Topic 9: Plant biology (HL)

9.1 Transport in the xylem of plants

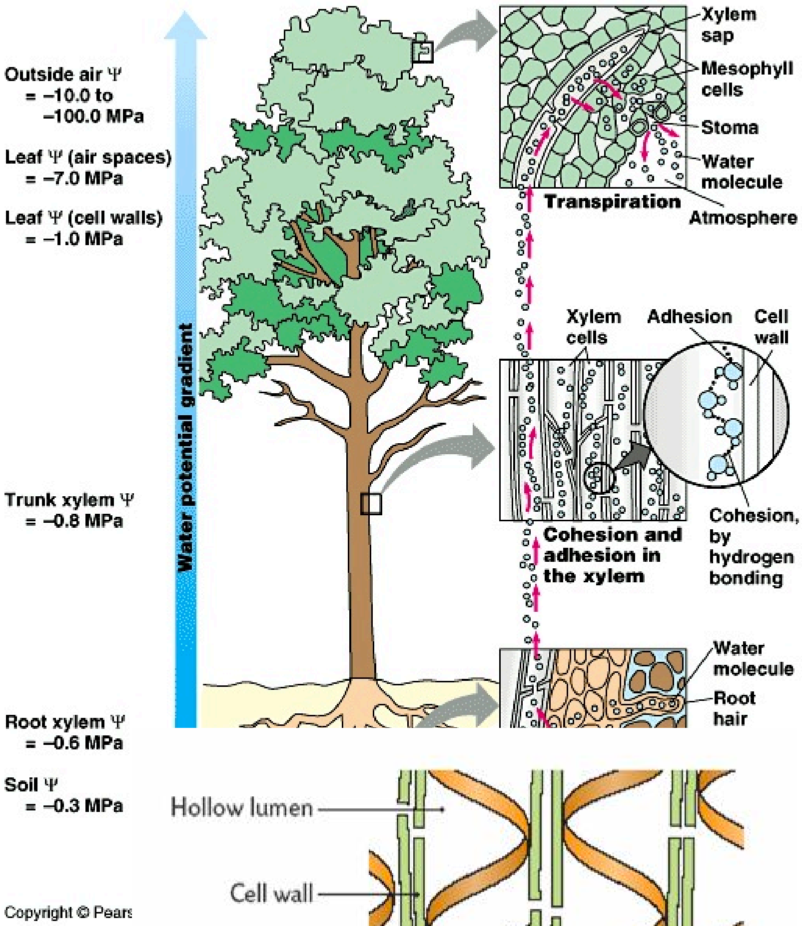
U1	Transpiration is the inevitable consequence of gas exchange in the leaf.
U2	Plants transport water from the roots to the leaves to replace losses from transpiration.
U3	The cohesive property of water and the structure of the xylem vessels allow transport under tension.
U4	The adhesive property of water and evaporation generate tension forces in leaf cell walls.
U5	Active uptake of mineral ions in the roots causes absorption of water by osmosis.
A1	Adaptations of plants in deserts and in saline soils for water conservation.
A2	Models of water transport in xylem using simple apparatus including blotting or filter paper, porous pots and capillary tubing.
S1	Drawing the structure of primary xylem vessels in sections of stems based on microscope images.
S2	Measurement of transpiration rates using potometers.
S3	Design of an experiment to test hypotheses about the effect of temperature or humidity on transpiration rates.

Water properties:

- **Cohesion**: like molecules attract to each other
- Water is a polar molecule that forms a **hydrogen bond** with other water molecules.
- The negatively charged oxygen atom of one water molecule forms a hydrogen bond with a positively charged hydrogen atom of another water molecule.
- This attractive force between these molecules is called cohesion which helps plants draw water from the root through the xylem to the leaf
- **Adhesion**: unlike molecules attract to each other
- Capillary action may occur: water will move up the capillary due to the interaction between water molecules and capillaries.

