Topic 9: Plant biology (13 hours)

9.1 Transport in the xylem of plants: Structure and function are correlated in the xylem of plants.

Understandings:

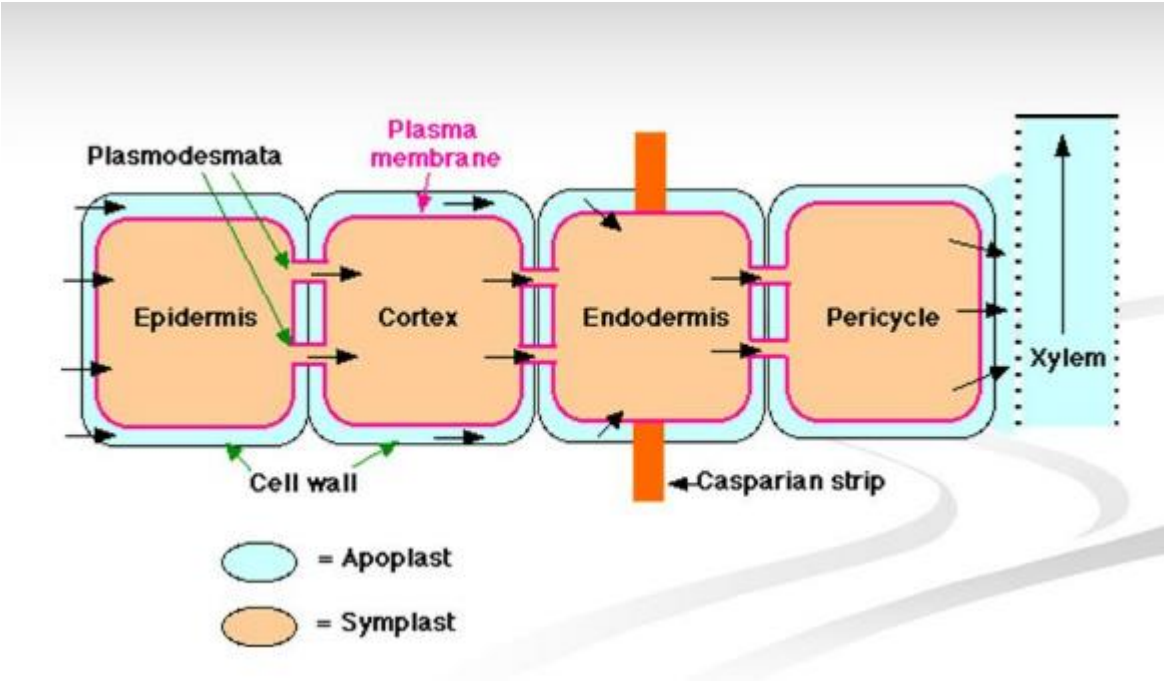
∑ **- Transpiration is the inevitable consequence of gas exchange in the leaf.**

- CO^2 is needed for photosynthesis to take place in the leaves and O^2 is released as a by-product of this process
- Gas exchange between these two gases occurs through the stomata
- When the stomata are open and gas is exchanged, water is also lost throughtranspiration
- Guard cells regulate transcription by opening and closing the stomata.
- Stomata open and close depending on the turgor pressure in the surrounding guard cells.
- When guard cells take in water, the turgor pressure increases, the cells swell causing them to bow outwards, thus opening the stoma.
- When the guard cells lose water, the turgor pressure decreases and the guard cells become flaccid, causing the stoma to close.
- There is also adhesion between water molecules and the inside of the xylem vessels.
- Cohesion and adhesion both help maintain the water column all the way up from the root to the leaf.

*****Data Based Question 407*****

∑ **- Plants transport water from the roots to the leaves to replace losses from 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.
- 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.
- Transpirational pull results from the combined forces of cohesion and adhesion
- Water moves into the roots by osmosis through the cell walls (apoplast pathway) and through the cytoplasm (symplast pathway) because the concentration of solutes inside the cells is greater than outside the root cells due to active transport of mineral and ions



∑ - The cohesive property of water and the structure of the xylem vessels allow transport under tension.

- 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 known as tracheids and vessel elements.
- The walls of the xylem are thickened and strengthened by a polymer called lignin
- 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.
- 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

∑ - The adhesive property of water and evaporation generate tension forces in leaf cell walls.

- Water evaporates from the surface of the cell wall

- Adhesion allows for water to be drawn through the cell wall from the xylem in the veins of the leaf, which is the nearest water supply
- Even though water pressure in the xylem is already low, the adhesive force between water and the cell walls is great enough to suck the water out of the xylem. This further lowers the pressure
- This low pressure creates a pulling force down through the stems to the tips of the roots
- This force effectively pulls water up from the roots to the leaves against the force of gravity
- The pulling of water up the xylem also depends on the cohesion between water molecules

∑ - Active uptake of mineral ions in the roots causes absorption of water by osmosis.

- If the mineral ion concentration of a certain ion is greater inside the root cellthan the surrounding soil, mineral ions have to be actively transported into 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 theelectrochemical 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

*****Data based Question – p.408*****

β - Application: Adaptations of plants in deserts and in saline soils for water conservation.

Xerophytes are plants that are adapted to grow in very dry conditions.

Adaptations

Reduced leaves

- Conifers and cactus plants both have reduced leaves; conifers have needlesand 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.

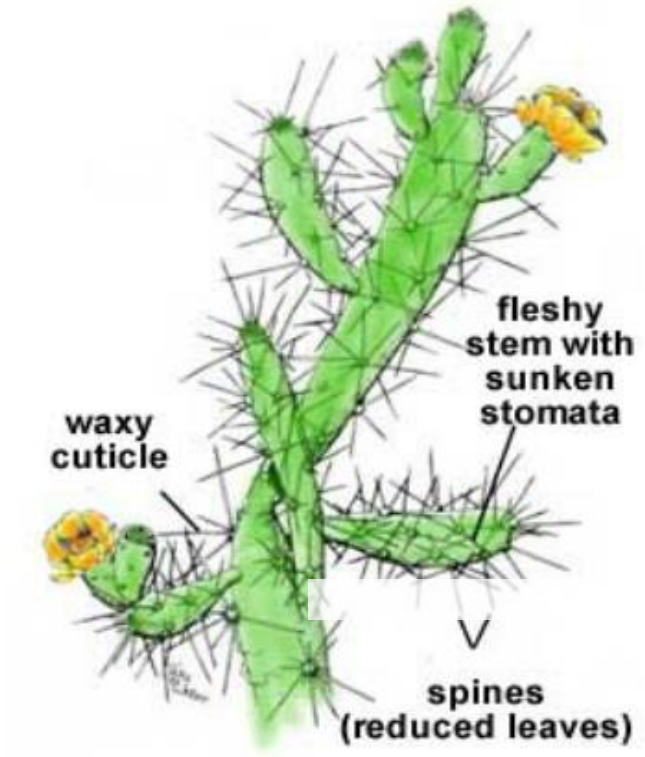
Thickened waxy cuticle

- 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.

