Characteristics of Plant Cells, Types of Cells and Tissues

Thursday, February 17, 2011
11:52 AM

- Phenotypic plasticity is more marked in plants than in animals
- In addition to plasticity, plant species have by natural selection accumulated characteristics of morphology that vary kittle within the species
- **Morphology** an organisms external form

Basic Concept 35.1

- Plants, like most animals have organs composed of different tissues, which in turn are composed of cells
- Basic morphology of vascular plants reflects their evolution as organisms that draw nutrients form below and above the ground

- Three basic organs evolved: roots, stems, and leaves
- They are organized into a **root system** and a
- Toots rely in sugar produced by photosynthesis in the shoot system and shoots rely on water and minerals absorbed by the root system
- Figure

Roots

- **Roots** are multicellular organs with important functions:
  - Anchoring the plant
  - Absorbing minerals and water
  - Storing organic nutrients
- A **taproot** system consist of one main vertical root that gives rise to **lateral roots** or branch roots
- Adventitious roots arise form stems or leaves
  - **Adventitious:** describing organs or other structure that arise in unusual position
- Seedless vascular plants and most leaves have a fibrous root system characterized by a mat of thin roots with no main root
- In most plants the absorption of water and mineral occurs primary near the tips of roots where vast number of tiny root hairs increase the surface area
- Prop Roots: grow on the outside to help stabilize the plant if soil isn't sturdy
- Strangling aerial roots:
- Pneumatophores
- Buttress Roots

Stems

- A **stem** is an organ consisting of
  - An alternating system of **nodes**, the points at which leaves are attached
  - **Internodes**, the stem segments between nodes
- An **axillary bud** is a structure that has the potential to form a lateral shoot, or branch
  - **Axil:** the angle between a branch or leaf and the stem it grows form
- An **apical bud**, or terminal bud is located near the shoot tip and causes elongation of a young shoot
- **Apical dominance** helps to maintain dormancy in most nonapical buds
- Many plants have modified stems
  - Rhizomes
  - Bulb: onion
  - Stolons
  - Tubers: potato

Leaves

- The **leaf** is the main photosynthetic organ of most vascular plants
- Leaves generally consist of a flattened **blade** and a stalk called the **petiole** which joins the leaf to a node of the stem
- Compound Leaf and Doubly Compound Leaf
- Monocots and eudicots differ in the arrangement of **veins**, the vascular tissue of leaves
  - Most monocots have parallel veins
  - Most eudicots have branching veins
- In classifying angiosperms, taxonomists may use leaf morphology as a criterion
- Some plant species have evolved modified leaves
  - Tendrils
  - Spines
  - Storage leaves
  - Reproductive leaves
  - Bracts: Poinsettia

Dermal, Vascular and Ground Tissues

- Each plant organ has dermal, vascular and ground tissues
- Each of these three categories forms a **tissue system**
- In nonwoody plants, the **dermal tissue system** consists of the **epidermis**

- In leaves and most stems, the **cuticle**, a waxy coating on the epidermal surface, helps prevent water loss
- In woody plants, protective tissues called **periderm** replace the epidermis in older regions of stems and roots
- *Trichomes*, hair-like outgrowths of the shoot epidermis, reduce water loss and reflect excess light
- They can also provide defense against insects by forming a barrier or secreting sticky fluids or toxic compounds
- The **vascular tissue system** carries out long distance transport of materials between roots and shoots
- The two vascular tissues are xylem and -phloem
- **Xylem** conveys water and dissolves minerals upward from roots into the shoots
- **Phloem** transports organic nutrients from where they are made to where the are needed
- The vascular tissue of a stem or root is collectively called the **stele**
- In angiosperms the stele of the root is a solid *central vascular cylinder*
- The stele of stems and leaves is divided into *vascular bundles*, strands of xylem and phloem
- Tissues that are neither dermal nor vascular ore the **ground tissue system**
- Ground tissue internal to the vascular tissue is **pith**, ground tissue external to the vascular tissue is **cortex**
- Ground tissue includes cells specialized for storage, photosynthesis and support

Common Types of Plants Cells

- Some major types of plant cells:
  - Parenchyma
  - Collenchyma
  - Schlerenchyma
  - Water-conducting cells of the xylem
  - Sugar-conducting cells of the phloem
- **Parenchyma Cells**
  - Mature parenchyma cells
    - Have thin and flexible primary walls
    - Lack secondary walls
    - Are the least specialized
    - Perform the most metabolic functions
    - Retain the ability to divide
- **Collenchyma Cells**
  - Collenchyma cells are grouped in strand and help support young parts of the plant shoot
  - They have thicker and uneven cell walls
  - The lack secondary walls
  - These cells provided flexible support without restraining growth
- **Sclerenchyma**
  - Sclerenchyma cells are rigid because of thick secondary walls strengthened with lignin
  - They are dead are functional maturity
  - There are two types
    - **Sclereids** are short and irregular in shapes and have thick lignified secondary walls
    - **Fibers** are long and slender and arranged in threads
- **Water-Conducting Cells of the Xylem**
  - The two types of water-conducting cells, **tracheids** and **vessel element** , are dead at maturity
  - Tracheids are found in the xylem of all vascular plants
  - Vessel elements are common to most angiosperms and a few gymnosperms
  - Vessel elements align end to end to form long micropipes called vessels
- **Sugar-Conducting Cells of the Phloem**
  - **Sieve-tube elements** are alive at functional maturity, though they lack organelles
  - **Sieve Plates** are the porous end walls that allow fluid to flow between cells along the sieve tube
  - Each sieve-tube element has a **companion cell** whose nucleus and ribosomes serve both cells
- **Plant Growth**
  - **Annuals** complete their life cycle in a year or less
  - **Biennials** require two growing seasons
  - **Perennials** live for many years
  - Plants display **indeterminate growth**
    - **Indeterminate Growth:** the organism continues to grow as long as it lives
  - Some plants organs display **determinate growth**
    - **Determinate Growth:** the organism stops growing once it reaches a certain size
  - **Meristems** are perpetually embryonic tissue an allow for indeterminate growth
    - **Apical Meristems** are located at the tips of roots and shoot and at the axillary buds of shoots
    - Apical meristems elongate shoots and roots, a process called **primary growth**
    - **Lateral meristems** are located in the vascular cambium and the cork cambium
      - The **vascular cambium** adds layers of vascular tissue called secondary xylem (wood) and secondary phloem
      - The **cork cambium** replaces the epidermis with periderm, which is thicker and tougher
    - **Lateral meristems** add thickness to plants, a process called **secondary growth**
  - Meristems give rise to *initials*, which remains in the meristem, and *derivatives* which become specialized in developing tissues
  - In woody plants, primary and secondary growth occur simultaneously but un different locations
- **Primary growth lengthens roots and shoots**
  - Primary growth produces the **primary plant body**, the parts of the root and shoot systems produced by apical meristems
  - Lateral roots arise form within the **pericycle**, the outermost cell layer in the vascular cylinder