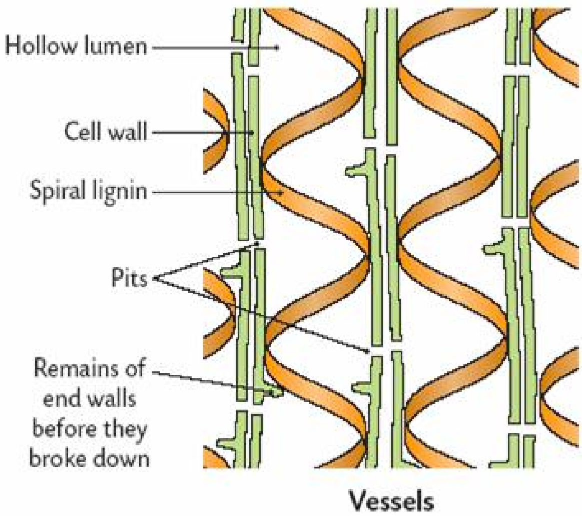
Transpiration:

- Evaporation occurs when some of the light energy absorbed by the leaf is converted to heat, thereby raising the temperature inside the leaf changing the water into water vapour.
- Transpiration is the evaporation of water from the leaves, stems and flowers. It is the movement of water vapour out of the leaf through **stomata**.
- The majority of water lost during transpiration is through openings on the bottom of the leaves called stomata.
- **Transpirational pull** results when water evaporates from the leaves and stems. More water is drawn up through the plant to replace the water that is lost.
- The loss of water generates a negative pressure and a **transpirational pull** on water molecules in the xylem.
- Transpirational pull results from the combined forces of cohesion and adhesion
- Water moves into the roots by osmosis through the cell walls and through the cytoplasm because the concentration of solutes inside the cells is greater than outside the root cells due to active transport of mineral and ions



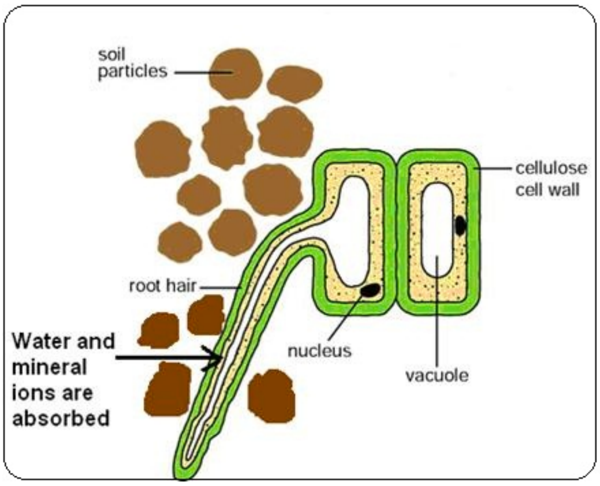
Structure of xylem:

- Xylem vessels are transport tissue found in vascular plants composed of a number of different types of cell, including long, continuous, thin, usually dead cells.
- Cell walls are **thickened** to make the xylem vessels stronger.
- The walls of the xylem are thickened and strengthened by a polymer called **lignin**
- Lignin may be deposited in different ways such as rings or spirals
- Since atmospheric pressure is greater than the pressure inside the xylem vessels, the ridged structure prevent them from collapsing
- The xylem is responsible for the transport of water and soluble mineral nutrients from the roots to the different parts of the plants that use water.



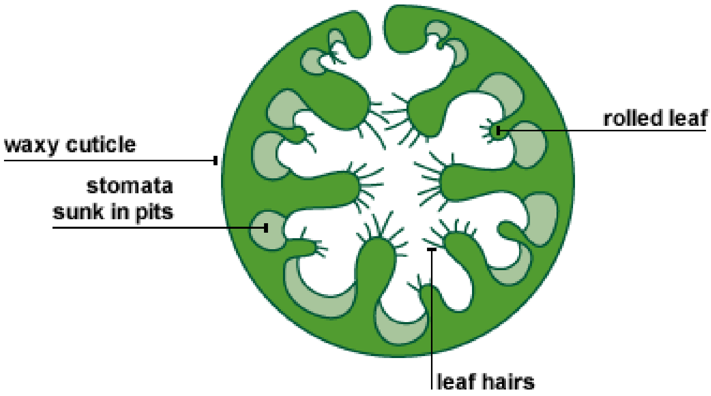
- This also allows minerals absorbed from the soil to be transported through the xylem to the leaves.