Stomata in pits surrounded by hair

- Stomata sunken in pits and presence of hair creates local humidity by trapping moist air close to the leaf.
- The sunken stoma also decreases exposure to air currents and the hair reduces air flow around the stomata.
- Both of these factors decrease water loss from the plant.

Other adaptations by xerophytes are **deep roots (**maximum water absorption),**water storage tissue** (specialized cells store water in cacti), **CAM and C_4plants** (have specialized techniques of CO_2 fixation) and **opening of stomata at night**

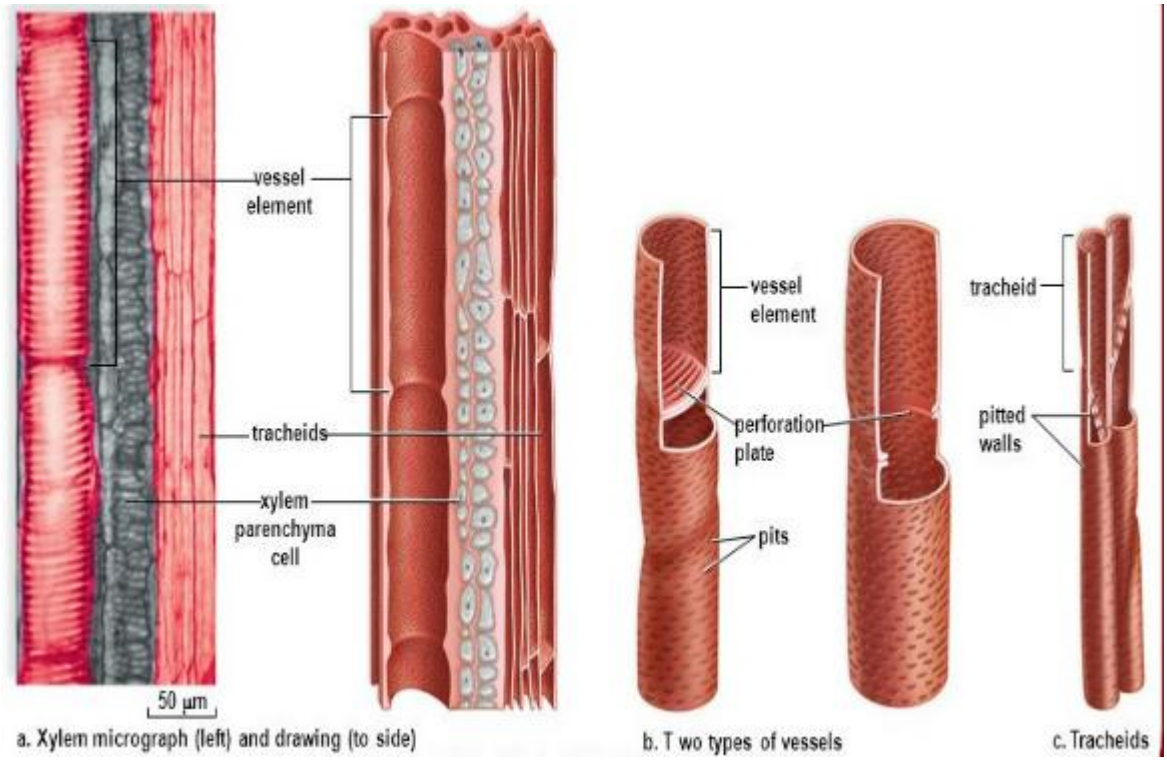


β - Application: Models of water transport in xylem using simple apparatus including blotting or filter paper, porous pots and capillary tubing.

Nature of science: Use models as representations of the real world—mechanisms involved in water transport in the xylem can be investigated using apparatus and materials that show similarities in structure to plant tissues.

- models allow one factor/aspect to be studied independently
- (glass) capillary tubes to model adhesion between water and xylem vessel walls
- porous pot to model flow in a xylem vessel due to transpiration from the leaf
- blotting paper OR porous pot OR other suitable material to model capillary attraction/adhesion

β - Skill: Drawing the structure of primary xylem vessels in sections of stems based on microscope images.



The McGraw-Hill Company

PRACTICAL

Measurement of transpiration rates using potometers. Design of an experiment to test hypotheses about the effect of temperature or humidity on transpiration rates.

Aims: The introduction of image processing software and digital microscopes increases further the ability to gather more data to ensure reliability. Measurement

of stomatal apertures and the distribution of stomata using leaf casts, including replicate measurements to enhance reliability, are possible experiments.

Online Transpiration Lab – IB Biology http://www.mhhe.com/biosci/genbio/virtual_labs/BL_10/BL_10.html

Transpiration Lab with Potometer

See handout on Manage Bac

Light

- Light causes the rate of transpiration to increase as the stomata open.
- Phototropins absorb the blue wavelength of visible light.
- This causes proton pumps to pump H^+ out of the cell, making the inside of the guard cell more negatively charged.
- This negative charge causes the uptake of K^+ ions, thus increasing the solute concentration inside the guard cells. Water flows into the guard cells by osmosis causing the stoma to open, thus increasing the transpiration rate.

Temperature

- As the temperature increases evaporation rates also increase. Increasing the temperature also raises the temperature inside the leaf.
- This speeds up the rate of diffusion between the air spaces inside the leaf and the air surrounding the leaf.
- The overall effect is an increase in the rate of transpiration.

Wind

- If there is no wind, the air surrounding a leaf becomes increasingly humid thusreducing the rate of transpiration.
- When wind is present, the humid air is carried away and replaced by drier air, thus increasing the rate of transpiration.