- **Secondary Growth adds girth to stems and roots in woody plants**
  - Secondary growth occurs in stems and roots of woody plants but rarely in leaves
  - The **secondary plant body** consists of the tissues produced by the vascular cambium and cork cambium
  - Secondary growth is characaristics
  - The vascular cambium is a cylinder if meristematic cells one cell layer thick
  - It develops form undifferentiated parenchyma cells
  - In cross section, the vascular cambium appears as a ring if initials
  - The initials increases the vascular cambium's circumference and add secondary xylem to the inside and secondary phloem to the outside
  - As a tree or woody shrub ages, the older layers of secondary xylem, the *heartwood*, no longer transport water and minerals.
  - The outer layers, known as *sapwood*, still transport materials through xylem
  - Older secondary phloem sloughs off and does not accumulate
  - Early wood, formed in the spring, has thin cell walls to maximize water delivery
  - Late wood, formed in the late summer, has thick walled cells and contributes more to stem support
  - In temperate region, the vascular cambium of perennials is dormant though the winter
  - Tree rings are visible where late and early wood meet and can be used to estimate a
  - Dendrochronology is the analysis of tree ring growth patterns, and can be used to study past climate change
- **The Cork Cambium and the Production of Periderm**
  - The cork cambium gives rise to the secondary plant body's protective covering periderm
  - **Periderm** consists of the cork cambium plus the layers of cork cells it produces
  - **Bark** consists of all the tissues external to the vascular cambium, including secondary phloem and periderm
  - **Lenticels** in the periderm allow for gas exchange between living stem or root cells and the outside air
- **Growth, Morphogenesis and Differentiation produce the Plant Body**
  - The three development process of growth, morphogenesis and cellular differentiation act in the concert to transform the fertilized egg into a plant
    - **Morphogenesis** is the development of body form and organization
  - **Growth: Cell Division and Cell Expansion**
    - By increasing cell number, cell division in meristems increase the potential for growth
    - Cell expansion accounts for the actual increase in plant size
    - Plant cells grow rapidly and "cheaply" by intake and storage of water in vacuoles
    - Plant cells expand primarily along the plant's main axis
    - Cellulose **microfibrils** in the cell wall restrict the direction of cell elongation
  - **The Plane and Symmetry of Cell Division**
    - The plane (direction) and symmetry of cell division are immensely important in determining plant form
    - The plane in which a cell divides is determined during late interphase
    - Microtubles become concentrated into a ring called the preprophase band that predicts the future plant plane
  - **Morphogenesis and Pattern Formation**
    - **Pattern Formation** is the development of specific structure in specific location
    - It is determined by positional information in the form of signals indicating to each cell it's location
    - Positional information may be provided by gradients of molecules
    - **Polarity**, having structural or chemical differences at opposite ends of an organism, provides one types of positional information
    - Polarization initiated by an asymmetrical first division of the plant zygote
  - **Gene Expression and Control of Cellular Differentiation**
    - In cellular differentiation, cells of a developing organism synthesize different proteins and diverge in structure and function even though they have a common genome
- Location and a Cell's Development Fate
  - Positional information underlies all the processes of development: growth, morphogenesis and differentiation
  - Cells are not dedicated early to forming specific tissues and organs
  - The cell's final position determines what kind of cell it will become
- **Shift in Developmental Phase Changes**
  - Plants pass through developmental phases called **phase changes**, developing from a juvenile phase to a adult phase
  - Phase changes occur within the shoot opical meristem
  - The most obvious morphological changes typically occur in leaf size and shape
- **Genetic Control of Flowering**
  - Flower formation involves a phase change from vegetative growth to reproductive growth
  - It is triggered by a combination of environmental ones and internal signals
  - Transition form vegetative growth to flowering is associated with the switch in on of floral **meristem identity genes**
  - Researchers have identified B classes of floral organ identity genes
  - The ABC model of flower formation identifies how floral organs identity genes direct the formation of the 4 types of flower organs

