Plant Hormones, Constituents, & Nutrition

Bio 1B, Fall '06

Professor Carlson

Lab Assignment
Due in last Plant Lab
Assignment graded by GSI each lab

Describe the following information for 10 different foods you have eaten:

1) Name of food
2) Major group this food comes from: Angiosperm (Monocot or Eudicot), Gymnosperm, or Protist (e.g., red algae, brown algae), Cyanobacteria (e.g., Spirulina)
3) What plant part is consumed (e.g., leaf, stem, root, flower, fruit, seed)
4) What plant tissue and/or cell type is consumed

Plant Hormones/Chemical Communication (Table 39.1)

Gibberellic Acid (Table 39.1, Fig. 39.10-11)

- **Seed germination (Fig. 39.11)**
- **Bud germination**
- **Stem elongation**
- **Flowering/Fruiting (Fig. 39.10)**

(Gibberellic Acid was originally isolated from the fungus *Gibberella fujikuroi,* which is a plant pathogen on rice that resulted in unusually long shoots)

Plant Hormones/Chemical Communication (Table 39.1)

Auxin (indole acetic acid) (Campbell Table 39.1, Fig 39.7)

- **Apical dominance**
- **Phototropism**
- **Stem/cell elongation** (Fig. 39.8)
- **Gravitropism**

Plant Hormones/Chemical Communication (Table 39.1)

Cytokinins (Table 39.1, Fig. 39.9)

- **Promote cell division & lateral bud outgrowth**
- **Inhibit leaf senescence**

Plant Hormones/Chemical Communication (Table 39.1)

Brassinosteroids (Table 39.1)

- **Steroid hormone**
- **Supports growth of xylem**
- **Supports elongation of stems & pollen tubes**
- **Inhibits leaf abscission**

Plant Hormones/Chemical Communication (Table 39.1)

Abscisic Acid (ABA) (Table 39.1)
- **Inhibits growth/stem elongation**
- **Supports seed dormancy** (Fig. 39.12)
- **Inhibits seed germination**
- **Closure of stomata in response to water stress**

Plant Hormones/Chemical Communication (Table 39.1)

Ethylene (Table 39.1)
- **Promotes fruit ripening**
- **Promotes leaf abscission** (Fig. 39.16)
- **Promotes senescence**
- **Inhibits stem elongation** (Fig. 39.13)
- **Inhibits gravitropism**

Plant defense mechanisms

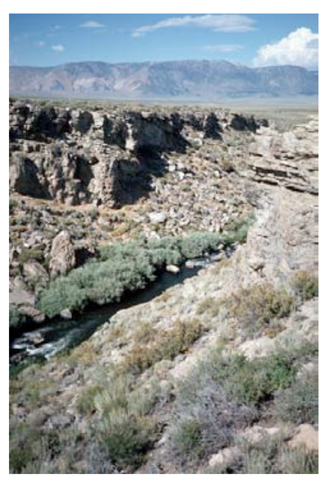
Hormones that Respond to Tissue Damage and Trigger Plant Defenses

- **oligosaccharins**
- **jasmonates**
- **systemin**
- **salicylic acid**

Plant defense mechanisms

Phytochemical repel herbivores/microbes

- **Oils from variety of herbs & spices repel insects**
- **Pine sap inhibits insect pests (e.g., bark beetles)**
- **Tannins & resins concentrate in heartwood of trees to prevent insect & microbial infestation and rotting**
- **Many alkaloids (e.g., caffeine, nicotine, morphine, and cocaine) repel herbivores & microbes**



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Plant defense mechanisms

Barriers to Entry:

- **Cuticle** (Fig 35.17)**:** matrix of cross-linked lipid molecules impregnated with extremely long-chained lipids
- **Spines, thorns, & prickles** (Fig 35.7b)

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Nutrient Acquisition

Heterotrophs: obtain nutrients from other organisms

- animals
- fungi

Autotrophs: produce own food through photosynthesis

- green plants

Photosynthesis (Figs 10.3, 10.10, page 183)

- Occurs in chloroplasts in green plant tissues
- Leaf parenchyma cells contain 40-50 chloroplasts
- **Chlorophyll** pigments in plants
- **convert energy from sunlight to chemical energy** in the form of **ATP & NADPH (an electron carrier)**
- **Carotenoids (carotene and xanthophylls):** absorb wavelengths of light that are not absorbed by chlorophyll and extend the range of wavelengths that can drive photosynthesis