Humidity

- Humidity is the amount of water vapour in the air.
- The lower the humidity is outside the cell, the greater the rate of diffusion ofwater is from inside the leaf through the stomata to the surrounding air.
- Therefore in low humidity conditions the transpiration rate increases.
- If the surrounding air has a high humidity, then the transpiration rate decreases.

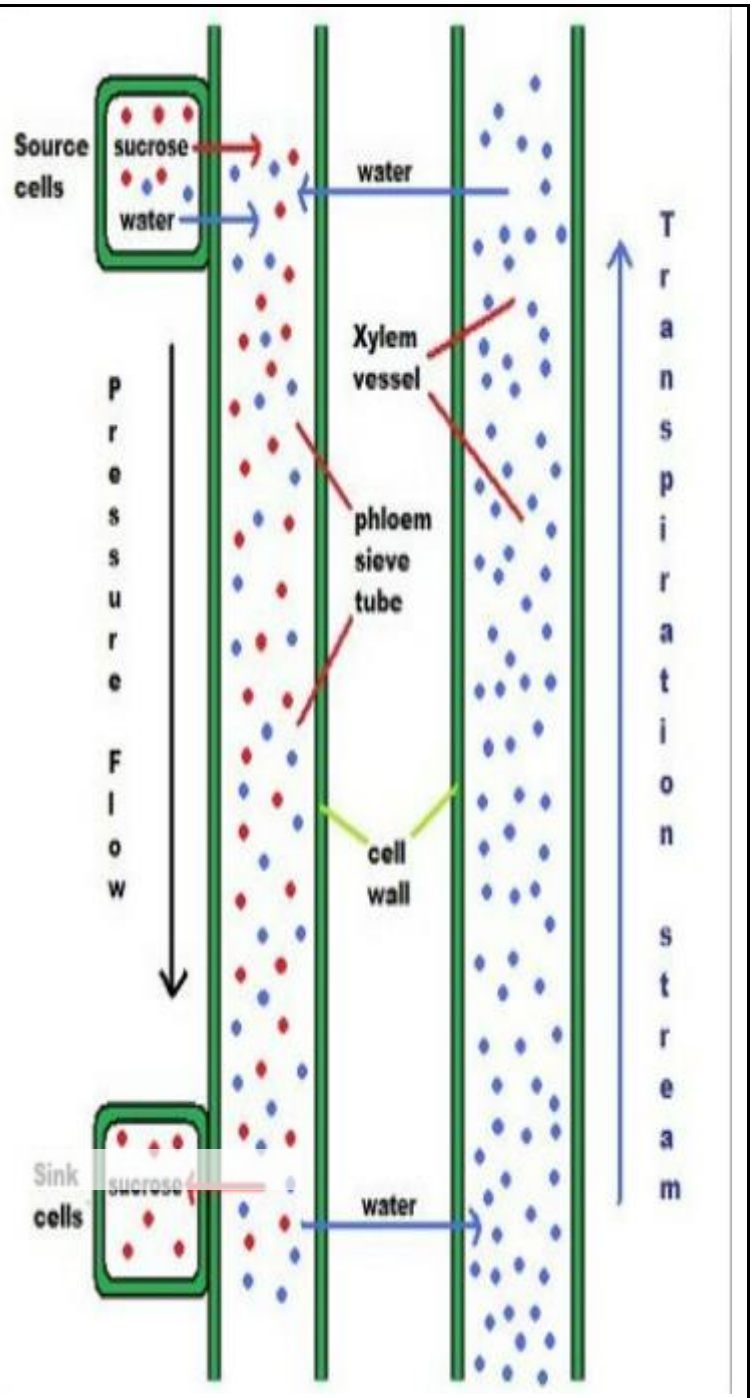
9.2 Transport in the phloem of plants: Structure and function are correlated in the phloem of plants.

Nature of science: Developments in scientific research follow improvements in apparatus—experimental methods for measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide were only possible when radioisotopes became available.

Understandings:

∑ - Plants transport organic compounds from sources to sinks.

- 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 calledsieve tube members (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.
- Phloem tubes cancarry 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



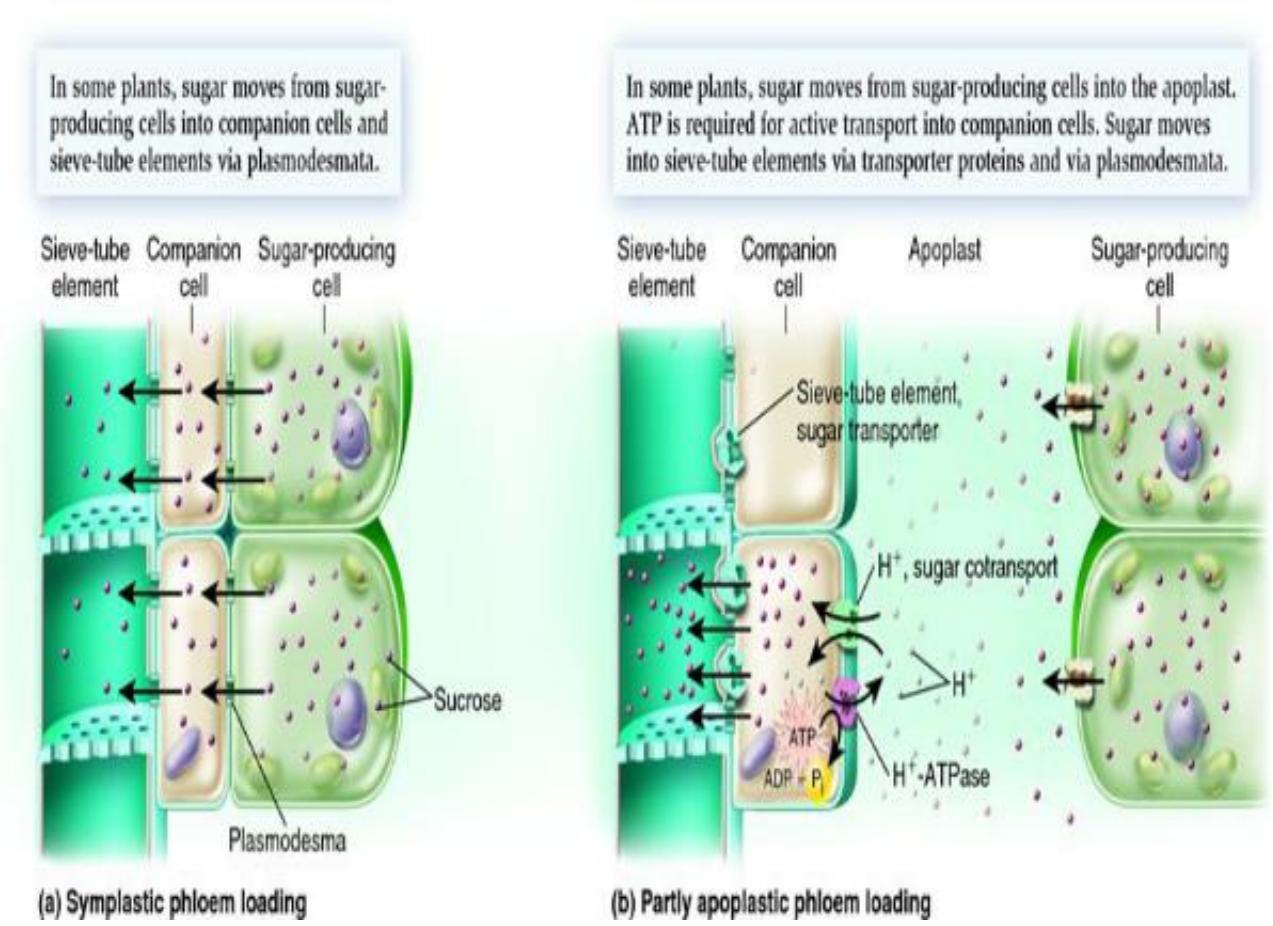
(deceases water potential). • Water from surrounding tissues, enters the sieve tube members by osmosis following a concentration gradient. • The water absorbed into the sieve tube creates hydrostatic pressure that forces the phloem sap to flow (bulk flow)towards the sink.	