Resource Acquisition and Transport in Vascular Plants

Thursday, March 03, 2011
12:00 PM

- **Resources:**
  - Light
  - Carbon Dioxide } Above Ground Shoot
  - Water
  - Minerals } Below Ground Root
- **Transport in vascular plants occurs on three scales**
  - Transport of water and solutes by individual cells, such as root hairs
  - Short distance transport of substance form cell to cell at the levels of tissues and organs
  - Long distance transport within xylem and phloem at the level at the whole plan t
- **Plasma Membranes**
  - The selective permeability of a plant cell's plasma membrane controls the movement of solutes in and out of cell
  - Specific transport proteins enable plant cells to maintain an internal environment different form their surroundings
- **Proton Pumps in Plant Cells**
  - Create H_2 ion gradient that is a form of potential energy that can be harnessed to do work
  - Contribute to a voltage known as a membrane potential
  - Plant cells use energy stored in the proton gradient and membrane potential to drive the transport of many different solutes
  - In the mechanism called co-transport a transport protein couples the passage of one solute to the passage of another
  - The "coattail" effect of co-transport is also responsible for the uptake if the sugar sucrose by plant cells
- **Water**
  - The movement of water is influenced by the solute concentration gradient (osmosis) and the pressure gradient (bulk flow)
  - The combined effect of solute concentrations and pressure may be expressed in terms of a water potential
  - Water flower from regions of increased H_2O potentials to regions decreased H_2O potential
  - Ψ represents the H2O potentials in units of H2O (ex. megapascals)
  - To a Ψ is the sum of the effect of solute concentration and pressure

$$\Psi = \Psi_S + \Psi_P$$

Ψ_S: solute potential (osmotic potential)
Ψ_P: pressure potential
Ψ_G: gravity potential
Ψ_H: humidity potential
Ψ_M: matrix potential (cohesion and adhesion)

  - The addition of solute reduces water potential
  - A plant cell has a plasma membrane, and so may have a different solute potential than its environment
  - A plant cell has a cell wall, and so may have a different pressure potential than its environment.
  - Water potential influences the movement of water between a plant cell and its environment
  - Although water can diffuse across a phospholipid membrane, channel proteins known as **aquaporins** increase the rate at which this movement takes place
  - Aquaporins do not affect the water potential
  - Fluid may be found in one several compartments in a plant
  - **Apoplast**: the continuum formed by the cell walls of the cells (plus extra-cellular spaces)
  - **Sympast**: the continuum formed by the cytosols of the cells
  - There are three routes for short-distance transport in a plant
  - Long distance transport requires bulk flow
  - Movement of fluid in the xylem and phloem is driven by pressure differences at opposite ends of the xylem vessels and sieve tubes
  - Water and mineral salts form the soil enter the plant through the epidermis of roots and ultimately flow to the shoot system
  - Root hairs account for much of the surface area of roots
  - Much of the absorption of water and minerals occur near root tips, where the epidermis is permeable to water and where root hairs are located
  - Most plants form mutualistic symbioses with fungi, known as **mycorrhizae**
  - Mycorrhizae facilitate the absorption of water and minerals form the soil
    - Mycorrhizae integrated structures consisting of plant roots united with fugal hyphae
  - Once soil solution enters the roots, the extensive surface area of cortical cell membranes enhances uptake of water and selected minerals
  - Water can cross the cortex via the symplast or apoplast
  - The endodermis is the innermost layer of cells in the root cortex surround the vascular cylinder
  - It functions as the last checkpoint for the selective passage of minerals form the cortex into the vascular tissue
  - The waxy Casparian strip of the endodermal wall blocks apoplastic transfer of mineral form the cortex to the vascular cylinder
  - Root cells pump ions into the apoplast (including the xylem), lowering the water potential
  - The Casparian strip prevents ions from diffusing out of the apoplast of the vascular cylinder
  - Water flows into the apoplast of the vascular cylinder, generating root pressure
  - Root pressure pushes water with dissolved minerals (xylem sap) up the xylem

- In most plants, root pressure is a minor mechanism driving the ascent of xylem sap
- At night, root pressure may be the only mechanism moving xylem sap, and may result in guttation
- Much more important than root pressure is transpirational pull
- Plants lose an enormous amount of water through transpiration, the loss of water vapor form leaves and other aerial parts of the plant
- Water vapor in the airspace of a leaf moves down its water potential gradient and exits the leaf via stomata
- Transpiration produces negative pressure (tension) in the leaf, which exerts a pulling force on water in the xylem, pulling water into the leaf
- The transpiration pull on xylem sap is transmitted all the way from the leaves to the root tips and even into the soil solution
- The effect of the negative water potential generated by transpiration is facilitated by **cohesion** and **adhesion**
- **Cohesion** water molecules sticking together due to hydrogen bonding
- **Adhesion** water molecules sticking to the hydrophilic walls of the xylem due to hydrogen bonding
- Cohesion transmits the pull of transcription form molecule to molecule all the way down into the roots and even into the soil
- Adhesion hold water molecules up against the pull of gravity
- About 95% of the water that a plant loses escapes through its stomata
- There may be as many 20 000 stomata per cm^2
- A single corn plant may transpire 60L of water in a growing season
- If the lost water is not replaced fast enough by absorption through the roots, the plant will lose water and wilt
- Stomata may close in order to reduce water loss
- Turgid guard cells are curved, leaving a space (open stoma) between them
- Flaccid guard cell are flat leaving little or no space between them (the stomata is closed)
- Water potential is controlled primarily by the movement of potassium ions
- Stomata are opened during the day response in response to light, carbon dioxide depleting and cercanidan rhythm
- Transpiration also results in the evaporative cooling, which can lower the temperature of a leaf and prevent the denaturation of various enzymes involved in photosynthesis and other metabolic processes

- **Phloem**
  - Phloem sap is mostly sucrose and water
  - Travels form a sugar source to a sugar sink
  - A sugar source is a plant organ that is a net producer of sugar, such as mature leaves
  - A sugar sink is an organ that is a net consumer or storer of sugar, such as a tuber or bulb
  - Sugar must be loaded into sieve-tube member before being exposed to sinks
  - In many plant species, sugar moves by symplastic and apoplastic pathways
  - Phloem loading typically requires active transport
  - Cotransport of sucrose and H^+ enable the cells to accumulate sucrose
  - Phloem sap moves through a sieve tube by bilk flow driven by positive pressure