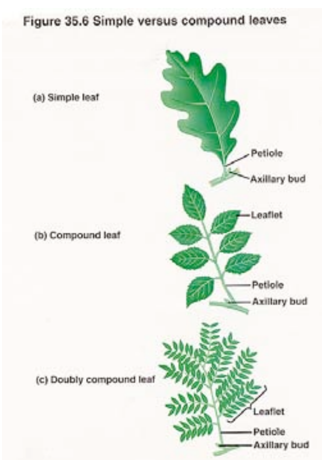


Figure 35.6 Simple versus compound leaves

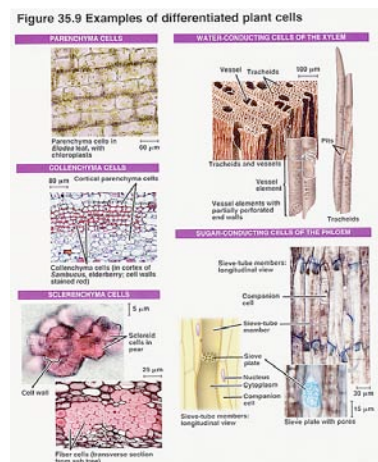


Figure 35.9 Examples of differentiated plant cells

Photosynthesis Equation

$6CO_2 + 12H_2O$ + light energy $\rightarrow$ $C_6H_{12}O_6$ (glucose) + $6O_2 + 6H_2$

Photosynthesis Equation

$6CO_2 + 12H_2O$ + light energy $\rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$
($C_6H_{12}O_6$ = glucose)

Simplest Form of Photosynthesis Equation
$CO_2 + H_2O$ + light energy $\rightarrow CH_2O + O_2 + H_2O$

Light-dependent reactions
Light energy + $H_2O \rightarrow$ chemical energy (ATP, NADPH) + O_2
(oxygen in O_2 derived from oxygen in H_2O)

Light-independent reactions (Calvin Cycle)
Chemical energy (ATP, NADPH) + $CO_2 \rightarrow CH_2O$
(Carbon in sugar is derived from carbon in CO_2)

Types of Photosynthesis

C3 plants use Calvin cycle

Adaptation to Dry Environments

- **C4 plants**
- **CAM plants**

C3 plants (Fig. 10.18)

- **Calvin cycle** takes place in each cell (Calvin was a professor at UC Berkeley!!)
- Use **rubisco enzyme** for initial fixation of carbon
- The **CO_2 is initially fixed into three carbon sugars**

Adaptation to Dry Environments

C4 plants (Fig 10.19, 10.20)

- **certain cells in the leaf sequester CO_2**
- use PEP carboxylase for initial fixation of carbon to **produce 4-carbon organic acids**
- **favored in dry climates** because it enhances photosynthetic efficiency by limiting the loss of carbon and ATP to photorespiration

Adaptation to Dry Environments

CAM Plants (Fig 10.20)

- succulents that live in conditions of high light intensity and water stress → **stomata are closed during the day to prevent water loss**
- **largely depend on night-time accumulation of CO_2**
- **store huge quantities of CO_2** in the form of sugars and sequester them in vacuoles
- during the day, these sugars are metabolized to release CO_2 and feed into Calvin cycle

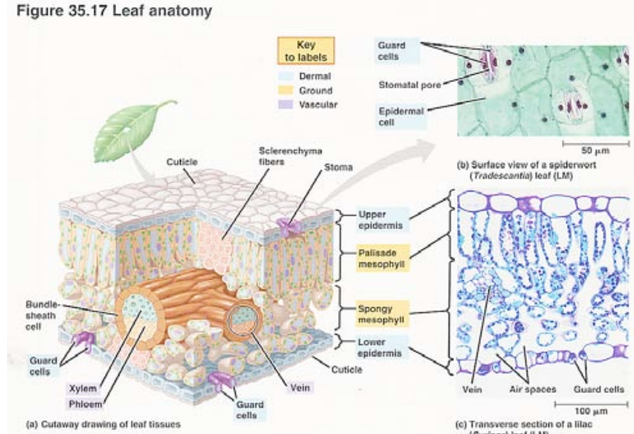
Gas exchange between atmosphere and plant via stomata in leaves

Stoma (stomata plural): guard cells & pores (Fig 10.3)