∑ **- Active transport is used to load organic compounds into phloem sieve tubes at the source.**

- Sugars are actively unloaded at the sink and water returns into the xylemtubes reinforcing the pressure gradient from the source to the sink.

- Water is recycled by the xylem, returning it from the sink back to the source.

- At the source sugars are loaded through active transport in a process called phloem loading
- In some plants sugars travel through cell walls from mesophyll cells to cell walls of companion cells and some sieve cells. Sugar is then actively transported into the phloem by a sucrose transport protein (Apoplast Pathway)
- Protons are pumped out of the companion cells from the tissues by active transport, using ATP as an energy source.
- This creates a proton gradient. H^+ binds with sucrose and flows back into the companion cell-sieve tube complex through a co-transport protein, following its concentration gradient, and pulling sucrose molecule with it into the cell.
- In other plants, sucrose can travel between cells through connections called plasmodesmata (symplast route)
- Once the sucrose reaches the companion cell, it is converted to an oligosaccharide, which maintains the sucrose concentration gradient



Video – https://www.youtube.com/watch?v=MxwI63rQubU

*****Data Based Questions p. 414-415*****

∑ - Incompressibility of water allows transport along hydrostatic pressure gradients.

- Build-up of sucrose and solutes, causes water to enter the companion cells through osmosis
- The incompressibility of water and ridged cell walls causes a build-up of pressure
- Water flows from high pressure to low pressure
- Sucrose is used as an energy source at the sink for growth or converted to starch for storage, reducing the amount of sucrose and thus reducing osmotic pressure
- Water that carried the solute is drawn back into the xylem

*****Data Based Questions p 415*****

∑ - High concentrations of solutes in the phloem at the source lead to water uptake by osmosis.

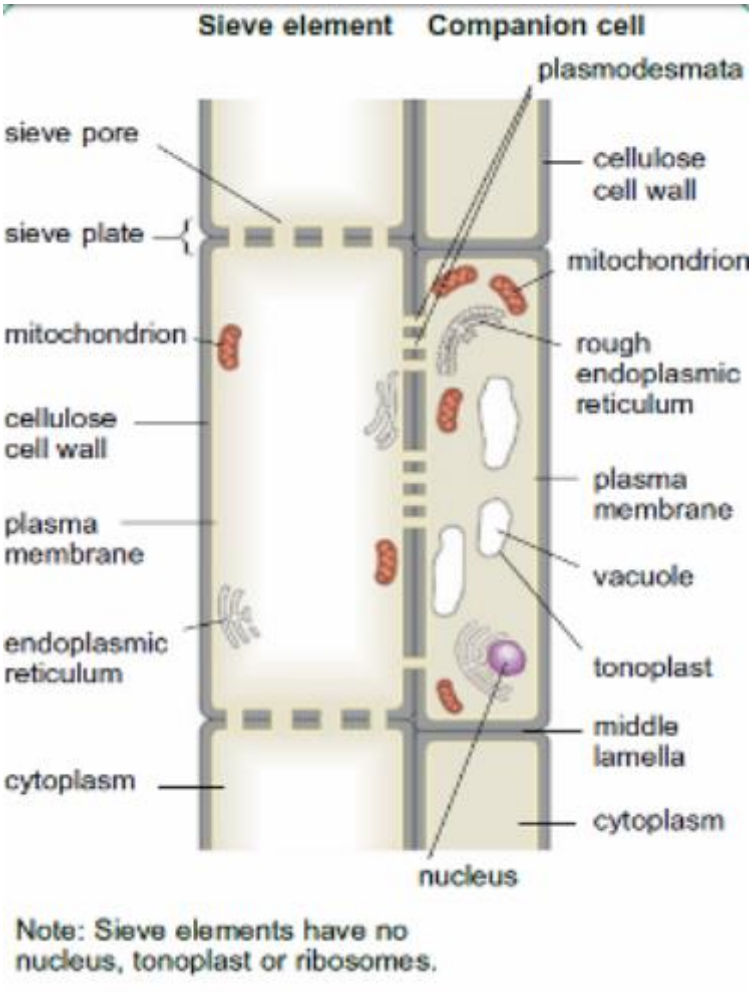
∑ - Raised hydrostatic pressure causes the contents of the phloem to flow towards sinks.