Soil and Plant Nutrition

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11:48 AM

- Plants derive most of their organic mass from the CO_2 of air but they also depend on soil nutrients such as water and minerals
- More than 50 chemical elements have been identified among the inorganic substances in plants, but not all of these are identified
- A chemical element is considered essential if it is required for plant to complete a life cycle
- Nine of the essential elements are called macronutrients because plants require them in relatively large amounts
- The remaining eight essential elements are known as micronutrients because plants need them in very small amounts
- The symptoms of mineral deficiency depends on the:
  - Nutrients function
  - Mobility of a nutrients within the plants
- Deficiency of a mobile nutrients usually affects older organs more than young ones
- Deficiency of a less mobile nutrients usually affects younger organs more than older ones
- Along with climate the major factors determining whether particular plants can grow well in a certain location are the texture and composition of the soil
- Distinct soil layers, or horizons, are often visible in vertical profile where there is a road cut or deep hole
  - Soil Horizon A: weathered mineral material mixed with organic material (humus) and living organic material
  - Soil Horizon B: partially weather mineral material with some organic material
  - Soil Horizon C: relatively unweather mineral material
- Soil horizon A is known as topsoil
- The top soil is the most important layer for the growth of most plants
- Topsoil is a mixture of mineral (inorganic) materials, humus and living organisms
- The mineral materials are derived from the breakdown of rocks
- The humus is organic materials in various stages of decomposition
- Soil composition refers to the soil's organic and inorganic chemical components
- Soil texture is the soil'd general physical structure
- Soil particle size:
  - Clay: <2μm
  - Silt: 2-20μm
  - Sand: 20-2000μm
- Loam: mixture of roughly equal amount of clay, silt and sand
- Gravel 2-64mm
- Smaller particles tend to have greater surface area exposed to water in the soil
- Greater surface area means more adhesion of water
- Soil with smaller particles tends to retain more water
- Soil with smaller particles tend to retain more minerals
- Soil with smaller particles tends to have less air
- Soil with smaller particles tends to have lower water potential
- Soils with a mix of particles sizes (ex loam) are typically the best
- Plant roots do not passively soak up water and minerals
- Humus is organic material resulting from the decomposition of dead organisms, feces, fallen leaves and other organic matter by organisms such as bacteria and fungi
- Contributes to the soil texture
- Increases soil's ability to exchange cations
- Topsoils is home to an astonishing variety of organisms, such as bacteria, fungi, algae and other "protists," insects, earthworms, plant roots and other organisms
- In fact topsoil is a complex and important ecosystem
- One way that this ecosystem is important to plants is through the fixation of nitrogen
- Nitrogen is often the mineral that limits plant growth
- Plants require nitrogen as a component of proteins, nucleic acids, chlorophyll and other important organic molecules
- Although the atmosphere is about 78% N_2, plants cannot use this to make organic molecules
- Nitrogen-fixing bacteria incorporate atmospheric nitrogen (N_2) into ammonia (NH_3).
- The enzyme nitrogenase is responsible, it requires chemical energy and typically is inactivated by O_2.
- Ammonia is not useable by plants, but it may be modified in the soil
- Plant nutritional adaptations often involve relationships with other organisms
- Two types of relationships plants have with other organisms are mutualistic:
  - Symbiotic nitrogen fixation
  - Mycorrhizae
- Symbiotic relationships with nitrogen-fixing bacteria provide some plant species with a built-it source of fixed nitrogen
- From an agricultural standpoint the most important and efficient symbioses between plants and nitrogen-fixing bacteria occur in the legume family (peas, beans and other similar plants)
- Along the roots of a legume are swellings called nodules composed of plants cells that have been "infected" by nitrogen-fixing *Rhizobium* bacteria
- Inside the nodule *Rhizobium* bacteria assume a form called bacteriods, which are contained within vesicles formed

by the root cell

- The development of a nitrogen-fixing root nodule depends on chemical dialogue between *Rhizobium* bacteria and root cells of their specific plant hosts
- The bacteria of a nodule obtain sugar form the pant and supply the plant with fixed nitrogen
- The agriculture benefits of symbiotic nitrogen fixation underlie crop rotation
- In this practice a non-legume such as maize is planted one year, and the following year a legume is planted to restore the concentration of nitrogen in the soil
- Mycorrhizae are modified roots consisting of mutualistic associations of fungi and roots
- The fungus benefits from a steady supply of sugar donated by the host plant
- In return, the fungus increase the surface area of water uptake and mineral sbsorption and supplies water and minerals to the host plant
- The ectomycorrhizae the mycelium of the fungus forms a dense sheath over the surface of the root
- The endomycorrhizae microscopic fungal hyphae extends into the root
- Epiphytes grow in other plants, but do not feed on them
- They typically, obtain water and minerals from rain, mostly through leaves
- Parasitic plants absorb sugars and minerals form the plants they grow on (some also carry out photosynthesis on their own)
- Many grow roots that grow into the host plant
- Carnivorous plants are photosynthetic but obtain some nutrients, such as nitrogen, from insects and other small animals

They typically grow in acids bogs and other habitats where soils are poor in nitrogen and other minerals