Active uptake of mineral ions:



- If the mineral ion concentration of a certain ion is greater inside the **root cell** than the surrounding soil, mineral ions have to be actively transported out of the root cell.
- Also the charged particles cannot directly cross the cell membrane because of the non-polar region inside the bilayer.
- **Proton pumps** use energy (ATP) to pump protons (H^+) out of the root cell into the surrounding soil.
- This results in a higher concentration of protons outside the root cells creating an electrochemical and concentration gradient.
- H^+ can combine with sucrose, NO_3^-, PO_4^{3-}, and other anions to bring them back into the root cell through **protein channels**, following the concentration gradient established by the proton pumps.
- K^+ ions can flow directly through special channels following the electrochemical gradient created by the proton pumps.
- Cations such as potassium can also enter the root cell through specialized potassium pumps that use ATP to pump K^+ directly into the cell.
- Since there is a greater concentration of ions or solutes inside the root cells, water will move into the root cells by osmosis
- Active uptake of mineral ions results in a higher concentration of minerals inside the root cells, thereby transporting water into the root cell by osmosis

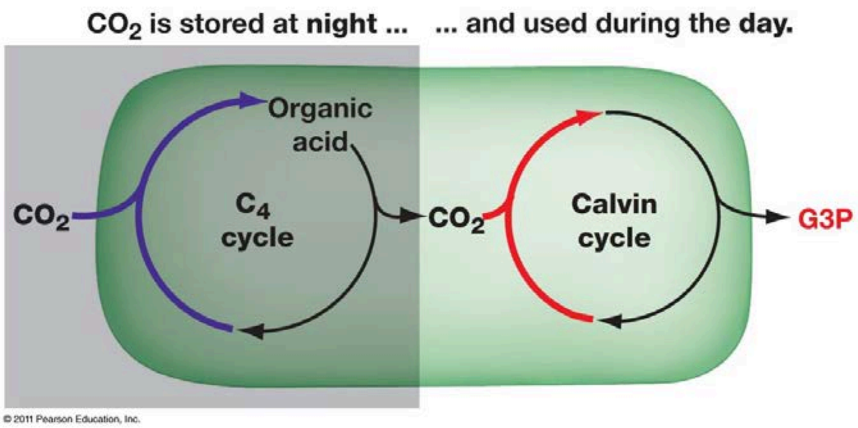
Xerophytes:



- Xerophytes are plants can survive in dry condition by reducing transpiration (water loss).
- **Reduced leaves**: conifers have needles and cacti have spines. This decreases the surface area available for transpiration, thus decreasing water loss.
- **Rolled leaves**: Stomata exist inside of rolled leaves. This creates local humidity within the rolled leaf, thus decreasing the leaf's exposure to air currents because water vapour evaporates into the small air space inside the rolled leaf rather than atmosphere. This decreases water loss through transpiration.
- **Reduced number of stomata:** Some xerophytes have a reduced number of stomata. By reducing the number of stomata, water loss through transpiration is decreased because there are fewer holes for evaporation to take place.
- **Thickened waxy cuticle**: Thick waxy cuticle makes the leaves and in some cases stems, more waterproof and impermeable to water. This prevents water loss through the epidermal cells.

CAM plants (Crassulacean acid metabolism):

- CO_2 is absorbed at night and store as C_4 compound
- During the day, photosynthesis can occur with stomata closed by using carbon storage C_4
- It can minimize the time period which stomata opens and loses water to surroundings.