- 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 osmosisfollowing 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

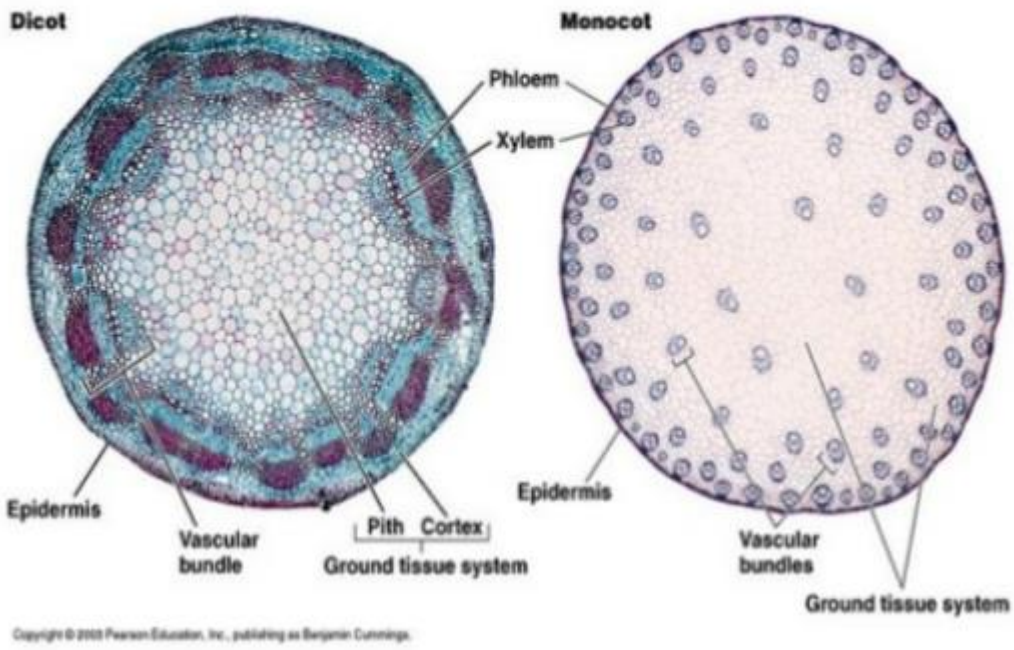
Applications and skills:

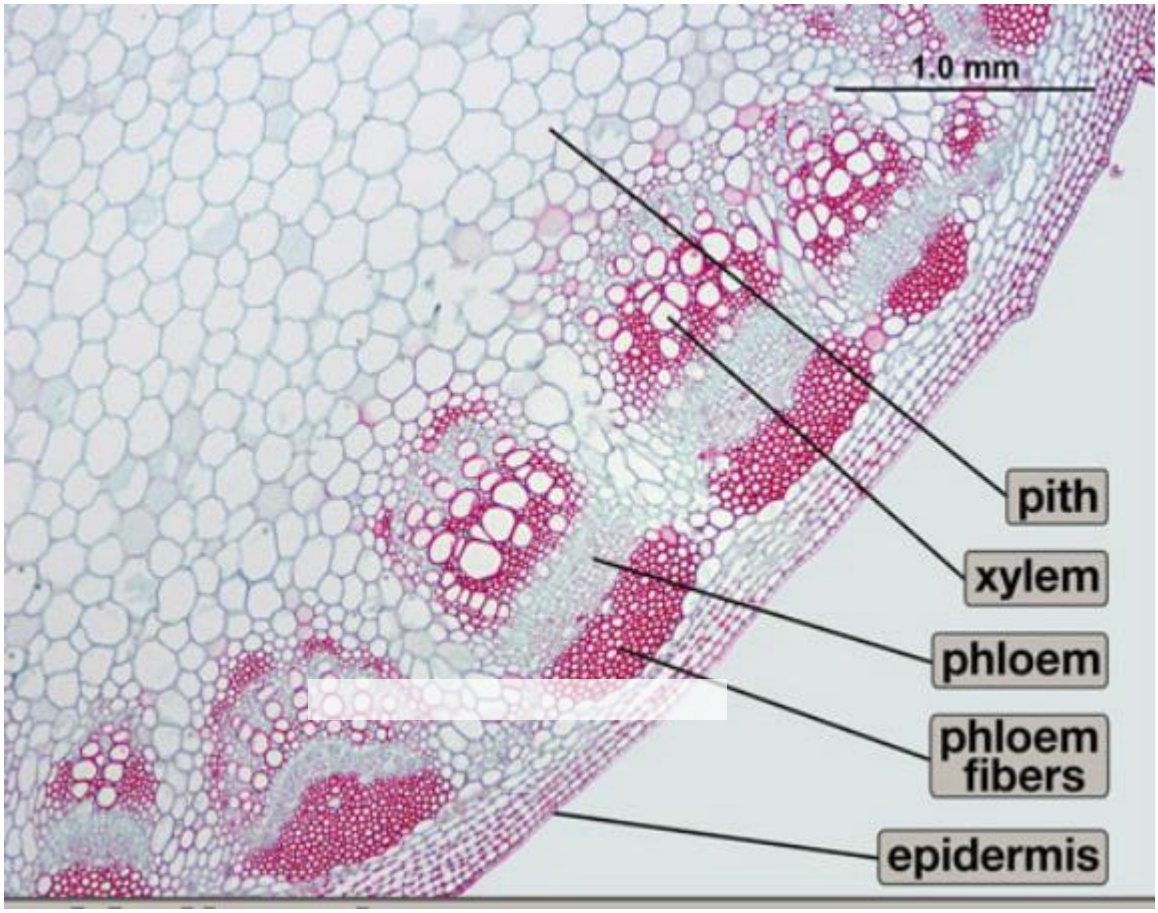
β - Application: Structure–function relationships of phloem sieve tubes.

Structure	**Function**
Sieve tube cell are living	Membranes help maintain sucrose and organic molecule concentration by active transport
Companion cells	Perform many of the genetic and metabolic functions of the sieve tube cell to maintain its viability
Mitochondria	Abundant to supply energy for active transport of sucrose
Infolding of plasma membrane	Increases phloem loading capacity using apoplastic pathway
Plasmodesmata	Connect the cytoplasm of companion cells with sieve tube members
Active-transport Proteins /enzymes	Allows for the accumulation of sucrose in the sieve tube/companion cell
Rigid Cell Walls of sieve–tube cells	Allows the creation of enough pressure to achieve the flow of phloem in the sieve-tube cell



β - Skill: Identification of xylem and phloem in microscope images of stem and root.