Guard cells: pair of bean-shaped cells

Pore: opening between guard cells

Figure 35.17 Leaf anatomy



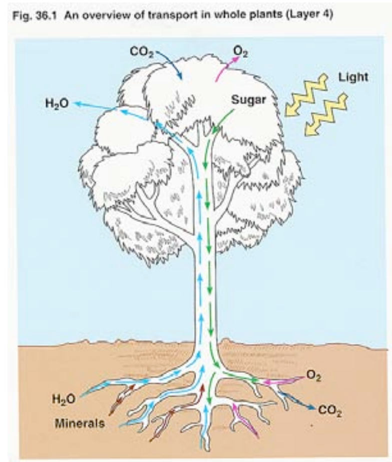
(a) Cutaway drawing of leaf tissues

(b) Surface view of a spiderwort (*Tradescantia*) leaf (LM)

(c) Transverse section of a lilac (*Syringa*) leaf (LM)

Gas exchange between atmosphere & plant via stomata in leaves

- **O_2 produced by plant released out of stomata pores into atmosphere where it is available for humans & animals to breath**
- **H_2O released out of the pores via evapo-transpiration**
- **in some species (e.g., coastal redwoods & Douglas Firs) during high fog conditions, H_2O can be absorbed from the air into the leaf through the stomata pores to provide H_2O for the plant**
- **During photosynthesis when CO_2 levels within leaf fall below optimal levels, the stomata open & CO_2 diffuses in from atmosphere**



CO_2 in Atmosphere & Global Warming

↑ **fossil fuel burning & deforestation** in past 100 years
→ ↑ **atmospheric CO_2**

↑ **atmospheric CO_2** contributes to **global warming**

Photosynthesis by green plants
→ removes CO_2 from the atmosphere
→ sequesters carbon in wood

Sugar produced by photosynthetic organisms
→ fuels cellular respiration and growth of plant

- sugars are typically stored in the form of **starch (long chains of glucose molecules)**
- transported in the form of the disaccharide, **sucrose (glucose attached to fructose) or** monosaccharide **(glucose or fructose)**

Photosynthetic organisms are eaten by animals and fungi

Directly or indirectly, many organisms get their energy from photosynthesis

Plant Pigments & Photosynthesis

Carotenoids
- **Carotenes** (e.g., **beta-carotene** in **carrots**; **lycopene** in **tomatoes**)
- **Xanthophylls** (e.g, **zeaxanthin** which gives **corn yellow color**)

Carotenoids in chloroplasts
- **extend range of wavelengths that drive photosynthesis**
- **Protect chlorophyll by acting as anti-oxidant** and **destroy free radicals that damage the chlorophyll molecules** (beta-carotene **also works a beneficial anti-oxidant in humans**)

During most of year the carotenoids are not visible in the leaves because the chlorophyll pigments cover them up. In fall, as the deciduous leaves are beginning to die, chlorophyll degenerates and the red, orange, and yellow carotenoids become visible

Flavonoid Pigment as Plant Suncreen

Flavonoids absorb ultraviolet radiation which

→ protects leaves & stems from damaging effects of UV

→ functions as a protective sunscreen for the plant

Plant Nutrition

Mineral and water uptake by roots and transport of fluids from roots up to leaves and shoot tips

Epidermal cells of roots with thin projections called root hairs that increase surface area

Micronutrients (Table 37.1)

- Required in small amounts e,g, iron, manganese, zinc, copper
- Often function as cofactors for certain enzymes

Macronutrients (Table 37.1)

- Present in large quantities e.g., carbon, hydrogen, nitrogen, phosphorous, magnesium, potassium
- Building blocks of nucleic acids, proteins, phospholipids, carbohydrates

Symbiotic relationships that enhance nutrient uptake

Mycorrhizal fungi (Fig. 37.12)

- **Ectomycorrhizal Fungi (EMF)** enhance absorption of **nitrogen**
- **Arbuscular mycorrhizal Fungi (AMF)** enhance absorption of **phosphorous**

Nitrogen fixing bacteria in roots (Fig. 37.10, 37.11)

- Common in Fabaceae (the bean family)
- *Rhizobium* is example of a nitrogen-fixing bacteria that lives in nodules of roots