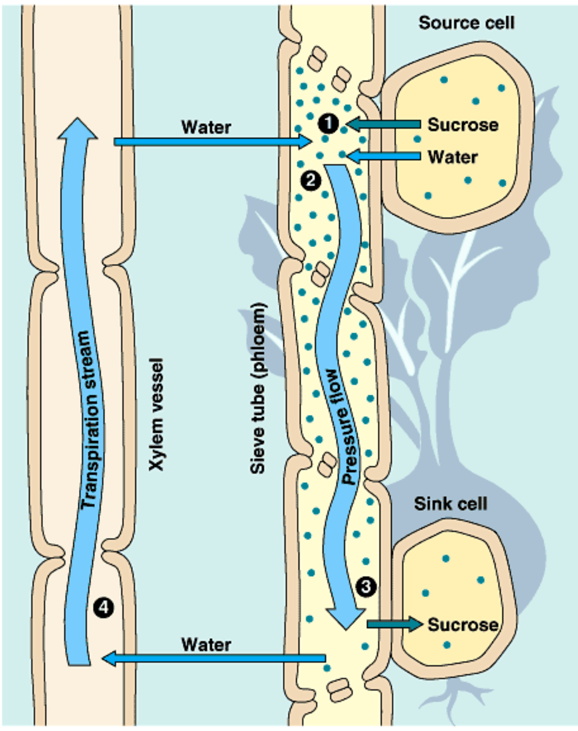
9.2 Transport in the phloem of plants

U1	Plants transport organic compounds from sources to sinks.
U2	Incompressibility of water allows transport along hydrostatic pressure gradients.
U3	Active transport is used to load organic compounds into phloem sieve tubes at the source.
U4	High concentrations of solutes in the phloem at the source lead to water uptake by osmosis.
U5	Raised hydrostatic pressure causes the contents of the phloem to flow towards sinks.
A1	Structure–function relationships of phloem sieve tubes.
S1	Identification of xylem and phloem in microscope images of stem and root.
S2	Analysis of data from experiments measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide.

Transportation in phloem:

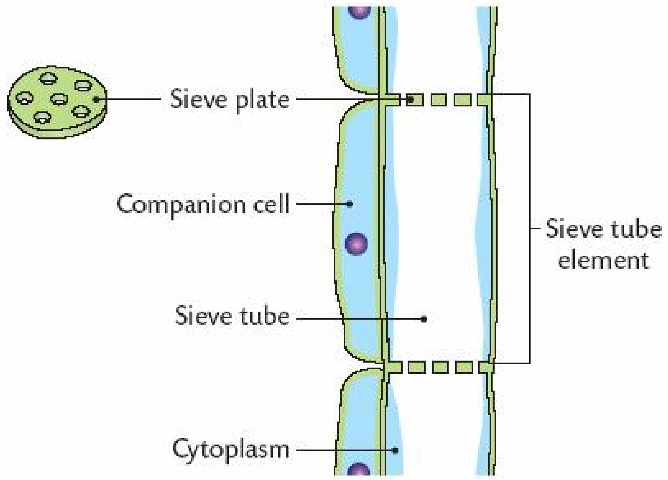
- Sources: site of photosynthesis
- **Sink**: storage of molecules
- Organic molecules such as sucrose and amino acids move from a source to a sink via phloem tubes in plants.
- Phloem tubes can carry sugars and amino acids in a variety of directions; depending on where the source and the sinks are located (sometimes roots can be sources or sinks).
- Sources produce sugars by photosynthesis in leaves or green stems or by hydrolysis of starch in storage vessels (germinating seeds or roots/tubers) and deliver these products via the phloem to the sink (roots, buds, stem, seeds, and fruits).
- At the source, sugar and other organic molecules are loaded into the sieve tube members thus increasing solute concentration within the sieve tube cells (deceases water potential).
- Water from surrounding tissues, enters the sieve tube members by osmosis following a concentration gradient.
- The water absorbed into the sieve tube creates hydrostatic pressure that forces the phloem sap to flow (bulk flow) towards the sink.

1. **Active transport** of sugar from leaves to phloem
2. Water concentration attracts water diffuses from xylem to phloem
3. High pressure is generated by water and sugar
4. Water and sugar moves down from leaves to root
5. **Active transport** moves sugar molecules to root cells
6. Water concentration decreases, water diffuses back to xylem
7. This will create low pressure, causing water to move up



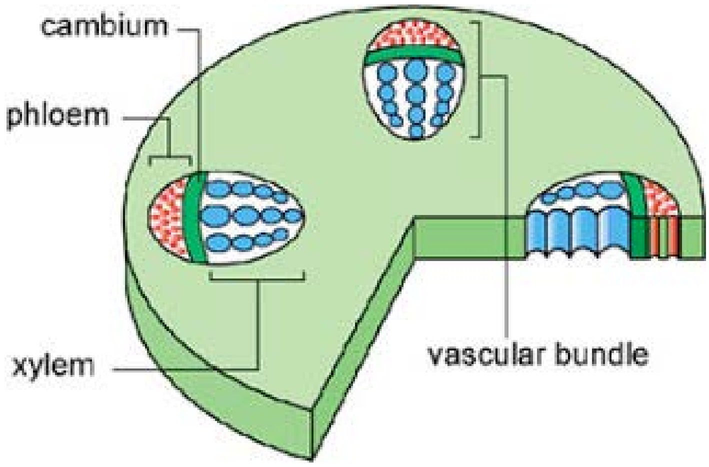
Structure of phloem:

