —> promotes primary growth, cell elongation and increases rates of cell division
  —> promotes apical dominance —> tip of a plant grows while the lateral buds do not
  —> concentrations may change in response to directional stimuli
- Cytokinins —> promote cell division (cytokinesis) and ensure roots and shoots grow at same rate
  —> promotes secondary growth (thickening) and help control branching rate of plant
  —> are also involved in stimulating the growth of fruit
- Gibbellerins —> trigger germination in dormant seeds (initiates plant growth)
  —> causes stem elongation by promoting cell elongation and cell division
- Ethylene —> gas —> acts as plant hormone and stimulates maturation and ageing (senescence)
  —> responsible for the ripening of certain fruit —> opposite of gibb. and auxins
  —> contributes to the loss of leaves (abscission) and the death of flowers
- Abscisic acid —> principally functions to inhibit plant growth and development
  —> promotes the death of leaves (abscission) and is responsible for seed dormancy
  —> generally initiates stress responses in plants (ex. winter dormancy)
  —> controls the closing of stomata and hence regulates water loss in plants

	Germination	Growth to Maturity	Flowering	Fruit Development	Abscission	Seed Dormancy
Gibberellin	✓	✓	✓	✓	✗	✗
Auxin	✗	✓	✓	✓	✗	✗
Cytokinins	✗	✓	✓	✓	✗	✗
Ethylene	✗	✗	✓	✓	✓	✗
Abscisic Acid	✗	✗	✗	✗	✓	✓

Monocotyledons vs Dicotyledons:



Germination stages:

1) Metabolic activation of a dormant seed
- Germination begins with the absorption of water, which causes gibberellin to be produced
- Gibberellin triggers the synthesis of amylase, which breaks down starch into maltose
- Maltose is either hydrolysed (to glucose) for energy, or polymerised (to cellulose) for cell wall—> used to promote cell division and the growth of a nascent shoot

2) Once the seed is metabolically activated, germination proceeds according to the following stages:
- The seed coat (testa) ruptures and the embryonic root (radicle) grows into the ground to extract key nutrients and minerals
- The cotyledon emerges and produces the growing shoot's first leaves
- The growing plant can be divided into the epicotyl (embryonic shoot), hypocotyl (embryonic stem) and developing roots