9 Plant biology

Introduction

- plants are highly diverse in structure and physiology
- act as producers in almost all terrestrial ecosystems
- plants have sophisticated methods of adapting growth to environment
- reproduction is influenced by biotic and abiotic environment

9.1 Transport in the xylem of plants

Transpiration

- plant leaves are primary organ of photosynthesis; involves synthesis of carbohydrates using light energy: carbon dioxide is raw material, oxygen is waste product
- waxy cuticle has very low permeability to essential carbon dioxide: has pores through epidermis: stomata
- transpiration: loss of water vapor from leaves and stems of plants
- plants minimize water losses through stomata using guard cells
- guard cells are in pairs and control aperture of stoma and adjust from wide open to closed
- guard cells found in all groups of land plants except in group liverworts

Xylem structure helps withstand low pressure

- xylem vessels: long continuous tubes with thickened walls; allow efficient transport of water
- thickened walls are impregnated with polymer lignin: strengthens walls to withstand very low pressures without collapsing
- mature xylem cells are nonliving; flow of water must be passive
- pressure inside xylem vessels is usually much lower than atmospheric pressure but rigid structure prevents collapsing
- cohesion: polar water molecules holding together (neg. oxygen part attracted to pos. hydrogen)
- adhesion: water attracted to hydrophilic parts of cell walls of xylem
- cohesion and adhesion ensure that water can be pulled up from xylem in continuous stream

Tension in leaf cell walls maintaining the transpiration stream

- water is drawn from nearest xylem vessel in veins of leaf due to adhesion when it evaporates
- even if pressure in xylem is low, adhesion is strong enough to suck it out of xylem
- low pressure generates a pulling force going down the stem to ends of roots: transpiration-pull: strong enough to move water against gravity: all energy is from thermal energy by transpiration
- pulling of water depends on cohesion; many liquids are unable to resist the pulling force
- cavitation: column of water breaking in xylem vessels, happens occasionally with water
- though water is liquid, it transmits pulling forces in same way as a solid rope

Active transport of minerals in the roots

- solute concentration inside root cells is greater than in soil: water uptake by osmosis
- most solutes in roots and soil are mineral ions
- concentration gradient between soil and root is established by active transport using protein pumps in plasma membranes; separate pumps for each type of ion
- mineral ions can only be absorbed if they make contact with appropriate pump protein: occurs by diffusion or mass flow when water carrying ions moves through soil
- some ions move through soil very slowly (bind to soil particles)
- certain plants developed relationship with fungus growing on surface of roots (sometimes into cells of root): thread-like hyphae of fungus grow into soil and absorb mineral ions (e.g. phosphate) and supply them to roots
- most plants supply sugars and other nutrients to fungus: mutualistic relationship (both benefit)

Replacing losses from transpiration

- water leaves through stomata by transpiration which is released by water from xylem
- transpiration, adhesion, cohesion forces pull water from roots which take in water by osmosis
- when water is in roots, it travels to xylem through cell walls (apoplast pathway) and cytoplasm (symplast pathway)

9.2 Transport in the phloem of plants

Translocation occurs from source to sink

- phloem tissue is found throughout plants; it is composed of sieve tubes which are made from specialized sieve tube cells which are separated by perforated walls called sieve plates
- sieve tube cells are closely associated with companion cells
- translocation: transport of organic solutes in plants (happens in phloem)
- phloem links part that need a supply of sugars and other solutes with parts that have a surplus
- source: areas where sugars and amino acids are loaded into phloem
- sink: areas where sugars and amino acids are unloaded and used
- sometimes sinks turn into sources and vice versa: phloem must be able to transport biochemicals in either direction; no valves or central pump
- fluid in phloem flows due to pressure gradients; energy is used so it is an active process

Phloem loading

- sucrose is most prevalent solute in phloem sap; not available for plant tissues to metabolize in respiration: good transport form of carbohydrate: will not be metabolized during transport
- plants differ in mechanism by which they bring sugars into phloem: process is phloem loading
- some species: significant amount travels in cell wall from mesophyll cells to cell walls of companion cells
- sometimes travels in sieve cells where sucrose transport protein actively transports sugar in (apoplast route): gradient is achieved by H^+ ions are transported out of companion cell from surrounding cells using ATP; H^+ flow down concentration gradient through co-transporter protein; energy released is used to carry sucrose into companion cell-sieve tube complex
- other species: sucrose travels between cells in plasmodesmata (symplast route); once sucrose reaches companion cell it is converted to oligosaccharide to maintain sucrose gradient

Pressure and water potential differences play a role in translocation

- build up of sucrose and other carbohydrates draws water into companion cells by osmosis: rigid cell walls and incompressibility of water result in build-up of pressure
- water flows from area of high pressure to area of low pressure
- at sink end, sucrose is withdrawn from phloem: either converted to starch or used as energy: loss of solute causes reduction in osmotic pressure so water that carried solute to sink is drawn back into transpiration stream in xylem

9.3 Growth in plants

Growth in plants

- most animals and some plant organs undergo determinate growth: defined embryonic period or growth stops when certain size is reached
- indeterminate growth: cells continue to divide indefinitely: usually plants
- many plant cells have totipotent cells: is what sets plant cells apart from most animals
- growth in plants is confined to regions called meristems (undifferentiated cells undergoing active cell division)
- primary meristems: found in tips of stems and roots: called apical meristems
- root apical meristem is responsible for growth of root; shoot apical meristem is at tip of stem
- many dicotyledonous (2 leaves in embryo of seed) plants develop lateral meristems