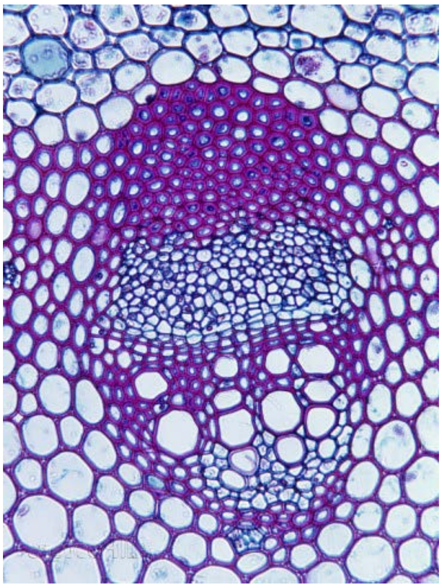
- Organic molecules such as sucrose and amino acids move from a source to a sink via phloem tubes in plants.
- Phloem is composed of living tissue called **sieve plates** (lack a nucleus) that are joined end to end to form a tube that conducts food materials throughout the plant. They are bordered by **companion cells** that carry out the cellular functions of a sieve-tube element.
- **Rigid cell walls** – building up for high pressure
- **Sieve plates** – large pores in cell wall speeding the transport between sieve element cells
- **Companion cells** – provide nutrients and energy to sieve element cells



Vascular bundle:

- Cambium layer – undifferentiated cells which can become xylem or phloem
- Pith – woody part in between vascular bundle
- Epidermis cells – surface cells
- Phloem – smaller tubes
- Xylem – larger tubes



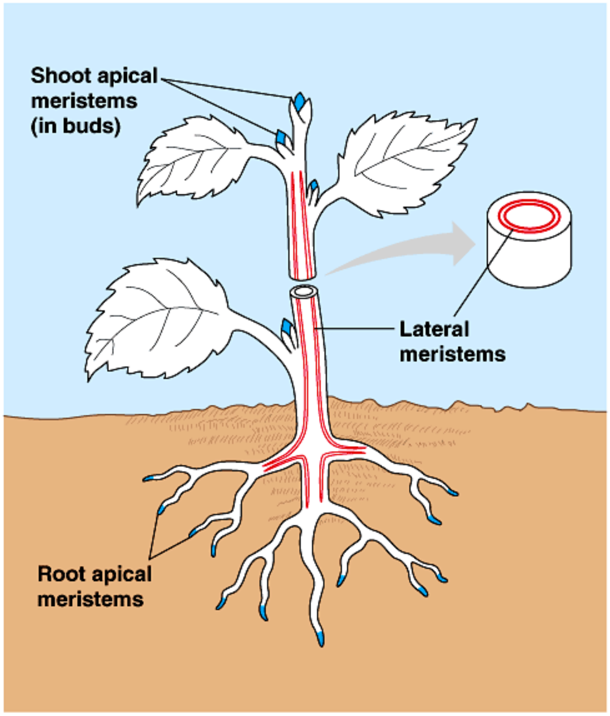


9.3 Growth in plants

U1	Undifferentiated cells in the meristems of plants allow indeterminate growth.
U2	Mitosis and cell division in the shoot apex provide cells needed for extension of the stem and development of leaves.
U3	Plant hormones control growth in the shoot apex.
U4	Plant shoots respond to the environment by tropisms.
U5	Auxin efflux pumps can set up concentration gradients of auxin in plant tissue.
U6	Auxin influences cell growth rates by changing the pattern of gene expression.
A1	Micropropagation of plants using tissue from the shoot apex, nutrient agar gels and growth hormones.
A2	Use of micropropagation for rapid bulking up of new varieties, production of virus-free strains of existing varieties and propagation of orchids and other rare species.

Meristem:

- Meristem tissues in all plants consist of undifferentiated cells (meristematic cells) that generate new cells for plant growth.
- Plant growth is generally indeterminate, which means cells will continue to grow indefinitely
- Meristems are areas where growth occurs and are composed of undifferentiated cells undergoing active cell division
- **Apical meristems** are at the tips of the roots and stems. They are responsible for primary growth of the plant
- **Lateral meristems** are responsible for secondary growth (increasing the diameter and thickness of the plant). They are located in **cambium layer**.
- Cells in the meristems undergo mitosis repeatedly to produce new cells and growth in a plant
- Root meristems are responsible for growth and extension of the root
- Shoot meristems creates cells responsible for shoot growth, but also create cells that will develop into flowers and leaves
- **Auxillary buds**: inactive meristem tissue. When the plant needs to grow a now branch, hormones will activate the bud and continue to grow.