β - Skill: Analysis of data from experiments measuring phloem transport rates using aphid stylets and radioactively-labelled carbon dioxide.

- Radioactively labeled carbon-14 contained within CO_2 can be fixed by plants by photosynthesis
- The carbon in these sugars created by photosynthesis, is metabolized by the plant and will be found in different molecules within the plat
- This carbon can be detected using film or radiation detectors
- Therefore the movement, use, and formation of these molecules can be traced

***** Data Based Questions p. 419*****

9.3 Growth in plants: Plants adapt their growth to environmental conditions.

Nature of science: Developments in scientific research follow improvements in analysis and deduction—improvements in analytical techniques allowing the detection of trace amounts of substances has led to advances in the understanding of plant hormones and their effect on gene expression.

Understandings:

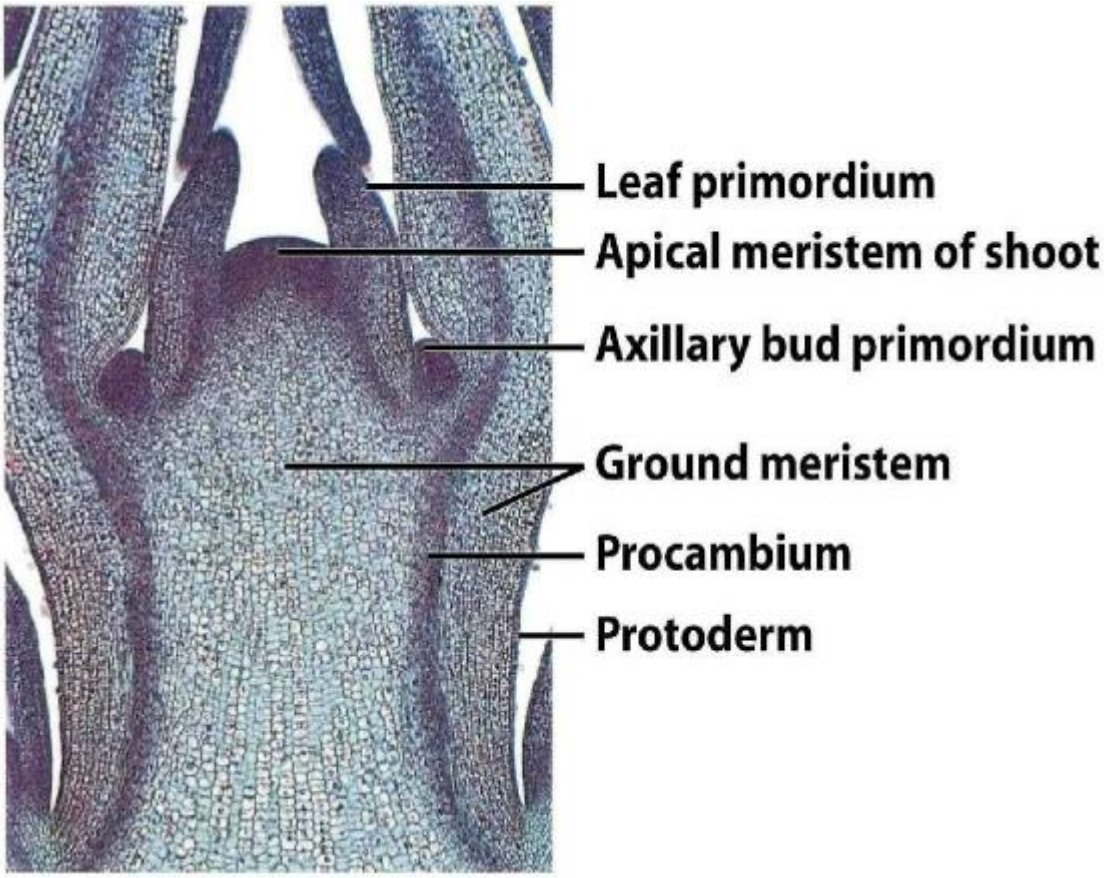
∑ - Undifferentiated cells in the meristems of plants allow indeterminate growth.

- 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
- Many plant cells, even fully differentiated types, can generate whole new plants containing cells that are totipotent
- This characteristic sets plants apart from most animals
- 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)
- Dicot plants have apical (primary growth) and lateral (secondary growth) meristems.

∑ - Mitosis and cell division in the shoot apex provide cells needed for extension of the stem and development of leaves.

- 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

- Apical meristems create additional meristems including protoderm (forms epidermis), procambium (forms vascular tissue) and ground meristem (forms pith)
- Leaf primordia forms leaves



∑ - Plant hormones control growth in the shoot apex. Auxin is the only named hormone that is expected.

- 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
- Indole-3-acetic acid (IAA) controls growth at the shoot apex and promotes elongation of cells in the stems of plants
- IAA is synthesized in the apical meristem and are transported down the stem to promote growth

∑ - Plant shoots respond to the environment by tropisms.