Photosynthesis

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12:20 PM

- Plants derive most of their organic ass form the CO2 of air, using energy from sunlight
- $6CO_2 + 12H_2O$ + light energy -> $C_6H_{12}O_6 + 6O_2 + 6H_2O$
- Photosynthesis is a redox process
- A redox reactions is a reduction-oxidation reaction: a reaction in which one atom is reduced and another is oxidized
- Reduction: gaining one or more electrons
- Oxidation: losing one or more electrons
- Reduction: $O_2 + 2e^- \rightarrow 2O^{2-}$
- Oxidation: $2Mg \rightarrow 2Mg^{2+} + 2e-$
- Redox: $2Mg + O_2 \rightarrow 2[Mg^{2+}O^{2-}]$
- Photosynthesis is a redox process: water is oxidized, carbon dioxide is reduced
- **Photosynthesis** includes two process:
  - **Light reactions**
  - **Light dependent reactions**
    - Occur in the grana
    - Split water, release oxygen , produce ATP and NADPH
  - **Dark reactions**
  - **Light-indepentdent readctions**
  - **Calvin cycle**
    - Occur in the stroma
    - Produce sugar from carbon dioxide using energy from ATP and NADPH
- The light reactions convert light energy to chemical energy in ATP and NADPH
- **PHYSICS**
  - Waves
    - Wavelength, frequency
    - Velocity/Frequency = Wavelength
  - Electromagnetic Waves
    - Waves in the electromagnetic field
    - Electromagnetic radiation
    - Occurs in packets called photons
  - The wavelength or frequency is correlated with the energy of the photons
  - High wavelength = low frequency: low energy photon
  - Low wavelength = high frequency: high energy photon
  - Different rays (gamma, X, UV, IR, micro, radio)
  - Pigment
    - A molecule that absorbs visible light
    - Each pigment absorbs only light of certain wavelengths
    - When a pigment absorbs light, it absorbs the energy from its photons
- The spectrophotometer is a machine that send light through pigments and measures the fraction of the light transmitted at each wavelength
- An absorption spectrum is a graph plotting light absorption versus wavelength
- Chlorophyll a is the main photosynthetic pigment
- Chlorophyll b is an accessory pigment other accessory pigments (carotenoids) absorbs different wavelength of light and pass the energy to chlorophyll a
- These pigments are found in the thylakoid membranes
- Pigments for photosynthesis are organized into photosystems
- A photosystem is composed of a reaction center surrounded by a number of light-harvesting complexes
- The light harvesting complexes consist of pigment molecules bound to particular proteins
- They funnel the energy of photons of light to the reaction center
- When a reaction-center chlorophyll molecule absorbs energy one of its electrons gets bumped up to a primary electron acceptor
- Linear (noncyclic) electron flow is the primary pathway of energy transformation in the light reactions
- This pathway involves two types of photosystems, I and II
- Under certain conditions photoexcited electrons take an alternate path
- Cyclic electrons flow is an alternate pathway of energy transformation in the light reactions
- This pathway involves one type of photosystem I
- Linear electron floe generates:
  - ATP
  - NADPH
  - O_2
- Cyclic electron flow generates:
  - ATP
- The Calvin Cycle uses ATP and NADPH to convert CO_2 to sugar
- It has three phases:
  - Carbon Fixation
    - In Organic carbon (in carbon dioxide) is incorporated into an organic molecule
  - Reduction
    - The organic molecule is converted into a sugar

        - Regeneration of the CO_2 Acceptor
            - Some sugar is converted into the molecule required for carbon fixation
- Plants that employ the typical process of carbon fixation described in this lecture (most plants) are known as C_3 plants, because the first organic product of carbon fixation is a three carbon compound
- On hot, dry days, they close their stomata
    - Conserves water
    - Limits access to carbon dioxide
        - Slows the Calvin Cycle
    - Causes oxygen to build up
        - Photorespiration
            - O_2 substitutes for CO2 in the active site of the enzyme rubisco
                - Slows the Calvin Cycle
- Alternative mechanisms of carbon fixation have evolved in hot, arid climates
- In C_4 plants, carbon dioxide is initially fixed into a four-carbon organic molecule in mesophyll cells
- The enzyme responsible is not affected by oxygen, so photorespiration does not occur
- The Calvin Cycle doesn't occur in these cells
- The four-carbon molecule passes through a plasmodesma to a bundle sheath cell, where it release carbon dioxide
- The carbon dioxide enters the Calvin Cycle in the stoma of the chloroplasts here
- These chloroplasts lack photosynthesis II, and oxygen levels remain low here
- In CAM plants, stomata open at night and close during the day
- On hot days this conserves water but prevents carbon dioxide from entering leaves
- At night carbon dioxide enters the leaves and is incorporated into organic acids
- During the day these organic acids release carbon dioxide, which can enter the Calvin Cycle

Cellular Respiration

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11:46 AM

- Living organisms require chemical energy
- Active transport
- Transcription
- Translation
- Cell division
- Energy typically flows into an ecosystem as sunlight, and eventually out of the ecosystem as heat
- The Calvin cycle is an anabolic pathway
- Anabolic pathway a metabolic pathway that consumes energy to synthesize a complex molecule from simpler compounds
- Catabolic pathway a metabolic pathway that releases energy by breaking down complex molecule to simpler compounds
- The breakdown of carbohydrate to release energy is a catabolic pathway
- Organic compounds posses potential energy as a result of their arrangement of atoms
- Cells break down organic compounds that are rich in potential energy into simpler molecules that have less potential energy
- This releases energy some of which may be used to do work the rest is lost as heat
- It is no usually convenient to obtain energy for cellular work directly from the breakdown of carbohydrates
- Cells instead break down carbohydrates to do the work of building high-energy molecules such as adenosine triphosphate (ATP)
- ATP may later be broken down into adenosine diphosphate (ADP) releasing energy plus phosphate that may do cellular work
- Cellular respiration is the most prevalent and efficient pathway that breaks down carbohydrates
- It consumes molecular oxygen and organic molecules (ex. glucose)
- It converts ADP + P into ATP
- Cellular respiration is:
    - A catabolic pathway
    - A redox process
        - Glucose is oxidizes
        - Oxygen is reduced
- Some redox reactions do not completely exchange electrons
- A redox reaction can be a change the degree of electron sharing in covalent bonds
- Electrons tend to mover "downhill" from a less to a more electronegative location
- Electrons in a more electronegative location have less potential energy
- Thus as electrons move to a more electronegative location they release energy
- Oxygen is very electronegative
- The oxidation of methane moves electrons to a lower energy state
- Thus the oxidation of methane released energy
- Similarly the oxidation of glucose releases energy
- In cellular respiration, electrons are transferred from glucose to oxygen, but not directly
- Electrons travel with a proton (hydrogen ion: H^+), forming a hydrogen atom (H)
- Hydrogen atoms are transferred to oxygen, but not directly
- Molecules such as NAD^+ are known as electron carriers
- NADH (the reduced form NAD^+) passes the electrons to the electrons transport chain
- The electrons transport chain allows the electrons to move to the lower energy levels step by step, releasing energy a little at a time
- This energy can then be used to drive the conversion of ADP + P into ATP
- Cellular respiration may be split into three stages
    - Glycolysis
    - The citric acid cycle catabolic process both
- Substrate level phosphorylation: a phosphate group is transferred directly from an organic substrate molecule to ADP, forming ATP
- electrons are picked up by electron carriers: NAD^+ and FAD
- Oxidative phosphorylation: electron transport and chemiosmosis
    - Electrons lose energy as they are passed step by step towards oxygen
    - This energy is used to add inorganic phosphate to ADP forming ATP
- For each glucose entering glycolysis, 2ATP are used up while 4 ATP are generated by substrate-level phosphylation, for net production of 2 ATP
- At the same time, 2 NAD^+ are reduced to 2 NADH + H^+
- Glycolysis releases less than 25% of the chemical energy stored in glucose
- Pyruvate is moved from the cytosole into the mitochondria matrix by active transport
- As it enters the matrix, pyruvate is picked up by a multi-enzyme complex that mediates three reactions:
- The carboxyl group (COO^- whit little chemical energy) is removed, forming CO^{2-}
- The remaining 2- carbon fragment is oxidized by NAD^+
- The resulting 2-carbon molecule (acetate) is attached to coenzyme A (forming acetyl CoA)
- Acetyl coenzyme A then feeds the acetyl group into the citric acid cycle