Role of mitosis in stem extension and leaf development

- cells in meristems undergo cell cycle (mitosis, cytokinesis) to produce more cells
- new cells absorb nutrients and water: increase in volume and mass
- shoot apical meristem throws off cells needed for growth of stem and produces groups of cells that develop into leaves and flowers
- with each division, one cell remains in meristem, other increases size and differentiates as it is pushed away from meristem region
- each apical meristem can give rise to additional meristems
- protoderm gives rise to epidermis; procambium gives rise to vascular tissue; ground meristem can give rise to pith

- chemical influences play role in determining which specialized cell is made from unspecialized plant cells
- young leaves: produced at sides of shoot apical meristems, are small bumps (leaf primordia)

Plant hormones affect shoot growth

- auxins are hormones with many functions: initiating growth of roots, influencing development of fruits, regulating leaf development
- most abundant auxin is indole-3-acetic-acid (IAA): controls growth in shoot apex, promotes elongation of cells in stems; very high concentrations inhibit growth
- IAA is synthesized in apical meristem of shoot and transported down stem for growth
- axillary buds are shoots that form at junction or node of stem and base of leaf
- regions of meristem are left behind at node; growth is inhibited by auxin from shoot apical meristem: apical dominance; the further distant a node is from shoot apical meristem, the lower concentration of auxin and its inhibition of growth is; additionally, cytokinin produced by root promote axillary bud growth
- gibberellins are another category of hormones that contribute to stem elongation

Plant tropisms

- rate and direction of stem and root growth are controlled by hormones
- two external stimuli (tropisms): light (phototropism) and gravity (gravitropism)
- stems grow towards source of brightest light (in absence of light: upwards)

Auxin influences gene expression

- first stage of phototropism is absorption of light by photoreceptors (proteins: phototropins)
- when phototropins absorb light of appropriate wavelength they change conformation: bind to receptors within cell which control transcription of specific genes: code for group of glycoproteins (PIN3 proteins) that transport auxin from cell to cell

Intracellular pumps

- position and type of PIN3 proteins can be varied to transport auxin where growth is needed
- phototropins detect light on one side of tip: auxin is transported laterally from side with brighter light to shaded side: stem grows into curve towards source of light
- leaves attached to stem receive more light and are able to photosynthesize at greater rate
- gravitropism is also auxin dependent; gravity from one side of root causes cellular organelles (statoliths) to accumulate on lower side of cells: PIN3 accumulate on bottom of cells
- high auxin concentrations inhibit root cell elongation so top cells elongate at faster rate causing root to bend downward
- pattern of auxin is opposite in root and shoot: in shoot promotes elongation, in root inhibits

9.4 Reproduction in plants

Flowering and gene expression

- vegetative structures: roots, stems, leaves grow after germination
- plant is in vegetative phase until trigger causes to change into reproductive phase (flowering)
- change happens when shoot meristems start producing parts of flowers instead of leaves
- flowers allow sexual reproduction, are produced by shoot apical meristem (reproductive shoot)
- temperature can play role in transforming leaf to flower-production; day length is main trigger, but plants measure duration of dark period
- short-day plants flower when dark period becomes longer (autumn)
- long-day plants flower during long days of summer when nights are short
- light either inhibits or activates genes that control flowering; in long-day plants the active form of pigment phytochrome leads to transcription of flowering time (FT gene)
- FT mRNA is transported to phloem to shoot apical meristem where it is translated to FT protein
- FT protein binds to transcription factor, leads to activation of many flowering genes

Photoperiods and flowering

- long-day plants flower in summer the nights have become short enough
- short-day plants flower in autumn when nights have become long enough
- length of darkness matters: pigment phytochrome measures length of dark periods

- phytochrome can switch between two forms: P_R and P_{FR}
- when P_R absorbs red light of wavelength 660nm it is converted into P_{FR}
- when P_{FR} absorbs far-red light (730nm) it is converted to P_R
- sunlight contains more light of wavelength 660nm (P_R to P_{FR}) but P_R is more stable so in darkness it changes gradually
- P_{FR} is active form of phytochrome and receptor proteins (for P_{FR}) are present in cytoplasm
- in long-day plants large amounts of P_{FR} remain at end of short nights to bind which promotes transcription of genes needed for flowering
- in short-day plants receptor inhibits transcription when P_{FR} binds; at end of long nights very little P_{FR} remains inhibition fails and plant flowers

Mutualism between flowers and pollinators

- sexual reproduction depends on transfer of pollen from stamen to stigma of another plant
- commonly transferred by animals (pollinators); wind and water are also possible
- mutualism: close association between two organisms where both benefit from relationship
- pollinators gain food (nectar) and plant gains means to transfer pollen

Pollinators, fertilization and seed dispersal

- after pollination comes fertilization: from each pollen grain on stigma a pollen tube containing male gametes grows down the style to ovary which is located inside ovule
- fertilized ovule develops into seed, ovary develops into fruit
- seed dispersal: seeds cannot move but travel long distances from parent plant, reduces competition between offspring and parent and helps spreading species
- type of seed dispersal depends on structure of fruit: dry and explosive, fleshy and attractive for animals to eat, feathery/winged to catch wind, covered in hooks to catch onto coats of animals