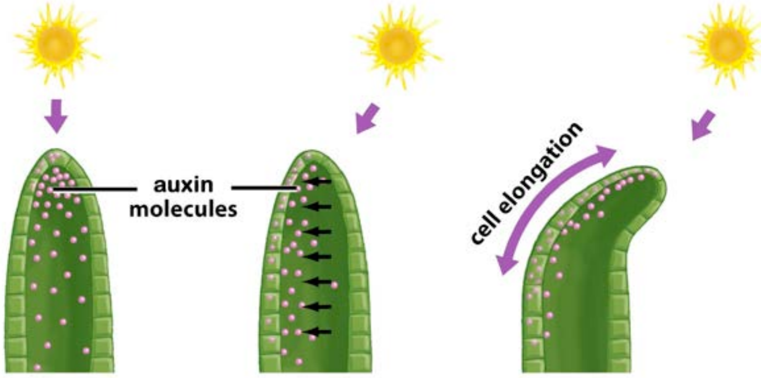
Hormones:

- Hormones are chemical messages produced and released by one part of an organism that has an effect in another location
- One of the main plant hormones is **auxin**
- Auxins initiate growth of roots, regulate leaf development, and influence the development of fruits
- High concentration of auxin promotes the growth in shoot.
- Low concentration of auxin inhibits the growth in root.

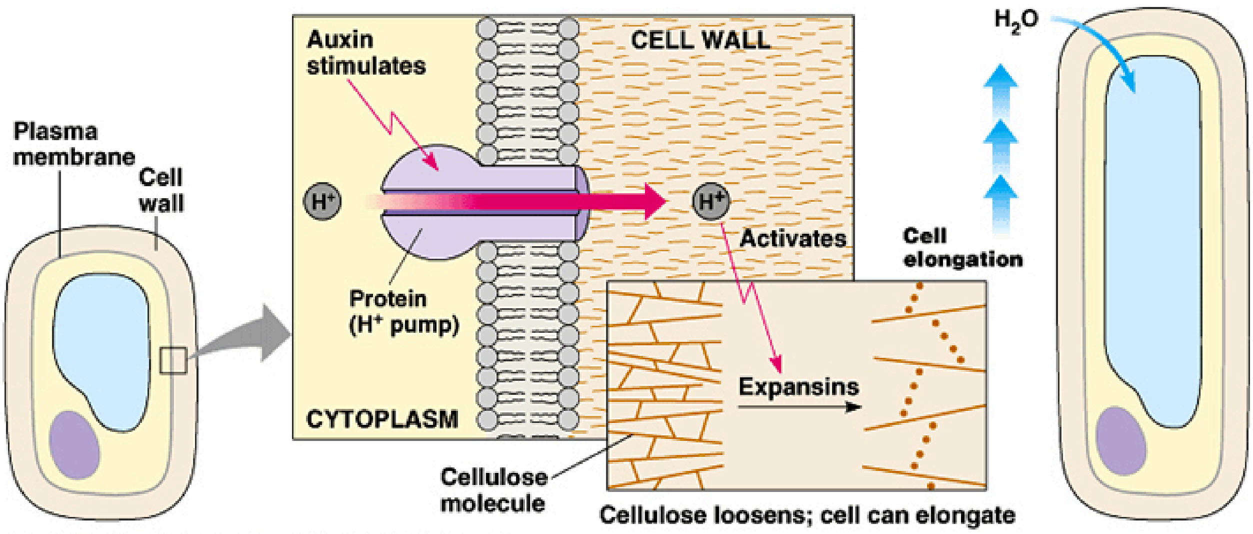
Tropisms:

- A tropism is growth or movement towards or away from an **external stimulus**, such as light, gravity or chemicals.
- Gravitropism is growth in response to gravity
- Phototropism is growth towards or away from an external light source.
- Generally in plants, shoots grow towards the light (**positive phototropism**) and roots grow away from the light (**negative phototropism**).
- Phototropism is essential for plants to make sure they grow towards the sunlight.
- Auxins are plant hormones that promote positive phototropism in plants
- Auxin concentration will increase in an area opposite to the direction of sunlight, thereby stimulating the fast growth of that area, leading to a turn of the shoot.