- Citric acid cycle
- Tricarboxilic acid

- For each acetyl group entering the citric acid cycle, 1 ATP is generated by substrate-level phosphorylation
- At the same time, 3 NAD^+ are reducing to 3 NADH + H^+ and 1 FAD is reduced to 1 $FADH^{2+}$
- Combining glycolysis, the conversion of pyruvate to coenzyme A, and the citric acid cycle
- For each glucose entering cellular respiration, there is a net production of 4 ATD, 10 NADH + H^+ and 2 $FADH^{2-}$

Plant Responses to Internal and External Signals

Tuesday, March 29, 2011
12:20 PM

- Plants, being rooted to the ground must respond to whatever environment change comes their way
- Plant cannot migrate to a watering hole seek shelter form wind
- An upside down seed cannot right itself
- For a stimulus to elicit a response certain cells must have an appropriate receptor
- Plants have cellular receptors that they use to detect important changes in their environment
- Signal transduction pathways link signal reception to response
- Internal and external signals are detected by receptors: proteins that change in response to specific stimuli
- Second messengers transfer and amplify signals from receptors to proteins that cause specific responses
- In most cases these responses to stimulation involve the increased activity of certain enzymes
- The two process through which activity in most commonly altered are transcription and post-translational modification
- Transcription factors bind directly to specific regions of DNA and control the transcription of specific genes
- Post-translational modification involves the activation of existing proteins
- **Etiolation:** plant morphological adaptations for growing in darkness
- A potato left growing in darkness will produce pale shoot and small leaves, and will lack elongated roots
- After potato is exposed to light the plant undergoes profound changes call de-etiolation, in which shoot and roots grow normally
- **Hormone:** in multicellular organisms, one of many types of secreted chemicals that are formed in specialized cells, travel in body fluids, and act on specific target cells in other parts of the body to change their functioning
- Plant hormones help coordinate growth, development and responses to stimuli
- In general, hormones control plat growth and development by affecting the division elongation and differentiation of cells
- Plant hormones are produced in very low concentration but a minute amount can have profound effect on the growth and development of a plant organ
- **Tropism:** a growth response that results in the curvature of whole plant organs towards or away from stimuli due to different rates of cell elongation
- In phototropism, the stimuli is light
- In positive phototropism, the plant organ curves towards the area with more light
- Hormones are often responsible for tropism
- The term *auxin* is used for any chemical substance that promotes cell elongation in different target tissues
- Produced mainly by shoot apical meristems and young leaves
- Transported mainly by xylem parenchyma
- One of its chief functions is to stimulate elongation in young stems
- According to a model called the acid growth hypothesis, proton pumps play a mojor role in the growth response of cells to auxin
- **Auxins**
  - Elongation of stems
  - Phototropism and geotropism
  - Formation and branching of roots
  - Cell division in the vascular cambium and differentiation of secondary xylem
  - Development of fruit
  - Apical dominance
  - The herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) is a synthetic auxin
  - Causes a plant to grow too fast, ultimately killing it
  - Monocots can rapidly inactivate 2,4-D and so are much mire resistant that eudicots
- **Cytokinins**
  - Cytokinins (with auxins) stimulate cell division and influence ell differentiation
  - Produced mainly by actively growing tissues in roots, embryos and fruits
  - Transported mainly by xylem
  - Auxins alone stimulate cell growth
  - Cytokinins alone have no effect
  - Auxins with cytokinins stimulate cell growth and division
  - The ratio of auxin concentrations to cytokinin concentration controls cell differentiation
  - Within a certain range of ratios of auxin concentration to cytokinin concentration cells remain undifferentiated
  - Increased auxin levels stimulate cells to differentiate to form a root
  - Increased cytokinin levels stimulate cells to differentiate to form a shoot
  - Cytokinins, auxin, and other factors interact in the control of apical dominance: the ability of a terminal bud to suppress development of auxillary buds
  - Cytokinins inhibit aging of certain plant organs
  - Florists sometimes use cytokinin sprays to keep cut flowers fresh
  - Gibberellins have a variety of effects, such as stem elongation, leaf and fruit growth, and see germination
  - Produced mainly by roots, young leaves, and embryos
  - Gibberellins promote cell growth and division in shoots
  - A surge in gibberellin production leads to the rapid growth of certain flower stalks
  - In many plants, both auxins and gibberellins are required to stimulate fruit development
  - Spraying Thompson seedless grapes with gibberellin
  - After water is imbibed, the release of gibberellins from the embryo signals the seeds to break dormancy and