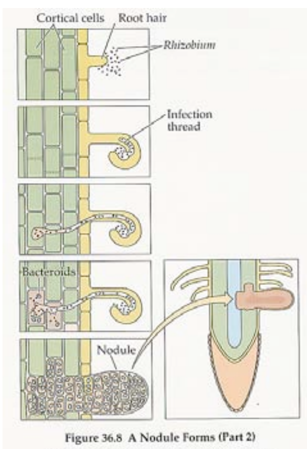


Figure 36.8 A Nodule Forms (Part 2)

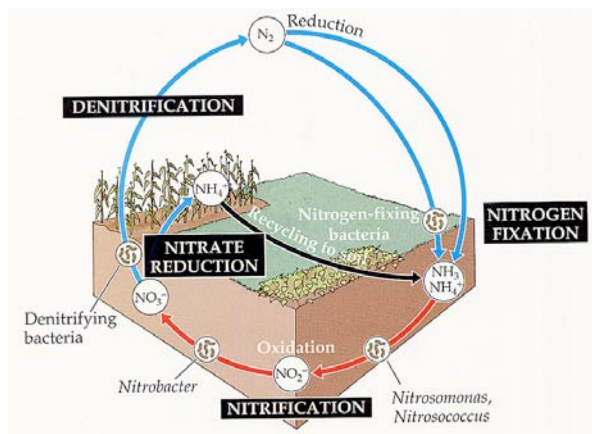


Figure 36.9 The Nitrogen Cycle

Plant Constituents

- **Protein**
- **Fats**
- **Carbohydrates**
- **Vitamins**
- **Minerals**
- **Phytochemicals/Secondary metabolite compounds**

Plant Constituents in Human Nutrition

Protein

- **macromolecules with carbon, hydrogen and nitrogen-containing amino acids in peptide linkages**
- **there are 20 amino acids of which 8 are essential in the human diet and all 8 of these are found in plant foods**

Plant Constituents in Human Nutrition

Carbohydrate: contain carbon and hydrogen

- **Small Molecule Carbohydrates**
  - **monosaccharides**
    - glucose
    - fructose
    - galactose
  - **disaccharides**
    - sucrose (glucose + fructose) is table sugar
    - lactose (glucose + galactose) is milk sugar
- **Larger Molecule Carbohydrates**
  - **polysaccharides (starch, glycogen, and cellulose)**

Plant Constituents in Human Nutrition

Fat: oily or greasy components that contain glycerol esters

Saturated fatty acids: possess no double bonds and are solid at room temperature

Unsaturated fatty acids: possess one or more double or triple bonds and are liquid at room temperature
- monounsaturated
- polyunsaturated

Essential fatty acids: unsaturated fats from plants essential in human diet
- Linoleic acid
- Linolenic acid

Omega-3- fatty acids: (flaxseed oil, walnut oil, salmon oil) unsaturated fatty acids with double bond three carbons from methyl moiety

Plant Constituents in Human Nutrition

Vitamins:

carbon containing organic substances present in minute amounts in food plants that are essential to normal metabolism

Minerals:

inorganic substances that contain elements other than carbon and are present in minute amounts in food plants

Phytochemicals/Secondary metabolite compounds:

organic substances present in minute amounts in food plants that may have beneficial effects for humans

Pharmaceuticals/Nutrients from Plants

–**Cannabinoids** (*Cannabis sativa & Theobroma cocoa*)
–**Opiates** (opium poppy, *Papaver somniferum*)
–**Cocaine** (*Erythroxylum coca*)
–**Muscarine** (*Amanita muscaria*)
–**Atropine** *(Atropa belladonna)*
–**Caffeine** (*Coffea, Camillia, Theobroma, Ilex*)
–**Nicotine** (*Nicotiana tobaccum*)
–**Capsacin** (chile pepper, *Capsicum*)
–**Ephredrine** (ma huang, *Ephedra sinica*)
–**Carotenoids** (beta-carotene in carrots; lycopene in tomatoes)
–**Flavonoids** (e.g., genistein in soybeans, *Glycine max*)
–**Lignins** (e.g., from flaxseed, *Linum usitatissimum)*

Examples of human physiological receptors named after plant compounds

- **Muscarinic receptors** named after **muscarine** from ***Amanita muscaria***
- **Nicotinic receptors** named after **nicotine** from ***Nicotiana tabacum***
- **Endorphin receptors** named after **morphine** from ***Papaver somniferum***
- **Cannabinoid receptors** named after **THC** from ***Cannabis sativa***
- **Capsaicin receptors** named after **capsaicin** from ***Capsicum***