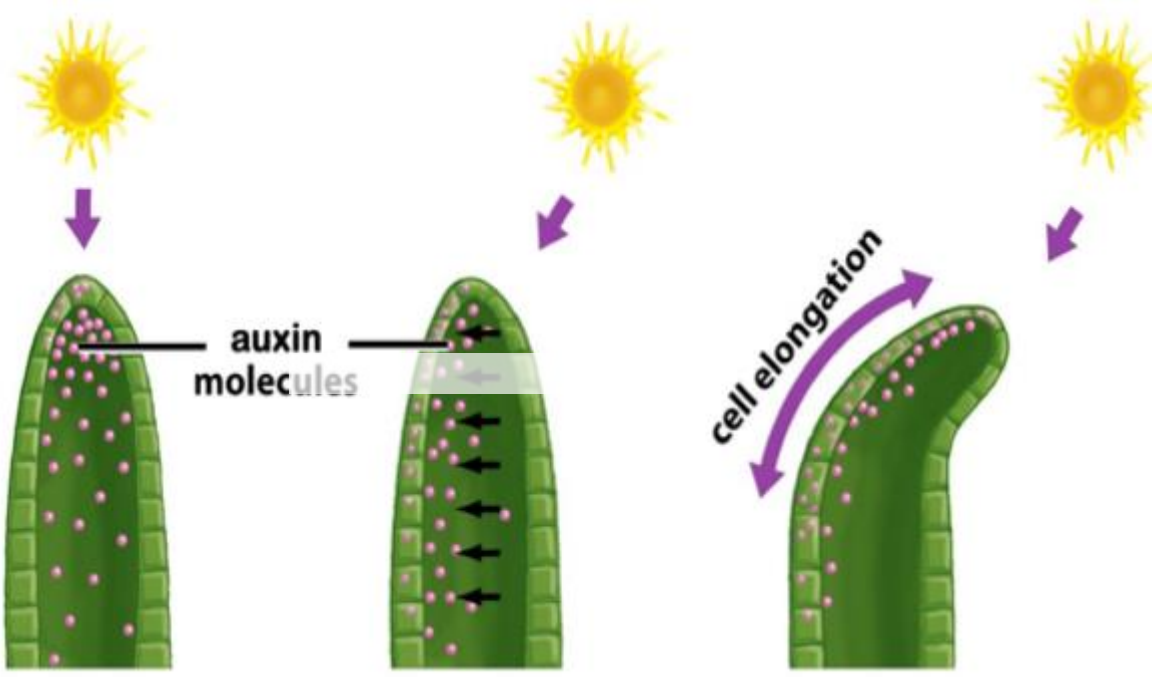
- A tropism is growth or movement towards or away from an external stimulus, such as light, gravity or chemicals.
- Gravitropism is growth in response to gravity
- Phototropism is growth towards or away from an external light source.

- 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 only work on plant cells with auxin receptors and increase the flexibility of plant cell walls in developing shoots
- This enables cell elongation on the side of the shoot necessary to cause growth towards the light

Video: https://www.youtube.com/watch?v=pi3P3uJOsN4

∑ - Auxin efflux pumps can set up concentration gradients of auxin in plant tissue.

- Phototropins (light receptors) in the tips of the plant detect 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

Video on auxin: https://www.youtube.com/watch?v=4-2DZo2ppAY

∑ - Auxin influences cell growth rates by changing the pattern of gene expression. Applications and skills:

- Absorption of light is by photoreceptor proteins called phototropins
- Certain wavelengths of light cause conformational changes and allows them to bind to certain receptors which control the expression of specific genes
- These genes code for a group of glycoproteins that help transport auxin from cell to cell

*****Data Based Questions p.424*****

β - Application: Micropropagation of plants using tissue from the shoot apex, nutrient agar gels and growth hormones.

- Micropropagation is an in vitro process that produces large number of cloned identical plants
- Micropropagation depends on the totipotency of pant 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 and cytokinin
- Is ratio of auxin to cytokinin is 50:50, and undifferentiated cell mass called a callus forms
- If ratio of auxin to cytokinin is greater than 10:1, a roots develop (rooting media)
- If the ratio is less than 10:1 shoots develop (shooting media)
- Once the plant has roots and shoots, it can be transferred to soil

β - Application: 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.

- 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

β - Skill: Investigations into tropisms could be carried out.

- Could develop a lab with tropisms to use for the internal assessment

Theory of knowledge: Plants communicate chemically both internally and externally. To what extent can plants be said to have language?

Video on if plants can talk https://www.youtube.com/watch?v=_yEJxvymDcE

BBC https://www.youtube.com/watch?v=Q-4w5xYLwiU

9.4 Reproduction in plants: Reproduction in flowering plants is influenced by the biotic and abiotic environment.

Understandings:

∑ - Flowering involves a change in gene expression in the shoot apex.

- Vegetative structures include the roots, stems and leaves, develop in young plants
- 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, 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

∑ - The switch to flowering is a response to the length of light and dark periods in many plants.

∑ - Flowering in so-called short-day plants such as chrysanthemums, is stimulated by long nights rather than short days.

- Photoperiodism 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.
- Phytochrome 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; Pr (inactive form) and Pfr (active form).

- Pr absorbs red light (660 nm) while Pfr absorbs far red light (730 nm) of the visible spectrum.
- During daylight hours when Pr absorbs red light it is converted to Pfr and whenPfr absorbs far red light it is converted back to Pr. Because there is more red light in sunlight, during the daylight, there if a build-up of Pfr.
- At night Pfr is slowly converted back into Pr. Therefore after a long day of sunlight (summer), there will be more Pfr in the plant than after a short day of sunlight (winter).
- In long day plants (plants that flower in the summer) Pfr stimulates flowering, thus in the summer when there is a build-up of Pfr, long day plants flower at the right time.
- In short day plants (plants that flower in the spring or autumn) Pfr inhibits flowering, thus preventing these plants from flowering in the summer months when the days are long.
- In autumn when the nights are long, very little Pfr remains in the plant, thus allowing flowering of short day plants at the right time of the year.

*****Data based questions p. 430*****

∑ - Success in plant reproduction depends on pollination, fertilization and seed dispersal.

∑ - Understand the differences between pollination, fertilization and seed dispersal

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.
- Fertilization is the fusion of male and female gametes to produce a diploid zygote. In flowering plants, a double fertilization occurs producing the embryo and the endosperm nucleus.
- 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.

∑ - Most flowering plants use mutualistic relationships with pollinators in sexual reproduction.

- 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 commonlypollen 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

*****Data Based Questions p.432*****

Applications and skills:

β - Application: Methods used to induce short-day plants to flower out of season.

- Growers can influence flowering of flowers out of season, by controlling the length of days and nights
- This is useful to produce flowers out of season used during specific holidays
- Florists can use this to cause certain flowers such as Poinsettias to flower earlier in the season (Thanksgiving instead of just Christmas)

Link http://aggie-horticulture.tamu.edu/ornamental/the-texas-poinsettia-producers-guide/cultural-characteristics/