germinate

- **Brassinosteriods**
  - Brassinosteriods stimulate shoot growth, and a number of other effects (some depend on concentration)
  - Produced throughout the plant
  - Act locally
  - Stimulate cell growth and division in shoots
  - Promote root growth at low concentrations
  - Inhibit root growth at high concentrations
  - Promote xylem differentiation
  - Inhibit phloem differentiation
  - Promote seed germination
- **Abscisic Acid (ABA)**
  - Inhibits growth
  - Produced throughout the plant
  - May be transported by xylem or phloem
  - Plays an important role in signaling seed dormancy and drought tolerance
  - Seed dormancy refers to the seed not germinating immediately
  - Drought tolerance is the ability to survive dry conditions
  - Seed dormancy has great survival value because it ensures that the seed will germinate only when there are optimal conditions
  - Certain conditions will cause a seed to lower or inactivate ABA, resulting in germination
  - In some cases the ration of ABA concentration to gibberellin concentration determines when a seed germinates
  - One of many mechanisms that may confer drought tolerance is the ability to close stomata
  - Roots that are stressed by water shortage may release ABA
  - Xylem carries the ABA to the leaves, where is causes potassium channels in guards cell plasma membranes to open
  - Potassium diffuses out of the guard cells increasing the water potential of these cells
  - Water then moves out of the guards cells, resulting in a loss of turgidity and closing of the stomata
  - ABA may also be produced by leaf cells subjected to water stress
- **Ethylene**
  - Stimulates fruit ripening, leaf abscission and the *triple response*
  - Produces throughout the plant
  - Acts locally
  - Fleshy fruits are generally tart, hard and green, traits that help to protect developing seeds from herbivores
  - Ripening is process that often makes the fruit sweet, soft and brightly colored, traits that help to attract animals that may disperse the seeds
  - Cell walls are broken down, starch is converted to sugar, new scents and pigments are produced
  - Stimulates the ripening process, and the production of more ethylene: positive feedback
  - Because it is a gas, ethylene can influence nearby fruit
  - Ripening may be sped up or slowed down by enclosing fruit or circulating fresh air between them
  - Leaves fall from deciduous trees to minimize water loss during periods of climatic stress
  - Leaves are the part of the tree where you loose the most amount of water
  - Before leaves fall, many essentials elements are salvaged form them and stored in stem parenchyma cells
  - Autumn colors in leaves are the result of newly-made red pigments combined with yellow and orange carotenoids that were already present
  - As the aging leaf produced less auxin, a layer of parenchyma cells at the base of the petiole becomes more sensitive to ethylene
  - These cells have thin cell walls which are further weakened by enzymes that hydrolyze polysaccharides
  - The triple response to mechanical stress is a growth maneuver that includes three changes:
    - Slowing of stem elongation
    - Thickening of the stem
    - Curvature that causes the stem to start growing horizontally
  - This helps a stem to grow around obstacles, such as rocks
  - Interactions between hormones and their signal transduction pathways make it difficult to predict what effect a genetic manipulation will have on a plant
  - Systems biology seeks a comprehensive understanding of plants that will permit successful modeling of plant functions
  - Responses to light are critical for plant success: light cues many key events in plant growth and development
  - Plants are sensitive not only to the presence of light but also its direction, intensity and wavelength (color)
  - Plants have two major classes of light receptors: blue-light photoreceptors and phytochromes
  - Various blue-light photoreceptors control hypocotyl elongation, stomatal opening and phototropism
  - Phytochromes regulate many of a plant's responses to light throughout its life
  - Many plant processes, such as transpiration and the synthesis of certain enzymes, oscillate during the day
  - Some of these changes are in response to changes in light level, temperature and humidity
  - Circadian rhythms are generally only approximately 24 hours
  - Plant circadian rhythms are typically synchronized with daily rhythms by daylight
  - Phytochrome conversion marks sunrise and sunset providing the biological clock with environmental cues
  - Photoperiod, the relative lengths of night and day, is the environmental stimulus plants use most often to detect the time of year
  - Some developmental processes, including flowering in many species, requires a certain photoperiod
  - In day-neutral plants, the timing of flowering is independent of day length
  - In short-day plants, flowering will only occur when days are shorter than some critical length
  - In long-day plants, flowering will only occur when days are longer than some critical length