Auxin efflux pumps:



- **Phototropins** (light receptors) in the tips of the plant detect sunlight.
- Axuin enters the cell by diffusion, **influx transporter proteins**.
- Axuin moves out of the cell by **effiux transporter proteins**.
- Transporter proteins can be activated/inhibited by stimuli such as sunlight.
- If the amount of sunlight is greater on one side of the plant, the phototropins trigger reactions that will cause the redistribution of auxin by efflux pumps to the dark side of the plant.
- High concentrations of auxins cause cells on the shaded side of the cell to swell and elongate.
- When auxin binds to a receptor in the nucleus, this activates a **proton pump**
- The proton pump moves **H^+ ions** into spaces in the **cell wall**, decreasing the pH
- This results in the breaking of the hydrogen bonds between **cellulose fibres**, resulting in **the swelling and elongation of these cells**.
- As the cells elongate and swell on one side of the plant the stem starts to curve towards the light source because of this uneven growth.
- The plant now is growing towards the light source (phototropism).
- For gravitropism auxin is redistributed to the side of the gravity
- Auxin in this case inhibits cell elongation and as the top part of the root grows and extends, the root turns towards the direction of the gravitational pull
- This is opposite to phototropism



Micropropagation:

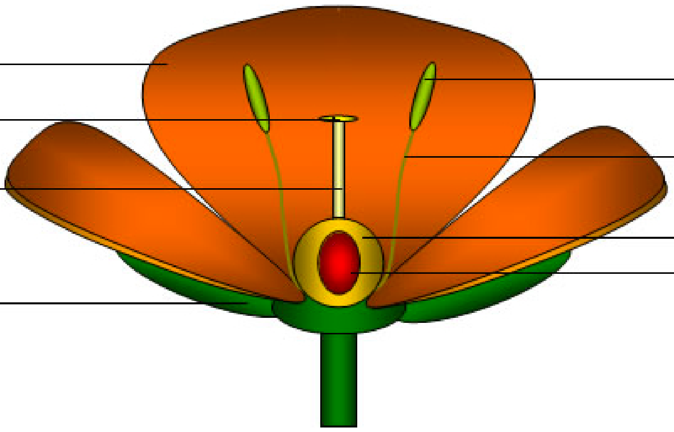
- Micropropagation is an in vitro process that produces large number of cloned identical plants
- Micropropagation depends on the totipotency of plant tissues
- Tissues from the stock plant are sterilized and cut into pieces called **explants**
- The explant is placed into a sterilized growth medium that contains plant growth hormones
- These hormones include auxin.
- Once the plant has roots and shoots, it can be transferred to soil
- Plant virus are usually transported in vascular tissue, which is not presented in meristems.
- Micropropagation of plants, allows for the production of **virus free strains** of plants
- It can also be used to produce plants with desirable characteristics much faster using less space
- You can also store little plantlets for long periods of times in liquid nitrogen, which would be valuable with endangered species.

9.4 Reproduction in plants

U1	Flowering involves a change in gene expression in the shoot apex.
U2	The switch to flowering is a response to the length of light and dark periods in many plants.
U3	Success in plant reproduction depends on pollination, fertilization and seed dispersal.
U4	Most flowering plants use mutualistic relationships with pollinators in sexual reproduction.
A1	Methods used to induce short-day plants to flower out of season.
S1	Drawing internal structure of seeds.
S2	Drawing of half-views of animal-pollinated flowers.
S3	Design of experiments to test hypotheses about factors affecting germination.