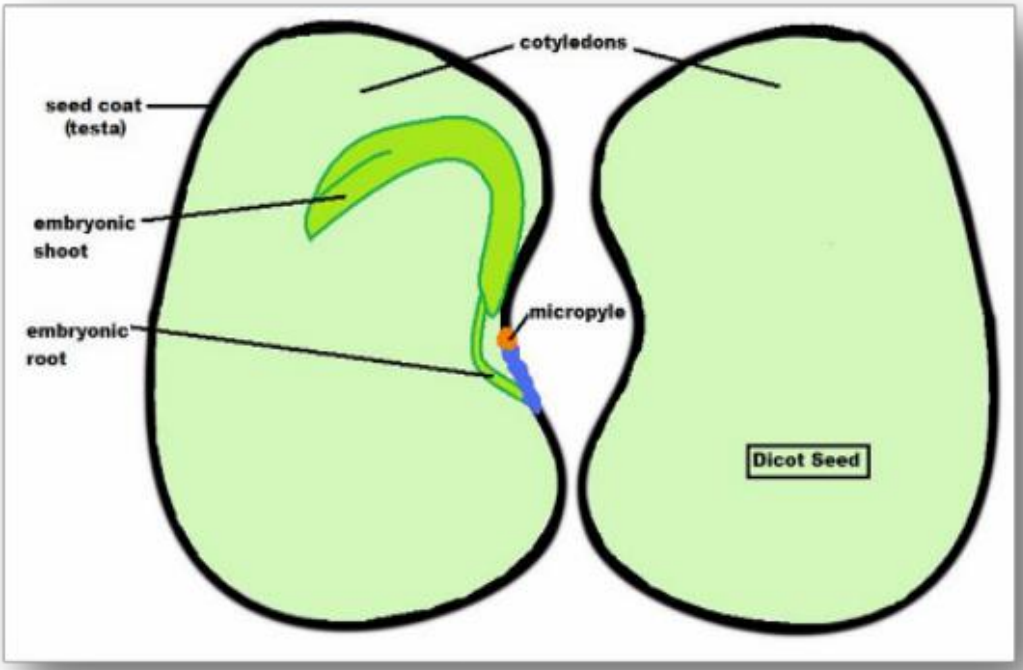
Video on flowering control https://www.youtube.com/watch?v=CPAsEyFl8r4

Nature of science: Paradigm shift—more than 85% of the world's 250,000 species of flowering plant depend on pollinators for reproduction. This knowledge has led to protecting entire ecosystems rather than individual species.

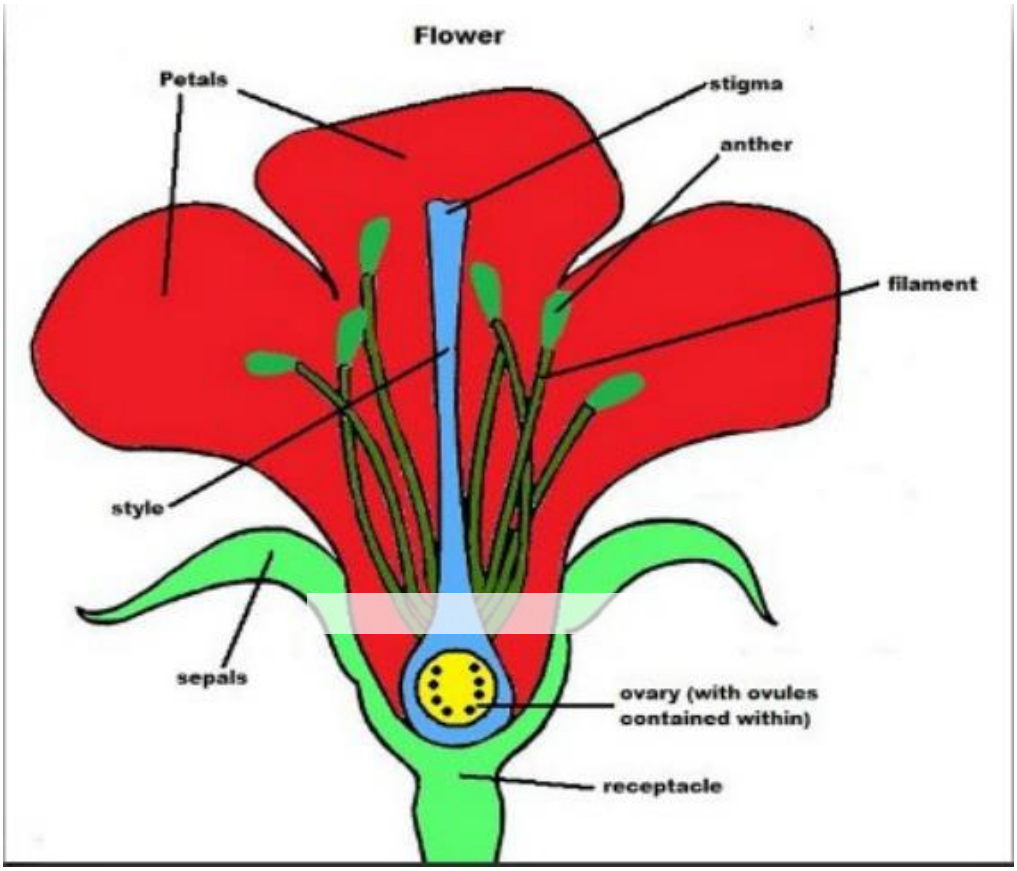
Video https://www.youtube.com/watch?v=3DJL9krbJOM

β - Application: The University of Göttingen, in Germany, conducted an extensive review of scientific studies from 200 countries for 115 of the leading global crops in 2005. They found that 87 of the crop plants depend to some degree upon animal pollination, including bees. This accounts for one-third of crop production globally.

β - Skill: Drawing internal structure of seeds.



β - Skill: Drawing of half-views of animal-pollinated flowers.



β - Skill: Design of experiments to test hypotheses about factors affecting germination.

GERMINATION PROCESS

- Seeds need water for germination. Water rehydrates the seed's tissuescausing the cells to expand and metabolism to become reactivated.
- Once metabolism has been reactivated embryonic growth can begin.
- The appropriate temperature is needed to allow enzymes to work efficiently during metabolic reactions.
- O_2 is needed for aerobic respiration to take place in the seed.
- Some plants have seeds that require specific variables in order for germination to take place such as fire or smoke, disruption of the seed coat, or removal of surface inhibitors by water.

- Water is absorbed by the seed through the micropyle and the seed coat.

- Water causes the release of a hormone called gibberellin or gibberellic acid (GA).

- GA causes the cells to expand and elongate, eventually allowing the root to break through the seed coat (testa).

- GA also stimulates the production of enzymes (specifically amylase) that hydrolyze starch located in the seed's endosperm into maltose.

- Maltose is further broken down into glucose which can be transported to areas of growth in the cell.

- Glucose is used in aerobic respiration to produce energy for growth of the embryonic root and shoot.