- In fact it is the length of the darkness hours that triggers flowering in short-days and long-day plants
- Phytochromes are responsible for determining darkness and are particularly sensitive to red light
- The flowering signal has not yet been chemically identified
- It is called florigen and it may be a hormone or change in relative concentrations of multiple hormones
- Whatever combination of environmental cues and internal signals is necessary for flowering to occur, the outcome is the transition of a bud's meristem from a vegetative to a flowering state
- Response to gravity is known as gravitropism
- Roots display positive gravitropism
- Stems display negative gravitropism
- Plants may detect gravity by the settling of statoliths
  - Specialized plastids containing dense starch grains
    - Chloroplasts are just one type of plastid
    - Meristems cells have proplastids
    - Each proplastid has an outer and inner membrane surrounding a stroma, with ribosomes and a loop of DNA
    - Proplastids replicate themselves, meristem initials retain proplatids, while in meristem derivatives the proplastids may mature into specific plastid types
    - Plastids
      - Proplastids: simple precursor to other plastids
      - Chloroplast: plastid specialized for photosynthesis
      - Amyloplast: plastid specialized for starch (amylum) storage
      - Chromoplast: plastid specialized for providing color (ex: in fruits and flowers)
- Response to gravity is known as
- Plants are sensitive to mechanical stimuli (touch)
- *Thigmomorphogenesis* refers to a change in form that results from mechanical perturbation
- Mechanical stimulation leads to an increase in calcium ion (Ca^{2+}) concentration in the cytosol, which triggers changes in gene expression
- In some cases, plants can move relatively rapidly in response to mechanical stimulation
- Mechanical stimulation causes potassium loss from certain cells at the base of each leaflet (Ex: Mimisa pudica, sensitive plant)
- Water follows by osmosis, so that these cells lose tugor
- Action potentials (involving Ca^{2+}) spread at 1 cm/sec, triggering the movement of other leaflets
- Environmental stresses have a potentially adverse effect on a plant's survival, growth, and reproduction
  - **Drought** (water deficiency)
    - Guard cells lose tugor and close stomata (abscisic acids also signal this), reducing transpiration
    - Water deficit reduces turgor in young leaves, which slows cell growth (abscisic acid also signals this), reducing leaf area
    - Water deficit reduces tugor in shallow roots, which slows cell growth, reducing growth of shallow roots but leaving deeper roots growing well
  - **Flooding** (root suffocation)
    - Oxygen deprivation stimulates ethylene production
    - Ethylene signals certain cells in the root cortex to go though apoptosis
      - Apoptosis: a program of controlled cell suicide
    - This leaves air tubes in the roots that help to supply oxygen to the roots
  - **Salt Stress** (lowered water potential)
    - Plasma membranes can keep salt out but it becomes very difficult to obtain water from the soil
    - Salt can be allowed into the cells to balance water potential, but sodium becomes toxic at high concentrations
    - Many plants produce less toxic organic solute to lower the water potential in root cells
  - **Heat Stress** (denaturing enzymes)
    - Transpiration cools leaves (a leaf may be up to 10°C lower than the surrounding air)
      - May lead to excess water loss
    - Many plants produce *heat shock proteins* that seem to stabilizes other proteins at higher temperatures
  - **Cold Stress** (plasma membrane changes)
    - Plasma membrane may crystallize, altering transport and protein function
    - Many plants increase the number if unsaturated fats in the phospholipid bilayer
    - An increase in sugar concentration in the cytosol resists freezing and retards dehydartion due to the freezing of the apoplast
  - **Herbivores** (animals that eat plants)
    - Plants employ physical, chemical and ecological defenses
    - Thorns, needles, hairs, sap and bark
    - Toxins, repellants
    - Attract other organisms that may attack herbivores
  - **Disease** (viruses, bacteria, fungi)
    - Plants have two lines of defense
    - Their first line of defense is a physical barrier to infection: the epidermis and/or periderm
    - Their second line of defense is a chemical attack that destroys the pathogen and prevents spread of the infection
    - A virulent pathogen is one that a plant has little specific defense against
    - An avirulent pathogen is one that may harm but not kill the host plant
    - The second line of defense is enhance by the plant's inherited ability to recognize certain pathogens
    - Gene-for-gene recognition is a widespread form of plant disease resistance that involves recognition of pathogen-derived molecules by the protein products of specific plant disease resistance (R) genes

- A hypersensitive response against an avirulent pathogen seals off the infection and kills both pathogen and host cells in the region of the infection
- Cells produce anti-microbial molecules and a hormone, modify their walls to deal off the area, then undergo apoptosis

Angioperm Reproduction and Biotechnology

Thursday, April 07, 2011
11:46 AM

- The life cycle of plants are characterized by an alternation of generations, in which multicellular haploid and diploid generations take turns producing each other
- The diploid plant, the *sporophyte*, produces haploid spores by meiosis
- Theses spores divide by mitosis, giving rise to the multicellular *gametophytes*, the male and female haploid plants that produce gametes
- Fertilization, the fusion of gametes, results in diploid zygotes, which divide by mitosis and form new sporophytes
- Over the course of seed plant evolution gametophytes became reduced in size and wholly dependent on the sporophyte for nutrients
- In angiosperms, the sporophyte is the dominant generation: it is larger, more conspicuous, and longer-lived than the gametophyte
- Angiosperm gametophytes are the most reduced of all plants, consisting of only a few cells,
- Bryophytes, seedless vascular plants, gymnosperms, angiosperms -> increasing dominance
- Seedless vascular plants, gymnosperms, angiosperms -> vascular tissues
- Gymnosperms, angiosperms -> seeds
- Angiosperms -> flowers, double fertilization, fruits
- Flower diagram
- Complete flowers have all four basic flower parts
- Incomplete flowers are missing one or more of these parts
- Perfect flower have both stamens and carpels
- Imperfect flowers are missing stamens or carpels
- The arrangement of flower parts is variable
- Flowers may be arranged in clusters, called *inflorescences*
- Each anther contains four pollen sacks (microsporangia)
- In each pollen sack are many diploid microspore mother cells (microsporocytes)
- Each microspore mother cell undegoes meiosis, forming four haploid *microspores*
- Each microspore undergoes mitosis, producing a male gametophyte made up of two cells that are covered by a spore wall
    - *Generative cell* and *tube cell*
- Pollination is the transfer of pollen from an anther to a stigma
- It is typically accomplished by wind, water or animals
- Bees, moths and butterflies, flies, birds, bats
- Many angiosperms have mechanisms that make it difficult or impossible for a flower to fertilize itself
- Certain genes may prevent successful self-fertilization
- Pollination, fertilization and double fertilization
- After fertilization, the calcium ion (Ca^{2+}) concentration in the zygote increases
- A block to polyspermy is established
- Early Development
    - Zygote -> sporophyte embryo
    - Cell with polar nuclei -> endosperm
    - Integument -> seed coat
    - Ovule -> seed
    - Ovary (often with other structures) -> fruit