Structure of the flower

- Anther: create pollens
- Stigma: pollen landing site
- Style: where pollen tubes grow down
- Petals: for attraction
- Sepals: protecting growing flower
- Ovary: contains **ovules** (eggs)
- Filament: support for stigma



Control of flowering

- **<u>Photoperiodism</u>** is a plant's response to light involving the lengths of day and night; which causes flowering in plants.
- It has been determined that the length of the night (darkness) not the length of the day (light) determines flowering in short-day and long-day plants.
- **<u>Phytochrome</u>** is the photoreceptor or a pigment that plants use to detect light.
- It is sensitive to light in the **red** and **far red** region of the visible spectrum.
- Two forms of phytochrome exist; P_r (inactive form) and P_{fr} (active form).
- P_r absorbs red light (660 nm) while P_{fr} absorbs far red light (730 nm) of the visible spectrum.
- During **daylight** hours when P_r absorbs red light it is converted to P_{fr} and when P_{fr} absorbs far red light it is converted back to P_r. Because there is more red light in sunlight, during the daylight, there if a build-up of P_{fr}.
- At **night** P_{fr} is slowly converted back into P_r. Therefore after a long day of sunlight (**summer**), there will be more P_{fr} in the plant than after a short day of sunlight (winter).
- In long day plants (plants that flower in the summer) P_{fr} stimulates flowering, thus in the summer when there is a build-up of P_{fr}, long day plants flower at the right time.
- In short day plants (plants that flower in the spring or autumn) P_{fr} inhibits flowering, thus preventing these plants from flowering in the summer months when the days are long.

Length of the daylight	P_r level	P_{fr} level
Long (summer)	low	high
Short (winter)	high	low

- **Critical night length**: minimum darkness needed to flower.
- In long day plants, such as **<u>iris</u>**, they only flower when day length reaches a critical period. P_{fr} builds up to a critical point.

- In short day plants, such as **chrysanthemum**, they only flower when length below a critical period. P_{fr} falls below a critical point.

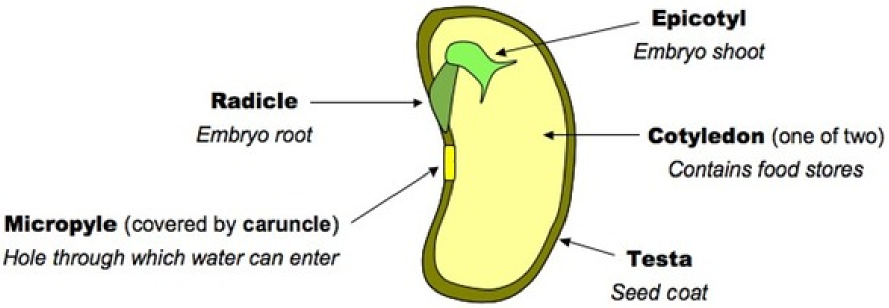
- Flowers, which allow the plant to sexually reproduce, develop from the shoot **apical meristem** and are called a reproductive shoot
- Temperature and day length (mostly period of darkness) can transform a leaf producing shoot into a flower producing shoot
- The amount of light a plant receives, play a role in the production of either **inhibitors or activators of genes** that control flowering
- In long day plants, the active form of the phytochrome pigment P_{fr}, leads to transcription of a gene that controls flowering (**FT gene**)
- The FT mRNA is transported to the shoot apical meristem in the phloem, where it is translated into the **FT protein**
- The protein binds to a transcription factor, which turns on many flowering genes, thus converting the leaf producing meristem into a flower producing reproductive meristem

Pollination:

- Pollination is the process in plants in which **pollen grains** (male gametes) are transferred to the female gametes (**ovules** contained within the carpel), thereby enabling fertilization and sexual reproduction.
- Seed dispersal is the movement or transport of seeds away from the parent plant. This decreases competition between parents and offspring and promotes diversity within the species. Seeds can be dispersed through gravity, wind, water and by animals.
- **Mutualism** is the relationship between two organisms, where both organisms benefit
- Sexual reproduction depends on the transfer of pollen stamen from one plant to the stigma of another plant
- Pollen can be transferred by wind and possibly water, but more commonly pollen is transferred by animals known as pollinators such as bees, butterflies, birds, and bats
- Pollinators gain food from nectar and the plant gains a method to transfer pollen to another plant to allow for sexual reproduction

Seed:

- Radicle: embryonic root
- Plumule: embryonic stem
- Micropyle: allow water to enter
- Scar: where the ovule to the ovary
- Testa: seed coat



- **Germination**: when seeds begin to grow.
- Water enters the seed through micropyle and activate the seed
- Hormones are activated, which will lead to the production of amylase.
- Amylase breaks down starch into maltose.
- Maltose is absorbed by plumuble and radicle.
- If the seed has a single leaf, it is **monocot**.
- If the seed has two leaves, it is **dicot**.